Aviation Rulemaking Advisory Committee

Airman Certification System Working Group

Interim Recommendation Report

November 7, 2019

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Yvette A. Rose
Chair, Aviation Rulemaking Advisory Committee
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591

Dear Ms. Rose,

On behalf of the Airman Certification System Working Group (ACSWG), we submit the following interim recommendation report to the Aviation Rulemaking Advisory Committee (ARAC) for consideration and implementation.

The FAA and the aviation industry have continued its collaborative effort to improve airman training and testing by establishing an integrated, holistic airman certification system that clearly aligns testing with the certification standards, guidance, and reference materials, and maintains that alignment.

As part of its ongoing effort, the ACSWG is submitting, for the committee's review, recommended content for a future Powered-Lift flying handbook. The draft represents a combination of Airplane Flying Handbook, Helicopter Flying Handbook, and brand new Powered-Lift content.

We strongly recommend and endorse the committee's transmittal of the working group recommendations to the FAA for further review, incorporation, and execution. We are confident that, by doing so, the safety of aviation will continue to markedly improve.

Sincerely,

David Oord
ARAC Vice-Chair & ACSWG Chair
Senior Director, Regulatory Affairs
Aircraft Owners and Pilots Association

Susan Parson
FAA Representative
Flight Standards Service
Federal Aviation Administration

Powered-Lift Flying Handbook

Content Recommendations

Recommended Powered-Lift Flying Handbook Content

Recommended Powered-Lift Flying Handbook Content

Recommended Powered-Lift Flying Handbook Content

Recommended Powered-Lift Flying Handbook Content

Introduction to Flight Training

Introduction

The overall purpose of primary and intermediate flight training, as outlined in this handbook, is the acquisition and honing of basic airmanship skills. *[Figure 1-1]* Airmanship is a broad term that includes a sound knowledge of and experience with the principles of flight, the knowledge, experience, and ability to operate an aircraft with competence and precision both on the ground and in the air, and the application of sound judgment that results in optimal operational safety and efficiency. *[Figure 1-2]* Learning to fly an aircraft has often been likened to learning to drive an automobile. This analogy is misleading. Since aircraft operate in a three-dimensional environment, they require a depth of knowledge and type of motor skill development that is more sensitive to this situation, such as:

- Coordination—the ability to use the hands and feet together subconsciously and in the proper relationship to produce desired results.
- Timing—the application of muscular coordination at the proper instant to make flight, and all maneuvers, a constant, smooth process.
- Control touch—the ability to sense the action of the aircraft and knowledge to determine its probable actions immediately regarding attitude and speed variations by sensing the varying pressures and resistance of the control surfaces transmitted through the flight controls.
- Speed sense—the ability to sense and react to reasonable variations of airspeed.

Figure 1-1. *Primary and intermediate flight training for powered-lift pilots may be conducted in helicopters or airplanes, teaches basic airmanship skills, and creates a good foundation for student pilots.*

An accomplished pilot demonstrates the knowledge and ability to assess a situation quickly and accurately and determine the correct procedure to be followed under the existing circumstance. He or she is also able to analyze accurately the probable results of a given set of circumstances or of a proposed procedure; to exercise care and due regard for safety; to gauge accurately the performance of the aircraft; to recognize personal limitations and limitations of the aircraft and avoid approaching the critical points of each; and the ability to identify, assess, and mitigate risk. The development of airmanship skills requires effort and dedication on the part of both the student pilot and the flight instructor, beginning with the very first training flight where proper habit formation begins with the student being introduced to good operating practices.

Every aircraft has its own particular flight characteristics. The purpose of primary and intermediate flight training; however, is not to learn how to fly a particular make and model aircraft. The underlying purpose of flight training is to develop the knowledge, experience, skills, and safe habits that establish a foundation and are easily transferable to any aircraft. The pilot who has acquired necessary skills during training, and develops these skills by flying training-type aircraft with precision and safe flying habits, is able to easily transition to more complex and higher performance aircraft. It should also be remembered that the goal of flight training is a safe and competent pilot; passing required practical tests for pilot certification is only incidental to this goal.

Role of the FAA

The Federal Aviation Administration (FAA) is empowered by the U.S. Congress to promote aviation safety by prescribing safety standards for civil aviation. Standards are established

Figure 1-2. *Good airmanship skills include sound knowledge of the principles of flight and the ability to operate an aircraft with competence and precision.*

for the certification of airmen and aircraft, as well as outlining operating rules. This is accomplished through the Code of Federal Regulations (CFR), formerly referred to as Federal Aviation Regulations (FAR). Title 14 of the CFR (14 CFR) is titled Aeronautics and Space with Chapter 1 dedicated to the FAA. Subchapters are broken down by category with numbered parts detailing specific information. *[Figure 1-3]* For ease of

Title 14 Code of Federal Regulations

Aeronautics and Space

CHAPTER 1 Federal Aviation Administration, Department of Transportation

Subchapter A	Definitions and General Requirements
Part 1	Definitions and Abbreviations
Subchapter B	Procedural Rules
Part 11	General Rulemaking Procedures
Part 17	Procedures for Protests and Contract Disputes
Subchapter C	Aircraft
Part 21	Certification Procedures for Products and Articles
Parts 23—31	Airworthiness Standards for Various Categories of Aircraft
Part 39	Airworthiness Directives
Part 43	Maintenance, Preventive Maintenance, Rebuilding and Alteration
Part 45	Identification and Registration Marking
Subchapter D	Airmen
Part 61	Certification: Pilots, Flight Instructors and Ground Instructors
Part 67	Medical Standards and Certification
Subchapter E	Airspace
Part 71	Designation of Class A,B,C,D and E Airspace Areas; Air Traffic Service Routes; and Reporting Points
Part 73	Special Use Airspace
Subchapter F	Air Traffic and General Operating Rules
Part 91	General Operating and Flight Rules
Part 97	Standard Instrument Procedures
Part 103	Ultralight Vehicles
Subchapter G	Air Carriers and Operators for Compensation or Hire: Certification and Operations
Part 110 - 139	General and Operating Requirements
Subchapter H	Schools and Other Certificated Agencies
Part 141	Pilot Schools
Part 142	Training Centers
Subchapter I	Airports
Part 150 - 169	
Subchapter J	Navigational Facilities
Part 170 - 171	
Subchapter K	Administrative Regulations
Part 183 - 193	

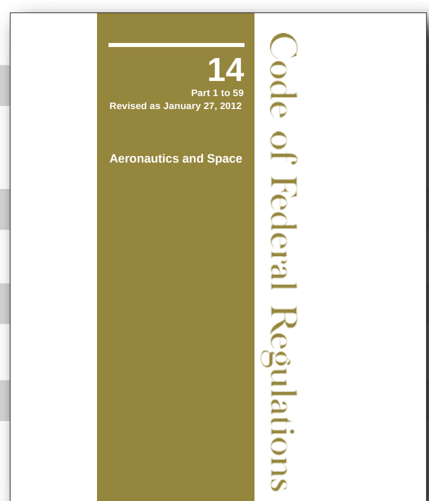


Figure 1-3. *Title 14 CFR, Chapter 1, Aeronautics and Space and subchapters.*

reference since the parts are numerical, the abbreviated pattern 14 CFR part is used (e.g., 14 CFR part 91).

While the various subchapters and parts of 14 CFR provide general to specific guidance regarding aviation operations within the U.S., the topic of aircraft certification and airworthiness is spread through several interconnected parts of 14 CFR.

- 14 CFR part 21 prescribes procedural requirements for issuing airworthiness certificates and airworthiness approvals for aircraft and aircraft parts. A standard airworthiness certificate, FAA Form 8100-2, is required to be displayed in the aircraft. *[Figure 1-4]* It is issued for aircraft type certificated in the normal, utility, acrobatic, commuter or transport category, and for manned free balloons. A standard airworthiness certificate remains valid as long as the aircraft meets its approved type design, is in a condition for safe operation and maintenance, and preventative maintenance and alterations are performed in accordance with 14 CFR parts 21, 43, and 91.
- 14 CFR part 39 is the authority for the FAA to issue Airworthiness Directives (ADs) when an unsafe condition exists in a product, aircraft, or part, and the condition is likely to exist or develop in other products of the same type design.
- 14 CFR part 45 identifies the requirements for the identification of aircraft, engines, propellers, certain replacement and modification parts, and the nationality and registration marking required on U.S.-registered aircraft.
- 14 CFR part 43 prescribes rules governing the maintenance, preventive maintenance, rebuilding, and alteration of any aircraft having a U.S. airworthiness certificate. It also applies to the airframe, aircraft engines, propellers, appliances, and component parts of such aircraft.
- 14 CFR part 91 outlines aircraft certifications and equipment requirements for the operation of aircraft in U.S. airspace. It also prescribes rules governing maintenance, preventive maintenance, and alterations. Also found in 14 CFR part 91 is the requirement to maintain records of maintenance, preventive maintenance, and alterations, as well as records of the 100-hour, annual, progressive, and other required or approved inspections.

While 14 CFR part 91 outlines the minimum equipment required for flight, the aircraft Flight Manual/Pilot's Operating Handbook (AFM/RFM/POH) lists the equipment required for the aircraft to be airworthy. The equipment list found in the AFM/POH is developed during the aircraft certification process. This list identifies those items that are required for airworthiness, optional equipment installed in addition to the required equipment, and any supplemental items or appliances.

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION-FEDERAL AVIATION ADMINISTRATION
STANDARD AIRWORTHINESS CERTIFICATE

1 NATIONALITY AND REGISTRATION MARKS	2 MANUFACTURER AND MODEL	3 AIRCRAFT SERIAL NUMBER	4 CATEGORY
N609AW	Leonardo AW609	43219	Transport

5 AUTHORITY AND BASIS FOR ISSUANCE

This airworthiness certificate is issued pursuant to 49 U.S.C. § 44704 and certifies that, as of the date of issuance, the aircraft to which issued has been inspected and found to conform to the type certificate therefore, to be in condition for safe operation, and has been shown to meet the requirements of the applicable comprehensive and detailed airworthiness code as provided by Annex 8 to the Convention on International Civil Aviation, except as noted herein.

Exceptions:

None

6 TERMS AND CONDITIONS

Unless sooner surrendered, suspended, revoked, or a termination date is otherwise established by the FAA, this airworthiness certificate is effective as long as the maintenance, preventative maintenance, and alterations are performed in accordance with Parts 21, 43, and 91 of the Federal Aviation Regulations, as appropriate, and the aircraft is registered in the United States.

DATE OF ISSUANCE	FAA REPRESENTATIVE		DESIGNATION NUMBER
01/20/2000	A.C. Wotton	*A.C. Wotton*	NE-XX

Any iteration, reproduction, or misuse of this certificate may be punishable by a fine not exceeding $1,000 or imprisonment not exceeding 3 years or both.
THIS CERTIFICATE MUST BE DISPLAYED IN THE AIRCRAFT IN ACCORDANCE WITH APPLICABLE FEDERAL AVIATION REGULATIONS.

FAA Form 8100-2 (04-11) Supersedes Previous Edition

Figure 1-4. *FAA Form 8100-2, Standard Airworthiness Certificate.*

Figure 1-5 shows an example of some of the required equipment, standard or supplemental (not required but commonly found in the aircraft) and optional equipment list for an aircraft. It is originally issued by the manufacturer and is required to be maintained by the Type Certificate Data Sheet (TCDS). An aircraft and its installed components and parts must continually meet the requirements of the original Type Certificate or approved altered conditions to be airworthy.

- 14 CFR part 61 pertains to the certification of pilots, flight instructors, and ground instructors. It prescribes the eligibility, aeronautical knowledge, flight proficiency training, and testing requirements for each type of pilot certificate issued.
- 14 CFR part 67 prescribes the medical standards and certification procedures for issuing medical certificates for airmen and for remaining eligible for a medical certificate.
- 14 CFR part 91 contains general operating and flight rules. The section is broad in scope and provides general guidance in the areas of general flight rules, visual flight rules (VFR), instrument flight rules (IFR), and as previously discussed aircraft maintenance, and preventive maintenance and alterations.

Flight Standards Service

Within the FAA, the Flight Standards Service (AFS) sets the aviation standards for airmen and aircraft operations

Sym:
Items in this listing are coded by a symbol indicating the status of the item. These codes are:
C Required item for FAA Certification.
S Standard equipment. Most standard equipment is applicable to all airplanes. Some equipment may be replaced by optional equipment.
O Optional equipment. Optional equipment may be installed in addition to or to replace standard equipment.

Qty: The quantity of the listed item in the aircraft. A hyphen (-) in this column indicates that the equipment was not installed.

ATA Item	Description	SYM	QTY	Part Number	Unit Weight	Arm
34-08	GPS 1 Antenna	C	1	12744-001	0.4	136.2
34-09	GPS 2 Antenna	S	1	12744-001	0.4	110.3
34-10	Transponder Antenna	C	1	12739-001	0.1	105.0
34-11	VOR/LOC Antenna	C	1	12742-001	0.4	331.0
34-12	Turn coordinator, modified	C	1	11891-001	1.8	118.0
34-13	GMA 340 audio panel	S	1	12717-050	1.5	121.5
34-14	GNS 420 (GPS/COM/NAV)	O	1	12718-004	5.0	121.0
34-15	GNS 420 (GPS/COM/NAV)	C	1	12718-051	5.0	121.0
34-16	GNS 420 (GPS/COM/NAV)	O	1	12718-051	5.0	122.4
	EMax engine monitoring					
34-17	• Data acquisition unit	O	1	16692-001	2.0	118.0
34-18	• Monitor cabin harness	O	1	16695-005	2.0	108.0
	Sky watch option					
34-19	• Sky watch inverter	O	1	14484-001	0.5	118.0
34-20	• Sky watch antenna nsti	O	1	14480-001	2.3	150.5
34-21	• Sky watch track box	O	1	14477-050	10.0	140.0
	Stormscope option					
34-22	• Processor	O	1	12745-050	1.7	199.0
34-23	• Antenna	O	1	12745-070	0.9	191.0
	Transponder option					
34-24	• Mode A/C transponder	C	1	13587-001	1.6	124.9
34-25	• Mode S transponder	O	-	15966-050	2.6	121.0
	TAWS option					
34-26	• KGP 560 processor	O	1	15963-001	1.3	117.0
	XM satellite option					
34-27	• XM WX/radio receiver	O	1	16121-001	1.7	114.0
34-28	• XM radio remote control	O	1	16665-501	0.2	149.3
61	**Propeller**					
61-01	• Hartzell propeller installation	C	1	15319-00X	79.8	48.0
61-02	• McCauley propeller installation	O	1	15825-00X	78.0	50.0
61-03	• Propeller governor	C	1	15524-001	3.2	61.7
71	**Power plant**					
71-01	• Upper cowl	C	1	20181-003	10.5	78.4
71-02	• Lower cowl LH	C	1	20182-005	5.4	78.4
71-03	• Lower cowl RH	C	1	20439-005	5.4	78.4
71-03	• Engine baffling installation	C	1	15460-001	10.7	78.4

Figure 1-5. *Example of some of the required, standard or supplemental and optional equipment for an aircraft.*

in the United States and for American airmen and aircraft around the world. The AFS is headquartered in Washington, D.C., and is broadly organized into divisions based on work function (Air Transportation, Aircraft Maintenance, Flight Technology, Training, Certification and Surveillance, a Regulatory Support Division based in Oklahoma City, OK, and a General Aviation and Commercial Division). Regional Flight Standards division managers, one at each of the FAA's nine regional offices, coordinate AFS activities within their respective regions.

The interface between AFS and the aviation community/general public is the local Flight Standards District Office (FSDO). The approximately ninety FSDOs are strategically located across the United States, each office having jurisdiction over a specific geographic area. *[Figure 1-6]* The individual FSDO is responsible for all air activity occurring within its geographic boundaries. The individual FSDOs are responsible for the certification and surveillance of air carriers, air operators, flight schools/training centers, airmen (pilots, flight instructors, mechanics and other certificate holders). Additional duties that are tasked to FSDO inspectors is accident investigation and enforcement actions. NOTE: Accident investigation and enforcement actions are a smaller part of a field inspectors job than surveillance and certification.

Each FSDO is staffed by Aviation Safety Inspectors (ASIs) whose specialties include operations, maintenance, and avionics. General Aviation ASIs are highly qualified and experienced aviators. Once accepted for the position, an inspector must satisfactorily complete indoctrination training conducted at the FAA Academy that includes airman evaluation and pilot testing techniques and procedures. Thereafter, the inspector must complete recurrent training on a regular basis. Among other duties, the FSDO inspector is responsible for administering FAA practical tests for pilot and flight instructor certificates and associated ratings. All questions concerning pilot certification (and/or requests for other aviation information or services) should be directed to the FSDO having jurisdiction in the particular geographic area. For specific FSDO locations and telephone numbers, refer to www.faa.gov.

Role of the Pilot Examiner

Pilot and flight instructor certificates are issued by the FAA upon satisfactory completion of required knowledge and practical tests. The administration of these tests is an FAA responsibility that the issuance of pilot and instructor certificates can be carried out at the FSDO level. In order to satisfy the public need for pilot testing and certification services, the FAA delegates certain responsibilities, as

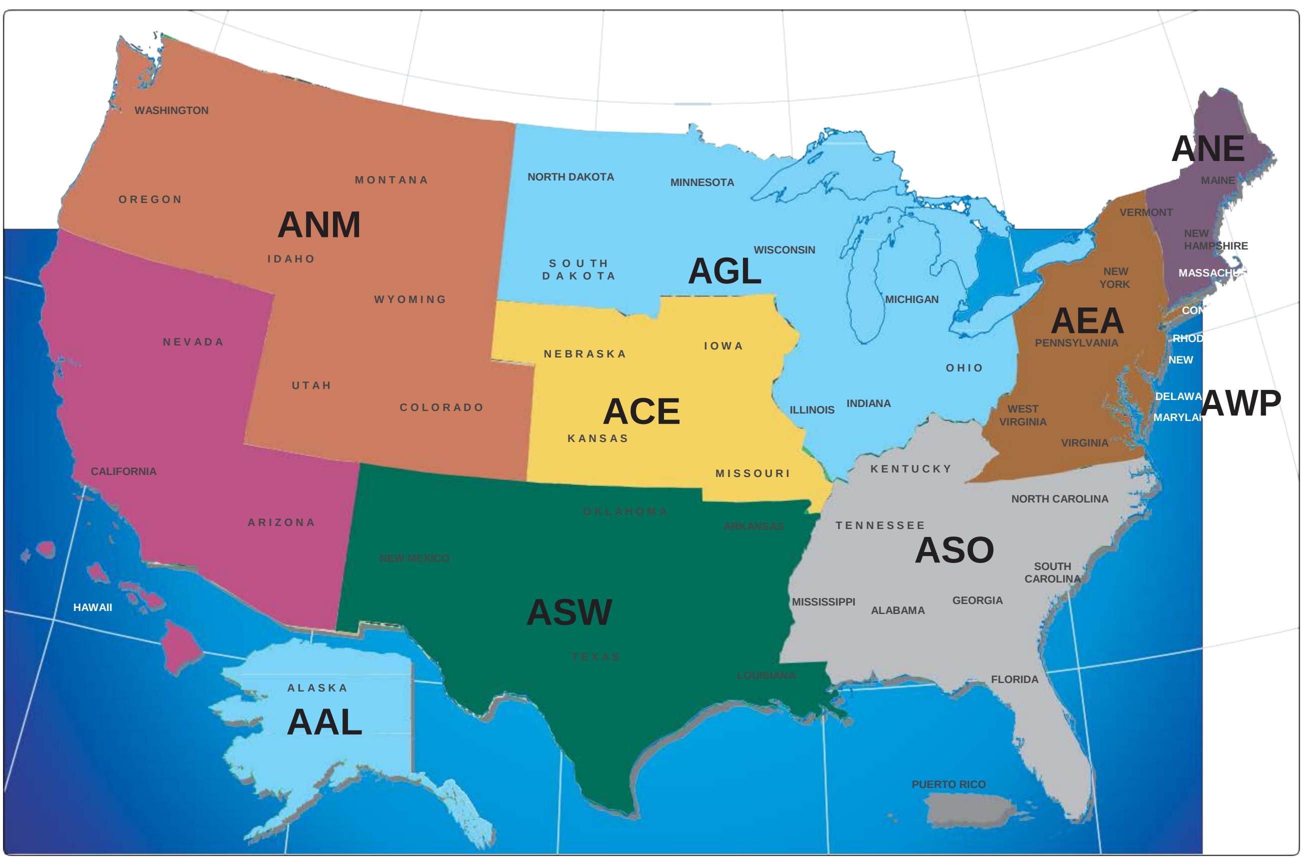


Figure 1-6. *Flight Standards District Office locations across the United States.*

the need arises, to private individuals who are not FAA employees. A Designated Pilot Examiner (DPE) is a private citizen who is designated as a representative of the FAA Administrator to perform specific (but limited) pilot certification tasks on behalf of the FAA and may charge a reasonable fee for doing so. Generally, a DPE's authority is limited to accepting applications and conducting practical tests leading to the issuance of specific pilot certificates and/or ratings. A DPE operates under the direct supervision of the FSDO that holds the examiner's designation file. A FSDO inspector is assigned to monitor the DPE's certification activities. Normally, the DPE is authorized to conduct these activities only within the designating FSDO's jurisdictional area.

The FAA selects only highly qualified individuals to be DPEs. These individuals must have good industry reputations for professionalism, high integrity, a demonstrated willingness to serve the public, and adhere to FAA policies and procedures in certification matters. A DPE is expected to administer practical tests with the same degree of professionalism, using the same methods, procedures, and standards as an FAA ASI. It should be remembered, however, that a DPE is not an FAA ASI. A DPE cannot initiate enforcement action, investigate accidents, or perform surveillance activities on behalf of the FAA. However, the majority of FAA practical tests at the recreational, private, and commercial pilot level are administered by FAA DPEs.

Role of the Flight Instructor

The flight instructor is the cornerstone of aviation safety. The FAA has adopted an operational training concept that places the full responsibility for student training on the authorized flight instructor. In this role, the instructor assumes the total responsibility for training the student pilot in all the knowledge areas and skills necessary to operate safely and competently as a certificated pilot in the National Airspace System (NAS). This training includes airmanship skills, pilot judgment and decision-making, hazard identification, risk analysis, and good operating practices. (See Risk Management Handbook, FAA-H-8083-2). *[Figure 1-7]*

An FAA Certificated Flight Instructor (CFI) has to meet broad flying experience requirements, pass rigid knowledge and practical tests, and demonstrate the ability to apply recommended teaching techniques before being certificated. In addition, the flight instructor's certificate must be renewed every 24 months by showing continued success in training pilots or by satisfactorily completing a flight instructor's refresher course or a practical test designed to upgrade aeronautical knowledge, pilot proficiency, and teaching techniques.

A pilot training program is dependent on the quality of the ground and flight instruction the student pilot receives. A good flight instructor has a thorough understanding of the learning process, knowledge of the fundamentals of instruction, and the ability to communicate effectively with the student pilot.

A good flight instructor uses a syllabus and insists on correct techniques and procedures from the beginning of training so that the student will develop proper habit patterns. The syllabus should embody the "building block" method of instruction in which the student progresses from the known to the unknown. The course of instruction should be laid out so that each new maneuver embodies the principles involved in the performance of those previously undertaken. Consequently, through each new subject introduced, the student not only learns a new principle or technique, but broadens his or her application of those previously learned and has his or her deficiencies in the previous maneuvers emphasized and made obvious. *[Figure 1-8]*

The flying habits of the flight instructor, both during flight instruction and as observed by students when conducting other pilot operations, have a vital effect on safety. Students consider their flight instructor to be a paragon of flying proficiency whose flying habits they, consciously or unconsciously, attempt to imitate. For this reason, a good flight instructor meticulously observes the safety practices taught to the students. Additionally, a good flight instructor carefully observes all regulations and recognized safety practices during all flight operations.

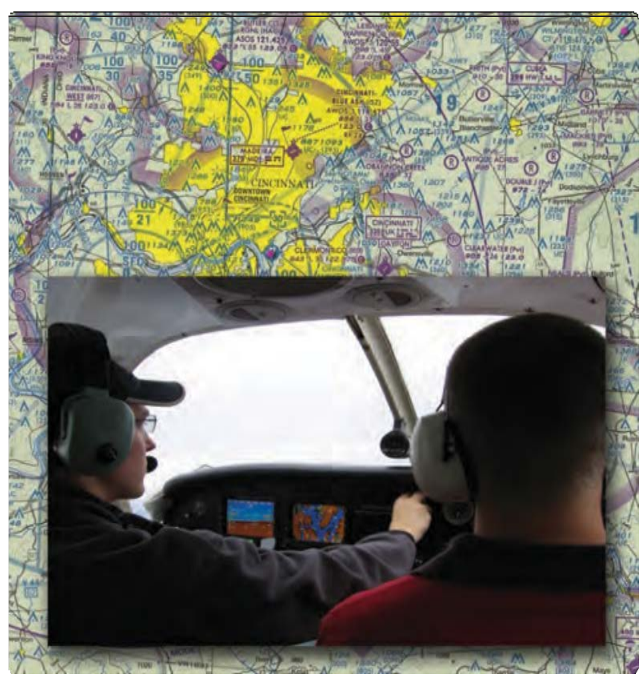


Figure 1-7. *The flight instructor is responsible for teaching and training students to become safe and competent certificated pilots.*

Lesson Stalls **Student** ____________ **Date** ____________

Objective	• To familiarize the student with the stall warnings and handling characteristics of the aircraft as it approaches a stall. To develop the student's skill in recognition and recovery from stalls.
Content	• Configuration of aircraft for power-on and power-off stalls. • Observation of aircraft attitude, stall warnings, and handling characteristics as it approaches a stall. • Control of aircraft attitude, altitude, and heading. • Initiation of stall recovery procedures.
Schedule	• Preflight Discussion ....10 • Instructor Demonstrations ....25 • Student Practice ....45 • Postflight Critique 10
Equipment	• Chalkboard or notebook for preflight discussion.
Instructor's actions	• Preflight—discuss lesson objective. • Inflight—demonstrate elements. Demonstrate power-on and power-off stalls and recovery procedures. Coach student practice. • Postflight—critique student performance and assign study material.
Student's actions	• Preflight—discuss lesson objective and resolve questions. • Inflight—review previous maneuvers including slow flight. Perform each new maneuver as directed. • Postflight—ask pertinent questions.
Completion standards	• Student should demonstrate competency in controlling the aircraft at airspeeds approaching a stall. Student should recognize and take prompt corrective action to recover from power-on and power-off stalls.

This is a typical lesson plan for flight training which emphasizes stall recognition and recovery procedures.

Figure 1-8. *Sample lesson plan for stall training and recovery procedures.*

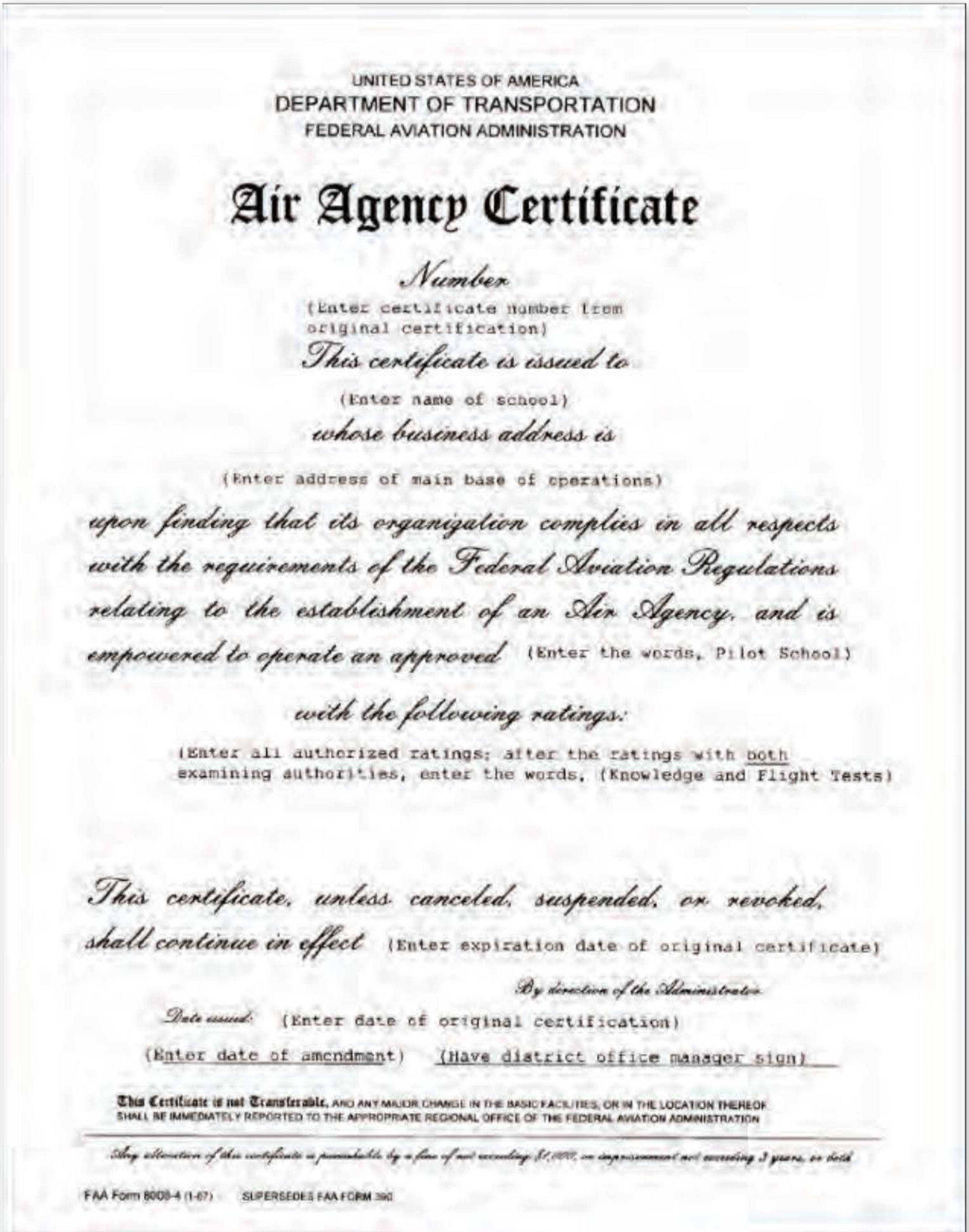
Generally, the student pilot who enrolls in a pilot training program is prepared to commit considerable time, effort, and expense in pursuit of a pilot certificate. The student may tend to judge the effectiveness of the flight instructor and the overall success of the pilot training program solely in terms of being able to pass the requisite FAA-practical test. A good flight instructor is able to communicate to the student that evaluation through practical tests is a mere sampling of pilot ability that is compressed into a short period of time. The flight instructor's role is to train the "total" pilot.

Sources of Flight Training

The major sources of flight training in the United States include FAA-approved pilot schools and training centers, non-certificated (14 CFR part 61) flying schools, and independent flight instructors. FAA-approved schools are those flight schools certificated by the FAA as pilot schools under 14 CFR part 141. *[Figure 1-9]*

Application for certification is voluntary, and the school must meet stringent requirements for personnel, equipment, maintenance, and facilities. The school must operate in accordance with an established curriculum that includes a training course outline (TCO) approved by the FAA. The TCO must contain student enrollment prerequisites, detailed description of each lesson including standards and objectives, expected accomplishments and standards for each stage of training, and a description of the checks and tests used to measure a student's accomplishments. FAA-approved pilot school certificates must be renewed every 2 years.

Renewal is contingent upon proof of continued high quality instruction and a minimum level of instructional activity. Training at an FAA-certificated pilot school is structured and because of this structured environment, the graduates of these pilot schools are allowed to meet the certification experience requirements of 14 CFR part 61 with less flight time. Many FAA-certificated pilot schools have DPEs on staff to administer FAA practical tests. Some schools have been granted examining authority by the FAA. A school with examining authority for a particular course(s) has the authority to recommend its graduates for pilot certificates or ratings



UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

Air Agency Certificate

Number
(Enter certificate number from original certification)

This certificate is issued to
(Enter name of school)

whose business address is
(Enter address of main base of operations)

upon finding that its organization complies in all respects with the requirements of the Federal Aviation Regulations relating to the establishment of an Air Agency, and is empowered to operate an approved (Enter the words, Pilot School)

with the following ratings:
(Enter all authorized ratings; after the ratings with both examining authorities, enter the words, (Knowledge and Flight Tests)

This certificate, unless canceled, suspended, or revoked, shall continue in effect (Enter expiration date of original certificate)

By direction of the Administrator

Date issued: (Enter date of original certification)

(Enter date of amendment) (Have district office manager sign)

This Certificate is not Transferable, AND ANY MAJOR CHANGE IN THE BASIC FACILITIES, OR IN THE LOCATION THEREOF SHALL BE IMMEDIATELY REPORTED TO THE APPROPRIATE REGIONAL OFFICE OF THE FEDERAL AVIATION ADMINISTRATION

Any alteration of this certificate is punishable by a fine of not exceeding $1,000, or imprisonment not exceeding 3 years, or both

FAA Form 8000-4 (1-67) SUPERSEDES FAA FORM 390

Figure 1-9. *FAA Form 8000-4, Air Agency Certificate.*

without further testing by the FAA. A list of FAA-certificated pilot schools and their training courses can be found at http://av-info.faa.gov/pilotschool.asp.

FAA-approved training centers are certificated under 14 CFR part 142. Training centers, like certificated pilot schools, operate in a structured environment with approved courses and curricula and stringent standards for personnel, equipment, facilities, operating procedures, and record keeping. Training centers certificated under 14 CFR part 142, however, specialize in the use of flight simulation (flight simulators and flight training devices) in their training courses.

There are a number of flying schools in the United States that are not certificated by the FAA. These schools operate under the provisions of 14 CFR part 61. Many of these non-certificated flying schools offer excellent training and meet or exceed the standards required of FAA-approved pilot schools. Flight instructors employed by non-certificated flying schools, as well as independent flight instructors, must meet the same basic 14 CFR part 61 flight instructor requirements for certification and renewal as those flight instructors employed by FAA-certificated pilot schools. In the end, any training program is dependent upon the quality of the ground and flight instruction a student pilot receives.

Practical Test Standards (PTS) and Airman Certification Standards (ACS)

Practical tests for FAA pilot certificates and associated ratings are administered by FAA inspectors and DPEs in accordance with FAA-developed Practical Test Standards (PTS) and Airman Certification Standards (ACS). *[Figure 1-10]* 14 CFR part 61 specifies the areas of operation in which knowledge and skill must be demonstrated by the applicant. The CFRs provide the flexibility to permit the FAA to publish PTS and ACS containing the areas of operation and specific tasks in which competence must be demonstrated. The FAA requires that all practical tests be conducted in accordance with the appropriate PTS and ACS and the policies set forth in the introduction section of the PTS and ACS.

It must be emphasized that the PTS and ACS are testing documents rather than teaching documents. Although the pilot applicant should be familiar with these books and refer to the standards it contains during training, the PTS and ACS is not intended to be used as a training syllabus. It contains the standards to which maneuvers/procedures on FAA practical tests must be performed and the FAA policies governing the administration of practical tests. An appropriately rated flight instructor is responsible for training a pilot applicant to acceptable standards in all subject matter areas, procedures, and maneuvers included in, and

Figure 1-10. *Airman Certification Standards (ACS) developed by the FAA.*

encompassed by, the tasks within each area of operation in the appropriate PTS and ACS. Flight instructors and pilot applicants should always remember that safe, competent piloting requires a commitment to learning, planning, and risk management that goes beyond rote performance of maneuvers. Descriptions of tasks and information on how to perform maneuvers and procedures are contained in reference and teaching documents, such as this handbook. A list of reference documents is contained in the introduction section of each PTS and ACS. It is necessary that the latest version of the PTS and ACS, with all recent changes, be referenced for training. All recent versions and changes to the FAA PTS and ACS may be viewed or downloaded at www.faa.gov.

Safety of Flight Practices

In the interest of safety and good habit pattern formation, there are certain basic flight safety practices and procedures that must be emphasized by the flight instructor, and adhered to by both instructor and student, beginning with the very first dual instruction flight. These include, but are not limited to, collision avoidance procedures including proper scanning techniques and clearing procedures, runway incursion avoidance, stall awareness, positive transfer of controls, and flight deck workload management.

Collision Avoidance

All pilots must be alert to the potential for midair collision and impending loss of separation. The general operating and flight rules in 14 CFR part 91 set forth the concept of "See and Avoid." This concept requires that vigilance shall be maintained at all times by each person operating an aircraft regardless of whether the operation is conducted under IFR or VFR. Pilots should also keep in mind their responsibility for continuously maintaining a vigilant lookout regardless of the type of aircraft being flown and the purpose of the flight. Most midair collision accidents and reported near midair collision incidents occur in good VFR weather conditions and during the hours of daylight. Most of these accident/incidents occur within 5 miles of an airport and/or near navigation aids. *[Figure 1-11]*

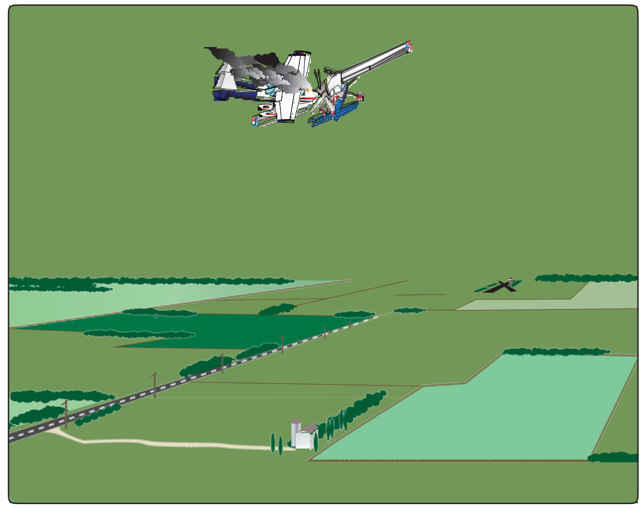


Figure 1-11. *Most midair collision accidents occur in good weather.*

The "See and Avoid" concept relies on knowledge of the limitations of the human eye and the use of proper visual scanning techniques to help compensate for these limitations. Pilots should remain constantly alert to all traffic movement within their field of vision, as well as periodically scanning the entire visual field outside of their aircraft to ensure detection of conflicting traffic. Remember that the performance capabilities of many aircraft, in both speed and rates of climb/descent, result in high closure rates limiting the time available for detection, decision, and evasive action. *[Figure 1-12]*

The probability of spotting a potential collision threat increases with the time spent looking outside, but certain techniques may be used to increase the effectiveness of the scan time. The human eyes tend to focus somewhere, even in a featureless sky. In order to be most effective, the pilot should shift glances and refocus at intervals. Most pilots do this in the process of scanning the instrument panel, but it is also important to focus outside to set up the visual system for effective target acquisition. Pilots should also realize that their eyes may require several seconds to refocus when switching views between items on the instrument panel and distant objects.

Proper scanning requires the constant sharing of attention with other piloting tasks, thus it is easily degraded by such

Figure 1-12. *Proper scanning techniques can mitigate midair collisions. Pilots must be aware of potential blind spots and attempt to clear the entire area that they are maneuvering in.*

psychological and physiological conditions, such as fatigue, boredom, illness, anxiety, or preoccupation.

Effective scanning is accomplished with a series of short, regularly-spaced eye movements that bring successive areas of the sky into the central visual field. Each movement should not exceed 10 degrees, and each area should be observed for at least 1 second to enable detection. Although horizontal back-and-forth eye movements seem preferred by most pilots, each pilot should develop a scanning pattern that is most comfortable to them and adhere to it to assure optimum scanning.

Peripheral vision can be most useful in spotting collision threats from other aircraft. Each time a scan is stopped and the eyes are refocused, the peripheral vision takes on more importance because it is through this element that movement is detected. Apparent movement is almost always the first perception of a collision threat and probably the most important because it is the discovery of a threat that triggers the events leading to proper evasive action. It is essential to remember, however, that if another aircraft appears to have no relative motion, it is likely to be on a collision course with you. If the other aircraft shows no lateral or vertical motion, but is increasing in size, take immediate evasive action.

The importance of, and the proper techniques for, visual scanning should be taught to a student pilot at the very beginning of flight training. The competent flight instructor should be familiar with the visual scanning and collision avoidance information contained in AC 90-48, Pilots' Role in Collision Avoidance, and the Aeronautical Information Manual (AIM).

There are many different types of clearing procedures. Most are centered around the use of clearing turns. The essential idea of the clearing turn is to be certain that the next maneuver is not going to proceed into another airplane's flightpath. Some pilot training programs have hard and fast rules, such as requiring two 90° turns in opposite directions before executing any training maneuver. Other types of clearing procedures may be developed by individual flight instructors. Whatever the preferred method, the flight instructor should teach the beginning student an effective clearing procedure and insist on its use. The student pilot should execute the appropriate clearing procedure before all turns and before executing any training maneuver. Proper clearing procedures, combined with proper visual scanning techniques, are the most effective strategy for collision avoidance.

Runway Incursion Avoidance

A runway incursion is any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in a loss of separation with an aircraft taking off, landing, or intending to land. The three major areas contributing to runway incursions are communications, airport knowledge, and flightdeck procedures for maintaining orientation. *[Figure 1-13]*

Taxi operations require constant vigilance by the entire flight crew, not just the pilot taxiing the aircraft. During flight training, the instructor should emphasize the importance of vigilance during taxi operations. Both the student pilot and the flight instructor need to be continually aware of the movement and location of other aircraft and ground vehicles on the airport movement area. Many flight training activities are conducted at non-tower controlled airports. The absence of an operating airport control tower creates a need for increased vigilance on the part of pilots operating at those airports. *[Figure 1-14]*

Planning, clear communications, and enhanced situational awareness during airport surface operations reduces the potential for surface incidents. Safe aircraft operations can be accomplished and incidents eliminated if the pilot is properly trained early on and throughout their flying career on standard taxi operating procedures and practices. This requires the development of the formalized teaching of safe operating practices during taxi operations. The flight instructor is the key to this teaching. The flight instructor should instill in the student an awareness of the potential for runway incursion, and should emphasize the runway incursion avoidance procedures. For more detailed information and a list of additional references, refer to Chapter 14 of the Pilot's Handbook of Aeronautical Knowledge.

Stall Awareness

In fixed wing airplane training, 14 CFR part 61 requires that a student pilot receive and log flight training in stalls and stall recoveries. *[Figure 1-15]* During this training, the flight instructor should emphasize that the direct cause of every stall is an excessive angle of attack (AOA). The student pilot should fully understand that there are several flight maneuvers that may produce an increase in the wing's AOA, but the stall does not occur until the AOA becomes excessive. This critical AOA varies from 16°–20° depending on the aircraft design. *[Figure 1-16]*

The flight instructor must emphasize that low speed is not necessary to produce a stall. The wing can be brought to an excessive AOA at any speed. High pitch attitude is not an absolute indication of proximity to a stall. Some powered-lift aircraft are capable of vertical flight with a corresponding low AOA. Most aircraft under wingborne lift are quite capable of stalling at a level or near level pitch attitude.

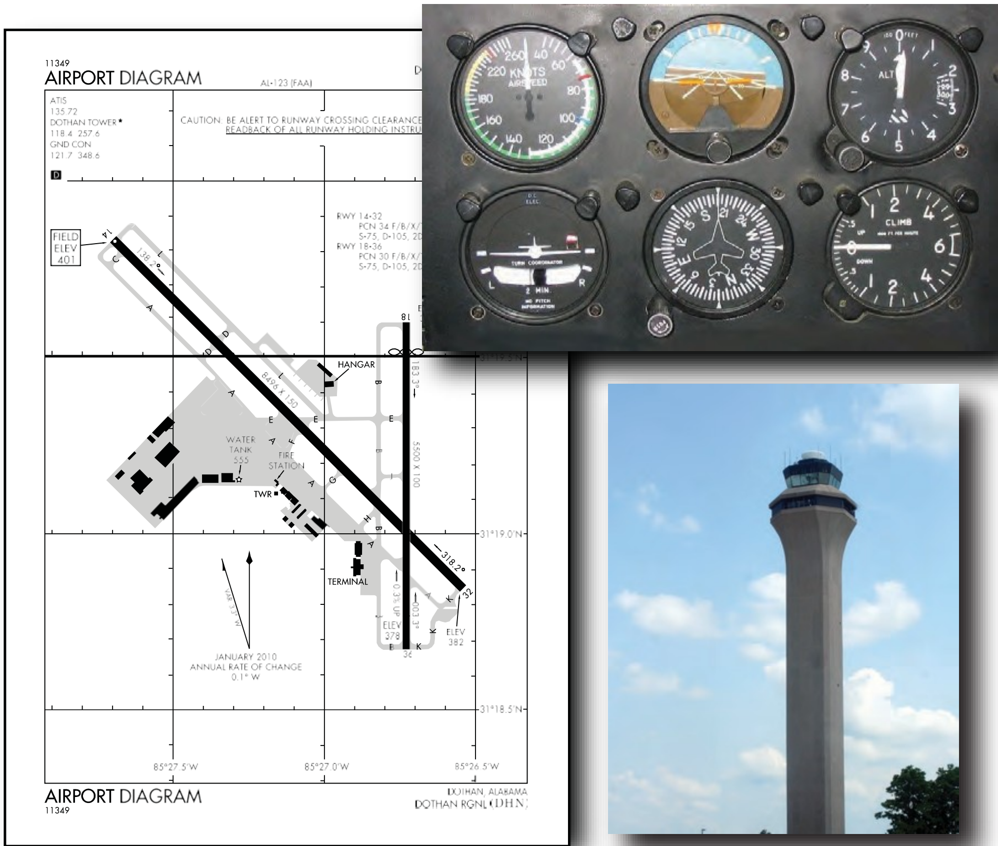


Figure 1-13. *Three major areas contributing to runway incursions are communications with air traffic control (ATC), airport knowledge, and flight deck procedures.*

Because of the nature and design of tilt rotor aircraft this awareness, avoidance and recovery from a stall condition is also vitally important, particularly in APLN mode flight, and will be practised during the type rating course.

The key to stall awareness is the pilot's ability to visualize the wing's AOA in any particular circumstance, and thereby be able to estimate his or her margin of safety above stall. This is a learned skill that must be acquired early in flight training and carried through the pilot's entire flying career.

Figure 1-14. *Sedona Airport is one of the many airports that operate without a control tower.*

The pilot must understand and appreciate factors such as airspeed, pitch attitude, load factor, relative wind, power setting, and aircraft configuration in order to develop a reasonably accurate mental picture of the wing's AOA at any particular time. It is essential to safety of flight that pilots take into consideration this visualization of the wing's AOA prior to entering any flight maneuver. Chapter 10, Basic Flight Maneuvers, discusses stalls in greater detail.

Use of Checklists

Checklists have been the foundation of pilot standardization and flight deck safety for years. *[Figure 1-17]* The checklist is a memory aid and helps to ensure that critical items necessary for the safe operation of aircraft are not overlooked or forgotten. Checklists need not be "do lists." In other words, the proper actions can be accomplished, and then the checklist used to quickly ensure all necessary tasks or actions have been completed. Emphasis on the "check" in checklist. However,

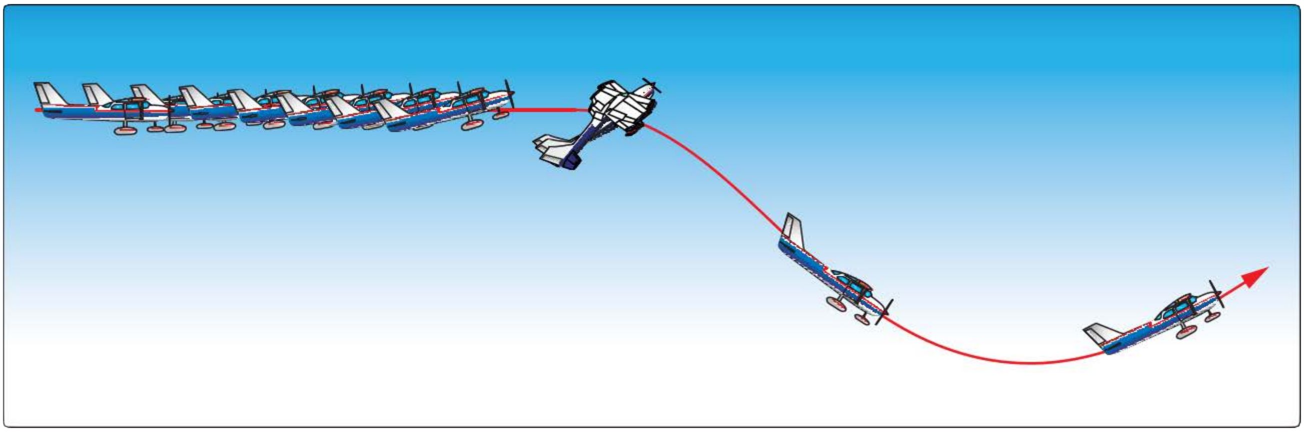


Figure 1-15. *All student pilots must receive and log flight training in stalls and stall recoveries prior to their first solo flight.*

checklists are of no value if the pilot is not committed to using them. Without discipline and dedication to using the appropriate checklists at the appropriate times, the odds are on the side of error. Pilots who fail to take the use of checklists seriously become complacent and begin to rely solely on memory.

The importance of consistent use of checklists cannot be overstated in pilot training. A major objective in primary flight training is to establish habit patterns that will serve pilots well throughout their entire flying career. The flight instructor must promote a positive attitude toward the use of checklists, and the student pilot must realize its importance.

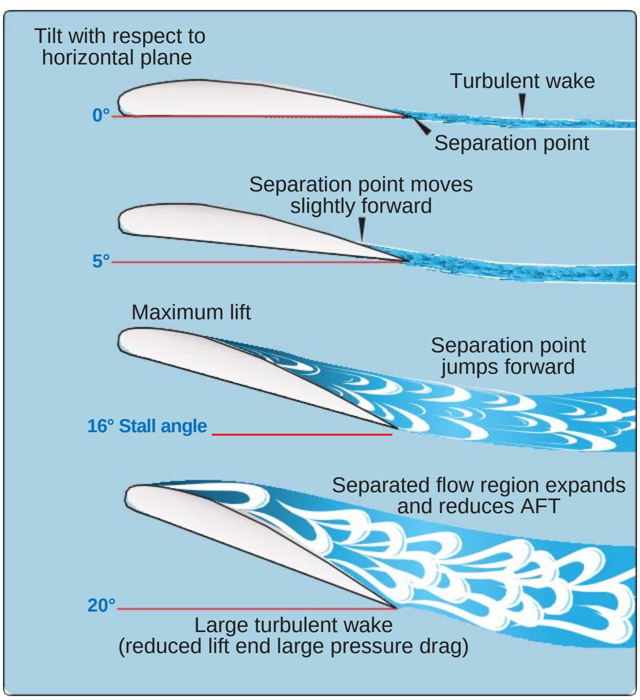


Figure 1-16. *Stalls occur when the airfoils angle of attack reaches the critical point which can vary between 16° and 20°.*

At a minimum, prepared checklists should be used for the following phases of flight. *[Figure 1-18]*

- Preflight Inspection
- Before Engine Start
- Engine Starting
- Before Taxiing
- Before Takeoff
- After Takeoff
- Cruise
- Descent
- Before Landing
- After Landing
- Engine Shutdown and Securing

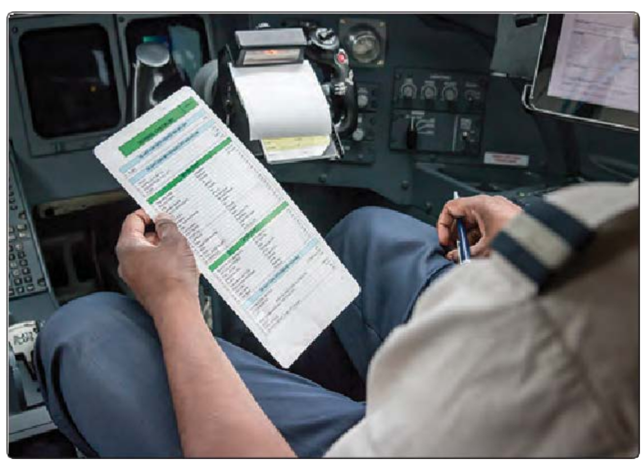


Figure 1-17. *Checklists have been the foundation of pilot standardization and flight safety for many years.*

Figure 1-18. *A sample before landing checklist used by pilots.*

Positive Transfer of Controls

During flight training, there must always be a clear understanding between the student and flight instructor of who has control of the aircraft. Prior to any flight, a briefing should be conducted that includes the procedures for the exchange of flight controls. The following three-step process for the exchange of flight controls is highly recommended.

When a flight instructor wishes the student to take control of the aircraft, he or she should say to the student, "You have the flight controls." The student should acknowledge immediately by saying, "I have the flight controls." The flight instructor should then confirm by again saying, "You have the flight controls." Part of the procedure should be a visual check to ensure that the other person actually has the flight controls. When returning the controls to the flight instructor, the student should follow the same procedure the instructor used when giving control to the student. The student should stay on the controls until the instructor says: "I have the flight controls." There should never be any doubt as to who is flying the aircraft at any one time. Numerous accidents have occurred due to a lack of communication or misunderstanding as to who actually had control of the aircraft, particularly between students and flight instructors. Establishing the above procedure during initial training ensures the formation of a very beneficial habit pattern.

Chapter Summary

This chapter discussed some of the concepts and goals of primary and intermediate flight training. It identified and provided an explanation of regulatory requirements and the roles of the various entities involved. It also offered recommended techniques to be practiced and refined to develop the knowledge, proficiency, and safe habits of a competent pilot.

Introduction to Powered-Lift

Introduction

A Powered-Lift is a heavier-than-air aircraft capable of vertical takeoff, vertical landing, and low speed flight that depends principally on engine-driven lift devices or engine thrust for lift during these flight regimes, and on nonrotating airfoil(s) for lift during horizontal flight. Powered-Lift are capable of both high speed cruise flight and a Vertical/Short Take Off and Land (V/STOL) or a Vertical Take Off and Landing (VTOL). Powered-Lift are categorized by the way the aircraft produces their V/STOL or VTOL capability. VTOL and V/STOL aircraft can take many forms including the the Vectored Thrust, the Lift Fan, and the Tiltrotor.

Powered-Lift History

The idea of VTOL aircraft is not a new concept. In fact, George Lehberger filed the first US patent for such an aircraft on May 28, 1929! Unfortunately, George Lehberger did not pursue VTOL technology any further than his patent (Published September 16, 1930 #US1775861 A).

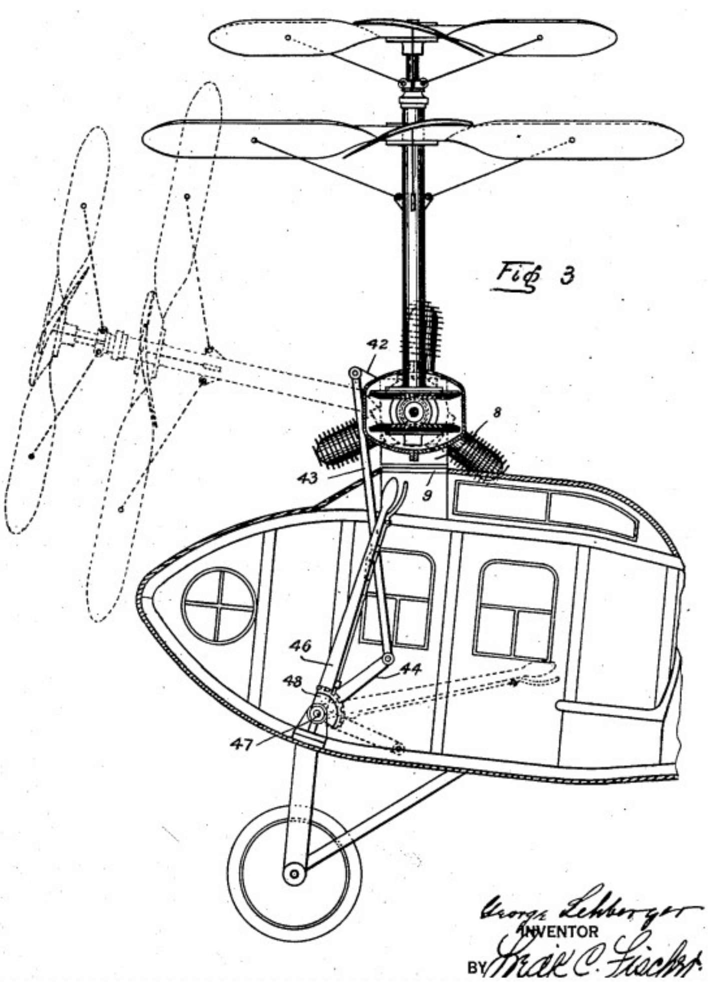


Figure 2-1. *Draft sketches of George Lehberger's Powered-Lift Patent*

In 1942 a German prototype the, Fa-269, was developed but never flew. The Fa269 underwent a large amount of wind tunnel testing along with work on gearboxes, drives and power-pivoting mechanisms. A full scale mock-up of the aircraft was built to demonstrate the VTOL concept, but much of the work was destroyed due to allied bombing raids during World War II. All work for the Fa269 was shelved in 1944.

In 1945, two employees of Kellet Aircraft began to design their own version of the tilt-rotor aircraft. Their model, the Model 1-G, made its first tethered flight at Bellanca Airfield, Delaware on June 15, 1954. The first untethered flight followed soon after on July 6th of that same year.

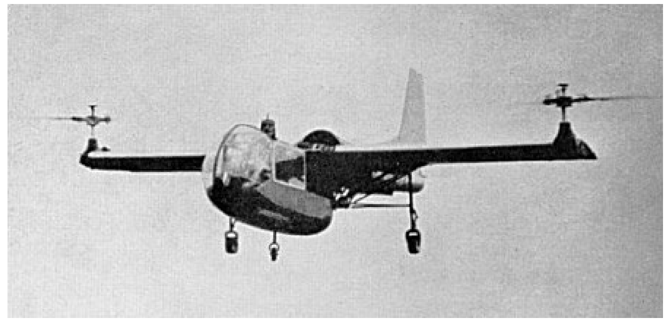


Figure 2-2. *Kellet Aircraft Model 1-G*

Although the 1-G never made the transition to and from wing-born flight, it was able to achieve 75° with more than 90% of lift being generated by the aircrafts wings. On July 20, 1955 the 1-G suffered control system failure causing it to crash in to the Delaware River. Although the aircraft was lost, the pilot was able to escape with only minor injuries.

Turbine Age

Prior to the beginning of World War II, engineers had already realized that engine driven propellers were the limiting factor of aircraft innovation. Propeller efficiency declined as blade tips approached the speed of sound. In order to advance aircrat design, a new method of propulsion was required, and military necessity provided the motivation to develop the gas turbine engine.

Nazi Germany was the first country to develop and fly a gas turbine, jet powered aircraft, the He 178 in August 1939. Despite this early success, technical difficulties prevented the Germans from actually fielding a jet-powered aircraft in time to improve their position in the war. Following the cessation of hostilitities, both the West and the Soviet Union leaned heavily on German innovation to fast track their aircraft development. The development of the turbojet engine enabled the development of one of the earliest powered-lift, the Vectored Thrust.

In 1951, at the urging of his contacts at the Department of the Navy, Charles H. Kaman modified his K-225 helicopter with a new kind of engine, the turbo-shaft engine. This adaptation of the turbine engine provided a large amount of horsepower to the helicopter with a lower weight penalty than piston engines, heavy engine blocks, and auxiliary components. On December 11, 1951, the K-225 became the first turbine-powered helicopter in the world. Two years later, on March 26, 1954, a modified Navy HTK-1, another Kaman helicopter, became the first twin-turbine helicopter to fly. However, it was the Sud Aviation Alouette II that would become the first helicopter to be produced with a turbine engine.

Improvements in fuels and engines during the first half of the 20th century were a critical factor in advanced aircraft development. In the second half of the 20th century, the availability of lightweight gas turbine engines led to the development of larger, faster, and higher-performance aircraft. The turbine engine has the following advantages over a reciprocating engine: less vibration, increased aircraft performance, reliability, and ease of operation.

Further innovation of the gas turbine engine led to many variants including the turbojet, turbofan and turboshaft. Each of these variants of the gas-turbine went on to inspire, and make possible, a later branch of developemnt in powered-lift aircraft. The difference being in how the aircraft create and direct the thrust produced.

Figure 2-3. *Powered-lift have been essential to military operations for nearly three decades.*

Uses

Due to the variety, unique design, and operating characteristics of Powered-Lift—their speed, ability to take off and land vertically, to hover for extended periods of time, and the aircraft's handling properties under low airspeed conditions—it has been chosen to conduct tasks that were previously not possible with aircraft lacking the flexibility inherent in Powered-Lift. Today, powered-lift are used for transportation, close-air-support, firefighting, search and rescue, and a variety of other jobs that require its special capabilities. *[Figure 1-3]*

Aircraft Configurations

The last two decades of the 20th Century, and first two decades of the 21st Century, have witnessed the powered-lift sector of aviation become a hub of innovation. First developed for the military in the 1970s and 1980s, all powered-lift technology remained relegated to the military sphere of aviation through the year 2003. That year saw the first civilian powered lift aircraft, the AW609, take flight.

The year 2020 saw the first powered-lift aircraft employed commercially, while the number of new powered-lift aircraft in development for the civilain market has multiplied 100-fold.

Existing production powered-lift configurations include the vectored thrust, the lift fan, and the tiltrotor.

Vectored Thrust

Thrust vectoring is the ability of a powered-lift to control the direction of the thrust from its engine(s) or motor(s) to control the attitude or angular velocity of the vehicle. For aircraft, the vectored thrust method was originally developed to provide upward vertical thrust as a means to give aircraft vertical (VTOL) or short (STOL) takeoff and landing ability. Subsequently, it was realized that using vectored thrust in combat situations enabled aircraft to perform various maneuvers not available to conventional-engined planes. To perform turns, aircraft that use no thrust vectoring must rely on aerodynamic control surfaces only, such as ailerons or elevator; aircraft with vectoring must still use control surfaces, but to a lesser extent.

No vectored thrust aircraft has been developed for non-military production.

Figure 2-4. *The AV-8B Harrier is a military vectored thrust powered-lift.*

Lift Fan

The Lift Fan is an aircraft propulsion system designed for use in the state of the art STOVL variant of the F-35 Lightning. Intended to replace the vectored thrust AV-8B Harrier II, this powered-lift attains its VSTOL ability by employing lift fan technology.

Instead of using lift engines or rotating nozzles on the engine fan like the Harrier, this powered-lift incoprorates a shaft-driven Lift Fan as well as a thrust vectoring nozzle for the engine exhaust. These two combined subsystems provide lift for a vertical takeoff and landing, and can also withstand the use of afterburners in conventional flight to achieve supersonic speeds.

No lift fan powered-lifts have been developed for non-military production.

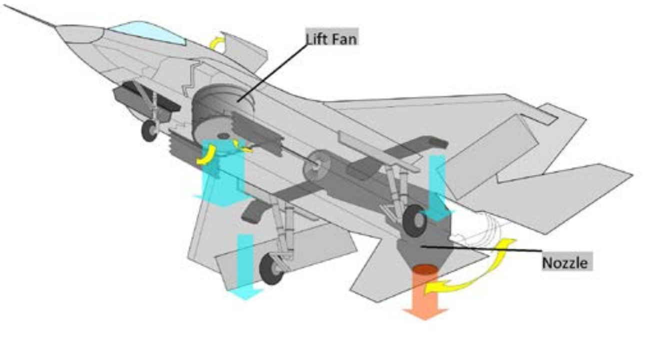


Figure 2-5. *The F-35 is a military lift-fan powered-lift.*

Tiltrotor

The Tiltrotor is an aircraft which uses rotor power for vertical takeoff and landing (VTOL), and converts to fixed-wing lift in normal flight. Like the other powered-lift variants, the tiltrotor was the product of military innovation and necessity

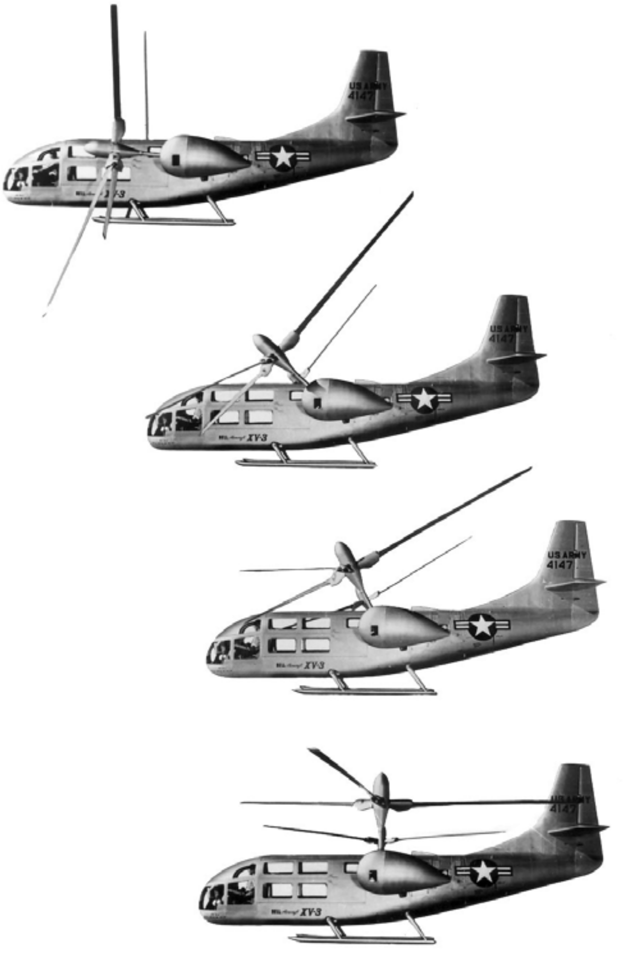


Figure 2-6. *Early Tiltrotor Bell XV-3*

The 1950s through 1970s saw continuous research into various "convertiplane" technologies including tiltwing, fixed pod, and rotating pod designs. The Bell XV-3 made the first successful transition and conversion to/from wingborne light in 1958.

In 1980, the US military suffered a tragic loss while trying to rescue 52 embassy staff members being held hostage in Iran. Due to the location of the embassy and number of people needing evacuation, a large and complex mix of aircraft would be needed inluding several cargo and troop transport helicopters, air tankers to refuel them, and ground support.

Tragically, the mission failed after one of the cargo helicopters air taxied into a refueling aircraft while in heavy brownout conditions, resulting in the loss of 8 service members and 2 aircraft. The realization of the need for a new type of aircraft that could take off and land vertically, carry troops, aerially refuel, and do so at top speed.

Following this tragedy, the US Department of Defense initated the JVX program. The US Navy and Marine Corps were given the lead and combined all the needs from the Navy, Marine Corps, Air Force and Army to set the requirements. The Bell/ Boeing Vertol team was awarded the contract in April 1983.

The JVX aircraft was designated the V-22 Osprey on January 15, 1985. The first prototypes were produced in March 1985, and full scale development commenced in 1986. The work was split between the two companies. Bell Helicopter manufactured the wing, nacelles, proprotors, drive system, tail surfaces, aft ramp, integrated the Rolls-Royce engines, and completed final assembly. Boeing Helicopters manufactured the fuselage, cockpit, avionics and flight controls.

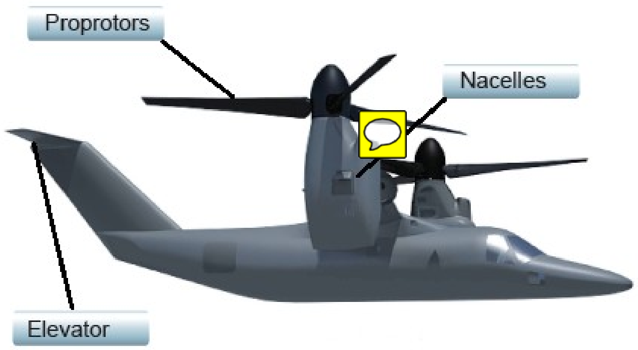


Figure 2-6. *The AW609 is the world's first production civilain tiltrotor. Tiltrotors use proprotors and rotating nacelles to achieve VTOL capability.*

The V-22 Osprey's unique characteristics indisputably had a transformative effect on military aviation operations. The aircraft was first deployed in combat in Iraq in 2007, and has proved itself to be a highly capable and successful military aircraft. The success of the V-22, resulted in the research and development of tiltrotors for non-military use.

The AW609 is the world's first commercial tiltrotor. Like the V-22, the AW609 combines the VTOL capabilities of a helicopter with the speed, range and service ceiling of a turboprop airplane. The AW609 is a twin engine, twin prop-rotor, high wing, T-tail design, with retractable landing gear. With its unique capabilities, the AW609 is ideally suited for many different roles including: Personnel transport, Aeromedical and Oil and Gas Industry (Offshore) Transport, Search and Rescue (SAR), and Parapublic Operations.

Scope

The tiltrotor design is the first and only powered-lift to acheive full production as of the publication of this handbook. As such, the majority of this guidance pertains to flying and operating a tiltrotor.

In developing this guidance, when information is applicable to powered-lift as a category, the term powered-lift will be used. If the information is tiltrotor specific, the term tiltrotor is used. As new and different powered-lift aircraft are developed and produced, this guidance will be revised and expanded.

Modes of Flight

There are two basic flight conditions for a tiltrotor—VTOL/Conversion (CONV) mode and Airplane (APLN) mode.

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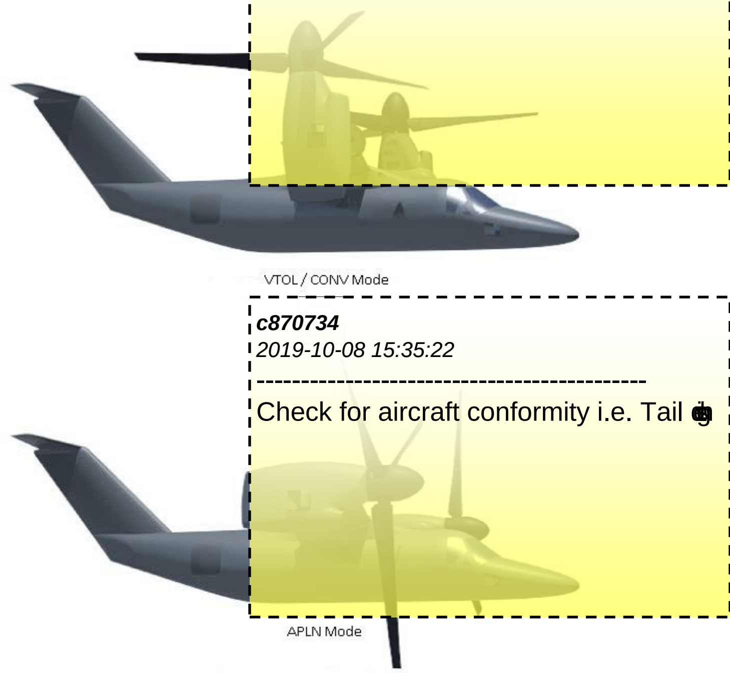

Figure 2-7. *Tiltrotors are capable of VTOL/CONV and APLN modes of flight.*

VTOL/CONV Mode

For hovering operations, the proprotors produce lift, thrust and control moments like that of a conventional helicopter with the aircraft is in VTOL/Conv mode. The nacelles will have a VTOL maneuvering range of approximately 20°, allowing movement both forward and aft of vertical.

In this mode, the proprotors are working much like a classic tandem-rotor helicopter configuration, with collective and cyclic pitch for blade control. With respect to a classic helicopter rotor system, the lateral control is not present.

Pitch variation on the proprotors is obtained with symmetrical pitch control, while yaw is controlled with an anti-symmetrical pitch control and roll attitude is obtained with differential collective pitch on the two proprotors and vertical lift is controlled utilizing parallel collective.

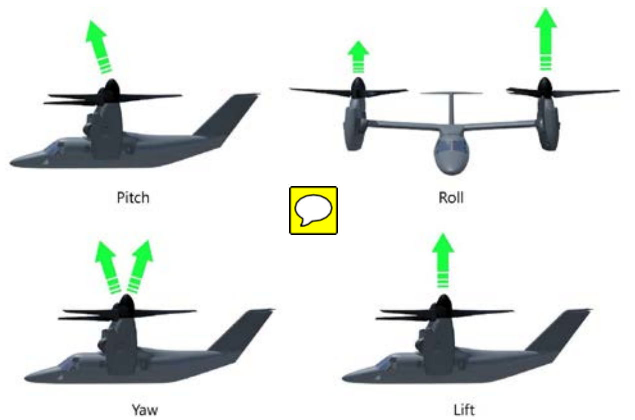

Figure 2-8. *VTOL/CONV Mode control response.*

APLN Mode

In a tiltrotor, APLN Mode is defined as nacelles fully rotated to the horizontal position (0°). While in the APLN mode, lift is fully generated by the wing and flight control movements control the aerodynamic surfaces. Depending on design, yaw is controlled by rudder, differential thrust in the proprotors, or a combination of the two.

Pitch variation is obtained using elevator deflection and the yaw with differential collective-pitch control. Roll attitude is obtained with differential flaperons and symmetrical collective pitch applied to the proprotors adjusts thrust to control airspeed.

The flaperons also act as flaps during the takeoff/landing phase, or to retard a stall at low speed.

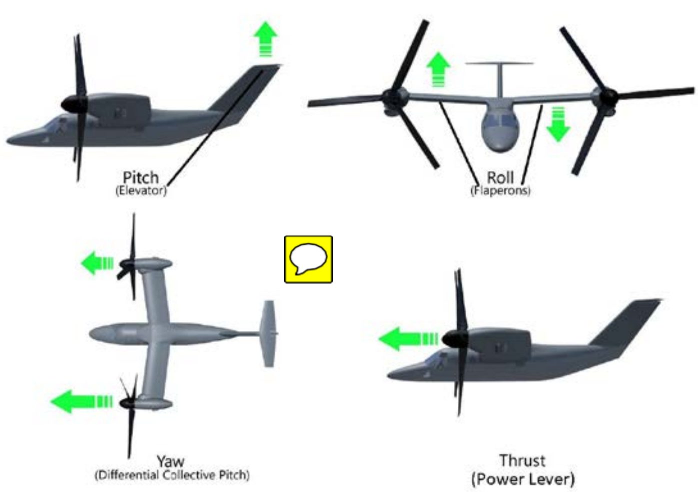

Figure 2-9. *APLN Mode control response.*

Controlling Flight

A tiltrotor has four flight control inputs: center stick, power lever, pedals, and nacelles.

Center Stick

The center stick is usually located between the pilot's legs and is similar to a joystick or helicopter cylic. Movement of the center stick generates aircraft response based on the mode of flight. In VTOL/CONV, the center stick can vary the pitch of the rotor bl[illegible] the main rotor system (i.e. through each cycle of rotation) to develop unequal lift. The result is to tilt the rotor disks in a particular direction resulting in the aircraft moving in that direction. If the pilot pushes the cyclic forward, the rotor disks tilt forward, and the rotor produces a thrust in the forward direction. Depending on aircraft design, lateral cyclic input may or may not be used. If designed with lateral cyclic control, when the pilot pushes the center stick to the side, the rotor disks tilts to that side to produce thrust in that direction, causing the aircraft to hover sideways. In aircraft designed without lateral cyclic control, sideward flight is acheived through differential collective.

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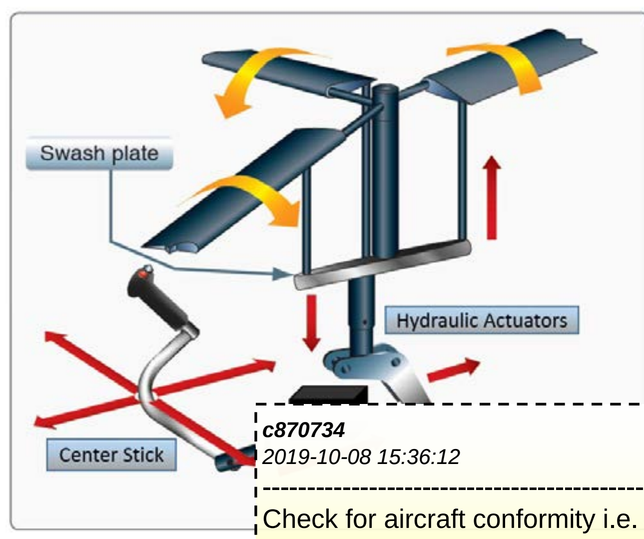

Figure 2-10. *Center stick controls changing the pitch of the rotor blades.*

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In a tiltrotor, collective changes may be made via lateral center stick, power lever, or pedals as determined by the mode of flight. The pitch angle of all the proprotor blades on a given side change collectively (i.e., all at the same time) and independently of their position. Therefore, if a collective input is commanded, all the blades on a respective proprotor change equally, increasing or decreasing total lift or thrust, with the result of the aircraft executing the desired maneuver.

Pedals

The pedals are located in the same position as the rudder pedals in a fixed-wing aircraft, and serve a similar purpose, namely to control the direction in which the nose of the aircraft is pointed. Depending on mode of flight, application of the pedal in a given direction commands differntial longitudinal cyclic (VTOL/CONV) or differential collective or rudder (APLN). In VTOL/COV, differential longitudinal cyclic tilts the proprotor disks in opposite direction, creating a yawing moment. In APLN mode, yaw is created either through the deflection of a tail rudder or by differential collective, which serves to reduce thrust from one proprotor, while increasing the other to create the yaw effect.

Power Lever

Like helicopter blades, proprotors are designed to operate at a specific rpm. The power lever controls the power produced by the engine, by creating a power demand signal to the Flight Control Computers (FCC). When the power lever is raised, the FCC commands more fuel flow to the engines, while simultaneusly telling the hydraulic actuators to drive the swashplates to increase blade pitch, creating more thrust. The FCCs (or in some cases a digital engine controller) maintain balance in the system by commanding enough engine power to keep the rotor rpm at a set speed throughout the range of blade pitch. *[Figure 2-11]*

VTOL/CONV Control Synergy

Despite the complexity of the task, the control inputs in a hover are simple and similar to a tandem helicopter. The center stick is used to eliminate drift, and control aircraft movement forward and back, right and left. The power lever is used to maintain altitude. The pedals are used to control nose direction or heading. The lack of a need for anti-torque makes the interaction of these controls less difficult than a conventional helicopter, since an adjustment in any one control does not necessitate requires an adjustment of the other two.

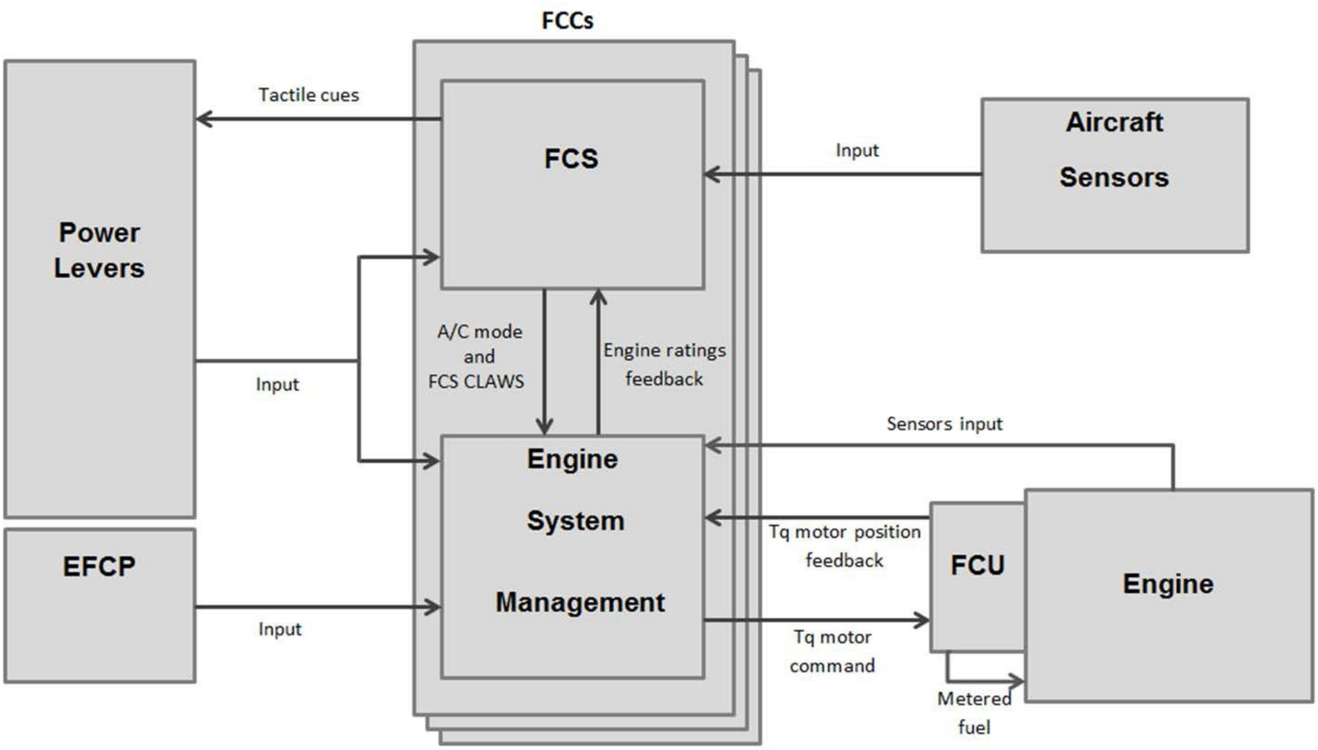

Figure 2-11. *Tiltrotors require automatic digital engine control*

Displacing the center stick forward causes the nose to pitch down, with a resultant increase in airspeed and loss of altitude. Aft center stick causes the nose to pitch up, slowing the aircraft and causing it to climb. In VTOL/CONV, a tiltrotor requires little pitch deflection up or down when the aircraft is stable in a hover. The variation from absolutely level depends on the aircaft's nacelle setting.

Raising the power lever while maintaining a constant airspeed and nacelle setting induces a climb. Lowering the power lever causes a descent. Given a fixed nacelle, coordinating these two inputs, down power lever plus aft center stick or up power lever plus forward center stick, results in airspeed changes while maintaining a constant altitude. The pedals serve the same function as in both a helicopter and a fixed-wing aircraft, to maintain balanced flight. This is done by applying a pedal input in whichever direction is necessary to center the ball in the turn and bank indicator. Flight maneuvers are discussed in greater detail throughout Chapter 10, Basic Flight Maneuvers.

Thrust Control

The common factor uniting all powered-lift is the ability to control thrust. As previously discussed, powered-lift aircraft may be differentiated by the way in which the aircraft produces and controls thrust.

Thrust control in a tiltrotor is accomplished through nacelle rotation. Nacelles are the pod-like structures located near the wingtip of most tiltrotors. The nacelles house the hydraulic conversion actuators and usually multiple transmissions which accept engine torque, reduce its speed, and provide that torque to the proprotor system.

In a tiltrotor, the term “Transition” refers to when the aircraft is accelerating and moving forward (increasing airspeed), from VTOL/Conv mode to APLN mode. The term “Conversion”, refers to when the aircraft is returning to VTOL/Conv mode, from APLN mode (decreasing airspeed and reconfiguring for low-speed flight, hovering, or landing). During the transition/Conversion (between VTOL/Conv and APLN modes, The FCCs automatically mix the different control modes, based on airspeed and nacelle position. This is usually transparent to the pilots.

"Fly-by-Wire"

Powered-lift Flight Control Systems (FCS) generally consist of mechanical cockpit controls, sensors, FCCs and actuators which enable the aircrew to control the aircraft. The FCS is designed to be a triple redundant, “fly-by-wire” system. Mechanical controls are usually limited to the cockpit and under-cockpit floor area. The FCS generates commands to the control actuators by processing signals from cockpit controls and various aircraft data sensors. All flight control actuator commands are computer generated.

The FCCs contain operating software which define the aircraft operating envelope governed by specific flight control laws (FCLAW). FCLAWs are a flight control design approach that integrates handling qualities, performance, and load limiting requirements, into the basic flight control software.

In tiltrotors, the FCLAWs protect critical proprotor, drivetrain, and airframe loading. It allows the pilot to focus on flying tasks without constant monitoring and control of structural loads. FCCs communicate with nearly all aircraft systems and sensors, receiving input signals and sensor data related to the atmospheric condition, flight situation and aircraft status.

In response to pilot command, the FCC’s generate an output signal which is executed by the aircraft hydraulic system which powers the actuators for the proprotor, flaperons, elevator actuators, and the nacelle transition/conversion system.

The FCC’s also generate a feedback signal to the fixed flight control in order to generate an adequate “force-feel” to the controls. The FCC’s also control the engine status and the power delivered.

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rename cyclic to centre stick and to power lever

Figure 2-12. *Example of mechanical, fixed flight controls which communicate pilot control inputs to the FCCs*

Chapter Summary

This chapter gives the reader an overview of the history and types of powered-lift, their many uses, and how it has developed throughout the years. The chapter also introduces basic terms and explanations of tiltrotor components, sections, and the theory behind how the tiltrotor flies.

Chapter 3

Aircraft Components, Sections, and Systems

Introduction

Chapter 2 of this handbook introduced several different powered-lift aircraft currently in use by the United States military. Powered-lift aircraft for civilian use will eventually be comprised of a wide variety of designs and concepts, but at current the only aircraft available are tiltrotors. This chapter discusses the components, sections, and systems found on most tiltrotor aircraft. The chapter introduces the major components/sections of a tiltrotor, and the systems that correlate with each. Knowing how the components and systems work on the aircraft enables the pilot to more easily recognize malfunctions and possible emergency situations. Understanding the relationship of these systems allows the pilot to make an informed decision and take the appropriate corrective action should a problem arise.

Airframe

The airframe, or fundamental structure, of a tiltrotor is primarily made from composite materials, often overlaid over aluminum spars or some combination of the two. Typically, a composite component consists of many layers of fiber-impregnated resins, bonded to form a smooth panel. Tubular and sheet metal substructures are usually made of aluminum, though stainless steel or titanium are sometimes used in areas subject to higher stress or heat. Airframe design encompasses engineering, aerodynamics, materials technology, and manufacturing methods to achieve favorable balances of performance, reliability, and cost. *[Figure 3-1]*

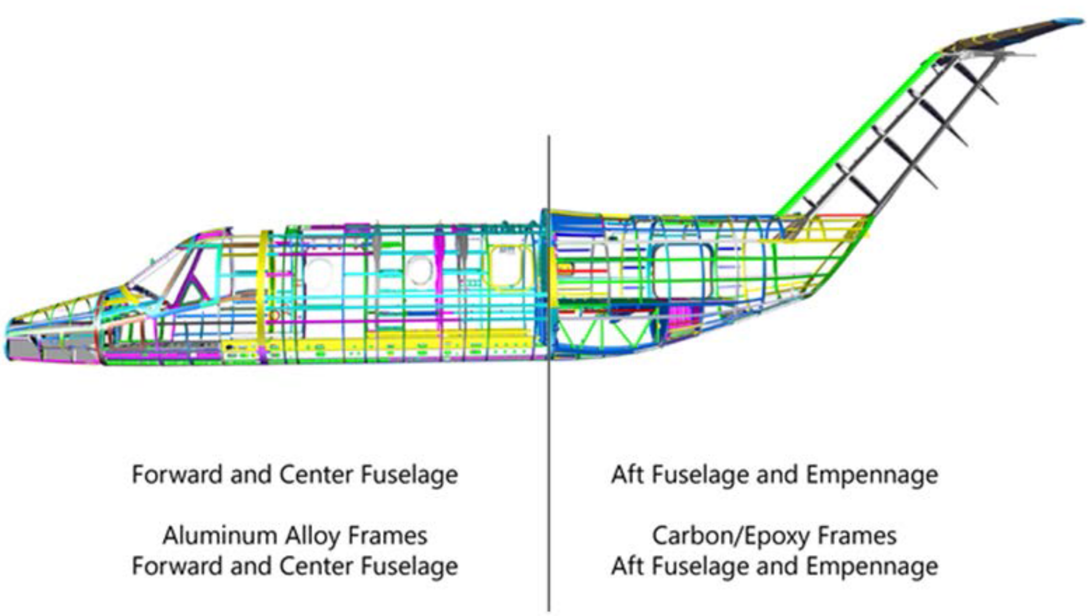


Figure 4-1. *Modern materials such as composites allow for lighter aircraft weights without compromising structural strength and integrity.*

Fuselage

The fuselage, the outer core of the airframe, is an aircraft's main body section that houses the cabin which holds the crew, passengers, and cargo. Aircraft cabins have a variety of seating arrangements. Most have the pilot seated on the right side, although there are some with the pilot seated on the left side or center. In tiltrotors, the fuselage is mated to the wings, and supporrts the transmission, avionics, flight controls, and the powerplant. *[Figure 4-1]*

Proprotor System

The proprotor system consist of two counter-rotating proprotors, which generate lift in VTOL/CONV mode and thrust while in APLN mode. The Proprotor system converts the power generated by the engines through a transmission into lift and thrust force to overcome the weight of the aircraft to achieve flight. Each proprotor consists of a mast, hub, and rotor blades. The mast is a hollow cylindrical metal shaft which extends upwards from and is driven and sometimes supported by the a transmission known as the Proprotor Gear Box (PRGB) . At the top of the mast is the attachment point for the rotor blades called the hub. The proprotor blades are then attached to the hub by any number of different methods. Proprotor systems are generally fully articulated.

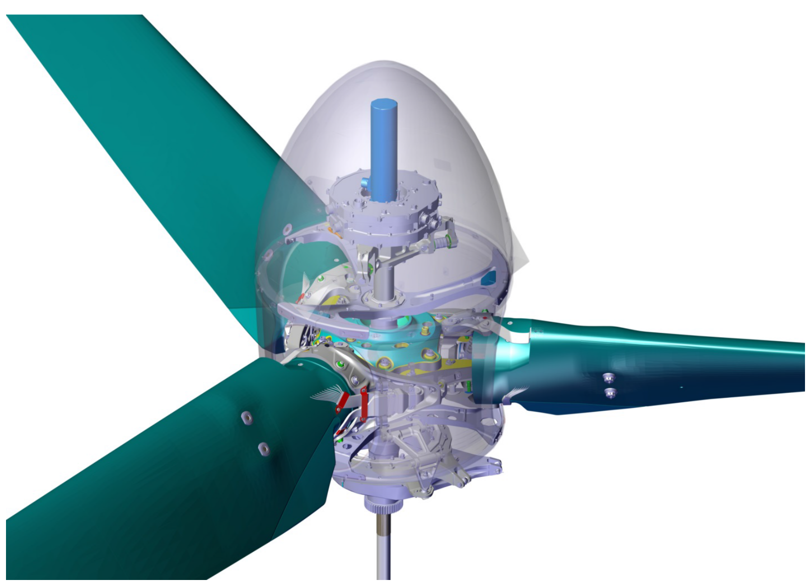


Figure 4-2. *The major components of a the proprotor system include the mast, the hub and the proprotor blades.*

Fountain Flow

A tiltrotor introduces a new airflow when it is in an inside ground effect (IGE) hover. It is called fountain flow and results from the two columns of air being pushed down by the two proprotors. As in any helicopter, the vertical column of air moves downward until it strikes the ground and then moves outward (while in ground effect). Along the centerline of the aircraft, especially forward and aft of the wing, the two columns move outward from the nacelle but inward toward the fuselage and then meet each other and turn vertical. This creates a fountain or upward flow around the fuselage that will buffet and shake it.

Figure X.X

The closer to the ground, the worse the effect. Because of this, tilt-rotor aircraft hover is the most stable when it is at least 20 feet above the ground. The best technique for transitioning through the turbulent altitudes below 20 feet is to continuously move vertically.

This means that to take off smoothly, the pilot should maintain a positive rate of climb right up to 20 feet. Do not stop anywhere along the climb. Conversely, to land from a 20 feet hover, the pilot should maintain a constant descent all the way to the ground. Try not to stop at any lower height above the ground. This means a constant, smooth power reduction all the way down to the ground because of course like any helicopter, reducing power a little bit only causes a small decrease in altitude above the ground as ground effect will stop a descent. Maintaining a constant rate of power reduction will prevent any stopping on the way down. As long as the aircraft does not stop moving vertically, the buffeting and shaking will not occur, either on takeoff or on landing.

The fountain flow may cause another effect on a tiltrotor depending on the design of the horizontal elevator. On the V-22, which has an H-tail, as the aircraft transitions forward for takeoff, the fountain flow will strike the horizontal elevator from below and cause a nose-down pitch moment. Conversely, because the AW609 has a T-tail which is significantly higher, it does not have this same characteristic.

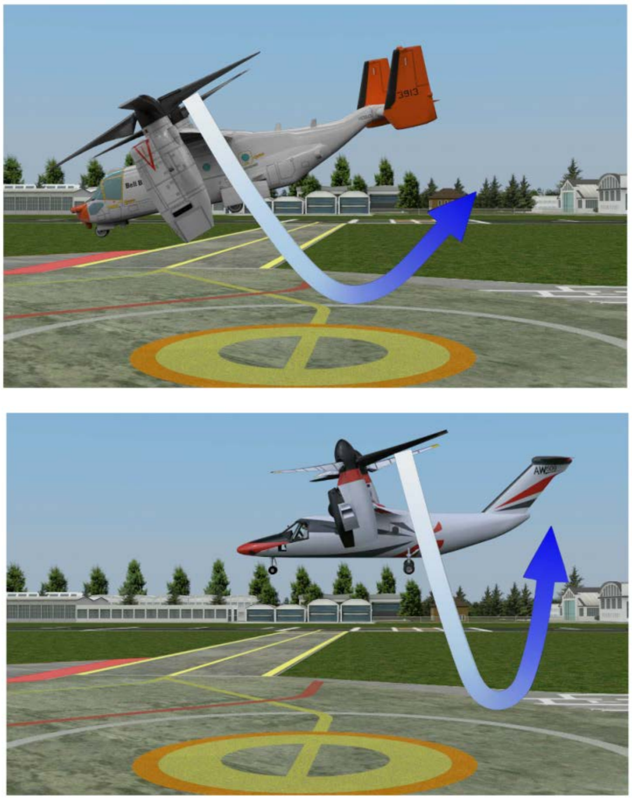


Figure X.X

Lateral Darting

In a low hover condition, the interaction between the airframe and the rotor downwash due to the ground plane may cause the aircraft to shuffle laterally with the wings level.

The downwash reflected by the ground causes a transient lateral side force phenomenon called lateral darting.

These lateral nudges appear randomly below 15 feet.

As a result, while hovering below 15 feet, small lateral inputs will be needed to prevent drift.

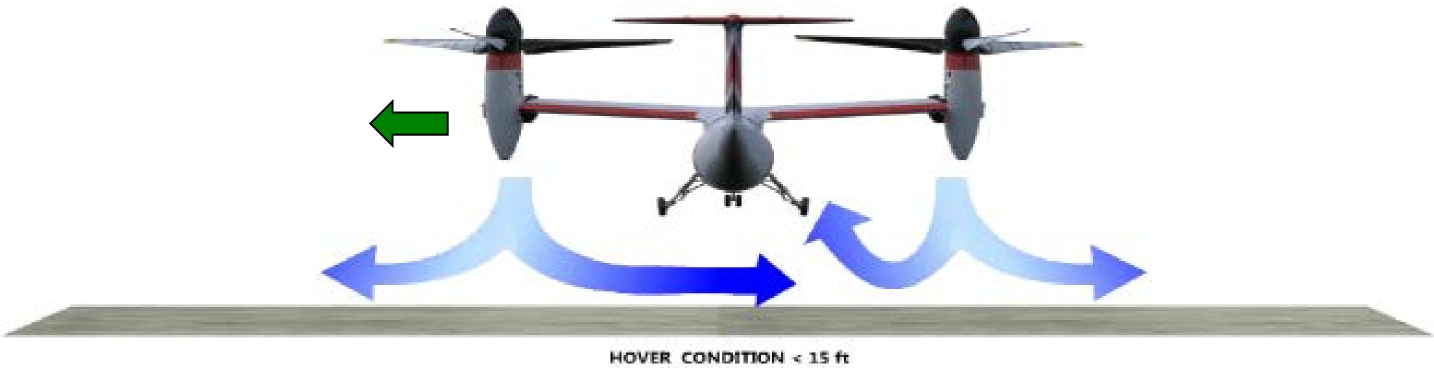


Figure X.X

Pitch-up with Sideslip

There is a downwash from the proprotor system which can be blown toward the empennage when the aircraft is slow and in a crosswind. In the V-22 with its H-tail, the downwash can be blown to where it is striking the upper surface of the horizontal elevator which causes a nose-up pitching moment. The flight control system, which is trying to maintain a particular attitude, will apply forward longitudinal control to compensate, without any pilot input or awareness.

This can happen on the AW609 but is appears to require a very specific set of circumstances because the T-tail is higher, actually about the same height as the proprotor system when hovering or in very slow flight. If the aircraft is in a descent, flying very slowly and the crosswind is a front-quartering crosswind, i.e. from a 45 or 315º azimuth off the nose, it appears possible that the downwash can be blown over the T-tail and an un-commanded pitch-up can occur.

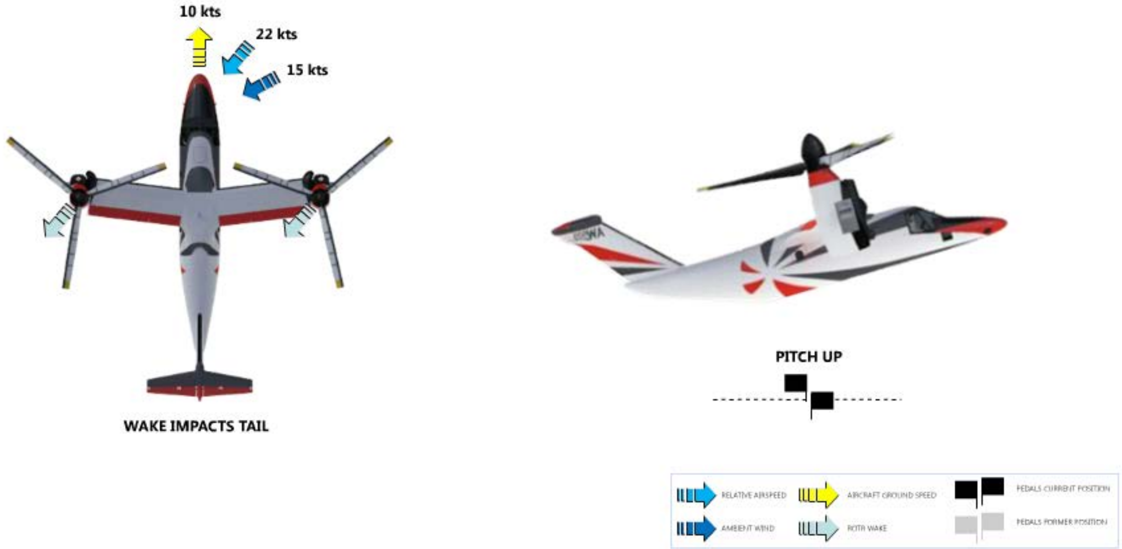


Figure X.X

The instinctive recovery technique for this is to apply forward stick, but forward nacelle works slightly better because the airflow is re-directed and eliminates the cause of the pitch-up. It is important to remember that the aircraft must be in a descent for this to happen. That means it could happen during an approach to a hover or approach to a no-hover landing. The fact that the aircraft must be at a slow forward speed means that it is likely that the aircraft is in the final stage of the approach and therefore, very near the ground. When executing an approach to a hover with a forward-quartering crosswind, the pilot should be aware of this possibility and prepared to move the nacelles forward if necessary or turn the aircraft into the prevailing wind if able []Figure]

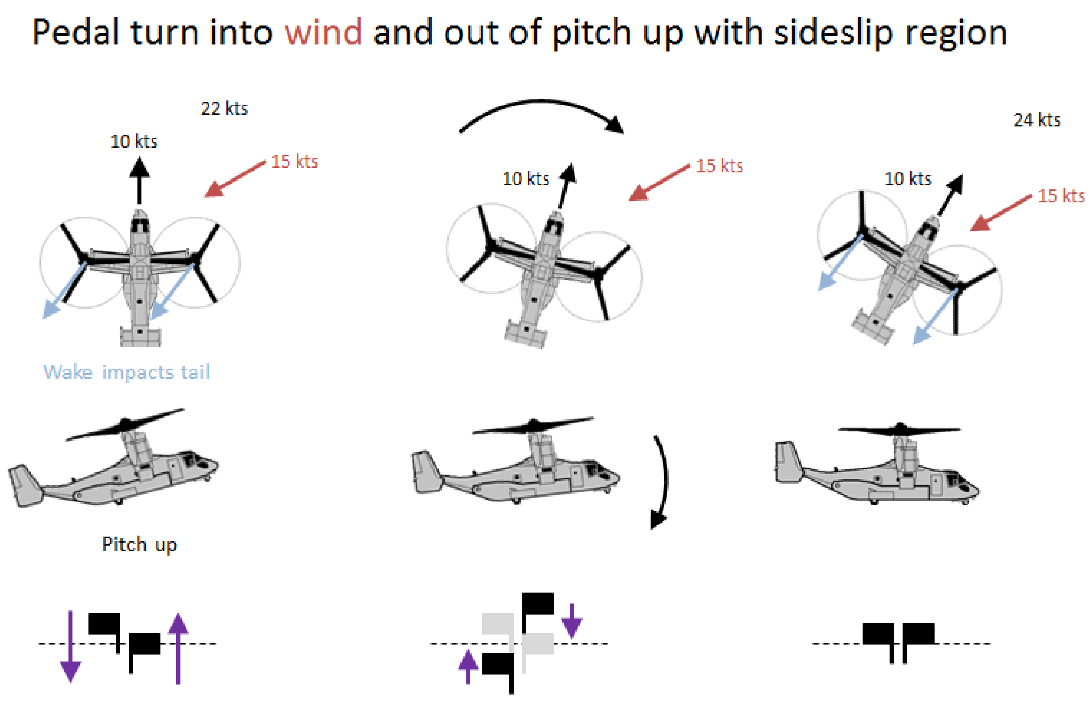


Figure X.X. *Recovery Pedal into Wind.*

Loss of Lift when Coming into a Hover

When the wind is very calm and the aircraft is being flown to either a hover or a no-hover landing at zero airspeed, the aircraft will exhibit a reduction in lift as it transitions below 8 knots airspeed. This reduction in lift is actually an increase in vertical drag as the proprotor downwash begins to flow directly on to the upper surface of the wing. An increase in power will stop the sink rate and stabilize the vertical speed, but it can occur near the ground during a no-hover landing so pilots should be aware and ready to apply power when landing in very calm winds.

Blowback on the Proprotor System during Sideslip (Cruise Configuration)

When the aircraft is in cruise configuration, the rotor systems still have the ability to flap in the same way as a helicopter rotor system (although they are limited to a smaller angle by the Control Power Management System (CPMS) . If a sideslip is put on the aircraft, the resulting airflow has the effect of causing proprotor flapping through blowback, the same term that we use for static stability in a helicopter in forward flight.

This blowback occurs as the sideslip component of the airflow comes across the proprotor introducing a component velocity of a horizontal flow at right angles to the nose of the aircraft. In the case of a right sideslip (nose left), as the blade moves across the topmost portion of its travel (it is similar to the advancing blade but is directly above the nacelle), it experiences an increase in velocity and hence an increase in lift (thrust) which causes it to flap forward (as a helicopter blade would flap upward) about 90 degrees later, or when level with the wing. As it travels across the bottom portion of its path, it experiences a decrease in velocity which causes a reduction in lift (thrust) which causes it to flap aft (down in a helicopter). This is blowback turned from a horizontal helicopter rotor system to a vertical airplane one. The effect here though is just the opposite. Instead of being a stabilizing influence (as in a helicopter maintaining airspeed), it is a de-stabilizing effect, causing the aircraft to yaw more and create more sideslip.

Pictured from above, if the aircraft were yawed to the left and had a right sideslip angle, the right-hand proprotor system would be flapping forward when it is outside of the wing and flapping aft when it is directly in front of the wing. The left-hand proprotor system would be flapping the same way, but now the blade directly in front of the wing is flapping forward and the outside blade is flapping aft. Both rotor systems are flapping in such a way that they change the angle of the thrust vector to the left of the nose and thus increase the sideslip angle.

This phenomenon was present in the AW609, however, recent changes to the “toe-in” angle of the proprotor systems have effectively reduced this characteristic to almost nothing.

Swirl

When the aircraft is in airplane mode, a roll input will cause a differential aileron/flaperon position, one aileron/flaperon travelling slightly upward and one travelling slightly down. The downward displaced flaperon has a low pressure area behind it and the upward displaced aileron/flaperon has a higher pressure area behind it. Because the ailerons/flaperons are full span, and also because the aircraft has a high-wing configuration, the airflow from the higher pressure area will travel across the top of the empennage to the lower pressure area as it travels aft. This has the effect of creating a faster flow as the airstream passes the vertical stabilizer on the downward control surfaceside and at high enough airspeeds will create a yawing moment. This yawing moment is countered by the vertical fin and the flight control system and so typically does not create sideslip.

Yoke Bending

In a tiltrotor, the yoke, made of a layered composite, flexes just like in some helicopters. And, just like a helicopter, when in VTOL mode the yoke flexes upward in a way that creates or allows some coning of the rotor system. However, when the aircraft is in airplane mode, it can flex both forward (comparable to upward) and aft (comparable to downward). When thrust is applied to the rotor system, the yoke is bending forward as the proprotor system is 'pulling' the aircraft through the air. However, when power is removed, such as an all-engines-inoperative condition, the yoke is bending aft, toward the wing as the blades are wind milling through the air. It will also flex aft when the power is reduced to minimum, and at high speed, the yoke bending can be large. It is important when doing high-speed dive recoveries not to reduce the power to minimum in order to slow down, but instead to add positive g loading and reduce the power only slightly.

High Flapping Angles with Rapid Power Application at High Nacelle Angles

When the aircraft is at 75º nacelle or greater with forward speed approximately 50 knots or faster, with the power nearly at the minimum for a descent, it is possible to cause the proprotor systems to flap to very high angles by making a large amplitude power input rapidly. The cause of this is the basic advancing and retreating blade concept as in a helicopter where the advancing blade has a higher tip speed than a retreating blade and hence the large increase in blade pitch leads to a large increase in lift. The retreating blade has a slower tip speed and so the sudden increase in blade pitch leads to a much lower increase in lift, remembering that velocity is squared in the lift equation. The large, and more importantly sudden, difference in lift leads to large flapping angles that the flight control system does not react to quickly enough. Pilots should apply power smoothly and at a moderate rate when transitioning from a descent to a climb at high nacelle angles.

Transitioning from VTOL to High-Speed Cruise and High-Speed Cruise to VTOL

When transitioning from VTOL to high-speed cruise mode the nacelles are travelling forward and the thrust vector is tilting forward. As the thrust vector tilts forward, the vertical component of that vector is shrinking or reducing. This happens in a helicopter too of course, but in a tiltrotor it is of greater magnitude because of the range of motion of the nacelles. Power must be applied to increase the overall vector so that the resultant vertical component will continue to provide sufficient lift to the aircraft. The wing is not going to provide lift until late in the transition process. Without a significant power application, the aircraft will descend during the transition. The vectors are shown in Figure 1.

Conversely, when the aircraft is converting from high-speed cruise to VTOL mode, an opposite effect occurs. As the rotor system is tilting upward, the vertical component of the thrust vector is increasing (from zero) and it is adding lift. However, the aircraft is still flying on the wing, so there is still significant wing-borne lift. Anytime the aircraft is transitioning from high-speed cruise to VTOL, initially the power must be reduced so that the increasing vertical component of the thrust vector does not cause an undesired climb.

Figure X.X. *Power needs to be applied to make up for the forward tilt of the thrust vector when the aircraft is not yet creating wing-borne lift.*

As the aircraft transitions from rotor-borne flight to wing-borne flight, the wing can begin to create lift just above the stall speed. But typically, the wing is not creating any lift yet because when flying in VTOL mode, even 50º nacelle, the aircraft is usually maintained somewhere near zero degrees of pitch attitude, and so the angle of attack on the wing is near zero. For the wing to begin creating lift, it must be loaded up, and at that slow airspeed, significant angle of attack must be applied. As the aircraft passes from 90 to 120 knots or so, the pitch attitude is increased in order to increase the wing's angle of attack. As the aircraft continues to accelerate, the pitch attitude must be decreased in order to maintain the same lift vector with the increases in velocity as with any fixed-wing aircraft.

On the AW609, pitch attitude will go from near zero (this actually depends on whether the aircraft is in a climb or level flight) to plus five degrees at 120 knots and eventually, about 200 knots, down to about 1-2º, as shown below in Figure 2.

Figure X.X. *Pitch attitude at 50 nacelle is near zero, then at slow speed the wing must be loaded up to create enough lift. Finally, at high speed, the pitch attitude is coming back down again.*

In a tiltrotor, any transition of the nacelles is also a shift in center of gravity (CG). As the nacelles go forward, the CG moves forward and vice versa. The good news is that if the aircraft is in CG limits in VTOL mode, it will be in CG limits in APLN mode. This is because the CG range shifts also. This CG shift does affect pitch attitude though and has to be compensated for by the flight control system and the pilot. Transitioning to high-speed cruise means a forward shift in cg so that the center stick must move aft to maintain a constant pitch attitude. When the nacelles are in motion, moving forward or aft, there is a pitching moment created on the fuselage, the effect of opposite and equal reaction. If the nacelles are going from VTOL to APLN mode, there is a nose-up pitching moment, and a pitch-down moment for the opposite nacelle motion. In the AW609 this pitch moment is countered by longitudinal control inputs from the Flight Control Computers (FCCs), inputs that are transparent to the pilot, through center stick movement.

When the aircraft is transitioning to APLN mode, so forward of 75º nacelle, differential longitudinal flapping is created when the aircraft has a roll rate (note: not a bank angle, but a rolling motion). The longitudinal flapping is created aerodynamically as a result of the motion of the aircraft. This peaks at about 60º nacelle angle. At VTOL nacelle angles such as 60º, this flapping occurs as a result of the rolling motion of the aircraft changing the induced flow into the rotor systems. Consider the aircraft rolling to its left. The left rotor system is moving downward which increases the angle of attack on the blades equally all around. But there is still an advancing blade and a retreating blade (because the aircraft is in forward flight in VTOL mode), so the advancing blade sees a greater increase in lift as it is outboard of and parallel to the wing. This increase in lift causes it to reach its peak flapping angle 90º later which makes it a longitudinal flapping motion. In this case, the left rotor system will tilt back, as if aft stick had been applied.

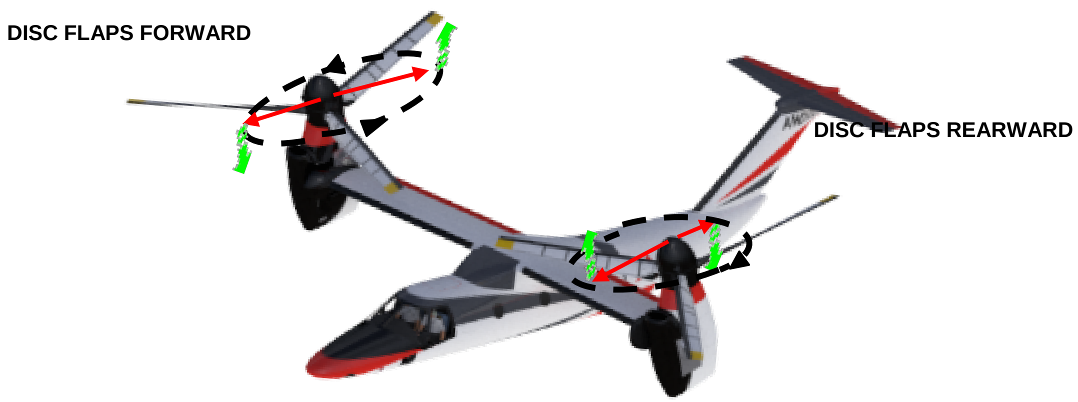


Figure X.X

Consider the same left roll in APLN mode. As the aircraft is rolling left, the blade travelling upward on the right side rotor system experiences a slight increase in velocity. That increase in velocity causes an increase in "lift" which causes it to reach its peak flapping angle 90º later. This flapping motion is now longitudinal flapping motion, this time flapping forward at the top of the rotor disk, as if *forward* longitudinal center stick had been applied (even though it can't be in high-speed cruise mode). On the opposite (left in this case) side, the effect is reversed. The downward travelling blade experiences a slight increase in velocity which causes an increase in lift. The downward travelling blade is outboard of the wing and so it reaches its peak flapping angle as it passes the bottom of the rotor disk. So it flaps forward at the bottom of the disk as if *aft* longitudinal center stick had been applied.

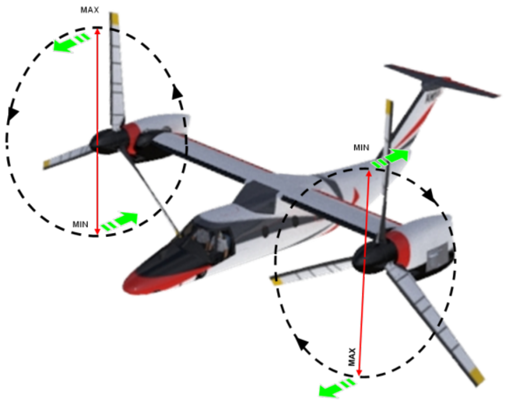


Figure X.X

The two tiltrotors operating today, the V-22 and the AW609, have automatic flaps. The flaps are scheduled with airspeed and it is all very transparent to the pilot. However, you may notice that in VTOL mode at very low airspeeds, the flaps appear to be nearly vertical when they are in their full down position. This is not done to create wing lift down to very slow speeds. This is done to reduce the wing's horizontal surface area on which the rotor downwash impinges on the aircraft creating a vertical form of drag that is opposing lift.

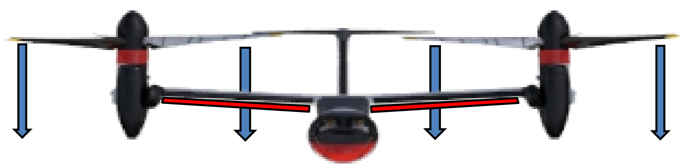


Figure X.X

Vortex Ring State

Vortex ring state describes an aerodynamic condition in which a helicopter may be in a vertical descent with 20% up to maximum power applied, and little or no climb performance. The term "settling with power" comes from the fact that the helicopter keeps settling even though full engine power is applied. In a normal outside-ground-effect (OGE) hover, the helicopter is able to remain stationary by propelling a large mass of air down through the main rotor. Some of the air is recirculated near the tips of the blades, curling up from the bottom of the rotor system and rejoining the air entering the rotor from the top.

This phenomenon is common to all airfoils and is known as tip vortices. Tip vortices generate drag and degrade airfoil efficiency. As long as the tip vortices are small, their only effect is a small loss in rotor efficiency. However, when the helicopter begins to descend vertically, it settles into its own downwash, which greatly enlarges the tip vortices. In this vortex ring state (VRS), most of the power developed by the engine is wasted in circulating the air in a doughnut pattern around the rotor.

In addition, the helicopter may descend at a rate that exceeds the normal downward induced-flow rate of the inner blade sections. As a result, the airflow of the inner blade sections is upward relative to the disk. This produces a secondary vortex ring in addition to the normal tip vortices. The secondary vortex ring is generated about the point on the blade where the airflow changes from up to down. The result is an unsteady turbulent flow over a large area of the disk. Rotor efficiency is lost even though power is still being supplied from the engine.

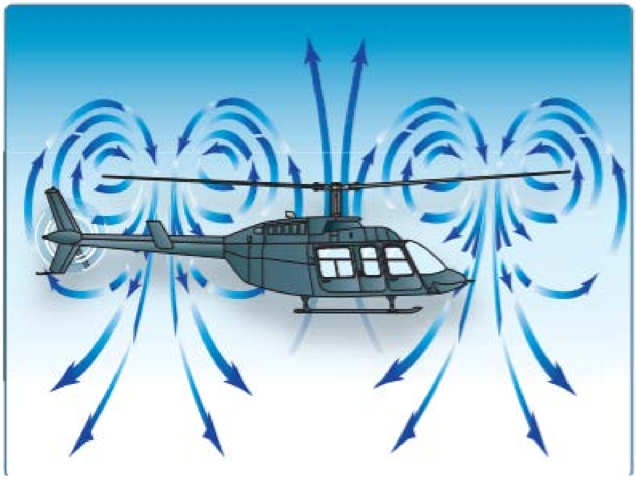


Figure X.X

A fully developed VRS is characterized by an unstable condition in which the helicopter experiences uncommanded pitch and roll oscillations, has little or no collective authority, and achieves a descent rate that may approach 6,000 feet per minute (fpm) if allowed to develop. A VRS may be entered during any maneuver that places the main rotor in a condition of descending in a column of disturbed air and low forward airspeed. Airspeeds that are below translational lift airspeeds are within this region of susceptibility to settling with power aerodynamics. This condition is sometimes seen during quick-stop type maneuvers or during recovery from autorotation.

The following combination of conditions is likely to cause settling in a VRS in any helicopter:

1. A vertical or nearly vertical descent of at least 300 fpm. (Actual critical rate depends on the gross weight, rpm, density altitude, and other pertinent factors.)
2. The rotor system must be using some of the available engine power (20–100%).
3. The horizontal velocity must be slower than effective translational lift.

Figure X.X

Some of the situations that are conducive to a VRS condition are: any OGE hover, specifically attempting an OGE hover at altitudes above the hovering ceiling of the helicopter, attempting an OGE hover without maintaining precise altitude control, pinnacle or rooftop helipads when the wind is not aligned with the landing direction, and downwind and steep power approaches in which airspeed is permitted to drop below 10 knots depending on the type of helicopter.

Tiltrotor Vortex Ring State

VRS in a tiltrotor is always going to occur on only one rotor system. This is a result of the lateral control laws of fly-by-wire tiltrotor control systems. If the aircraft has a high rate of descent with very low airspeed (typically the same conditions as for entering VRS in a helicopter), the control system will try to maintain a wings-level attitude (assuming that is what the pilot is commanding, i.e. the stick is centered). As the two rotor systems begin to experience the initial stages of VRS, small perturbations about the roll axis will occur. The flight control system will make lateral control inputs to counter these perturbations and, if other conditions are right, eventually, one of the lateral control inputs will be large enough to cause the onset of VRS.

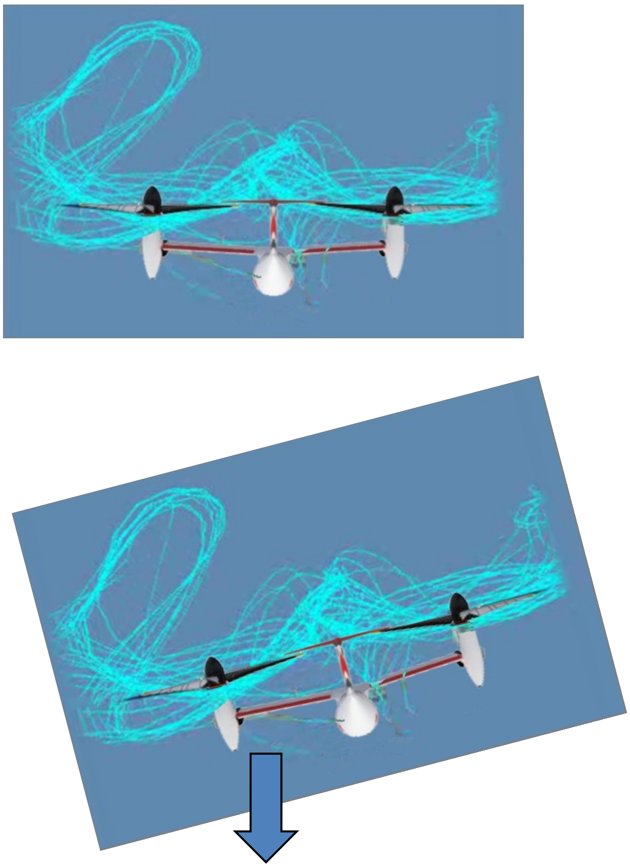


Figure X.X

That is because the lateral control inputs are increases in collective pitch on one side and decreases on the other. The increase in collective pitch aggravates the VRS onset and the decrease will delay the onset. That is why only one rotor system will enter VRS and this means that VRS is going to cause an un-commanded roll of the aircraft.

In AW609 flight test, it was found to be recoverable by simply rotating the nacelles forward. Typically, to be slow enough to get to VRS, the nacelles are about 87º. Simply holding the nacelle control forward will drive them to 75 º and recover the aircraft to level flight. Any other control inputs, such as lateral control or power inputs will only aggravate the situation and should be avoided. Since the AW609 lateral control uses only differential collective pitch in VTOL mode, it has an earlier onset than the V-22 which uses a combination of lateral center stick pitch and differential collective pitch.

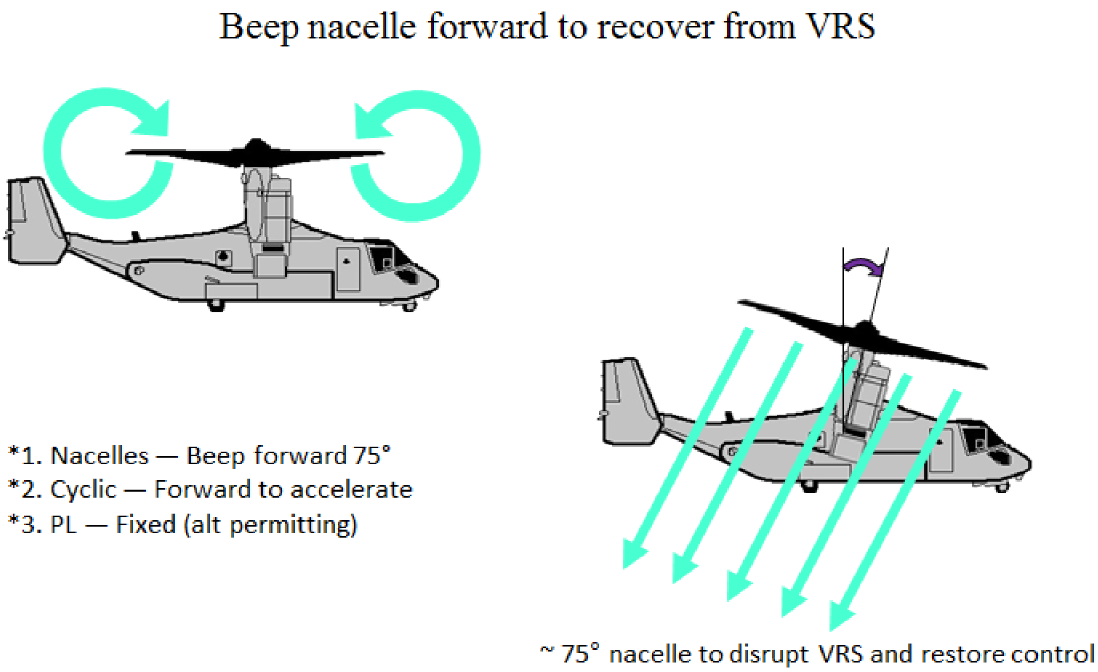


Figure X.X. *Recovery from VRS.*

Stall

Wing stall is influenced by blades passing by the leading edge. The proprotors rotate such that they are going upward as they pass the wing. This has the effect of increasing the angle of attack (AoA) on the wing. Also, the proprotor blade passing the wing is nearly the full span of the wing and so it influences the full wingspan. There is a pronounced buffet prior to the actual wing stall. Additionally, the counter-rotating proprotor systems lead to a very benign stall for the aircraft. No roll rate develops in the stall of a tiltrotor because of this. Recovery is no different than that of a fixed-wing aircraft.

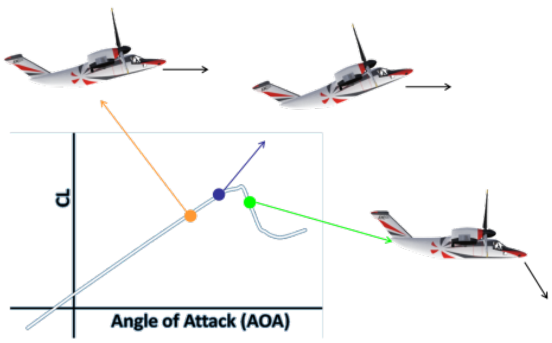


Figure X.X

In the AW609, although flying near V_{MIN} at 50 degrees nacelle angle is not called a "stall," it is possible to stall the aircraft when the power is reduced too much. The aircraft exhibits stall characteristics and it is an actual wing stall. This is a condition where the aircraft is in a descent and flying below the wing stall speed. Above the wing stall speed, the aircraft lift is both wing-borne and rotor-borne. However, below stall speed, it is only rotor-borne. In level flight below stall speed, the AoA is small and nowhere near the stall AoA, so there is no wing buffet. If the power is reduced for a high rate of descent, the wing will begin to exhibit stall characteristics because of the change in AoA. At 90 knots (V_{MIN} for 50 degrees nacelle) in level flight, there are no stall characteristics. However, in a descent at 90 knots where the AoA is greater because of the flight path angle, the wing is stalled, and will exhibit a standard stalled wing buffet.

Figure X.X

Aircraft Shake

Vortices trailing over the elevator on the AW609 will occur under certain conditions and it feels like an airplane stall even though the aircraft is not in high-speed cruise mode. This occurs when the nacelles are somewhere near vertical and the airspeed is about 40 knots and the aircraft is flying in level flight. For it to occur, it has to be the right combination of nacelle angle and pitch attitude. What is happening is that the vortices from the rotor systems' inboard portion of the rotor arc are passing over the elevator and causing the vibration. It is not a condition the AW609 flies in very often.

Figure X.X

Chapter 5

Rotorcraft Flight Manual

Introduction

Title 14 of the Code of Federal Regulations (14 CFR) part 91 requires pilot compliance with the operating limitations specified in approved rotorcraft manuals, markings, and placards. Originally, flight manuals were often characterized by a lack of essential information and followed whatever format and content the manufacturer deemed appropriate. This changed with the acceptance of the General Aviation Manufacturers Association (GAMA) specification for a Pilot's Operating Handbook, which established a standardized format for all general aviation airplane and rotorcraft flight manuals. Additionally, the FAA has provided, through varios Advisory Circulars, explicit guidance on the requirements of flight manuals. In some aircraft, the term "Pilot's Operating Handbook (POH)" may be used in place of "Rotorcraft Flight Manual (RFM)."

However, if "Pilot's Operating Handbook" is used as the main title instead of "Rotorcraft Flight Manual," a statement must be included on the title page indicating that the document is the Federal Aviation Administration (FAA) approved Rotorcraft Flight Manual (RFM). *[Figure 5-1]*

Figure 5-1. *The RFM is a regulatory document in terms of the maneuvers, procedures, and operating limitations described therein.*

Not including the preliminary pages, an FAA-approved RFM may contain as many as ten sections. These sections are: General Information; Operating Limitations; Emergency Procedures; Normal Procedures; Performance; Weight and Balance; Aircraft and Systems Description; Handling, Servicing, and Maintenance Supplements; and Safety and Operational Tips. Manufacturers have the option of including a tenth section on safety and operational tips and an alphabetical index at the end of the handbook.

Preliminary Pages

While RFMs may appear similar for the same make and model of aircraft, each flight manual is unique since it contains specific information about a particular aircraft, such as the equipment installed, and weight and balance information. Therefore, manufacturers are required to include the serial number and registration on the title page to identify the aircraft to which the flight manual belongs. If a flight manual does not indicate a specific aircraft registration and serial number, it is limited to general study purposes only.

Most manufacturers include a table of contents, which identifies the order of the entire manual by section number and title. Usually, each section also contains its own table of contents. Page numbers reflect the section being read, 1-1, 2-1, 3-1, and so on. If the flight manual is published in looseleaf form, each section is usually marked with a divider tab indicating the section number or title, or both. The emergency procedures section may have a red tab for quick identification and reference.

General Information (Section 1)

The general information section provides the basic descriptive information on the rotorcraft and the powerplant. In some manuals there is a three-view drawing of the rotorcraft that provides the dimensions of various components, including the overall length and width, and the diameter of the proprotors. This is a good place for pilots to quickly familiarize themselves with the aircraft. Pilots need to be aware of the dimensions of the aircraft since they often must decide the suitability of an operations area for themselves, as well as hanger space, landing pad, and ground handling needs.
Pilots can find definitions, abbreviations, explanations of symbology, and some of the terminology used in the manual at the end of this section. At the option of the manufacturer, metric and other conversion tables may also be included.

Operating Limitations (Section 2)

The operating limitations section contains only those limitations required by regulation or that are necessary for the safe operation of the rotorcraft, powerplant, systems, and equipment. It includes operating limitations, instrument markings, color coding, and basic placards. Some of the areas included are: airspeed, altitude, proprotor, and powerplant limitations, including fuel and oil requirements; weight and loading distribution; and flight limitations.

Instrument Markings

Instrument markings may include, but are not limited to, green, red, and yellow ranges for the safe operation of the aircraft. The green marking indicates a range of continuous operation. The red range indicates the maximum or minimum operation allowed while the yellow range indicates a caution or transition area.

Airspeed Limitations

Airspeed limitations are shown on the airspeed indicator or flight display by color coding or on placards or graphs in the aircraft. A red line on the airspeed indicator shows the airspeed limit beyond which structural damage could occur. This is called the never exceed speed, or V_{NE}. The normal operating speed range is depicted in green or by a green arc. A blue line is sometimes added to show the maximum safe autorotation speed. *[Figure 5-2]*

Another restriction on maximum airspeed for level flight with maximum continuous power (V_H) may be the availability of power. An increase in power required due to an increase in weight, or by G producing maneuvers, may decrease V_H. A decrease in power available caused by increased density altitude or by weak or faulty engines also decreases V_H.

Altitude Limitations

If the aircraft has a maximum operating density altitude, it is indicated in this section of the flight manual. Sometimes the maximum altitude varies based on different gross weights.

Proprotor Limitations

Low rotor revolutions per minute (rpm) does not produce sufficient lift, and high rpm may cause structural damage, therefore rotor rpm limitations have minimum and maximum values.

There are two different rotor rpm limitations: power-on and power-off. Power-on limitations apply anytime the engine is turning the rotor and is depicted by a fairly narrow rpm range. A yellow or amber color may be included to show a transition range, which means that operation within this range is limited due to the possibility of increased vibrations or harmonics. This range may be associated with changing RPMs between VTOL/CONV and APLN . Power-off limitations apply anytime the engine is not turning the rotor, such as when in an autorotation. In this case, the green operating range is greater than the power-on arc, indicating a larger opereatweating range.

Powerplant Limitations

The powerplant limitations area describes operating limitations on the aircraft's engines including such items as rpm range, power limitations, operating temperatures, and fuel and oil requirements. Most turbine engines and some reciprocating engines have a maximum power and a maximum continuous power rating. The "maximum power" rating is the maximum power the engines can generate and is usually limited by time. The maximum power range is depicted by yellow or amber on the engine power instruments, with a red indicating the maximum power that must not be exceeded. "Maximum continuous power" is the maximum power an engine can generate continually.

Press Alt. (1,000 ft.)	V_{NE}—MPH IAS							Gross Weight
F OAT	**8**	**4**	**6**	**8**	**10**	**12**	**14**	
0	109	109	105	84	61	--	--	More than 1,700 lb
20	109	109	94	72	49	--	--	
40	109	103	81	59	--	--	--	
60	109	91	70	48	--	--	--	
80	109	80	59	--	--	--	--	
100	109	70	48	--	--	--	--	
0	**109**	**109**	**109**	**109**	**98**	**77**	**58**	1,700 lb or less
20	**109**	**109**	**109**	**109**	**85**	**67**	**48**	
40	**109**	**109**	**109**	**96**	**75**	**57**	**--**	
60	**109**	**109**	**108**	**84**	**66**	**48**	**--**	
80	**109**	**109**	**95**	**74**	**57**	**--**	**--**	
100	**109**	**108**	**84**	**66**	**48**	**--**	**--**	

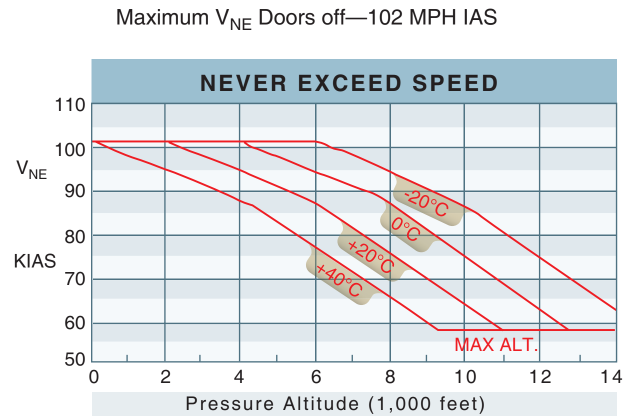


Figure 5-6. *Various V_{NE} placards.*

Weight and Loading Distribution

The weight and loading distribution area contains the maximum certificated weights, as well as the center of gravity (CG) range. The location of the reference datum used in balance computations should also be included in this section. Weight and balance computations are not provided here, but rather in the weight and balance section of the FAA-approved RFM.

Flight Limitations

This area lists any maneuvers which are prohibited, such as acrobatic flight or flight into known icing conditions. If the aircraft can only be flown in visual flight rules (VFR) conditions, it is noted in this area. Also included are the minimum crew requirements, and the pilot seat location, if applicable, where solo flights must be conducted.

Placards

All rotorcraft generally have one or more placards displayed that have a direct and important bearing on the safe operation of the rotorcraft. These placards are located in a conspicuous place within the cabin and normally appear in the limitations section. Since V_{NE} changes with altitude, this placard can be found in all helicopters. *[Figure 5-6]*

Emergency Procedures (Section 3)

Concise checklists describing the recommended procedures and airspeeds for coping with various types of emergencies or critical situations can be found in this section. Some of the emergencies covered include: engine failure in a hover and at altitude, fires, and systems failures. The procedures for restarting an engine and for ditching in the water might also be included.

Manufacturers may first show the emergencies checklists in an abbreviated form with the order of items reflecting the sequence of action. This is followed by amplified checklists providing additional information to clarify the procedure. To be prepared for an abnormal or emergency situation, learn the first steps of each checklist, if not all the steps. If time permits, refer to the checklist to make sure all items have been covered. For more information on emergencies, refer to Chapter 15, Aircraft Emergencies.

Manufacturers are encouraged to include an optional area titled Abnormal Procedures, which describes recommended procedures for handling malfunctions that are not considered to be emergencies. This information would most likely be found in larger aircraft.

Normal Procedures (Section 4)

The normal procedures section is the section most frequently used. It usually begins with a listing of airspeeds that may enhance the safety of normal operations. It is a good idea to learn the airspeeds that are used for normal flight operations. The next part of the section includes several checklists, which cover the preflight inspection, before starting procedure, how to start the engine, ground checks, takeoff, approach, landing, and shutdown. To avoid skipping an important step, always use a checklist when one is available. More information on maneuvers can be found in Chapter 10, Basic Maneuvers, and Chapter 13, Advanced Maneuvers.

Performance (Section 5)

The performance section contains all the information required by the regulations and any additional performance information the manufacturer determines may enhance a pilot's ability to operate the aircraft safely. Although the performance section is not in the limitation section and is therefore not a limitation, operation outside or beyond the flight tested and documented performance section can be expensive, slightly hazardous, or outright dangerous to life and property. If the aircraft is certificated under 14 CFR part 29, part 25, or a combination of the two then the performance section may very well be a restrictive limitation. In any event, a pilot should determine the performance available and plan to stay within those parameters.

These charts, graphs, and tables vary in style but all contain the same basic information. Some examples of the performance information that can be found in most flight manuals include a calibrated versus indicated airspeed conversion graph, hovering ceiling versus gross weight charts, and a height-velocity diagram. *[Figure 5-7]* For information on how to use the charts, graphs, and tables, refer to Chapter 8, Performance.

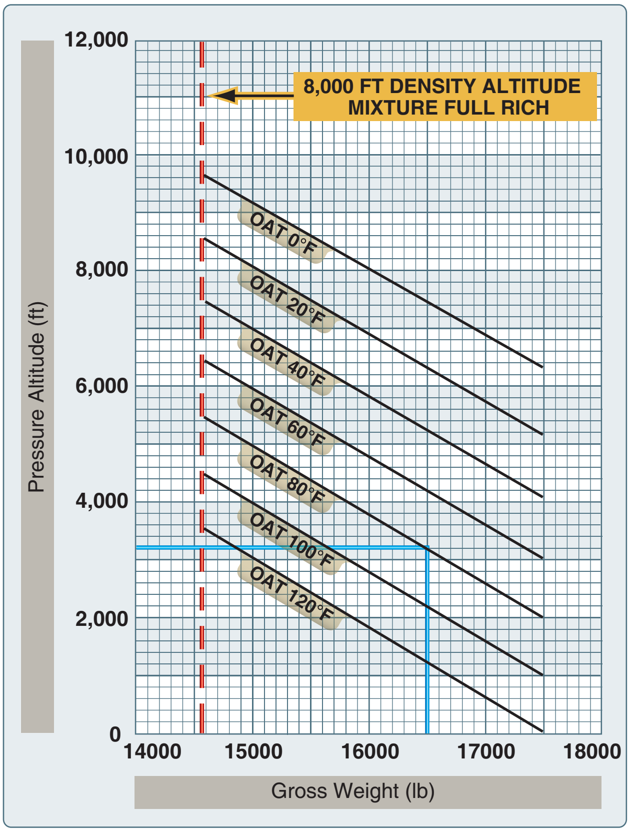


Figure 5-7. *One of the performance charts in the performance section is the In Ground Effect Hover Ceiling versus Gross Weight chart. This chart can be used to determine how much weight can be carried and still operate at a specific pressure altitude or, if carrying a specific weight, what the altitude limitation is.*

Weight and Balance (Section 6)

The weight and balance section should contain all the information required by the FAA that is necessary to calculate weight and balance. To help compute the proper data, most manufacturers include sample problems. Weight and balance is detailed in Chapter 7, Weight and Balance.

Aircraft and Systems Description (Section 7)

The aircraft and systems description section is an excellent place to study all the systems found on an aircraft. The manufacturers should describe the systems in a manner that is understandable to most pilots. For larger, more complex aircraft, the manufacturer may assume a higher degree of knowledge. For more information on helicopter systems, refer to Chapter 3, Components, Sections, and Systems.

Handling, Servicing, and Maintenance (Section 8)

The handling, servicing, and maintenance section describes the maintenance and inspections recommended by the manufacturer, as well as those required by the regulations, and airworthiness directive (AD) compliance procedures. There are also suggestions on how the pilot/operator can ensure that the work is done properly.

This section also describes preventative maintenance that may be accomplished by certificated pilots, as well as the manufacturer's recommended ground handling procedures, including considerations for hangaring, tie down, and general storage procedures for the aircraft.

Supplements (Section 9)

The supplements section describes pertinent information necessary to operate optional equipment installed on an aircraft that would not be installed on a standard aircraft. Some of this information may be supplied by the aircraft manufacturer, or by the maker of the optional equipment. The information is then inserted into the flight manual at the time the equipment is installed.

Since civilian manuals are not updated to the extent of military manuals, the pilot must learn to read the supplements after determining what equipment is installed and amend their daily use checklists to integrate the supplemental instructions and procedures. This is why air carriers must furnish checklists to their crews. Those checklists furnished to the crews must incorporate all procedures from any and all equipment actually installed in the aircraft and the approved company procedures.

Safety and Operational Tips (Section 10)

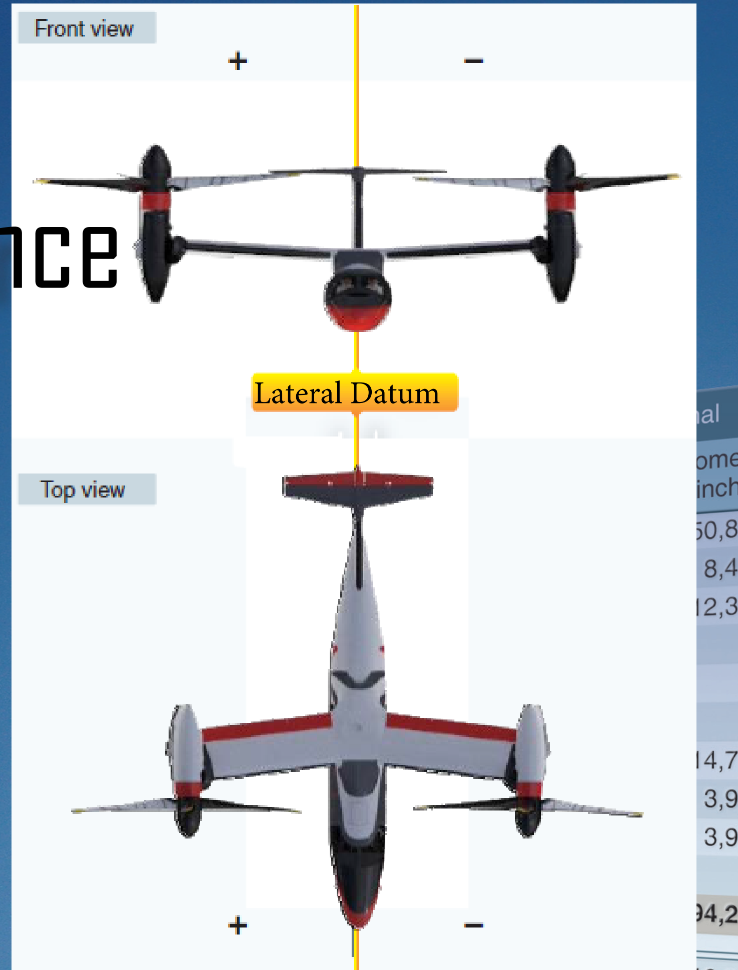
The safety and operational tips section is optional and contains a review of information that could enhance the safety of the operation. Some examples of the information that might be covered include: physiological factors, general weather information, fuel conservation procedures, and recommendations that if not adhered to could lead to an emergency.

Chapter Summary

This chapter familiarized the reader with the RFM. It detailed each section and explained how to follow and better understand the flight manual to enhance safety of flight.

Chapter 6

Weight and Balance



Introduction

It is vital to comply with weight and balance limits established for powered lift aircraft. Operating above the maximum weight limitation compromises the structural integrity of the aircraft and adversely affects performance. Balance is also critical because, on some fully loaded aircraft, center of gravity (CG) deviations as small as three inches can dramatically change an aircraft's handling characteristics. Operating an aircraft that is not within the weight and balance limitations is unsafe. Refer to FAA-H-8083-1, Aircraft Weight and Balance Handbook, for more detailed information.

Weight

When determining if an aircraft's within the weight limits, consider the weight of the basic aircraft, crew, passengers, cargo, and fuel. Although the effective weight (load factor) varies during maneuvering flight and conversion/ transition, this chapter primarily considers the weight of the loaded aircraft while at rest.

It is critical to understand that the maximum allowable weight may change during the flight. When operations include OGE hovers, confined areas, flight in APLN or CONV mode, planning must be done to ensure that the aircraft is capable of lifting the weight during all phases of flight. The weight may be acceptable during the early morning hours, but as the density altitude increases during the day, the maximum allowable weight may have to be reduced to keep the aircraft within its capability.

The following terms are used when computing a aircraft's weight.

Basic Empty Weight

The starting point for weight computations is the basic empty weight, which is the weight of the standard aircraft, optional equipment, unusable fuel, and all operating fluids including engine and transmission oil, and hydraulic fluid for those aircraft so equipped. Some aircraft might use the term "licensed empty weight," which is nearly the same as basic empty weight, except that it does not include full engine and transmission oil, just undrainable oil. If flying an aircraft that lists a licensed empty weight, be sure to add the weight of the oil to computations.

Maximum Gross Weight (MGW)

The maximum weight of the aircraft. Most helicopters have an internal maximum gross weight, which refers to the weight within the aircraft structure and an external maximum gross weight, which refers to the weight of the aircraft with an external load. The external maximum weight may vary depending on where it is attached to the aircraft. Some large cargo aircraft may have several attachment points for sling load or winch operations. These aircraft can carry a tremendous amount of weight when the attachment point is directly under the CG of the aircraft.

Weight Limitations

Weight limitations are necessary to guarantee the structural integrity of the aircraft and enable pilots to predict aircraft performance accurately. Although aircraft manufacturers build in safety factors, a pilot should never intentionally exceed the load limits for which an aircraft is certificated. Operating below a minimum weight could adversely affect the handling characteristics of the aircraft. During single-pilot operations in some aircraft, a pilot may need to use a large amount of forward center stick in order to maintain a hover. By adding ballast to the aircraft, the center stick position is closer to the CG, which gives a greater range of control motion in every direction. When operating at or below the minimum weight of the aircraft, additional weight also improves autorotational characteristics since the autorotational descent can be established sooner. In addition, operating below minimum weight could prevent achieving the desirable rotor revolutions per minute (rpm) during autorotations.

Operating above a maximum weight could result in structural deformation or failure during flight, if encountering excessive load factors, strong wind gusts, or turbulence. Weight and maneuvering limitations also are factors considered for establishing fatigue life of components. Overweight, meaning overstressed, parts fail sooner than anticipated. Therefore, premature failure is a major consideration in determination of fatigue life and life cycles of parts.

Although an aircraft is certificated for a specified maximum gross weight, it is not safe to take off with this load under some conditions. Anything that adversely affects takeoff, climb, hovering, and landing performance may require off-loading of fuel, passengers, or baggage to some weight less than the published maximum. Factors that can affect performance include high altitude, high temperature, and high humidity conditions, which result in a high density altitude. In-depth performance planning is critical when operating in these conditions.

Balance

An aircrafts performance is not only affected by gross weight, but also by the position of that weight. It is essential to load the aircraft within the allowable CG range specified in the AFM/RFM's weight and balance limitations.

Center of Gravity

Ideally, a pilot should try to balance an aircraft perfectly so that the fuselage remains horizontal in hovering flight, with hover nacelle set and center stick centered.. Since the fuselage acts as a pendulum suspended from the proprotors, changing the CG changes the angle at which the aircraft hangs from the proprotor. When the CG is directly under the rotor mast, the aircraft hangs horizontally; if the CG is too far forward of the mast, the aircraft hangs with its nose tilted down requiring aft center stick and forward nacelle; if the CG is too far aft of the mast, the nose tilts up, requiring forward center stick and aft nacelle. Both conditions may lead to a lack of center stick authority. *[Figure 6-1]*

CG Forward of Forward Limit

A forward CG may occur when a heavy pilot and passenger take off without baggage or proper ballast located aft of the proprotor mast. This situation becomes worse if the fuel tanks are located aft of the rotor mast because as fuel burns the CG continues to shift forward.

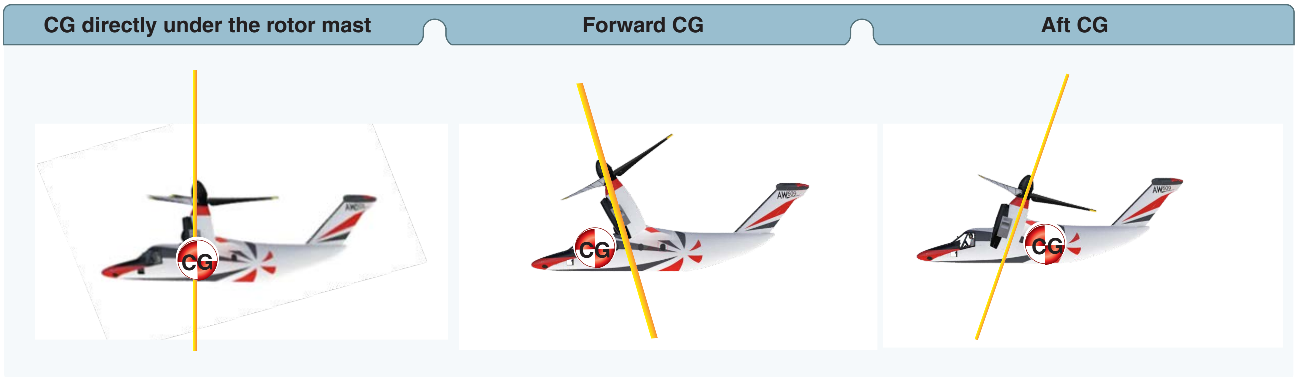


Figure 6-1. *The location of the CG strongly influences how the aircraft handles.*

This condition is easily recognized when coming to a hover with normal hover nacelle set following a vertical takeoff. The aircraft has a nose-low attitude, and excessive rearward displacement of the center stick control and forward nacelle is needed to maintain a hover in a no-wind condition. Do not fly in this condition. In CONV mode flight a pilot could lose rearward center stick control as fuel is consumed for a forward nacelle setting. In APLN mode progressivly more aft center stick will be required to maintain altitude, for a given speed. During autorotaion with full aft nacelle there may be insufficient aft center stick authority to adequetly flare the aircraft during the manuever. This could resuly in higher ground speeds and lower than normal NR, with potentially catastrophic results. During deceleration, more aft center stick and nacelle is required. This will extend the distance to decelerate the aircraft and due to the increasingly higher nose attitude will reduce forward visibilty.

When determining whether a critical balance condition exists, it is essential to consider the wind velocity and its relation to the displacement of thecenter stick control and nacelle setting.

CG Aft of Aft Limit

Without proper ballast in the cockpit, exceeding the aft CG may occur when:

- A lightweight pilot takes off solo with a full load of fuel located aft of the proprotor mast.
- A lightweight pilot takes off with maximum baggage allowed in a baggage compartment located aft of the proprotor mast.
- A lightweight pilot takes off with a combination of baggage and substantial fuel where both are aft of the proprotor mast.

A pilot can recognize the aft CG condition when coming to a hover following a vertical takeoff. The aircraft will have a tail-low attitude, and will need excessive forward displacement of center stick control with aft nacelle to maintain a hover in a no-wind condition with a level attitude.

If flight is continued in this condition, it may be impossible to fly in the upper allowable airspeed range, in CONV mode, due to inadequate forward center stick authority to maintain a nose-low attitude. In addition, with an extreme aft CG, gusty or rough air could accelerate the aircraft to a speed faster than that produced with full forward center stick control. In this case, dissymmetry of lift and blade flapping could cause the rotor disk to tilt aft. With full forward center stick control already applied, a pilot might not be able to lower the rotor disk, resulting in possible loss of control, or exceedding the flapping limitations of the proprotor system. In APLN mode higher pitch up attitudes will be required to maintain altitude, this will reqiure more power as drag is increased. The aircraft may also be limited during the descent as forward center stick limits are reached.

Lateral Balance

The lateral balance should also be checked prior to flight as there may be situations that could affect the lateral CG, such as a heavy pilot and a full load of fuel on one side of the aircraft (especially during OEI conditions), its position should be checked against the CG envelope. If carrying external loads in a position that requires large lateral center stick control displacement to maintain level flight, fore and aft center stick effectiveness could be limited dramatically. Manufacturers generally account for known lateral CG displacements by locating external attachment points opposite the lateral imbalance. Examples are placement of hoist systems attached to the side, and wing stores commonly used on military aircraft for external fuel pods or armament systems.

Weight and Balance Calculations

When determining whether a aircraft is properly loaded, two questions must be answered:

1. Is the gross weight less than or equal to the maximum allowable gross weight (MGW)?

2. Is the CG within the allowable CG range, and will it stay within the allowable range throughout the duration of flight including all loading configurations that may be encountered?

To answer the first question, just add the weight of the items comprising the useful load (pilot, passengers, fuel, oil (if applicable) cargo, and baggage) to the basic empty weight of the helicopter. Ensure that the total weight does not exceed the maximum allowable gross weight.

To answer the second question, use CG or moment information from loading charts, tables, or graphs in the AFM/RFM. Then using one of the methods described below, calculate the loaded moment and/or loaded CG and verify that it falls within the allowable CG range shown in the AFM/RFM.
It is important to note that any weight and balance computation is only as accurate as the information provided. Therefore, ask passengers what they weigh and add a few pounds to account for the additional weight of clothing, especially during the winter months. Baggage should be weighed on a scale, if practical. If a scale is not available, compute personal loading values according to each individual estimate. *Figure 6-2* indicates the standard weights for specific operating fluids. The following terms are used when computing a helicopter's balance.

Aviation Gasoline (AVGAS)	6 lb/gal
Jet Fuel (JP-4)	6.5 lb/gal
Jet Fuel (JP-5)	6.8 lb/gal
Reciprocating Engine Oil	7.5 lb/gal*
Turbine Engine Oil	Varies between 6 and 8 lb/gal*
Water	8.35 lb/gal

*Oil weight is given in pounds per gallon while oil capacity is usually given in quarts; therefore, convert the amount of oil to gallons before calculating its weight. Remember, four quarts equal one gallon.

Figure 6-2. *When making weight and balance computations, always use actual weights if they are available, especially if the aircraft is loaded near the weight and balance limits.*

Reference Datum

Balance is determined by the location of the CG, which is usually described as a given number of inches from the reference datum. The horizontal reference datum is an imaginary vertical plane or point, arbitrarily fixed somewhere along the longitudinal axis of the aircraft, from which all horizontal distances are measured for weight and balance purposes. There is no fixed rule for its location. It may be located at the rotor mast, the nose of the aircraft, or even at a point in space ahead of the aircraft. *[Figure 6-3]*

Figure 6-3. *While the horizontal reference datum can be anywhere the manufacturer chooses, some manufacturers choose the datum line at or ahead of the most forward structural point on the aircraft, in which case all moments are positive. This aids in simplifying calculations. Other manufacturers choose the datum line at some point in the middle of the aircraft in which case moments produced by weight in front of the datum are negative and moments produced by weight aft of the datum are positive.*

The lateral reference datum is usually located at the center of the aircraft. The location of the reference datum is established by the manufacturer and is defined in the AFM/RFM. *[Figure 6-4]*

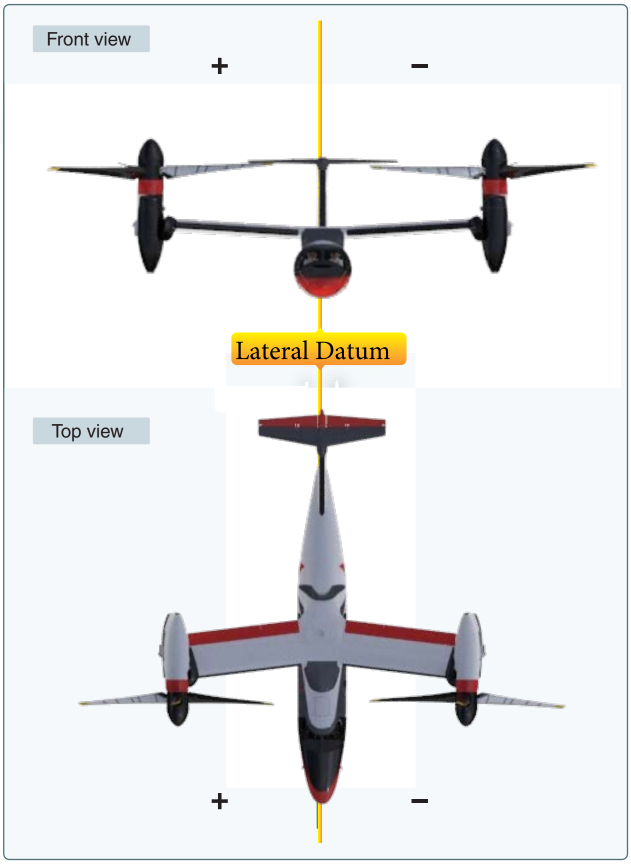


Figure 6-4. *The lateral reference datum is located longitudinally through the center of the aircraft; therefore, there are positive and negative values.*

Chapter Summary

This chapter has discussed the importance of computing the weight and balance of the aircraft. The chapter also discussed the common terms and meanings associated with weight and balance.

Chapter 7

Performance

Introduction

A pilot's ability to predict the performance of an aircraft is extremely important. It helps to determine how much weight the aircraft can carry before takeoff, if the aircraft can safely hover at a specific altitude and temperature, the takeoff distance required to climb above obstacles during a running takeoff, and what the maximum climb rate will be. In tiltrotor's, pilots must also be able to calculate the amount of runway required for a rolling takeoff, and what the aircraft's performance will be in the event of an emergency such as a powerplant failure.

Factors Affecting Performance

A tiltrotor's performance is dependent on the power output of the engines and the lift produced by the proprotors and wings. Any factor that affects engine, wing and proprotor efficiency affects performance. The three major factors that affect performance are density altitude, weight, and wind. The Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25, discusses these factors in great detail.

Moisture (Humidity)

Humidity alone is usually not considered an important factor in calculating density altitude and aircraft performance; however, it does contribute. There are no rules of thumb used to compute the effects of humidity on density altitude but some manufacturers include charts with 80 percent relative humidity columns as additional information. There appears to be an approximately 3–4 percent reduction in performance compared to dry air at the same altitude and temperature, so expect a decrease in hovering and takeoff performance in high humidity conditions. Although 3–4 percent seems insignificant, it can be the cause of a mishap when already operating at the limits of the aircraft.

Weight

Most performance charts include weight as one of the variables. By reducing the weight of the aircraft, a pilot may be able to take off or land safely at a location that otherwise would be impossible. However, if ever in doubt about whether a takeoff or landing can be performed safely, delay your takeoff until more favorable density altitude conditions exist. If airborne, try to land at a location that has more favorable conditions, or one where a landing can be made that does not require a hover.

Winds

Wind direction and velocity also affect hovering, takeoff, and climb performance. Translational lift occurs any time there is relative airflow over the rotor disk. This occurs whether the relative airflow is caused by aircraft movement or by the wind. As headwind speed increases, translational lift increases, resulting in less power required to hover.

The wind direction is also an important consideration. Headwinds are the most desirable as they contribute to the greatest increase in performance. Strong crosswinds and tailwinds may adversely affect power required to takeoff and hover. Some aircraft even have a critical wind azimuth or maximum safe relative wind chart. Operating the aircraft beyond these limits could cause entry into pitch up with sideslip conditions, or reduced control authority as the wind velocity interacts with the aircraft structure.

Takeoff and climb performance is greatly affected by wind. When taking off into a headwind, effective translational lift is achieved earlier, resulting in more lift and a steeper climb angle. When taking off with a tailwind, more distance is required to accelerate through translation lift.

Performance Charts

In developing performance charts, aircraft manufacturers make certain assumptions about the condition of the aircraft and the ability of the pilot. It is assumed that the aircraft is in good operating condition and the engine is developing its rated power. The pilot is assumed to be following normal operating procedures and to have average flying abilities. Average means a pilot capable of doing each of the required tasks correctly and at the appropriate times.

Using these assumptions, the manufacturer develops performance data for the aircraft based on actual flight tests. However, they do not test the aircraft under each and every condition shown on a performance chart. Instead, they evaluate specific data and mathematically derive the remaining data.

Due to the nature of powered lift aircraft ,and in particular titlrotor, performance charts have been developed to cover APLN mode and VTOL/CONV Mode flight regimes.

Autorotational Performance

Most autorotational performance charts state that autorotational descent performance is a function of airspeed and is essentially unaffected by density altitude and gross weight. Keep in mind that, at some point, the potential energy expended during the autorotation is converted into kinetic energy for the flare and touchdown phase of the maneuver. It is at that point that increased density altitudes and heavier gross weights have a great impact on the successful completion of the autorotation. The proprotor disks must be able to overcome the downward momentum of the aircraft and provide enough lift to cushion the landing. With increased density altitudes and gross weights, the lift potential is reduced and a higher collective pitch angle (angle of incidence) is required. The aerodynamics of autorotation has been presented in detail in Chapter 4, Aerodynamics of Flight.

Hovering Performance

Tiltrotor performance revolves around whether or not the aircraft can be hovered before an alternate departure or rolling takeoff technique is required.. More power is required during the hover than in any other flight regime. Obstructions aside, if a hover can be maintained, a takeoff can be made, especially with the additional benefit of translational lift. Hover charts are provided for in ground effect (IGE) hover and out of ground effect (OGE) hover under various conditions of gross weight, altitude, temperature, and power. The IGE hover ceiling is usually higher than the OGE hover ceiling because of the added lift benefit produced by ground effect. See Chapter 4, Aerodynamics of Flight, for more details on IGE and OGE hover. A pilot should always plan an OGE hover when landing in an area that is uncertain or unverified.

As density altitude increases, more power is required to hover. At some point, the power required is equal to the power available. This establishes the hovering ceiling under the existing conditions. Any adjustment to the gross weight by varying fuel, payload, or both, affects the hovering ceiling. The heavier the gross weight, the lower the hovering ceiling. As gross weight is decreased, the hover ceiling increases.

Sample Hover Problem 1

You are to fly a photographer to a remote location to take pictures of the local wildlife. Using *Figure 7-1*, can you safely hover in ground effect at your departure point with the following conditions?

A. Pressure Altitude...............................8,000 feet

B. Temperature...+15 °C

C. Takeoff Gross Weight.........................12,500 lb

RPM...102 percent

First enter the chart at 8,000 feet pressure altitude (point A), then move right until reaching a point midway between the +10 °C and +20 °C lines (point B). From that point, proceed down to find the maximum gross weight where a 2 foot hover can be achieved. In this case, it is approximately 12,800 pounds (point C).

Since the gross weight of your aircraft is less than this, you can safely hover with these conditions.

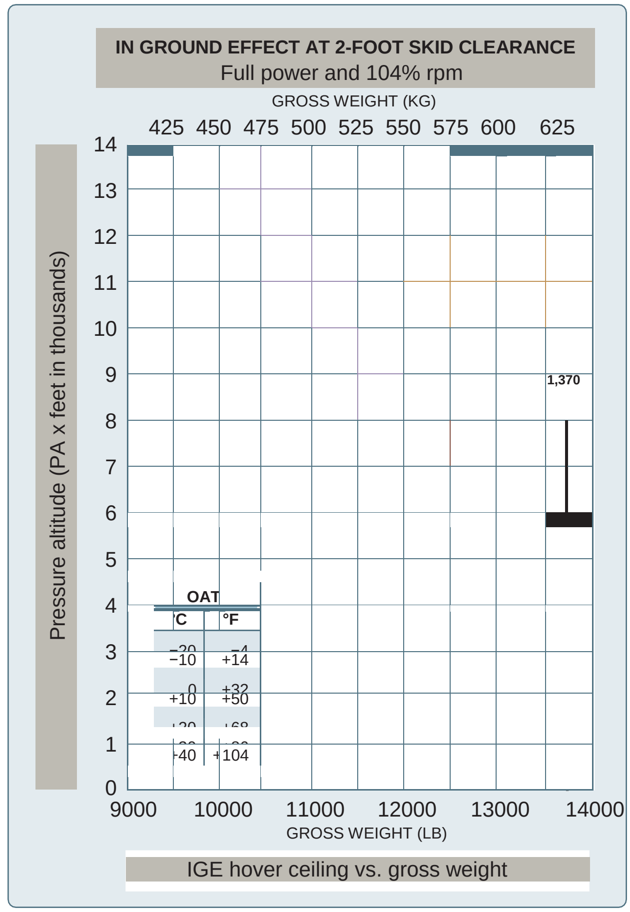


Figure 7-1. *In ground effect hovering ceiling versus gross weight chart.*

Sample Hover Problem 2

Once you reach the remote location in the previous problem, you will need to hover OGE for some of the pictures. The pressure altitude at the remote site is 9,000 feet, and you will use 1,000 pounds of fuel getting there. (The new gross weight is now 11,500 pounds.) The temperature will remain at +15 °C. Using *Figure 7-2*, can you accomplish the mission?

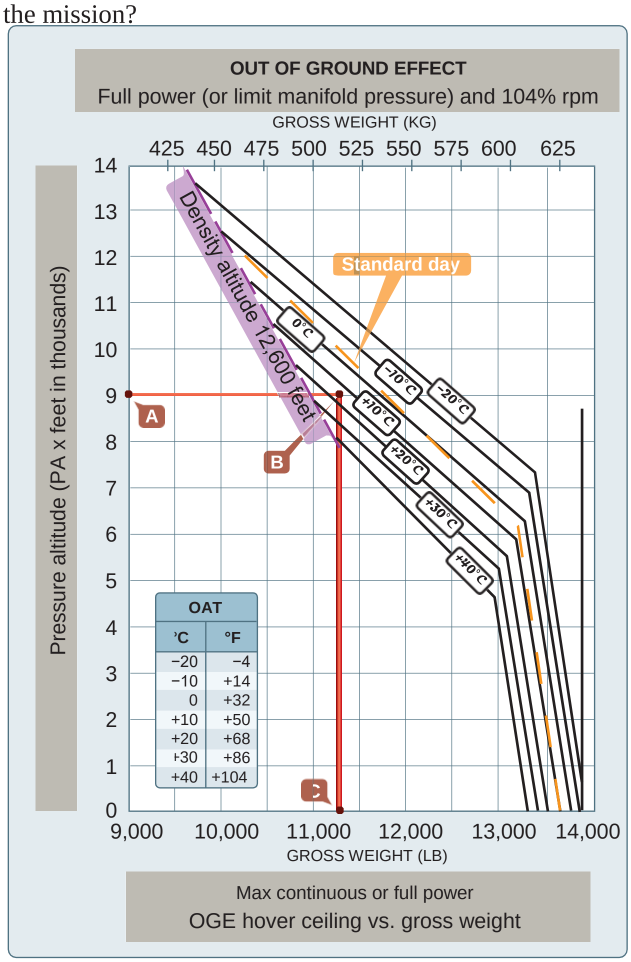


Figure 7-2. *Out of ground effect hover ceiling versus gross weight chart.*

Enter the chart at 9,000 feet (point A) and proceed to point B (+15 °C). From there, determine that the maxi mum gross weight to hover OGE is approximately 11,300 pounds (point C). Since your gross weight is higher than this value, you will not be able to hover in these conditions. To accomplish the mission, you will need to remove approximately 200 pounds before you begin the flight.

These two sample problems emphasize the importance of determining the gross weight and hover ceiling throughout the entire flight operation. Being able to hover at the takeoff location with a specific gross weight does not ensure the same performance at the landing point. If the destination point is at a higher density altitude because of higher elevation, temperature, and/or relative humidity, more power is required to hover there. You should be able to predict whether hovering power will be available at the destination by knowing the temperature and wind conditions, using the performance charts in the aircraft flight manual, and making certain power checks during hover and in flight prior to commencing the approach and landing.

For aircraft with dual engines, performance charts provide torque amounts for both engines.

Sample Hover Problem 3

Using *Figure 7-3*, determine what torque is required to hover. Use the following conditions:

A. Pressure Altitude . . . .9,500 feet

B. Outside Air Temperature . . . . 0 °C

C. Gross Weight. . . . . 14,250 lb

D. Desired Hover Height . . . . 5 feet

First, enter the chart at 9,500 feet pressure altitude, then move right to outside air temperature, 0 °C. From that point, move down to 14,250 pounds gross weight and then move left to 5 foot langing gear height. Drop down to read 66 percent torque required to hover.

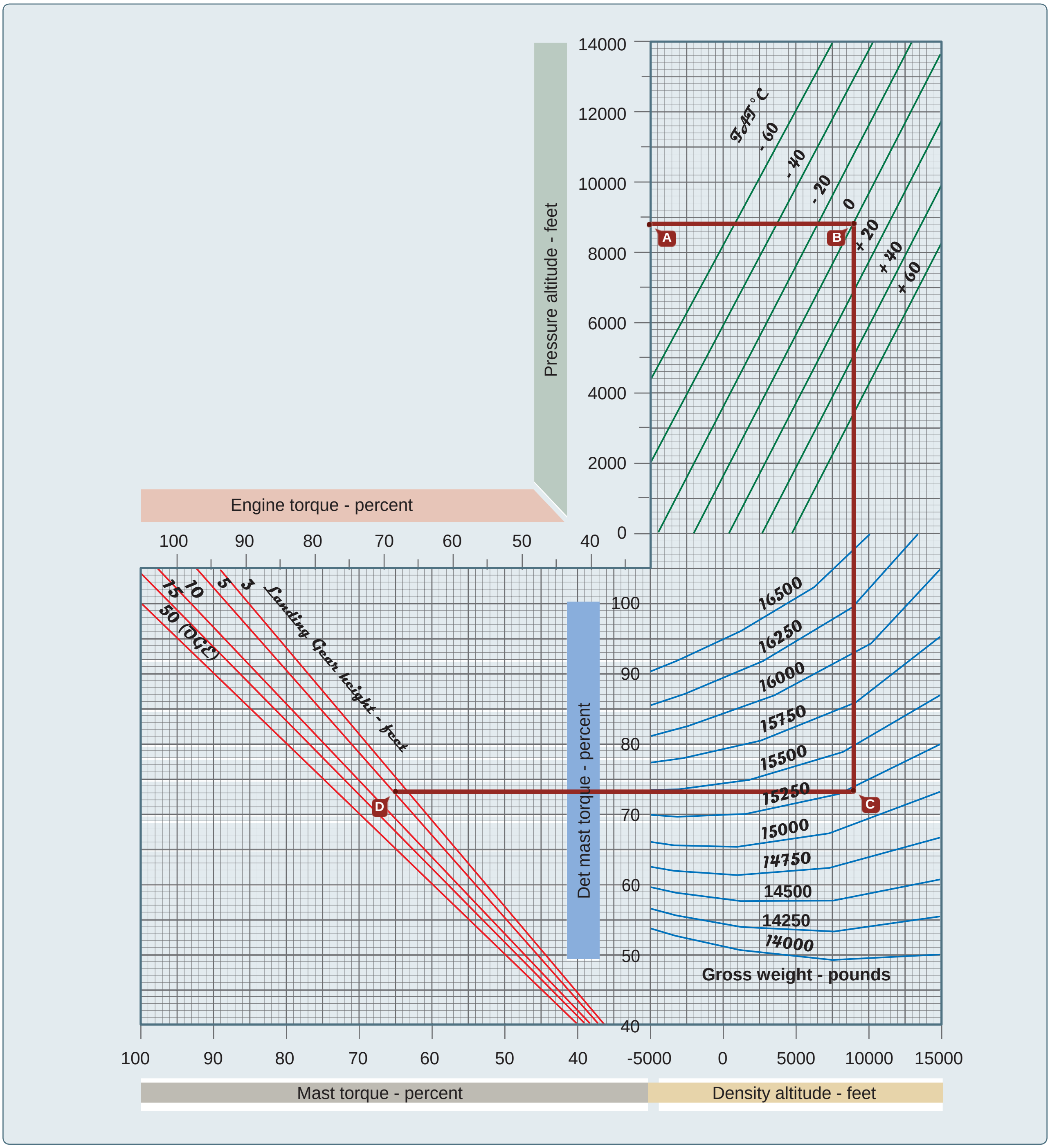


Figure 7-3. *Torque required for cruise or level flight.*

Rolling Takeoff Calculations

A rolling take off (RTO) can be used when the aircraft is not capable of hover performance, due to the factors discussed, or when operating at higher gross weights. Before conducting a rolling takeoff (RTO), the pilot should check the POH/AFM performance charts to determine the predicted performance and decide if the aircraft is capable of a safe rolling takeoff and climb for the conditions and location. *[Figure 5-2]* As in hover operation, high density altitudes reduce engine and

propeller performance, increase takeoff rolls and decrease climb performance. A more detailed discussion of density altitude and how it affects aircraft performance can be found in the Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-25, as revised).

Sample Rolling Takeoff Problem

You have flown to a remote airfield in the Colorado Rocky Mountains to pick up a rock band and fly them to their next concert in California. They are traveling with a lot of equipment, and you need a full fuel load to get to your destination. A short, 2000 foot, concrete runway is available at the departure location. Using *Figure 7-3*, can you safely conduct a rolling takeoff fromyour departure point with the following conditions?

A. Density Altitude................................8,000 feet

B. Runway Available...............................2,000 feet

C. Takeoff Gross Weight........................17,250 lb

First enter the chart at 8,000 feet desity altitude (point A), then move right until reaching a point mid way between the 17,000 and 18,000 pound gross weight lines. From that point, proceed down to find the runway length in which a rolling can be achieved. In this case, it is approximately 1,380 feet (point C).

Using the same principles, you can determine that approximatel 2,750 feet of takeoff distance is needed to clear a 50 foot obstacle.

Since your runway available is longer than 1,380 feet, you can safely conduct a rolling takeoff with these conditions.

The pilot could not use this runway to clear a 50 foot obstacle, as the computed 2,750 feet exceeds the available runway length.

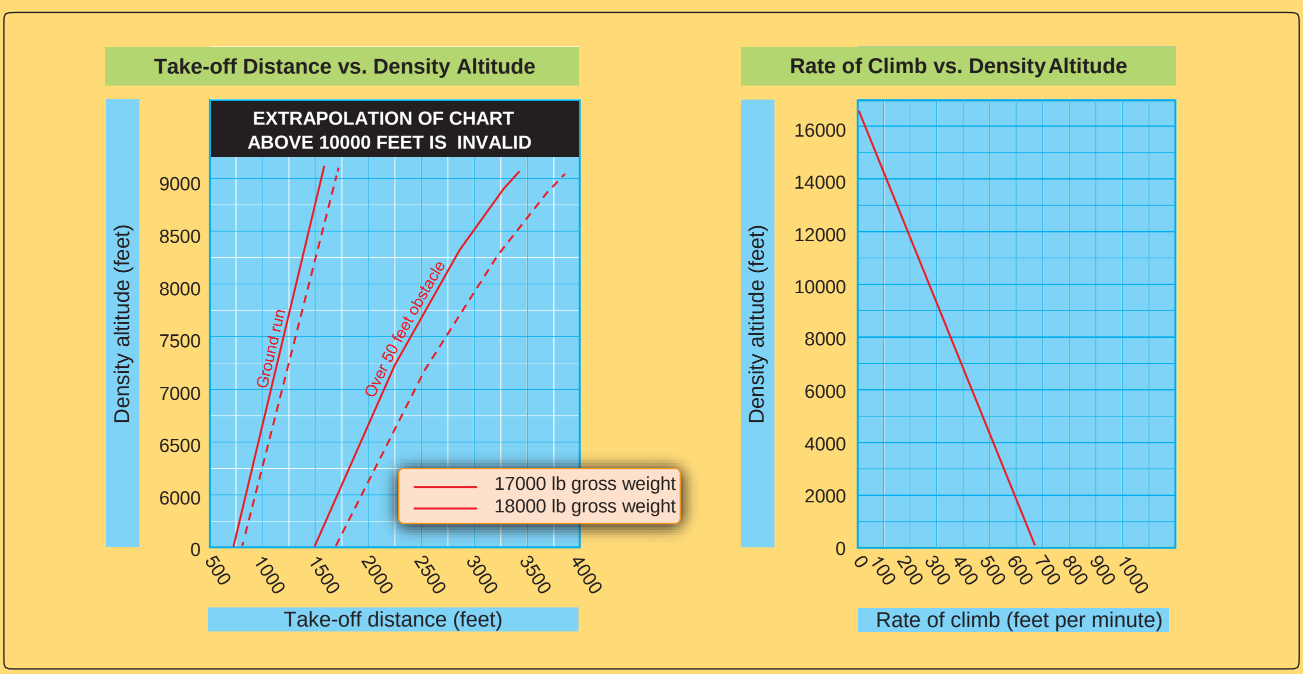


Figure 7-3. *Performance chart examples.*

Climb Performance

Most of the factors affecting hover and takeoff performance also affect climb performance. In addition, turbulent air, pilot techniques, and overall condition of the aircraft can cause climb performance to vary.

A aircraft flown at the best rate-of-climb speed (V_Y) obtains the greatest gain in altitude over a given period of time. This speed is normally used during the climb after all obstacles have been cleared and is usually maintained until reaching cruise altitude. Rate of climb must not be confused with angle of climb. Angle of climb is a function of altitude gained over a given distance. The V_Y results in the highest climb rate, but not the steepest climb angle, and may not be sufficient to clear obstructions.

The best angle of climb speed (VX) depends upon the power available. If there is a surplus of power available, the aircraft can climb vertically, so VX is zero. Wind direction and speed have an effect on climb performance, but it is often misunderstood. Airspeed is the speed at which the aircraft is moving through the atmosphere and is unaffected by wind. Atmospheric wind affects only the groundspeed, or speed at which the aircraft is moving over the Earth's surface. Thus, the only climb performance affected by atmospheric wind is the angle of climb and not the rate of climb.

When planning for climb performance, it is first important to plan for torque settings at level flight. Climb performance charts show the change in torque, above or below torque, required for level flight under the same gross weight and atmospheric conditions to obtain a given rate of climb or descent.

Sample Cruise or Level Flight Problem

Determine torque setting for cruise or level flight using *Figure 7-4*. Use the following conditions:

Pressure Altitude.. 8,000 feet

Outside Air Temperature.................................... +15 °C

A. Indicated Airspeed.......................................170 knots

B. Maximum Gross Weight...............................16,000 lb

With this chart, first confirm that it is for a pressure altitude of 8,000 feet with an OAT of 15°. Begin on the left side at 80 knots indicated airspeed (point A) and move right to maximum gross weight of 16,000 lb (point B). From that point, proceed down to the torque reading for level flight, which is 74 percent torque (point C). This torque setting is used in the next problem to add or subtract cruise/descent torque percentage from cruise flight.

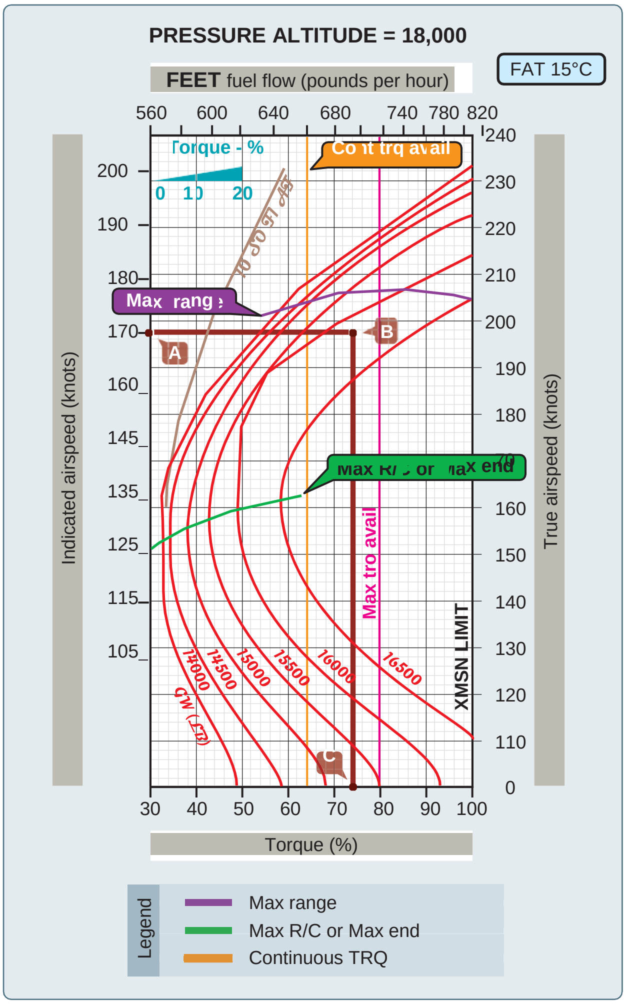


Figure 7-4. *Maximum rate-of-climb chart.*

Sample Climb Problem

Determine climb/descent torque percentage using *Figure 7-5*. Use the following conditions:

A. Rate of Climb or Descent. . . . . 500 fpm

B. Maximum Gross Weight . . . . 5,000 lb

With this chart, first locate a 500 fpm rate of climb or descent (point A), and then move to the right to a maximum gross weight of 15,000 lb (point B). From that point, proceed down to the torque percentage, which is 15 percent torque (point C). For climb or descent, 15 percent torque should be added/subtracted from the 74 percent torque needed for level flight. For example, if the numbers were to be used for a climb torque, the pilot would adjust torque settings to 89 percent for optimal climb performance.

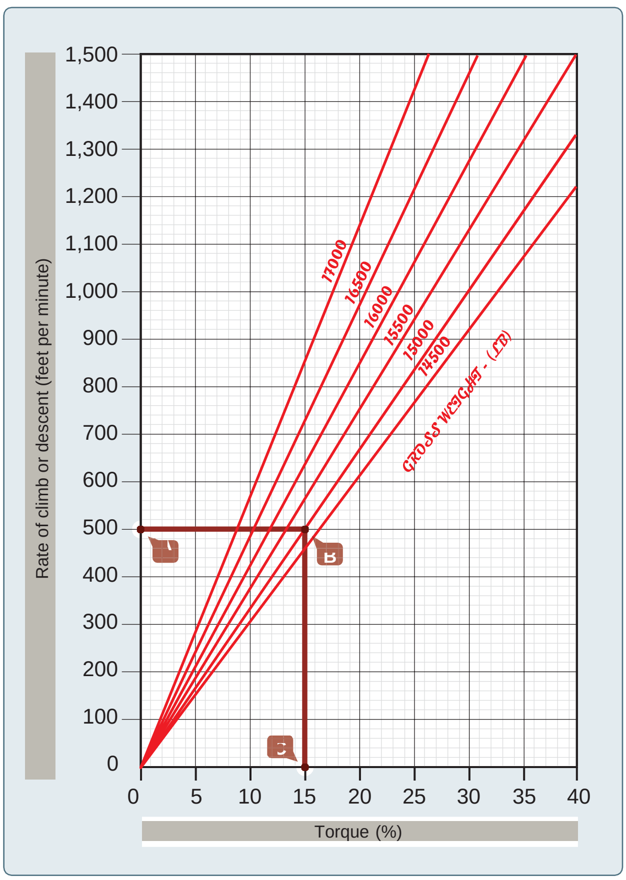


Figure 7-5. *Climb/descent torque percentage chart.*

Sample One Engine Inoperative Climb Problem

Pilots must be familiar with the aircraft's capabilities in the event of a serious emergency, such as a powerplant failure. If one engine fails at any time after takeoff or during landing, the aircraft's performance can vary based on:

a. Density Altitude.

b. Aircraft Gross Weight

c. Nacelle Setting / Mode of Flight

Determine the OEI climb rate using *Figure 7-6*. Use the following conditions:

A. Density Altitude. . . . . 5000 fpm

B. Maximum Gross Weight . . . . .17500 pounds

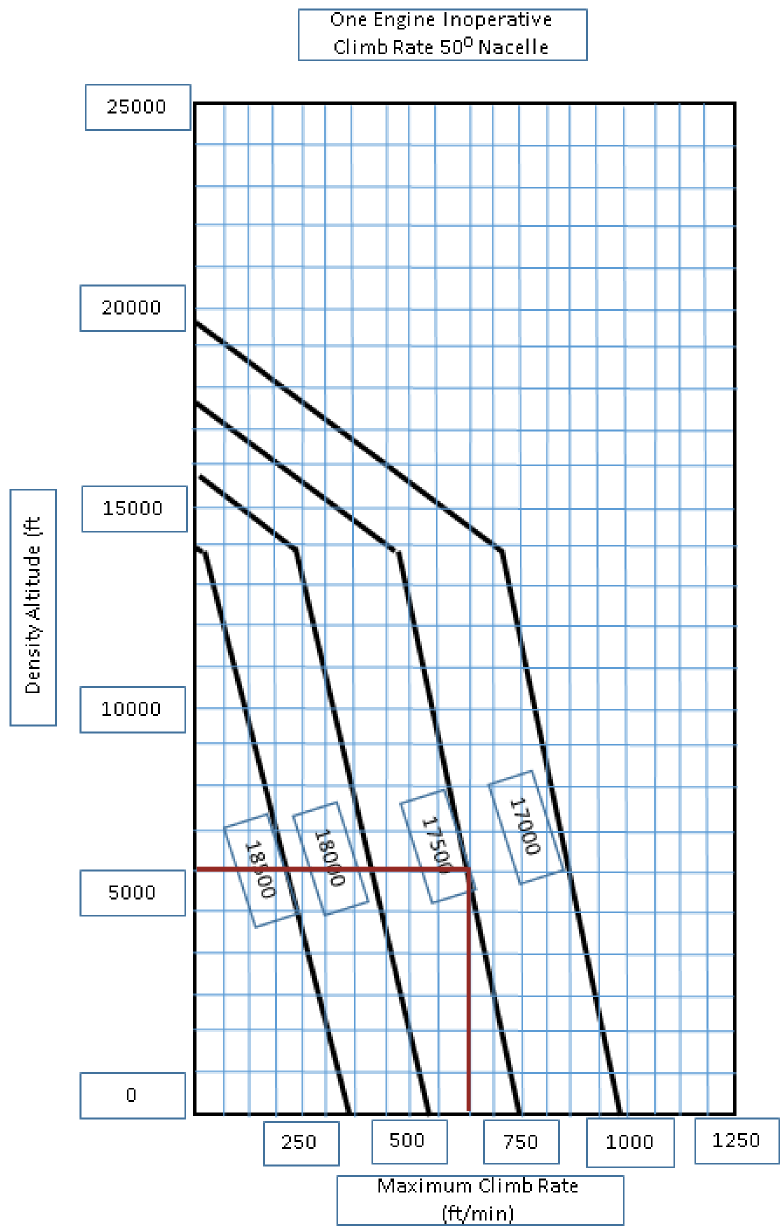


Figure 7-6. OEI *Climb Rate*

With this chart, first locate the 5000 foot Density Altitude line, and then move to the right to a maximum gross weight of 17,500 lb. From that point, proceed down to the climb rate, which is approximately 675 ft/min.

Chapter Summary

This chapter discussed the factors affecting performance: density altitude, weight, and wind. Five sample problems were also given with performance charts to calculate different flight conditions and determine the performance of the aircraft.

Powerplant Starting

Aircraft engines vary substantially and specific procedures for engine starting must be accomplished in reference to approved powerplant start checklist as detailed in the aircraft's FM. However, some generally accepted hazard mitigation practices and procedures are outlined.

Prior to engine start, the pilot must ensure that the area surrounding the aircraft is clear of persons, equipment, and other hazards from coming into contact with the aircraft, proprotor and exhaust. The pilot must be aware of what is behind the aircraft prior to powrplant start.

A proprotor system can produce substantial downwash velocities, which may result in damage to property and injure those on the ground. The hazard of debris being blown into persons, property or the aircraft itself must be mitigated by the pilot. He must assess the surface and location that the aircraft is to be started on and ensure that acceptable mitigation has been taken to prevent or minimize blowing loose articles, producing Foreign Object Damage (FOD). This can be achieved during the pre-flight walk around stage.

At all times before engine start, the anti-collision lights should be turned on. For night operations, the position (navigation) lights should also be on.

Just prior to starter engagement, the pilot should, to his best ability, ensure that risk of FOD is minimized to any external personnel by warning them of the impending start i.e. hand signals and waiting for a response from anyone who may present before engaging the starter.

Although modern powerplant are electronically controlled by systems such as ECC and FADEC the pilot must keep one hand on the engine control lever whilst monitoring start indications in case of HOT start or a failed start. In both cases the start sequence will be terminated and the appropriate actions will be taken as laid down in the AFM/QRH.

Digital displays have removed many of the issues of trying to remember numerous figures regarding pressures and temperatures. Instead the displays are adaptive and change to configure for the start sequence. The pilot has only to monitor whether the gauge is in the appropriate color range i.e. Red/Amber/Green and its trend or speed of increase. This does not alleviate the pilot from his requirement to comprehensively understand the aircraft he is operating, but allows the work cycle to be eased during high workload events such as starting.

Powerplant starter generators are electric motors designed to produce rapid rotation of the engine compressor for starting. Once the start is complete and the powerplant is self sustaining the starter will switch and begin generating electricity for aircraft supply and recharging the batteries. These electric motors are not designed for continuous duty and should the powerplant not start within the times laid down in the AFM then the start should be terminated and the starter cool down period followed. The AFM/QRH will list starter generator run times and numbers of starting cycles as life is drastically shortened from high heat through overuse.

Dependent on where the start was terminated i.e. if fuel has been placed in to the combustion chamber, then a venting run will have to be followed. This is done to ensure that any excess fuel has been removed from the powerplant to prevent a subsequent hot start. This "vent" run will count as a complete start cycle.

The pilot should always be attentive for sounds, vibrations, smell or smoke that are not consistent with normal operational experience. He should also be monitoring any external personnel for warning indications via hand signals as well as possible calls from ATC. Any concerns should lead to a shutdown and further investigation.

Forward Surface Taxi

Taxiing is the controlled movement of the aircraft under its own power while on the surface. Ground taxiing will be necessary for the safe operation of the aircraft and the safety of those on the ground around it. Ground taxiing may be particularly desirable when parking close to buildings, ground equipment, vehicles, or other aircraft. Since an aircraft is moved under its own power between a parking area and the takeoff point, the pilot must thoroughly understand and be proficient in taxi procedures.

Before beginning to ground taxi always ensure that the area is suitable to taxi on, clear of hazards, obstructions and any checks are carried out. Taxiing checklists are sometimes specified by the AFM/POH, and the pilot must accomplish any items that are required.

If there are no specific checklist items, taxiing still provides an opportunity to verify the operation and cross-check of the flight instruments. In general, the flight instruments should indicate properly with the airspeed at or near zero (depending on taxi speed, wind speed and direction, and lower limit sensitivity); the attitude indictor should indicate pitch and roll level (depending on aircraft attitude) with no flags; the altimeter should indicate the proper elevation within prescribed limits; the turn indictor should show the correct direction of turn with the ball movement toward the outside of the turn with no flags; the directional gyro should be set and crossed checked to the magnetic compass and verified accurate to the direction of taxi; and the vertical speed indictor (VSI) should read zero. These checks can be accomplished on conventional mechanical instrumented aircraft or glass cockpits.

An essential requirement in conducting safe taxi operation is where the pilot maintains situational awareness of the ramp, parking areas, taxiways, runway environment, and the persons, equipment and aircraft at all times. Without such awareness, safety may be compromised. Depending on the airport, heliport, helipad, parking, ramp, and taxiways may or may not be controlled. As such, it is important that the pilot completely understand the environment in which they are operating.

At small, rural airports these areas may be desolate with few aircraft which limits the potential hazards; however, as the complexity of the airport increases so does the potential for hazards. Regardless of the complexity, some generally accepted procedures are appropriate.

The pilot should make themselves familiar with the parking, ramp, and taxi environment. This can be done by having an airport diagram, if available, out and in view at all times. [Figure X-X]

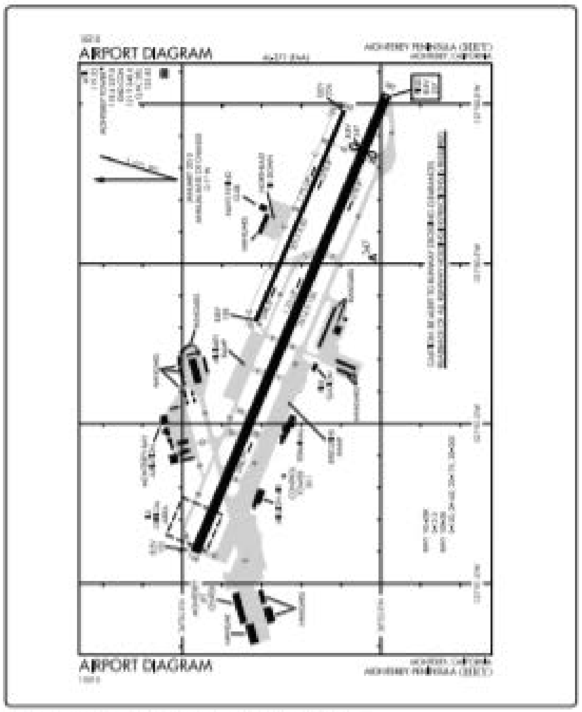


Figure 2-13. *Airport Diagram of Monterey Peninsula (MRY), Monterey, California*

The pilot must be vigilant of the entire area around the aircraft to ensure that the aircraft and proprotors clear all obstructions. If, at any time, there is doubt about a safe clearance from an object, the pilot should stop the aircraft and check the clearance. It may be necessary to have the aircraft towed or physically moved by a ground crew.

Begin by releasing the parking brake and begin to rotate the nacelles forward sufficiently to start the movement. Power may need to be added if starting up a slope or the aircraft is heavy. The center stick should be centralized to minimize flapping loads on the proprotor.

Note

Be aware of the possibility of ground resonance following power lever application. Be ready to take corrective action as necessary: by lowering the power to zero and shutting off both engines immediately or lifting to the hover if the aircraft is ready for flight.

As the aircraft begins to move, a brake check will be carried out to ensure correct function of the foot brakes. To check the operation of the brakes you will need to remove your feet from the floor and apply equal pressure to the foot brakes on top of the pedals. Call "Braking" so the pilot not flying (PNF) and any passengers are aware of the aircraft coming to a stop. It is important that the nacelle, center stick, and power positions are maintained while the brake check is conducted. Otherwise, you may not be checking that the brakes are working and may be using other controls to stop the aircraft.

Note

Repeated mishandling such as overuse of the center stick will generate excessive flapping and can cause damage to the mast or elastomeric bearings.

Once the aircraft has started moving, remove the power added and control speed through nacelle modulation. Under the guidance of your instructor at this early stage, it may be appropriate to move the center stick a small amount to compensate for any crosswind element. Control the speed through nacelle modulation and pedal brakes, if required.

When taxiing, the pilot's eyes should be looking outside the aircraft scanning from side to side while looking both near and far to assess routing and potential conflicts.

A safe taxiing speed must be maintained. The primary requirements for safe taxiing are positive control, the ability to recognize any potential hazards in time to avoid them, and the ability to stop or turn where and when desired, without undue reliance on the brakes. Pilots should proceed at a cautious speed on congested or busy ramps.

The pilot should also be aware of his downwash generated by the prorotors and the effect it may have on other aircraft, persons and lose objects i.e. dust, leafs, snow etc. In certain aircraft, there will be an option to set the engine mode switch to "Taxi," which reduces the normal rotor speed (NR) and the amount of downwash generated by the prop-rotors.

While taxiing, ground speed (GS) can be monitored on the primary flight display (PFD) in the GS display if fitted, as well as visually through the side windows. An apparent fast walking pace is a good reference, but never to exceed the ground taxi and turn limitations as listed in the AFM.

The pilot should aim to accurately place the aircraft centered on the taxiway at all times. Some taxiways have above ground taxi lights and signage that could impact the aircraft or nacelles if the pilot does not exercise accurate control. When yellow taxiway centerline stripes are marked, this is more easily accomplished by the pilot visually placing the centerline stripe so it is under the center of the aircraft fuselage.

To reduce speed and stop, transition the nacelles rearwards. Amount and rate of transition will depend upon the speed of taxi and the available stopping distance. Apply the pedal brakes ensuring the aircraft comes to a complete halt. Set the nacelles to vertical, and apply the parking brake.

Maneuvering while Ground Taxiing

A positive lookout must be given and maintained while maneuvering. Particular attention should be paid to nose, tail, and proprotor clearance for all obstacles during the turn.

Anticipation of the turn is required as the aircraft has a large turn radii. A speed reduction may be required to ensure the aircraft is within speed limitations for the turn.

Use the left and right pedal inputs to turn the aircraft in the desired direction with some lateral center stick into the turn to maintain a level fuselage attitude as the lateral C of G will move during the turn. For particularly tight turns or restricted areas, application of in turn foot brake can be applied to assist the turn.

Swerves are most likely to occur when turning from a downwind heading toward an up wind heading. In moderate to high-wind conditions, the aircraft may weathervane increasing the swerving tendency.

To stop the turn, begin to apply the opposite pedal prior to reaching the desired direction of travel since the response is not immediate. A combination of pedal and foot brake may be required for a quicker roll out.

Rearward Ground Taxi

The aircraft should only be taxied rearwards when no other method (such as ground towing) is available and should only be carried out when obstacle clearance is assured in all directions.

Complete the Taxi Checks as before. The movement will be initiated through rotating the nacelles rearwards. The power lever may be required to be raised to initiate movement but is lowered once movement has started.

Again, once the aircraft has started moving, control the speed through nacelle modulation and pedal brakes if required.

To reduce speed and stop, transition the nacelles forward. Amount and rate of transition will depend upon the speed of taxi and the available stopping distance. Apply the pedal brakes, ensuring aircraft comes to a complete halt, set the nacelles to vertical, and apply the parking brake.

Common Errors

- Overuse of the center stick, which generates excessive flapping, potentially causing damage to the mast or elastomeric bearings.
- Failure to remove any power applied, which produces excessive speed.
- Braking without removing the driving force (i.e. power or thrust vector).
- Poor anticipation of the turn and the subsequent rollout.
- Moving too fast into the turn, exceeding turn speed limitations, or severe roll off the aircraft.
- After stopping the aircraft, not setting the nacelles to vertical and putting on the parking brake.

Inside Ground Effect (IGE) Hover Maneuvers

The following exercises will familiarize pilots with some of the specific handling characteristics of tilt rotor equipped powered-lift aircraft. The tilt rotor has the ability to maintain a precision hover with various nose attitudes. This allows the adjustment of the fuselage angle for a number of applications and to increase the pilot's field of view during an approach.

Use the trim system to assist with precision aircraft control. Precise and accurate control becomes critical when maneuvering the aircraft in areas close to the ground and obstacles.

Hover Nacelle Drill

The hover nacelle drill teaches the basic coordination required for the two longitudinal controls—nacelle and cyclic—during slow speed operations.

Establish the aircraft in a inside ground effect hover (IGE), with a slightly higher than normal hover height, and trim the aircraft to level attitude. Slowly rotate the nacelles to full aft while simultaneously applying forward cyclic to maintain ground position over a spot, and stop any rearward drift. Maintain the aircraft in a stationary hover with full aft nacelle and with sufficient nose down pitch (approximately 10º). Scan forward and to the side to help maintain ground position and maintain the desired height by cross referencing with the RADALT, if available. The aircraft should be trimmed throughout the maneuver. Use the 4-way trim switch and/or momentarily press the Force Trim Release (FTR) once in the desired attitude with drift under control.

Slowly rotate the nacelles forward, approximately 15-20^0, while simultaneously applying aft center stick to maintain ground position. To maintain the aircraft in a stationary hover, approximately 10º nose up attitude will be required through aft center stick application. When complete, reset to hover nacelle and adjust the center stick to maintain ground position. Re-trim the aircraft and descend to a normal hover height.

Note

The forward nacelle will be limited to no less than 80^0 because during forward nacelle rotation, if pressure is maintained on the nacelle thumb wheel the nacelle will continue forward and could result in an excessive tail low attitude when applying aft center stick to maintain position. In the MV22, this is a major consideration as there is no automatic protection against excessive forward nacelle at low airspeeds. The AW609 has inbuilt protection to prevent the nacelles from moving forward of 75^0 below 40 Kts.

Common Errors

- Rapid movement of the nacelle with slow center stick correction allowing fore and aft drift to develop.
- Poor or slow scan allowing undetected drift to develop.
- Climbing during the maneuver placeing the aircraft in or near the avoid curve.
- Descending during the manuenver placing the tail in close proximity to the ground.

Hover Taxi

Forward hovering flight is normally used to move an aircraft to a specific location, and it may begin from a stationary hover. During the maneuver, constant groundspeed, altitude, and heading should be maintained. Use a hover taxi when operating below 25 feet AGL. [Figure xx]. A tilt rotor equipped powered-lift aircraft has the ability to taxi in several different ways depending on the distance to be covered.

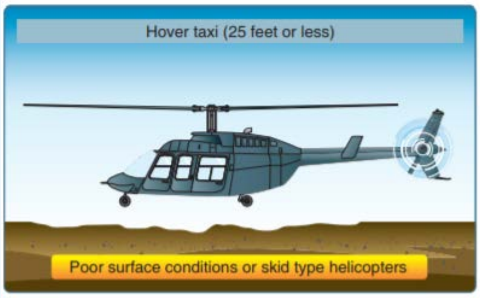


Figure 9-4. *Hover taxi.*

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Before starting, pick out two references directly in front and in line with the aircraft. These reference points should be kept in line throughout the maneuver. [Figure 9-2]

Figure 9-2. *To maintain a straight ground track, use two reference points in line and at some distance in front of the helicopter.*

Fixed Nacelle Forward Hover Taxi (Suitable for Short Distances)

From a stable inside ground effect (IGE) hover height, use the center stick to lower the nose attitude and begin to move the aircraft forward. Push the center stick against the spring pressure, using the beep trim, or depress the Force Trim Release (FTR) switch momentarily until the desired attitude is achieved then release. The rate of application and nose down attitude selected will vary the hover taxi speed. Initially, increase the power to maintain height while the center of gravity shifts forward and the aircraft moves off the ground cushion. If sufficient forward speed is developed, reduce the power to compensate for increased translational lift. As the movement begins, return the center stick toward the neutral position to maintain low ground speed—no faster than a brisk walk.

To decelerate or stop the forward movement, apply aft center stick and return the center stick toward the neutral position to prevent rearward acceleration as the aircraft stops. If using trim for the taxi, re-trim to the hover attitude and reset the power setting to maintain normal hover height.

Throughout the maneuver, maintain a constant groundspeed and ground track with center stick. Maintain heading, which in this maneuver is parallel to the ground track, with the yaw pedals, and a constant altitude with the power.

Common Errors

- Over aggressive application of center stick allowing the speed to build up too quickly.
- Not maintaining height, which includes sinking due to insufficient power or climbing due to translational lift.
- Overly aggressive deceleration with a nose high attitude, reducing the forward visibility and putting the tail low to the ground.

Fixed Nacelle Sideways Hover Taxi

Before starting, pick out three references; one on aircraft heading and two in line with the planned direction of travel. These reference points will assist with maintaining aircraft heading and ground track throughout the maneuver.

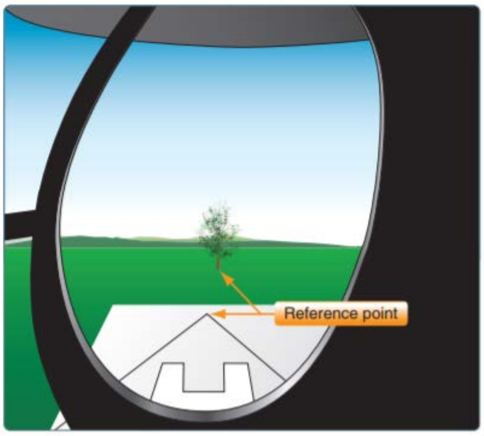

Figure 9-3. *The key to hovering sideward is establishing at least two reference points that help maintain a straight track over the ground while keeping a constant heading.*

From a stable inside ground effect (IGE) hover height, ensure the area is clear and then apply pressure onto the center stick in the direction of required travel. Once the initial movement has started, reduce the pressure on the center stick to control the speed. Scan to the front of the aircraft and maintain heading by using the pedals. There will be a tendency to descend in the direction of travel; therefore, height is controlled by increasing the power. To stop the sideways movement, apply opposite center stick to decelerate and then center as the aircraft speed approaches zero. Remove any power that was added to maintain height.

Forward Hover Taxi (Suitable for All Distances and in All Directions)

Before starting, pick out two reference points, one near and one far, in front and in line with the aircraft. These reference points should be kept in line throughout the maneuver.

From a stable inside ground effect (IGE) hover, slowly rotate the nacelle forward in 1-2º increments to achieve desired speed while keeping a nose level attitude. Upon achieving 10-15 knots ground speed (KGS), adjust the nacelles sufficiently aft to prevent additional acceleration. Adjust the power to maintain height. Be aware higher taxi speeds will generate translational lift, which could produce a climbing tendency.

Before reaching the intended hover spot, rotate the nacelles aft to decelerate. As the aircraft comes to a halt, reset to hover nacelle. Throughout the maneuver, it is desired to maintain an aircraft level attitude, however, as in the fixed nacelle taxi, the center stick can be used to initiate the movement or assist in deceleration if the action needs to be expedited.

Rearward Hover Taxi

Rearward hovering flight may be necessary to move the helicopter to a specific area when the situation is such that forward or sideward hovering flight cannot be used. During the maneuver, maintain a constant groundspeed, altitude, and heading. Due to the limited visibility behind an aircraft, it is important that the area behind the aircraft be cleared before beginning the maneuver. Use of ground personnel is recommended.

Before commencing this maneuver, aircraft clearance must be assured. From a stable inside ground effect (IGE) hover, slowly rotate the nacelle aft, initially 1-2º, until rearward movement begins. Once movement has started, decrease the aft nacelle slightly to prevent unwanted acceleration. Maintain height with power. Prior to reaching the intended hover spot, reset the nacelles slightly forward of the hover nacelle position and lower the aircraft nose slightly to reduce ground speed to zero. Reset hover nacelle position and re-trim the aircraft.

Note

Height control is easier at lower speeds. Translational lift quickly builds, and lift is also generated by the wing. Effective translational lift is caused by two factors in the tilt-rotor:

1. Increase in rotor efficiency with forward speed; and
2. Down force on the wing caused by prop-rotor downwash. (Downwash is removed as the downwash is blown aft of the wing with forward airspeed.)

The same is true for rearwards taxi, but sideways hover taxi requires a slight increase in power due to the upwind prop-rotor downwash interaction with the downwind prop-rotor downwash because downwash remains on the wing.

Common Errors

- Excessive use of the center stick rather than keeping a level attitude and using nacelles to maneuver.
- Misjudging the nacelle/groundspeed response time when controlling forward or aft movement resulting in an overshoot of the intended stopping point.
- Insufficient altitude in sideways flight, which allows the bottom of the nacelle cowling to come close to the ground.
- Allowing the nose to drift off heading in sideways flight (toward the direction of travel).

Vertical Takeoff to an IGE Hover

A vertical takeoff to a hover involves flying the aircraft from the ground vertically to a hover height of twenty feet, while maintaining a constant heading. Once the desired hover height is achieved, the aircraft should remain nearly motionless over a reference point at a constant altitude and on a constant heading. The maneuver requires a high degree of concentration and coordination.

Technique

The pilot on the controls needs to clear the area left, right, and above to perform a vertical takeoff to a hover. The pilot should remain focused outside the aircraft and if required, obtain a clearance to take off from ATC. If necessary, the pilot not flying (PNF) should assist in clearing the aircraft and warn of any obstacles and any unannounced or unusual drift/altitude changes.

Heading control, direction of turn, and rate of turn in a hover are all controlled by using the pedals. Hover height, rate of ascent, and the rate of descent are controlled by increasing or decreasing power. Aircraft position and the direction of travel are controlled by attitude via the center stick and nacelle modulation.

After receiving the proper clearance and ensuring that the area is clear of obstacles and traffic, begin the maneuver with MPOG and the center stick in a neutral position, or slightly into the wind. The FTR can now be depressed and held in until the aircraft becomes airborne.

The nacelles are moved forward 2-3^0 to establish "hover nacelle". Hover Nacelle is the setting at which the aircraft will be in a level attitude in the hover. This nacelle angle will vary dependent on the strength of the wind, the stronger the wind the farther forward the nacelles will need to be.

Smoothly increase the power until the aircraft becomes light on wheels. At the same time apply pressure and counter pressure on the pedals to ensure the heading remains constant. Continue to apply pedals as necessary to maintain heading and coordinate the center stick to control any tendency to drift whist maintaining a vertical ascent. After leaving the ground release the FTR and continue the climb to hover height. Avoid loitering at low hover heights or light weight on the landing gear. Unsteady aerodynamics in ground effect significantly increase workload and increase the likelihood of a PIO. In tilt-rotor a continuous climb to hover height is required to prevent any lateral darting at low hover heights.

As the aircraft leaves the ground, check for proper attitude control response and aircraft center of gravity. A slow ascent will allow for stopping if responses are outside the normal parameters indicating hung or entangled landing gear, center of gravity problems, or control issues. If a roll or tilt begins, decrease the power and determine the cause of the roll or tilt.

Upon reaching the desired hover altitude, adjust the flight controls as necessary to maintain position over the intended hover area. Re-trim the aircraft using either the FTR with a momentary press or the 4 way trim switch, to remove any tendency to drift. Student pilots should be reminded that while at a hover an aircraft level attitude is desirable. A nose low or high condition is generally caused by an in correct nacelle angle.

Once trimmed and stabilized, check the engine instruments and note the power required to hover. Excessive movement of any flight control requires a change in the other flight controls. For example, if the aircraft drifts to one side while hovering, the pilot naturally moves the center stick in the opposite direction. When this is done, part of the vertical thrust is diverted, resulting in a loss of altitude. To maintain altitude, increase the power. Depending on nacelle position, increasing power may incite forward or aft drift.

This could lead to over controlling the aircraft, especially with over use of the FTR. However, as level of proficiency increases, problems associated with over controlling decrease. Aircraft controls are usually more driven by pressure than by gross control movements.

Common Errors

- Failing to ascend vertically as the aircraft becomes airborne.
- Pulling excessive power to become airborne, causing the aircraft to gain too much altitude.

- Over controlling the aircraft, unstable hover, over use of the FTR.
- Nose low or high in the hover.

Hover Maneuvers IGE

These exercises are to familiarize the student pilot with the characteristics of the Tilt-rotor aircraft when operating IGE. These exercises must be flown accurately, particularly when maneuvring the aircraft in areas close to obstacles. The trim system must be used correctly to minimize pilot workload, keep the aircraft under control and complete the exercise within parameters.

Pedal Turns

Pedal turns are carried out using the conventional technique of pedal to control rate of turn, center to maintain the turn about a datum point and power lever to maintain height. Nacelles will generally be set at hover nacelle, however, in strong winds as the aircraft is turned downwind adjustment of nacelle may be required inorder to maintain ground position without extreme aircraft pitch. Turns will be conducted about the center of gravity of the aircraft. Awareness of the effect of pedal application upon power, particularly at max gross weight must be monitored. Awareness of the tail structure and prop rotor blades in relation to obstacles during spot turns is essential.

Established in an IGE hoevr and check the area is clear for both nose and tail of the aircraft. To initiate the turn, apply pedal in the required direction of turn whilst maintaining ground position with center stick. The rate of application and deflection of the pedal will control the speed/rate of the turn. Conduct a continuous scan from the inturn direction back through the 12 o'clock and then down onto the instruments.

Control the rate of turn by varying the pressure on the inturn foot pedal and once the turn is started reduce pedal input to maintain a constant turn rate. Use the center stick to maintain ground position and avoid over use of the Force trim button.

Prior to the maneuver always check the aircraft is within the wind limits for the exercise. In strong wind conditions a higher than normal nose attitude may be required as the aircraft is turned downwind. If center stick control or visibility becomes an issue it may be required to apply some aft nacelle. If this is the case ensure the nacelles are reset as the aircraft is turned back into wind to prevent drift.

Continue the turn towards the rollout heading, and as it approached begin to center the pedals. Opposite pedal may be required if the turn rate was high. Once the aircraft is backon desired heading, reset hover nacelle, if adjusted during the turn, and retrim the aircraft.

Turns about the Nose

Turns about the nose is an exercise in coordination and allows the aircraft to be turned whilst maintaining the nose over a fixed point. This will require a larger area of operation than a pedal turn alone.

Established in the IGE hover, checking the area is clear for both nose and tail of the aircraft. Initiate the maneuver by applying pressure to the foot pedal in the required direction of turn and simultaneously apply opposite center stick.

Maintain the aircraft nose over the spot with longitudinal center stick corrections and throughout the maneuver maintain height with the power lever.

Scan to the side, in the direction of travel to check the area remains clear and any height changes are identified. Scan ahead of the aircraft to ensure the nose position reamins fixed and glance at the instruments to check rate of turn and roll out heading. Continue the turn until approahing the desired heading, center the pedals and the center stick. Allow the motion to stop and then retrim, if required.

Square Patterns

Your instructor will direct you to manoeuver the aircraft around a fixed point utilizing the techniques you have learnt in hover taxiing and hover turns. The aim is to display flight control coordination, smoothness and scan technique. The first patterns will generally be flow to the right as this affords best lookout for the PF who will be sat in the right seat.

The patterns used are:

1. **Constant heading**: The aircraft is maoeuvered around a designated square box on the ground whilst maintaing a constant heading. Refer to Figure below.

2. **Parallel Heading:** The aircraft is maoeuvered around a designated square box on the ground by executing a series of sideways taxi followed by 90^0 pedal turn. Refer to Figure below.

3. **Perpendicular pattern**: The aircraft is maoeuvered around a designated square box on the ground by executing a series of sideways taxi followed by turn about the nose of the aircraft. Figure below.

Air Taxi

An air taxi is the preferred method when aircraft movements cover greater distances within an airport or heliport boundary. *[Figure 9-5]* It is expected that the aircraft will remain below 100 feet above ground level (AGL) with an appropriate airspeed and avoid over flying other aircraft, vehicles, and personnel.

Figure 9-5. *Air taxi.*

Commented [WA1]: Change toPL

Technique

Before starting, determine the appropriate airspeed and altitude combination to remain out of the cross-hatched or shaded areas of the height-velocity diagram. Additionally, be aware of crosswind conditions that may affect aircraft control. Pick out two references directly in front of the aircraft for the ground path desired. These reference points should be kept in line throughout the maneuver.

From a stable hover height, apply forward nacelle—initially 5-8º to accelerate the aircraft to approximately 30 knots ground speed (KGS). Maintain an aircraft level attitude with aft center stick and adjust power to maintain height or to climb to desired transit height as required. Be aware that an initial tendency to descend will quickly be replaced by a tendency to climb as translational lift is produced and the wing becomes effective.

Prior to the desired ground speed, rotate the nacelles 2-3º aft to stabilize the speed and stop any further acceleration. Remember, changes in groundspeed commanded by varying nacelle angle take more time to develop than those commanded by changes in nose attitude. For this reason, pilots must anticipate and initiate groundspeed changes with nacelle sooner than when using center stick only.

To stop the aircraft, rotate the nacelles fully aft. Power may need to be reduced initially as the thrust vector is tilted upwards to prevent a climb. In some cases, longitudinal center stick inputs may be required to achieve a more immediate aircraft response.

Maintain an aircraft level attitude with center stick and as translational lift is reduced, increase power to prevent the aircraft from sinking and developing an ROD. Reset the hover nacelle and stabilize the aircraft back into a hover. If the aircraft has climbed during the maneuver, descend down to normal hover height.

Note

Height control is easier at lower speeds. Translational lift quickly builds, and lift is also generated by the wing. Effective translational lift is caused by two factors in the tilt-rotor:

1. Increase in rotor efficiency with forward speed; and
2. Down force on the wing caused by prop-rotor downwash. (Downwash is removed as the downwash is blown aft of the wing with forward airspeed.)

Common Errors

- Over controlling during the maneuver.
- Overuse of the force trim button.
- Rapid application of the nacelle controller, which will requires an equally rapid reaction with nose up or down.
- Exceeding 80º nacelle. The attitude will be very nose high, which will reduce visibility and place the tail of the aircraft closer to the ground.
- Poor or slow scan.

- Staring close in,not utilizing distance markers.
- Poor Anticipation.
- Allowing a high rate of descent (ROD) to develop in the latter stages with low airspeed with the danger ofVortex Ring State (VRS).

Takeoff and Climb from a Hover

A normal takeoff from a hover is an orderly transition to forward flight and is executed to increase altitude safely and expeditiously. During the takeoff, fly a profile that avoids the cross-hatched or shaded areas of the height-velocity diagram.

The departure from the hover can be conducted in several ways, depending on whether or not there are obstacles directly in the flight path or if vertical clearance is required during the takeoff. Before any takeoff, ensure the aircraft is ready, clearance has been obtained, the crew is briefed, and the areas ahead and above are clear.

Bring the aircraft to a hover and make a performance check, which includes power, balance, and flight controls. The power check should include an evaluation of the amount of excess power available; that is, the difference between the power being used to hover and the power available at the existing altitude and temperature conditions. The balance condition of the aircraft is indicated by the position of the center stick and nacelles when maintaining a stationary hover with a level attitude. Wind will necessitate some variation in nacelle setting i.e. stronger wind nacelles will be further forward as compared to a no wind condition. Flight controls must move freely, and the aircraft should respond normally. Then, visually clear the surrounding area.

Figure

Clear Area (Unobstructed)

From an IGE hover (1), gradually rotate the nacelles forward to start an aircraft acceleration whilst, maintaining height with power and aft center stick to maintain a near level attitude (2).

Be aware that as the nacelles are rotated forward, the center of gravity (C of G) of the nacelles moves forward of the wing line. This results in an overall shift in aircraft C of G, which causes a nose down pitching moment. Additionally, the forward rotation of the thrust vector causes a nose down pitching moment during transition to forward flight. Left uncorrected, these characteristics will cause the aircraft to descend.

Briefly hold the nacelle angle constant to allow positive airspeed to develop, before smoothly continuing nacelle forward rotation (3) while simultaneously applying sufficient power to establish the desired rate of climb (ROC) and departure angle (4).

Figure 9-7. *The helicopter takes several positions during a normal takeoff from hover.*

Commented [WA1]: Change to tilt rotor

Note

Some aircraft have in built protection to prevent the nacelles from being rotated forward of 75^0 below 40 KIAS to prevent excessive forward nacelle rotation with insufficient speed. This condition could result in a severe nose down pitching moment, which could exceed longitudinal center stick authority. In aircraft without this protection, ensure there is sufficient speed before forward nacelle rotation. If you encountered this hazardous position the recovery action is to rotate the nacelles to the rear, as aft center stick will have little effect.

With the onset of translational lift, there will be a significant tendency to climb without increasing power due to higher rotor efficiency and lift generated by the wing.Adjust the power to maintain the desired rate of climb, allowing the aircraft to accelerate past the recommended speed, towards V_Y before configuring the aircraft as per the manufacturer’s instructions.

Anticipate achieving the desired climb speed and set an aircraft pitch attitude to maintain it, continuing the climb to the desired altitude. Anticipate the altitude by 10% of the ROC and level the aircraft by reducing power and adopting an accelerative attitude towards the desired airspeed.

Vertical (Obstructed)

From the normal hover height, smoothly apply power to affect a positive ROC to climb the aircraft vertically. Once obstacle clearance is assured, smoothly rotate nacelles forward, modulating the rate in order to maintain the climb.

Be aware that as the nacelles are rotated forward, the C of G of the nacelles moves forward of the wing line. This resultant is an overall shift in aircraft C of G that will cause a nose down pitching moment. Additionally, the forward rotation of the thrust vector causes a nose down pitching moment during transition to forward flight. Left uncorrected, these characteristics will cause the aircraft to descend.

Set aircraft pitch 2-3º below the horizon to expedite airspeed increase and prevent the nose from rising due to blow back. This could stop the aircraft from accelerating and result in riding the bottom of the conversion corridor. This results in a slower than normal transition, and decreases aircraft stall margin.

Once through translational lift, trim the aircraft nose back to or near level attitude.
As the airspeed increases, the wing begins to produce positive lift, and the control surfaces become increasingly effective. Continue the climb and work to trim out control pressures.

When trimming the aircraft, use the Force Trim Release to reset the center stick and actuators before refining trim using the four-way trim switch. Focus on making all control inputs smooth and steady. The fly by wire (FBW) systems are very responsive. Multiple FTR inputs will reduce the flight control system (FCS) computer's ability to maintain steady flight.

Maintain takeoff direction and endeavor to keep the relative wind ±30º from the nose of the aircraft for maximum climb capability and reduced flapping effects. Allowing the aircraft to weathervane with the wind, while using center stick and pedals to remain on course, is preferred over strictly maintaining the nose in the same direction of travel.

Continue climbing and accelerating toward the required altitude and airspeed and when able, the conduct after takeoff checks.

Throughout the maneuver, scan the instruments and lookout well ahead and laterally. This will assist in identifying changes in heading, ground speed (GS) and ground position.

Figure

Common Errors

- Overuse of the force trim release.
- Making abrupt nacelle changes.
- Staring at the instruments with poor lookout.
- Failure to control aircraft pitch attitude during the transition.

Normal Takeoff

The rolling takeoff must be used when the gross weight of the aircraft exceeds the vertical takeoff capability. The rolling takeoff may also be used for operational considerations.

The pilot must consult the Pilot's Operating Handbook (POH) or Aircraft Flying Manual (AFM) to ensure the aircraft is approved for a takeoff under the existing conditions, there is sufficient performance and runway length for the takeoff, the takeoff surfaces are firm and of sufficient length to permit the aircraft to gradually accelerate to normal liftoff and climb-out speed and maintain obstruction clearance.

Prior to commencing the rolling takeoff technique, takeoff and land data must be calculated to determine appropriate takeoff technique, refusal speed, acceleration and stopping distance, and single engine max climb performance. His should be conducted as part of the pre-flight actions and reconfirmed in the aircraft.

The takeoff should be conducted as nearly into the wind as possible. Since the aircraft depends on airspeed, a headwind provides some of that airspeed even before the aircraft begins to accelerate into the wind. Secondly, a headwind decreases the ground speed necessary to achieve flying speed. Slower ground speeds yield shorter ground roll distances and allow use of shorter runways while reducing wear and stress on the landing gear.

Takeoff Roll

Use the techniques described in the ground taxi section to move the aircraft into position for takeoff. Align the aircraft and nose wheel with the runway and set the required nacelle angle, holding runway position with the brakes applied. Maintain an aircraft level attitude with center stick.

With all checks completed, ATC clearance given and the aircraft ready for takeoff, release the foot brakes and increase power. As the aircraft starts to roll forward, assure both feet are on the pedals so the toes or balls of the feet are on the main portions, not on the toe brake. At all times, monitor the engine instruments for indications of a malfunction during the takeoff roll and be prepared to reject if required.

As the airplane gains speed, the pedals are used to keep the nose of the aircraft pointed down the runway and parallel to the centerline. As the speed of the takeoff roll increases, the aircraft will begin to develop both translational and wing borne lift, which will generate the desire to climb.

Use center stick controls into any crosswind to keep the airplane centered on the runway centerline and application of forward center stick may be required to keep the aircraft on the runway until the desired takeoff speed is achieved. This would normally be V_{TOSS}.

The pilot should avoid using the foot brakes for steering purposes as this will slow acceleration, lengthen the takeoff distance, and possibly result in severe swerving.

As the speed continues to increase, all of the flight controls will gradually become effective enough to maneuver the aircraft about its three axes. At this point, the aircraft is being flown more than it is being taxied. As this occurs, progressively smaller pedal deflections are needed to maintain direction.

The student may tend to move the controls through wide ranges, as a consequence, overcontrol the aircraft. The situation may be aggravated by overuse of the FTR, and an apparent sluggish reaction of the aircraft to these movements. The flight instructor must help the student learn proper trim control and aircraft reactions. The instructor should always stress using the proper outside reference to judge airplane motion, coupled with an instrument cross check.

For takeoff, the student should always be looking far down the runway at two points aligned with the runway. For the first practice the flight instructor should have the student pilot follow through lightly on the controls and point out the outside references that provide the clues for how much control movement is needed and how the pressure and response changes as airspeed increases. With practice, the student pilot should become familiar with the aircraft's response to acceleration to lift off speed, corrective control movements needed, and the outside an inside references necessary to accomplish the takeoff maneuver.

Liftoff

At takeoff speed or V_{TOSS}, smoothly increase the power to maximum continuous take off power in around two to four seconds. As the aircraft lifts from the runway surface maintain a level pitch attitude with aft center stick to prevent the nose form tucking under during lift off.

The ideal takeoff attitude is a level attitude, requiring only minimum pitch adjustments shortly after the aircraft lifts off to attain the speed for the best rate of climb (V_Y). [Figure xx] The pitch attitude necessary for the aircraft to accelerate to V_Y speed should be demonstrated by the instructor and memorized by the student. Flight instructors should be aware that initially, the student pilot may have a tendency to hold excessive aft center stick pressure just after lift-off, resulting in an abrupt pitch-up and deceleration.

The scan must be intensified at this critical point to attain/maintain proper aircraft pitch and bank attitude. A novice pilot often has a tendency to fixate on the aircraft's pitch attitude and/or the airspeed indicator and neglect bank control of the aircraft.

Initial Climb

Upon lift-off, the aircraft should be flying at the pitch attitude that allows it to accelerate to V_Y, with a power setting to achieve the required/desired ROC. This is the speed at which the aircraft gains the most altitude in the shortest period of time. If the aircraft has not been properly trimmed, some aft center stick pressure may be required to hold this attitude until V_Y is established.

Once a positive rate of climb is established, the pilot should clean the aircraft by retracting the flaps and landing gear (if equipped). Many modern Powered Lift aircraft have automatic scheduling flaps, so no action is required.

It is recommended that takeoff power be maintained until reaching an altitude of at least 200 feet above the surrounding terrain or obstacles. The combination of V_Y and takeoff power assures the maximum altitude gained in a minimum amount of time. This gives the pilot more altitude from which the aircraft can be safely maneuvered in case of an engine failure or other emergency.

Since the power on the initial climb is set at the takeoff power setting, the airspeed is controlled by making slight pitch adjustments using the center stick. Pilots must remember the climb pitch will be lower when the aircraft is heavily loaded, or power is limited by density altitude.

With the correct pitch attitude attained, the pilot should trim to it while cross-checking against outside visual references and inside at the AI. Trimming can be achieved with either the FTR or the 4 way trim switch to relieve any center stick control pressures. This will make it easier to hold a constant airspeed.

After the recommended climb airspeed (V_Y) has been established and a safe maneuvering altitude has been reached, the pilot can reduce the power to achieve his desired rate of climb (ROC) and continue to the intended operating altitude or transition for onward flight.

During initial climb, it is important that the takeoff path remain aligned with the runway to avoid drifting into obstructions or into the path of another aircraft that may be taking off from a parallel runway.

A flight instructor should help the student identify two points inline ahead of the runway to use as a tracking reference. As long as those two points are inline, the aircraft is remaining on the desired track. Proper scanning techniques are essential to a safe takeoff and climb, not only for maintaining attitude and direction, but also for avoiding collisions near the airport.

Common Errors

- Failing to review POH/AFM and performance charts prior to takeoff.
- Failing to adequately clear the area prior to taxiing into position on the active runway.
- Abrupt application of power.
- Failing to check engine instruments for signs of malfunction after applying takeoff power or prior to liftoff.
- Overcorrecting in yaw during ground roll.
- Failing to achieve V_{TOSS} prior to lifting from the runway.

- Failing to attain proper lift-off attitude.
- Allowing the nose to drop on lift off.
- Overcontrolling during initial climb-out and lack of trimming.
- Limiting scan or staring to areas directly ahead of the aircraft causing a wing to drop immediately after liftoff.
- Failing to attain/maintain best rate-of-climb airspeed (V_Y) or desired climb airspeed.

Crosswind Takeoff

While it is usually preferable to take off directly into the wind whenever possible or practical, there are many instances when circumstances or judgment indicate otherwise. Therefore, the pilot must be familiar with the principles and techniques involved in crosswind takeoffs as well as those for normal takeoffs. A crosswind affects the aircraft during takeoff much as it does during taxiing and the pilot must be aware of the interaction effects of the wind on upwind and downwind proprotors systems (as discussed in the aerodynamics chapters).

Takeoff Roll

The technique used during the initial takeoff roll in a crosswind is generally the same as the technique used in a normal takeoff roll, except that the pilot must apply center stick pressure into the crosswind. This tilts the thrust axis into the wind, therefore, less initial takeoff performance should be expected until the aircraft is wings-level in coordinated flight in the climb.

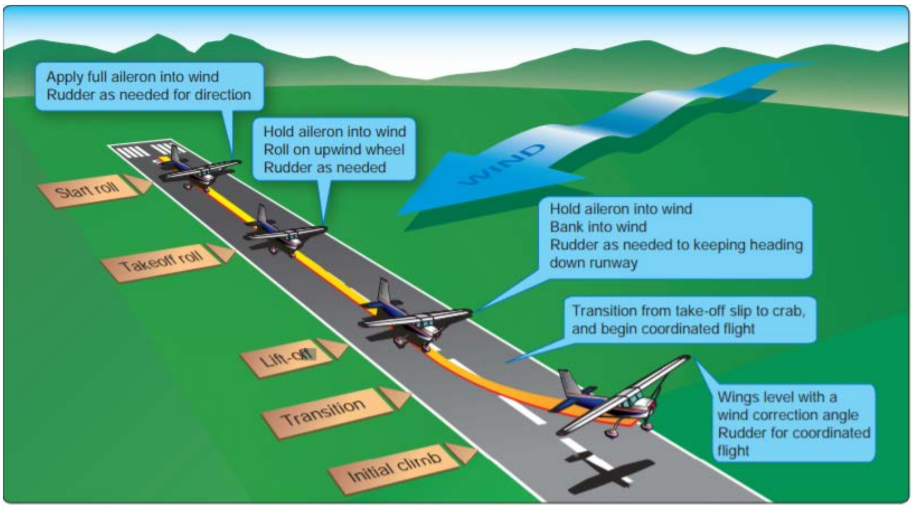

Figure 5-4. *Crosswind roll and takeoff climb.*

Commented [WA1]: Needs adjusting for PL

While taxiing into takeoff position, it is essential that the pilot check the windsock and other wind direction indicators for the presence of a crosswind. Modern aircraft are often equipped with Air Data Computers (ADC) that will give this information, even on the ground.

If a crosswind is present, the pilot should apply sufficient lateral center stick pressure into the wind while beginning the takeoff roll to prevent a sideways movement or skid. The pilot should maintain this control position, as the aircraft accelerates, the pilot should only apply enough lateral pressure to keep the aircraft laterally aligned with the runway centerline. While holding center stick pressure into the wind, the pilot should use the pedals to maintain a straight takeoff path. [Figure 5-4]

Through pedal inputs keep the aircraft pointed parallel with the runway centerline, while using the center stick to keep the aircraft laterally aligned with the centerline.

During crosswind takeoffs the upwind proprotor will be experiencing more lift due to increased airflow and flapback, as compared to the downwind proprotor. This will generate a tendency to roll away from the wind. The pilot must maintain lateral (into wind) center stick throughout the takeoff roll to prevent the upwind wing from rising. If the upwind wing rises, the amount of wing surface exposed to the crosswind will increase, which may cause the aircraft to "skip.

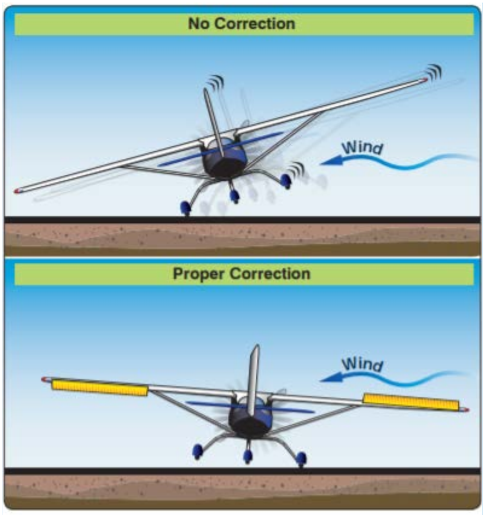

Figure 5-5. *Crosswind effect.*

Commented [WA2]: Needs changing to PL

During a crosswind takeoff roll, it is important that the pilot hold sufficient center stick pressure into the wind not only to keep the upwind wing from rising but to hold that wing down so that the aircraft sideslips into the wind enough to counteract drift immediately after lift-off.

At takeoff airspeed (V_{TOSS}) a smooth but very definite lift-off can be made through application of power, allowing the aircraft to leave the ground under positive control while the pilot establishes the proper amount of wind correction, avoiding excessive side-loads on the landing gear and preventing possible damage.

As the wheels leave the runway, the aircraft begins to drift sideways with the wind as ground friction is no longer a factor in preventing lateral movement. To minimize this lateral movement the pilot must establish and maintain the proper amount of crosswind correction prior to lift-off by applying center stick pressure into the wind. The pilot must also apply pedal pressure, as needed, to prevent weathervaning.

Initial Climb

With a correct crosswind correction applied, the aircraft will maintain alignment with the runway while accelerating and then maintain that alignment once airborne. As takeoff acceleration occurs, the efficiency of the wing will increase with aircraft speed and the proprotors will start to experience similar airflows across them. The tendency for the upwind wing to lift will gradually reduce as the airspeed increases.

The center stick, having been initially leaned into the wind, can be relaxed to the extent necessary to prevent a roll into wind and to keep the aircraft aligned with the runway.

Due to the lateral center stick pressure, as the aircraft becomes airborne, the wing that is upwind will have a tendency to be lower relative the other wing requiring simultaneous opposite center stick application and pedal input to maintain runway alignment.

As the aircraft establishes its climb, the nose should be turned into the wind to offset the crosswind, wings brought to level, and pedal input adjusted to maintain runway alignment (crabbing or cross controlling). [Figure 5-6]

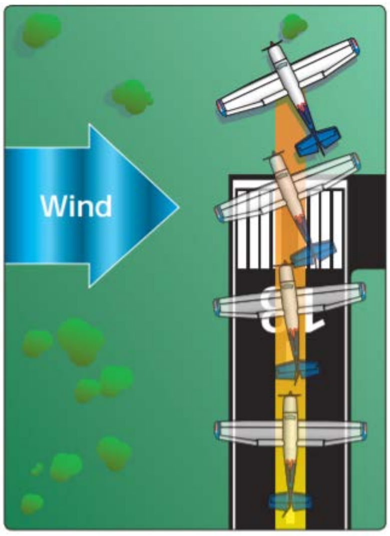

Figure 5-6. *Crosswind climb flightpath.*

Commented [WA3]: Change to PL

Unlike landing, the runway alignment (staying over the runway and its extended centerline) is paramount to keeping the aircraft parallel to the centerline. However, because the force of a crosswind may vary markedly within a few hundred feet of the ground, the pilot should check the ground track frequently and adjust the wind correction angle, as necessary. The remainder of the climb technique is the same used for normal takeoffs and climbs.

Common Errors

- Failing to review AFM performance and charts prior to takeoff.
- Failing to adequately clear the area prior to taxiing onto the active runway.
- Upwind wing drop on takeoff.
- Poor ground track due to insufficient pedal input.

Chapter 10

Basic Flight Maneuvers

Introduction

From the previous chapters, it should be apparent that no two aircraft perform the same way. Even when flying the same model of powered-lift, wind, temperature, humidity, weight, and equipment make it difficult to predict just how the aircraft will perform. Flight instructors face the challenge of teaching new powered-lift pilots about attitude, stall and thrust setting awareness, which requires understanding the motions of flight. A tiltrotor in APLN mode rotates in bank, pitch, and yaw while also moving horizontally, vertically, and laterally. In VTOL/CONV mode, the four fundamentals still apply, but in a different way. The four fundamentals (straight-and-level flight, turns, climbs, and descents) are the principle maneuvers that control the aircraft during flight.

Where possible, techniques provided in this chapter have been developed to be applicable to powered-lift aircraft in general. As only tiltrotor aircraft exist for civil use in the powered-lift category, much of the guidance and techniques provided are specific to tiltrotor aircraft. Tiltrotor specific information has been identified by the use of the term "tiltrotor" or the use of terms such as “nacelle.”

Because aircraft performance varies with weather conditions and aircraft loading, specific nose attitudes and thrust control/power settings are not detailed in this handbook. In addition, this chapter does not detail every attitude of an aircraft in the various flight maneuvers, nor every move that must be made in order to perform a given maneuver.

When a maneuver is presented, there is a brief description, followed by the technique to accomplish the maneuver. In most cases, there is a list of common errors at the end of the discussion. The chapter begins by addressing the four fundamentals in VTOL/CONV, before moving on to APLN mode flight.

The Four Fundamentals VTOL/CONV

There are four fundamentals of flight upon which all maneuvers are based: straight-and-level flight, turns, climbs, and descents. All controlled flight maneuvers consist of one or more of the four fundamentals of flight. If a student pilot is able to perform these maneuvers well, and the student’s proficiency is based on accurate “feel” and control analysis rather than mechanical movements, the ability to perform any assigned maneuver is only a matter of obtaining a clear visual and mental conception of it. The flight instructor must impart a good knowledge of these basic elements to the student, and must combine them and plan their practice so that perfect performance of each is instinctive without conscious effort. The importance of this to the success of flight training cannot be overemphasized. As the student progresses to more complex maneuvers, discounting any difficulties in visualizing the maneuvers, most student difficulties are caused by a lack of training, practice, or understanding of the principles of one or more of these fundamentals.

Guidelines

Good practices to follow during maneuvering flight include:

1. Move the center stick and thrust control devices only as fast as trim, torque, and aircraft control can be maintained. When entering a maneuver and the trim, or power reacts quicker than anticipated, pilot limitations have been exceeded. If continued, an aircraft limitation will be exceeded. Perform the maneuver with less intensity until all aspects of the machine can be controlled. The pilot must be aware of the sensitivity of the flight control, and avoid abrupt control inputs.
2. Anticipate changes in aircraft performance due to gross weight or environmental conditions. Proper preflight planning, and referencing the manufacturer's performance charts is essential to avoid any unwanted surprises.
3. Anticipate the following characteristics during aggressive maneuvering flight, and adjust or lead with power as necessary to maintain trim and balanced flight:
    - Left turns, power required increases because the direction of thrust is less vertical.
    - Right turns, power required increases because the direction of thrust is less vertical.
    - Application of aft center stick, power required adjusts based on thrust control setting.
    - Application of forward cyclic power required adjusts based on thrust control setting.
    - Always leave a way out.
    - Know where the winds are.
    - Engine failures occur during power changes and cruise flight
    - Crew coordination is critical. Everyone needs to be fully aware of what is going on, and each crewmember has a specific duty
    - In steep turns, the nose drops. In most cases, energy (airspeed) must be traded to maintain altitude as the required excess engine power may not be available (to maintain airspeed in a 2G/60° turn, rotor thrust/engine power must increase by 100 percent). Failure to anticipate this at low altitude endangers the crew and passengers. The rate of pitch change is proportional to gross weight and density altitude.
    - Exceeding aircraft limitations during flight may occur as the aircraft unloads from high G maneuvers. This is due to insufficient power reduction following the increase to maintain consistent airspeed and altitude when G-loading is increased (dive recovery or recovery from high G-turn to the right).
    - Normal landings usually require high power settings, with terminations to a hover requiring the highest power setting.
    - The center stick and thrust control position relative to the horizon determines the aircraft’s travel and attitude.

- Moving nacelles forward, initially power required to maintain altitude as thrust vector is tilted forward away from the vertical then application of aft center stick to maintain altitude as the aircraft begins to generate wingborne lift. Power will then maintain speed.

- Moving nacelles aft, initially power reduced to maintain altitude as thrust vector is tilted vertically away from the horizontal then application of forward center stick to maintain speed as the aircraft begins to generate rotor borne lift. Power will then maintain altitude.

Integrated Flight Instruction

When introducing basic flight maneuvers to a beginning pilot, it is recommended that the "Integrated" or "Composite" method of flight instruction be used. This means the use of outside references and flight instruments to establish and maintain desired flight attitudes and airplane performance. *[Figure 10-5]* When beginning pilots use this technique, they achieve a more precise and competent overall piloting ability. Although this method of aircraft control may become second nature with experience, the beginning pilot must make a determined effort to master the technique.

As the beginner pilot develops a competent skill in visual reference flying, the flight instructor should further develop the beginner pilot's effectiveness through the use of integrated flight instruction; however, it is important that the beginner pilot's visual skills be sufficiently developed for long-term, safe, and effective aircraft control. *[Figure 10-5]*

The basic elements of integrated flight instruction are as follows:

- The pilot visually controls the aircraft's attitude in reference outside to the natural horizon. At least 90 percent of the pilot's attention should be devoted to outside visual references and scanning for airborne traffic. The process of visually evaluating pitch and bank attitude is nearly an imperceptible continuous stream of attitude information. If the attitude is found to be other than desired, the pilot should make precise, smooth, and accurate flight control corrections to return the airplane to the desired attitude. Continuous visual checks of the outside references and immediate corrections made by the pilot minimize the chance for the airplane to deviate from the desired heading, altitude, and flightpath.
- Aircraft attitude is validated by referring to flight instruments and confirming performance. If the flight instruments display that the aircraft's performance is in need of correction, the required correction must be determined and then precisely, smoothly, and accurately applied with reference to the natural horizon. Aircraft attitude and performance are then rechecked by referring to flight instruments. The pilot then maintains the corrected attitude by reference to the natural horizon.
- The pilot should monitor aircraft performance by making quick snap-shots of the flight instruments. No more than 10 percent of the pilot's attention should be inside the cockpit. The pilot must develop the skill to quickly focus on the appropriate flight instruments and then immediately return to the visual outside references to control aircraft attitude.

The pilot should become familiar with the relationship between outside visual references to the natural horizon and the corresponding flight instrument indications. For example, a pitch attitude adjustment may require a movement of the pilot's reference point of several inches in relation to the natural horizon, but corresponds to a seemingly insignificant movement of the reference bar on the attitude indicator. Similarly, a deviation from a desired bank angle, which is obvious when referencing the wingtips or cowling relative to the natural horizon, may be imperceptible on the airplane's attitude indicator to the beginner pilot.

The most common error made by the beginner pilot is to make pitch or bank corrections while still looking inside the cockpit. It is also common for beginner pilots to fixate on the flight instruments—a conscious effort is required by them to return to outside visual references. For the first several hours of instruction, flight instructors may choose to use flight instrument covers to develop a beginning pilot's skill or to correct a pilot's poor habit of fixating on instruments by forcing them to use outside visual references for aircraft control.

The use of integrated flight instruction does not, and is not intended to prepare pilots for flight in instrument weather conditions. The most common error made by the beginning student is to make pitch or bank corrections while still looking inside the cockpit. Control pressure is applied, but the beginning pilot, not being familiar with the intricacies of flight by references to instruments, including such things as instrument lag and gyroscopic precession, will invariably make excessive attitude corrections and end up "chasing the instruments." Aircraft attitude by reference to the natural horizon, however, is immediate in its indications, accurate, and presented many times larger than any instrument could be. Also, the beginning pilot must be made aware that anytime, for whatever reason, aircraft attitude by reference to the natural horizon cannot be established and/or maintained, the situation should be considered a bona fide emergency.

VTOL/CONV Straight-and-Level Flight

Straight-and-level flight is flight in which constant altitude and heading are maintained. The attitude of the thrust control device relative to the horizon determines the airspeed. Aircraft design determines the attitude when stabilized at a given thrust control, airspeed and altitude. Altitude is primarily controlled by use of the power lever.

Technique

To establish forward flight, the thrust control device must be tilted forward to obtain the necessary horizontal component of thrust.

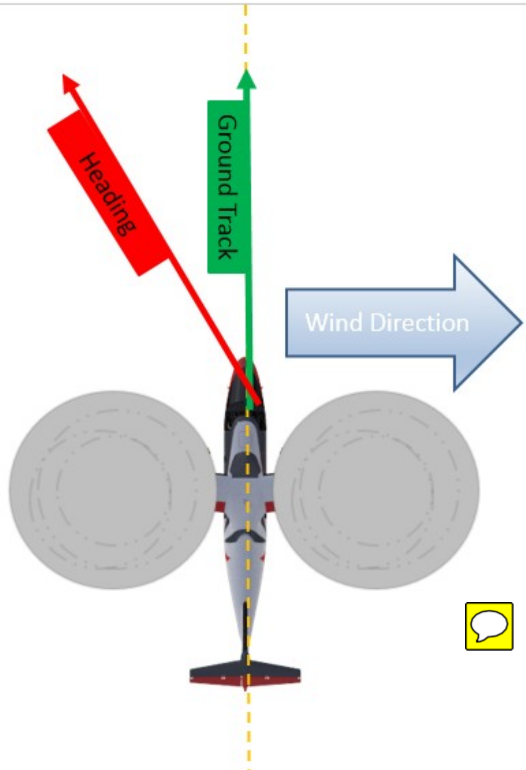

Figure 10-1. *To compensate for wind drift at altitude, crab the aircraft into the wind.*

Increasing the horizontal component of thrust will cause the airspeed to increase. With power held constant, this change will reduce the vertical component of thrust, causing the aircraft to descend. In order to counteract this, the pilot must find the correct power setting to maintain level flight by adjusting the power lever. *[Figure 9-10]* As airspeed increases, the aircraft fixed and adjustable control surfaces aid in trimming the aircraft longitudinally. In tiltrotors, this reduces the amount of nose tuck that would occur as the nacelles and aircraft CG shift forward.

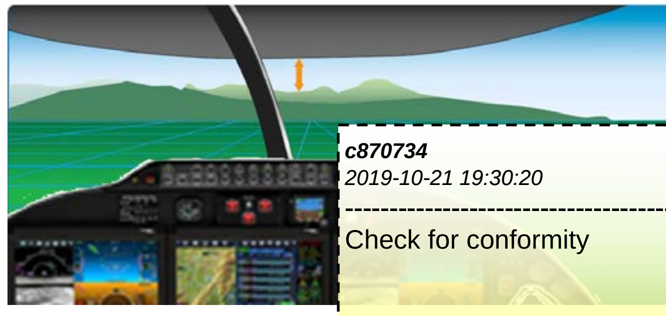

Figure 10-2. *Maintain straight-and-level flight by adjusting thrust control device forward but adjusting power as necessary to maintain a constant airspeed and altitude. The natural horizon line can be used as an aid in maintaining straight-and-level flight. If the horizon line begins to rise, slight power may be required or the nose of the aircraft may be too low.*

When in straight-and-level flight, any increase in the power lever, while holding airspeed/thrust control constant, causes the aircraft to climb.

A decrease in power, while holding airspeed constant, causes the aircraft to descend.

To increase airspeed in straight-and-level flight, transition the thrust control device forward, and increase power as necessary to maintain altitude. To decrease airspeed, apply rearward thrust control, and lower the power lever, as necessary, to maintain altitude. This can also be achieved by pitching the aircraft forward(nose down) to accelerate or nose up to decelerate or by a combination of aircraft pitch and thrust control device movement.

Smooth control inputs is essential to avoid pilot induced oscillations (PIO). Although fly-by-wire controls are highly responsive, there may be a slight delay in control reaction, and it is necessary to [illegible] of the aircraft. When making center stick and thrust control inputs to control the altitude or airspeed of an aircraft, take care not to overcontrol.

Depending on aircraft design, some powered-lift may be aerodynamically unstable. If a gust or turbulence causes the nose to drop, the nose may tend to continue to drop instead of returning to a straight-and-level attitude as it would on a fixed-wing aircraft. Therefore, a pilot must remain alert and fly the aircraft attentively at all times.

Common Errors

1. Improper aircraft trim technique.
2. Failure to maintain desired airspeed.
3. Failure to hold proper control position to maintain desired ground track.
4. Failure to allow the aircraft to stabilize at new airspeed.
5. Failure to maintain altitude when accelerating/decelerating.

VTOL/CONV Turns

A turn is a maneuver used to change the heading of the aircraft.

Technique

Before beginning any turn, the area in the direction of the turn must be cleared not only at the aircraft's altitude, but also above and below.

To enter a turn from straight-and-level flight, apply sideward movement of the center stick in the direction the turn is to be made. This can be achieved by applying pressure to the center stick, use of the 4 way trim switch or depressing the FTR, moving the center stick and then releasing the FTR.This is the only control movement needed to start the turn. Do not use the pedals to assist the turn, only apply pedal as needed to maintain balanced flight. Keeping the fuselage in the correct streamlined position around the vertical axis facilitates the aircraft flying forward with the least drag. In fly-by-wire aircraft, control reaction may vary with software and aircraft design. Trim is indicated by a centered ball on a turn and slip indicator.
However, in most tiltrotors the rapidity and amplitude (steepness) of a turn depends on the rate at which the center stick is displaced. The aircraft's flight control system will maintain that turn and angle of bank until a new lateral rate is introduced such as a command back to neutral. While in the turn, increase the power to maintain altitude.
Depending on the degree of bank, additional forward thrust control may be required to maintain airspeed.

Rolling out of the turn to straight-and-level flight is the same as the entry into the turn except that the movement of the center stick is applied in the opposite direction. Since the aircraft continues to turn as long as there is any bank, start the rollout before reaching the desired heading. A good general rule is to anticipate the roll out by 1 degree for every 1 degree AOB.
The discussion on level turns is equally applicable to making turns while climbing or descending. The only difference is that the aircraft is in a climbing or descending attitude rather than that of level flight. If a simultaneous entry is desired, merely combine the techniques of both maneuvers—climb or descent entry and turn entry. When recovering from a climbing or descending turn, the desired heading and altitude are rarely reached at the same time.

Common Errors

1. Failure to maintain altitude during the turn.
2. Pitching up and decelerating in turns to the left
3. Allowing the nose to drop and accelerating in turns to the right.
4. Not anticipating the roll out heading sufficiently. Poor trim technique.

VTOL/CONV Normal Climb

The entry into a climb from a hover has already been described in Chapter 9; therefore, this discussion is limited to a climb entry from cruising flight.

Technique

To enter a climb in a powered-lift while maintaining airspeed, the first actions are increasing the power lever, and adjusting the pedals as necessary to maintain a centered ball in the slip/skid indicator. Depending on thrust control setting, moving the power lever up may require an adjustment of the center stick to direct all of the increased power into lift and maintain the airspeed. Remember, a powered-lift in VTOL/CONV can climb with the nose down and descend with the nose up. In a tiltrotor maintaining a fixed nacelle setting, aircraft attitude changes mainly affect airspeed, not climb or descent. Therefore, the climb attitude is approximately the same as level flight in a stable climb, depending on the aircraft's horizontal stabilizer design.
With a fixed attitude the climb will be initiated with the application of power, which will control the ROC. An acronym used is PAT, Power Attitude, Trim. To level of from the climb simply remove the power applied maintain the attitude required for the airspeed and re-trim the aircraft. PAT.

If the pilot wishes to climb faster, with a decreased airspeed, then the climb can be initiated with aft cyclic In this case use APT. Attitude, Power , Trim.. Depending on initial or entry airspeed for the climb, the climb can be accomplished without increasing the power, if a much slower airspeed is acceptable. However, as the airspeed decreases, the airflow over the wing decreases,necessitating more power application.

To level off from a climb, start adjusting the attitude to the level flight attitude a few feet prior to reaching the desired altitude. The amount of lead depends on the rate of climb at the time of level-off (the higher the rate of climb, the more the lead). Generally, the lead is 10 percent of the climb rate. For example, if the climb rate is 500 feet per minute (fpm), you should lead the level-off by 50 feet.

To begin the level-off, apply center stick to adjust and maintain a level flight attitude. Maintain climb power until the airspeed approaches the desired cruising airspeed, then lower the power lever to obtain cruising power. Throughout the level-off, maintain heading with the pedals.

Common Errors

1. Improper power and airspeed control.
2. Improper directional control.
3. Lack of anticipation in the level off, exceeding desired altitude.

VTOL/CONV Normal Descent

A normal descent is a maneuver in which the aircraft loses altitude at a controlled rate in a controlled attitude.

Technique

To establish a normal descent from straight-and-level flight at cruising airspeed, lower the power lever to obtain desired descent power setting based on thrust control setting and adjust pedals to maintain heading. If cruising airspeed is the same as or slightly above descending air speed, simultaneously apply the necessary center stick pressure to obtain the approximate descending attitude. If the pilot wants to decelerate, the thrust control device must be moved aft, the aircraft pitched up or a combination of both. If the pilot desires to descend with increased airspeed, then forward thrust control, pitching nose down or a combination of both will achieve the the desired results. Depending on aircraft design, as the aircraft stabilizes at a forward airspeed, the fuselage attitude will streamline due to the airflow over the horizontal stabilizer. As the airspeed changes, the airflow over the vertical stabilizer or fin changes, so the pedals may have to be adjusted, depending on the aircraft design.

In a tiltrotor in VTOL/CONV, the pilot should always remember that the total lift and thrust control is provided by a combination of nacelle angle and aircraft attitude. If a certain airspeed is desired, it will require a certain nacelle, aircraft attitude and power setting for level flight. However, given fixed nacelles, if the center stick is moved, the thrust-versus-lift ratio is changed. Aft center stick directs more power to lift, and altitude increases. Forward center stick directs more thrust horizontally, and airspeed increases. If the nacelles and power lever are not changed and there is a change only in center stick, aft cyclic results in a climb, and forward center stick results in a descent with the corresponding airspeed changes.

To level off from the descent, lead the desired altitude by approximately 10 percent of the rate of descent. For example, a 500 fpm rate of descent would require a 50 foot lead. At this point, increase power to obtain cruising power, and apply pedals to maintain heading. Adjust the thrust control to obtain cruising airspeed and center stick for a level flight attitude as the desired altitude is reached.

Common Errors

1. Erratic angle of decent during training.
2. Delayed initiation of level-off, which results in recovery below the desired altitude.
3. Improper heading control.
4. Undesired speed change in the descent.

Transitions and Conversions

In a tiltrotor, the term "Transition" refers to when the aircraft is accelerating and moving the nacelles forward towards the horizontal (increasing airspeed), from VTOL/Conv mode to APLN mode. The term "Conversion", refers to when the aircraft is returning to VTOL/Conv mode, from APLN mode (decreasing airspeed and reconfiguring for low-speed flight, hovering, or landing). The nacelles are moving from the vertical to a more horizontal position. During the transition/Conversion (between VTOL/Conv and APLN modes, a tiltrotor automatically mixes the different control modes, based on the airspeed and nacelle positions. This is tr

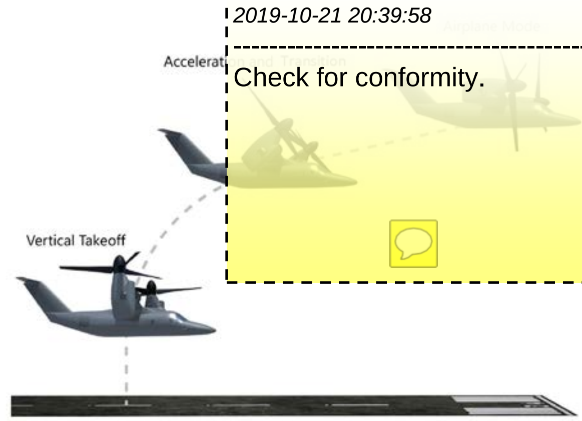

Figure 10-3. *Tiltrotors rotate nacelles to transition to APLN mode*

Conversion Corridor

Tiltrotor aircraft are often designed with, and employ, an established "conversion corridor." The conversion corridor exists to aid the pilot in transitioning and converting the aircraft within design limitations, and only allows nacelle movement when the aircraft is within the appropriate airspeed envelope..

The upper conversion protection boundary allows transition and conversion maneuvers to be performed without placing undue stresses on the proprotor hub assembly. There may also be additional weight and density altitude limitations to minimize elevated hub loads in these regions as per the manufacturer's procedures. The lower conversion protection boundary balances the combination of the vertical component of proprotor thrust and wing lift in an attempt to prevent wing stall due to premature transition.

The conversion corridor is usually relatively wide. Pilots can expect an airspeed band of 60 to 100 knots to be available for a given nacelle angle. However, in order to maximize performance, field of view, and minimize structural loads, flight near the middle of the corridor is recommended. Additionally, pilots must diligently plan when it is appropriate to begin converting and transitioning based on aircraft and environmental considerations. Flight in high altitude, high temperature, and heavy aircraft gross weight conditions can significantly extend the distance travelled during a conversion for a landing, and may result in a balked landing.

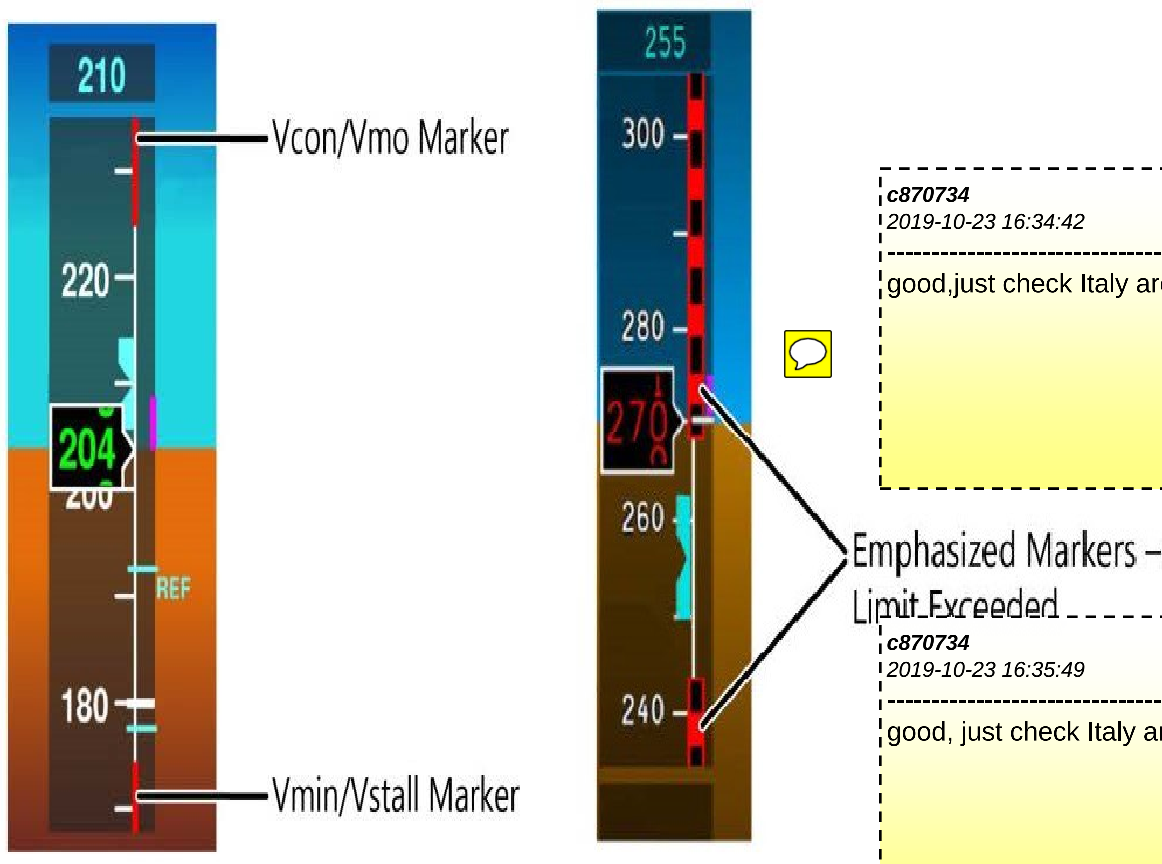

Figure 10-4. *Example of Conversion Corridor protection*

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Some aircraft have been designed to remove all conversion protection during emergency situations, such as an all engines inoperative condition, where the immediate conversion to an autorotative state is desirable.

Transition to APLN Mode

This section will explain the procedures for aircraft transition from VTOL mode to APLN mode, which is fundamental to the flying the tiltrotor. Instructors should ensure beginning tiltrotor pilots transition manually to develop pilot handling skills. Use of automation, if available, can be utilized once these skills have been mastered.

In tiltrotors transitioning to APLN mode, the conversion corridor is primarily an airspeed limit. There is a minimum airspeed and a maximum airspeed for each nacelle angle. The limits are there to keep blade flapping to within design parameters.

If the pilot is flying above the maximum airspeed for a nacelle setting , the center stick will be very far forward, and the tip path plane is tilted very far forward resulting in high flapping angles. The design of most proprotor systems, employ elastomeric bearings that will heat up over time. Elastomeric bearing heat buildup is lowest when the flapping angles are small. Flying outside the nacelle airspeed limits may result in excessive wear on flight critical parts.

Airspeeds limits are normally clearly marked by manufacturers.

Establish the aircraft in straight and level flight at the most forward VTOL nacelle setting, at the manufacturer's recommended airspeed. Smoothly initiate transition to the desired CONV nacelle setting, allowing airspeed to build. As required, lower the nose 1-2° to an accelerative attitude, this will assist in opening the conversion corridor, allowing the forward movement of the nacelles to continue.

Raise the power lever and trim aft center stick to counteract any rate of descent.as the nacelles continue forward toward. Re-trim nose attitude to achieve the desired CONV mode cruise speed and set power lever to maintain level flight. The power to maintain flight at a CONV mode nacelle setting will be higher than either VTOL or APLN modes. Prior to further aircraft transition, ensure the landing gear has been retracted.

From a stable CONV mode, with the gear retracted, smoothly increase power lever, and transition the nacelles forward towards APLN mode. As the nacelles move forward, the aircraft may have a nose down tendency. Counter any nose down, and prevent aircraft descent, by applying sufficiently aft center stick to maintain altitude.

Simultaneously raise the power lever and continue to accelerate towards the desired speed. As the nacelles reach APLN mode, some tiltrotors may incorporate an N_R reduction to improve efficiency. N_R reduction will also cause an acceleration in the aircraft.

Once established in APLN mode, aircraft control uses nose attitude to control altitude, and power lever to control speed. Allow the aircraft to accelerate to cruise, and trim for straight and level flight.

Conversion to VTOL CONV Mode

To begin the conversion from APLN mode reduce power from cruise power setting. Initially, maintain altitude with aft center stick. As required by manufacturer's procedures, increase N_R. This N_R increase may require a slight nose pitch down to avoid entering an unintended climb, and altitude deviations.

At the recommended airspeed, initiate aircraft conversion by rotating the nacelles aft towards CONV mode. A decelerative nose high attitude may have to be maintained to open the conversion corridor, and assist the deceleration. As the nacelles rotate aft, the aircraft may exhibit a strong tendency to climb. Control this with a combination of power lever and lowering the nose attitude to maintain altitude.

As the nacelles approach the desired CONV cruise nacelle, adjust aircraft pitch to a nearly level attitude. Continually adjust aircraft pitch and power to maintain altitude at desired cruise airspeed.

For further conversion to VTOL mode, lower power lever and initially apply aft center stick to maintain altitude and decelerate the aircraft.

Rotate the nacelles aft. As the nacelles become more vertical, the aircraft may have a strong tendency to develop a rate of climb. Apply forward center stick to maintain a level attitude and reduce power to maintain altitude.

As the nacelles approach VTOL mode, adjust pitch and power to maintain altitude at the desired airspeed, and re-trim the aircraft.

Common Errors

1. Erratic altitude control during transitions and conversions.
2. Allowing the aircraft to deviate from the conversion corridor during transitions and conversions.
3. Forgeting to reduce N_R as required, during transition to APLN mode.

Straight-and-Level Flight APLN mode

Straight-and-level flight occurrs when heading and altitude are constantly maintained. The four fundamentals are in essence a derivation of straight-and-level flight. As such, the need to form proper and effective skills in flying straight and level should not be understated. Precise mastery of straight-and-level flight is the result of repetition and effective practice. Perfection in straight-and-level flight comes only as a result of
the pilot understanding the effect and use of the flight controls, properly using the visual outside references, and the utilization of snap-shots from the flight instruments in a continuous loop of information gathering. A pilot must make effective, timely, and proportional corrections for deviations in the airplane's direction and altitude from unintentional slight turns, descents, and climbs to master straight-and-level flight.

Straight-and-level flight is a matter of consciously fixing the relationship of a reference point on the aircraft in relation to the natural horizon. *[Figure 3-6]* The establishment of reference points should be initiated on the ground as the reference points depends on the pilot's seating position, height, and manner of sitting. It is important that the pilot sit in a normal manner with the seat position adjusted, which allows for the pilot to see adequately over the instrument panel while being able to fully depress the rudder pedals to their maximum forward position without straining or reaching.
With beginner pilots, a flight instructor will likely use a dry erase marker or removable tape to make reference lines on the windshield or cowling to help the beginner pilot establish visual reference points. Vertical reference lines are best established on the ground, such as when the airplane is placed on a marked centerline, with the beginner pilot seated in proper position. Horizontal reference lines are best established with the airplane in flight, such as during slow flight and cruise

configurations. The horizon reference point is always the same, no matter what altitude, since the point is always on the horizon, although the distance to the horizon will be further as altitude increases. There are multiple horizontal reference lines due to the pitch attitude requirements of the maneuver; however, these teaching aids are generally needed for only a short period of time until the beginning pilot understands where and when to look during the various maneuvers.

In some commercial aircraft the manufacturer has designed an Datum eye point reference unit. This device ensures that each flying crew member has the correct eye reference for instrument and outside scan for their seat position. In order to operate the aircraft as intended it can be seen that all pilots must use the same reference datum. This is normally achieved by adjusting the seating position in both vertical and fore/aft axis.

Some aircraft will also have adjustable rudder pedals and/or control yoke/joy stick to ensure the pilot's view is in alignment with the design eye position. To highlight the significance of the design eye position, sitting just 1 inch below the reference point on a Boeing 767 will result in losing 40 meters of ground vision during final approach.

Straight Flight

Maintaining a constant direction or heading is accomplished by visually checking the lateral level relationship of the aircraft's wingtips to the natural horizon. In tiltrotor's, any necessary bank corrections are made with the pilot's coordinated use of flaperons and yaw control (rudder or differential collective). *[Figure 3-7]* The pilot should understand that anytime the wings are banked, the aircraft turns. The objective of straight flight is to detect small deviations as soon as they occur, thereby necessitating only minor flight control corrections. The bank attitude information can also be obtained from a quick scan of the attitude indicator (which shows the position of the wings relative to the horizon) and the heading indicator (which indicates whether flight control pressure is necessary to change the bank attitude to return to straight flight).

It is possible to maintain straight flight by simply exerting the necessary pressure with the flaperons or yaw control independently in the desired direction of correction. However, the practice of using the flaperons and yaw control independently is not correct and makes precise control of the aircraft difficult. The correct bank flight control movement requires the coordinated use of flaperons and yaw control. Straight-and-level flight requires almost no application of flight control pressures if the airplane is properly trimmed and the air is smooth. For that reason, the pilot must not form the habit of unnecessarily moving the flight controls. The pilot must learn to recognize when corrections are necessary and then to make a measured flight control response precisely, smoothly, and accurately. Pilots may tend to look out to one side continually, generally to the right due to the pilot's right seat position and consequently focus attention in that direction. This not only gives a restricted angle from which the pilot is to observe, but also causes the pilot to exert unconscious pressure on the flight controls in that direction. It is also important that the pilot not fixate in any one direction and continually scan outside the aircraft, not only to ensure that the attitude is correct, but also to ensure that the pilot is considering other factors for safe flight. Continually observing both wingtips has advantages other than being the only positive check for leveling the wings. This includes looking for aircraft traffic, terrain and weather influences, and maintaining overall situational awareness.

Level Flight

In learning to control the aircraft in level flight, it is important that the pilot be taught to maintain a light touch on the flight controls using fingers rather than the common problem of a tight-fisted palm wrapped around the flight controls. The pilot should exert only enough pressure on the flight controls to produce the desired result. The pilot should learn to associate the apparent movement of the references with the control pressures which produce attitude movement. As a result, the pilot can develop the ability to adjust the change desired in aircraft attitude by the amount and direction of pressures applied to the flight controls without the pilot excessively referring to instrument or outside references for each minor correction.

The pitch attitude for level flight is first obtained by the pilot being properly seated, selecting a point toward the aircraft's nose as a reference, and then keeping that reference point in a fixed position relative to the natural horizon. *[Figure 3-8]* The principles of attitude flying require that the reference point to the natural horizon position should be cross-checked against the flight instruments to determine if the pitch attitude is correct. If not, such as trending away from the desired altitude, the pitch attitude should be readjusted in relation to the natural horizon and then the flight instruments cross-checked to determine if altitude is now being corrected or maintained. In level flight maneuvers, the terms "increase the back pressure" or "increase pitch attitude" implies raising the aircraft's nose in relation to the natural horizon and the terms "decreasing the pitch attitude" or "decrease pitch attitude" means lowering the nose in relation to the natural horizon. The pilot's primary reference is the natural horizon.

For all practical purposes, airspeed remains constant in straight-and-level APLN mode flight if the power setting is also constant. Intentional airspeed changes, by increasing or decreasing the power, provide proficiency in maintaining straight-and-level flight as the airspeed is changing. Pitching moments may also be generated by extension and retraction of landing gear, or other drag producing devices. Exposure to the effect of the various configurations should be covered in any specific airplane checkout.

A common error of a beginner pilot is attempting to hold the wings level by only observing the aircraft's nose. Using this method, the nose's short horizontal reference line can cause slight deviations to go unnoticed; however, deviations from level flight are easily recognizable when the pilot references the wingtips and, as a result, the wingtips should be the pilot's primary reference for maintaining level bank attitude. This technique also helps eliminate the potential for flying the aircraft with one wing low and correcting heading errors with the pilot holding opposite pedal. A pilot with a bad habit of dragging one wing low and compensating with opposite yaw pressure will have difficulty in mastering other flight maneuvers.

Common errors in the performance of straight-and-level flight are:

- Attempting to use improper pitch and bank reference points to establish attitude.
- Forgetting the location of preselected reference points on subsequent flights.
- Attempting to establish or correct attitude using flight instruments rather than the natural horizon.
- "Chasing" the flight instruments rather than adhering to the principles of attitude flying.
- Mechanically pushing or pulling on the flight controls rather than exerting accurate and smooth pressure to affect change.
- Not scanning outside the cockpit to look for other aircraft traffic, weather and terrain influences, and not maintaining situational awareness.
- A tight palm grip on the flight controls resulting in a desensitized feeling of the hand and fingers, which results in overcontrolling the airplane.
- Habitually flying with one wing low or maintaining directional control using only the rudder control.
- Failure to make timely and measured control inputs when deviations from straight-and-level flight are detected.
- Inadequate attention to sensory inputs in developing feel for the airplane.

Level Turns APLN mode

A turn is initiated by banking the wings in the desired direction of the turn through the pilot's use of the flaperons. Left flaperon flight control pressure causes the left wing to lower in relation to the pilot. Right flaperon flight control pressure causes the right wing to lower in relation to the pilot. In other words, to turn left, lower left wing with flaperon by left center stick.

To turn right, lower right wing with right center stick. Depending on bank angle and aircraft design, at many bank angles, the aircraft will continue to turn with center stick neutralized. So the sequence should be like the following: (1) bank aircraft, adding either enough power or pitching up to compensate for the loss of lift (change in vector angle of lift); (2) adjust controls as necessary to stop bank from increasing and hold desired bank angle; (3) use the opposite center stick to return aircraft to level; (4) adjust center stick to again neutralize the ailerons (along with either power or pitch reduction) for level flight.

A turn is the result of the following:

- The flaperons bank the wings and so determine the rate of turn for a given airspeed. Lift is divided into both vertical and horizontal lift components as a result of the bank. The horizontal component of lift moves the aircraft toward the banked direction.

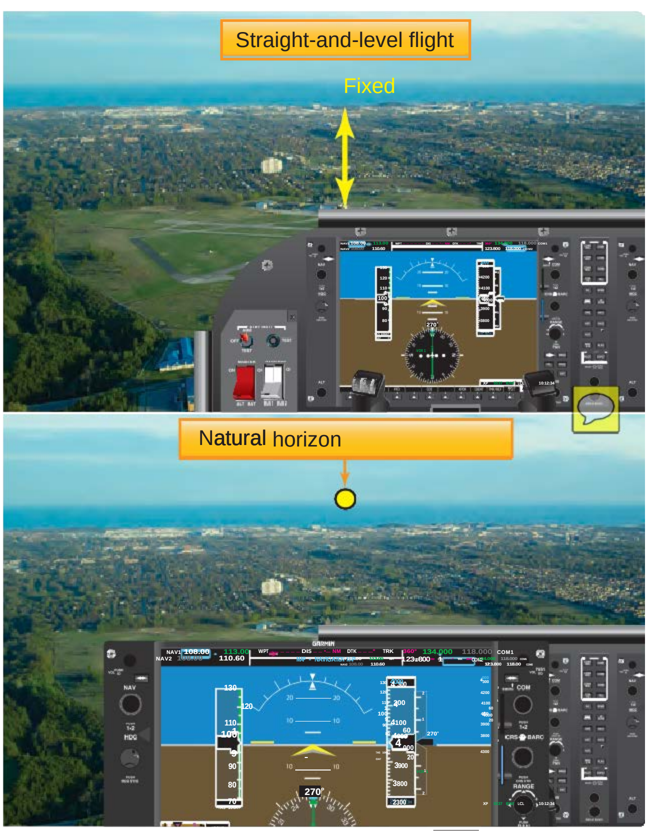

Figure 10-5. *Nose reference for straight-and-level flight.*

- The elevator pitches the nose of the aircraft up or down in relation to the pilot and perpendicular to the wings. If the pilot does not add power, and there is sufficient airspeed margin, the pilot must slightly increase the pitch to increase wing lift enough to replace the wing lift being diverted into turning force so as to maintain the current altitude.
- The vertical fin on an aircraft does not produce lift. Rather the vertical fin is a stabilizing surface and produces no lift if the airplane is flying straight ahead. The vertical fin's purpose is to keep the aft end of the aircraft behind the front end.
- The power lever controls the thrust applied, which can increase/decrease airspeed to adjustthe radius of the turn.
- The pilot uses yaw control to offset any adverse effects developed by the wing's differential lift and the engine/proprotor. The yaw control does not turn the aircraft. Instead, it is used to maintain coordinated flight.

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For the purposes of this discussion, turns are divided into three classes: shallow, medium, and steep.

- Shallow turns—bank angle is approximately 20° or less. This shallow bank is such that the inherent lateral stability of the aircraft slowly levels the wings unless aileron pressure in the desired direction of bank is held by the pilot to maintain the bank angle.
- Medium turns—result from a degree of bank of approximately 20° to 45°. At medium bank angles, the aircraft's inherent lateral stability does not return the wings to level flight. As a result, the aircraft tends to remain at a constant bank angle without and flight control pressure held by the pilot. The pilot neutralizes the flaperon flight control pressure to maintain the bank.
- Steep turns—result from a degree of bank of approximately 45° or more. The airplane continues in the direction of the bank even with neutral flight controls unless the pilot provides opposite flight control flaperon pressure to prevent the aircraft from overbanking. The of opposite flight control pressures is dependent of various factors, such as bank angle, flight control software logic, and airspeed. In general, a noticeable level of opposite flaperon flight control pressure is required by the pilot to prevent overbanking.

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Figure 10-6. *Level turn to the left.*

When an aircraft is flying straight and level, the total lift is acting perpendicular to the wings and to the Earth. As the aircraft is banked into a turn, total lift is the resultant of two components: vertical and horizontal. *[Figure 3-11]* The vertical lift component continues to act perpendicular to the Earth and opposes gravity. The horizontal lift component acts parallel to the Earth’s surface opposing centrifugal force. These two lift components act at right angles to each other, causing the resultant total lifting force to act perpendicular to the banked wing of the aircraft. It is the horizontal lift component that begins to turn the aircraft.

In constant altitude, constant airspeed turns, it is necessary to increase the AOA of the wing when rolling into the turn by increasing back pressure on the elevator, as well as the addition of power to counter the loss of speed due to increased drag. This is required because total lift has divided into vertical and horizontal components of lift. In order to maintain altitude, the total lift (since total lift acts perpendicular to the wing) must be increased to meet the vertical component of lift requirements (to balance weight and load factor) for level flight.

The purpose of yaw control in a turn is to coordinate the turn. As lift increases, so does drag. When the pilot deflects the flaperons to bank the aircraft, both lift and drag are increased on the rising wing and, simultaneously, lift and drag are decreased on the lowering wing. *[Figure 3-12]* This increased drag on the rising wing and decreased drag on the lowering wing results in the aircraftyawing opposite to the direction of turn. To counteract this adverse yaw, yaw control pressure is applied simultaneously with flaperon in the desired direction of turn. This action is required to produce a coordinated turn. Coordinated flight is important to maintaining aircraft control.

Situations can develop when a pilot is flying in uncoordinated flight and depending on the flight control deflections, may support pro-spin flight control inputs. This is especially hazardous when operating at low altitudes, such as when operating in the airport traffic pattern. Pilots must learn to fly with coordinated control inputs to prevent unintentional loss of control when maneuvering in certain situations.

During uncoordinated flight, the pilot may feel that they are being pushed sideways toward the outside or inside of the turn. *[Figure 3-13]* A skid is when the pilot may feel that they are being pressed toward the outside of the turn and toward the inside of the turn during a slip. The ability to sense a skid or slip is developed over time and as the “feel” of flying develops, a pilot should become highly sensitive to a slip or skid without undue reliance on the flight instruments.

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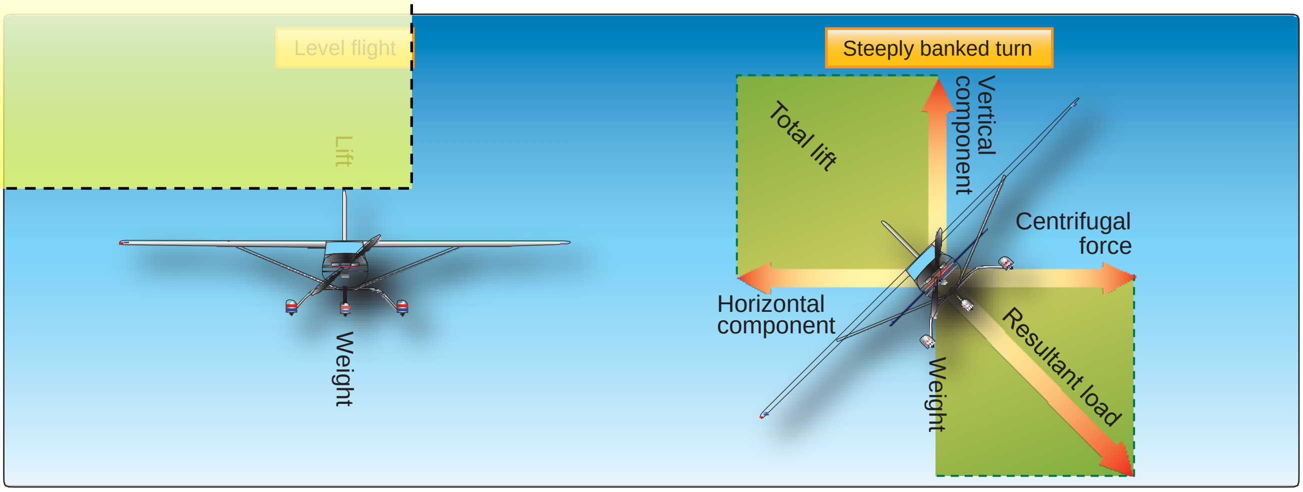

Figure 10-7. *When the airplane is banked into a turn, total lift is the resultant of two components: vertical and horizontal.*

Turn Radius

To understand the relationship between airspeed, bank, and radius of turn, it should be noted that the rate of turn at any given true airspeed depends on the horizontal lift component. The horizontal lift component varies in proportion to the amount of bank. Therefore, the rate of turn at a given airspeed increases as the angle of bank is increased. On the other hand, when a turn is made at a higher airspeed at a given bank angle, the inertia is greater and the horizontal lift component required for the turn is greater, causing the turning rate to become slower. *[Figure 3-14]* Therefore, at a given angle of bank, a higher airspeed makes the radius of turn larger because the aircraft turns at a slower rate.

As the radius of the turn becomes smaller, a significant difference develops between the airspeed of the inside wing and the airspeed of the outside wing. The wing on the outside of the turn travels a longer path than the inside wing, yet both complete their respective paths in the same unit of time.

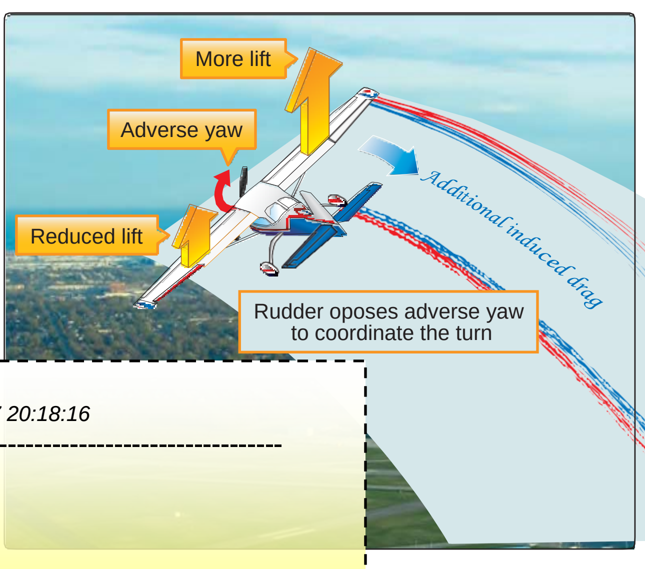

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Figure 10-8. *The rudder opposes adverse yaw to help coordinate the turn.*

Therefore, the outside wing travels at a faster airspeed than the inside wing and, as a result, it develops more lift. This creates an overbanking tendency that must be controlled by the use of opposite flaperon when the desired bank angle is reached. *[Figure 3-15]* Because the outboard wing is developing more lift, it also produces more drag. The drag causes a slight slip during steep turns that must be corrected by use of yaw control.

Establishing a Turn

On most aircraft, the top surface of the instrument panel is fairly flat, and its horizontal surface to the natural horizon provides a reasonable indication for initially setting the degree of bank angle. *[Figure 3-16]* The pilot should then cross-check the flight instruments to verify that the correct bank angle has been achieved. Information

obtained from the attitude indicator shows the angle of the wing in relation to the horizon.

The pilot's seating position in the aircraft is important as it affects the interpretation of outside visual references. A common problem is that a pilot may lean away from the turn in an attempt to remain in an upright position in relation to the horizon. This should be corrected immediately if the pilot is to properly learn to use visual references. *[Figure 3-17]*

Because most aircraft have side-by-side seating, a pilot does not sit on the aircraft's longitudinal axis, which is where the aircraft rot… to one side, typicall… longitudinal axis. Due to parallax erro… this makes the nose of the aircraft appear to rise whe… lowering in relation t… o the longitudinal axis) and the nose of the aircraft appear… to descend when making right turns (due to pilot elevatin… g in relation to the longitudinal axis). *[Figure 3-18]*

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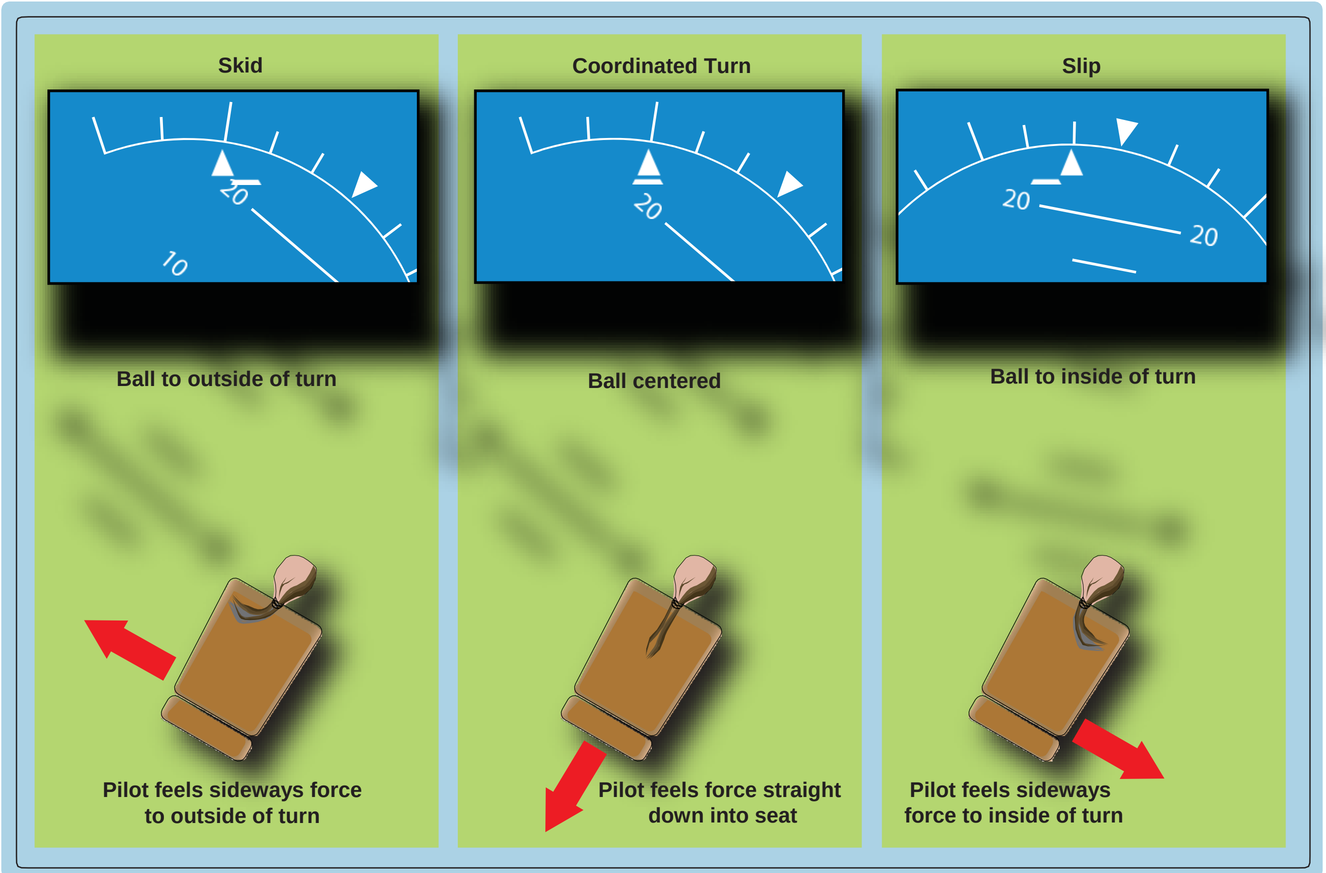

Figure 10-9. *Indications of a slip and skid.*

Beginning pilots should not use large flaperon and yaw control inputs. This is because large control inputs produce rapid roll rates and allows little time for the pilot to evaluate and make corrections. Smaller flight control inputs result in slower roll rates and provide for more time to accurately complete the necessary pitch and bank corrections.

Some additional considerations for initiating turns are the following:

- If the aircraft's nose starts to move before the bank starts, the yaw control is being applied too soon.
- If the bank starts before the nose starts turning or the nose moves in the opposite direction, the yaw control is being applied too late.
- If the nose moves up or down when entering a bank, excessive or insufficient elevator back pressure is being applied.

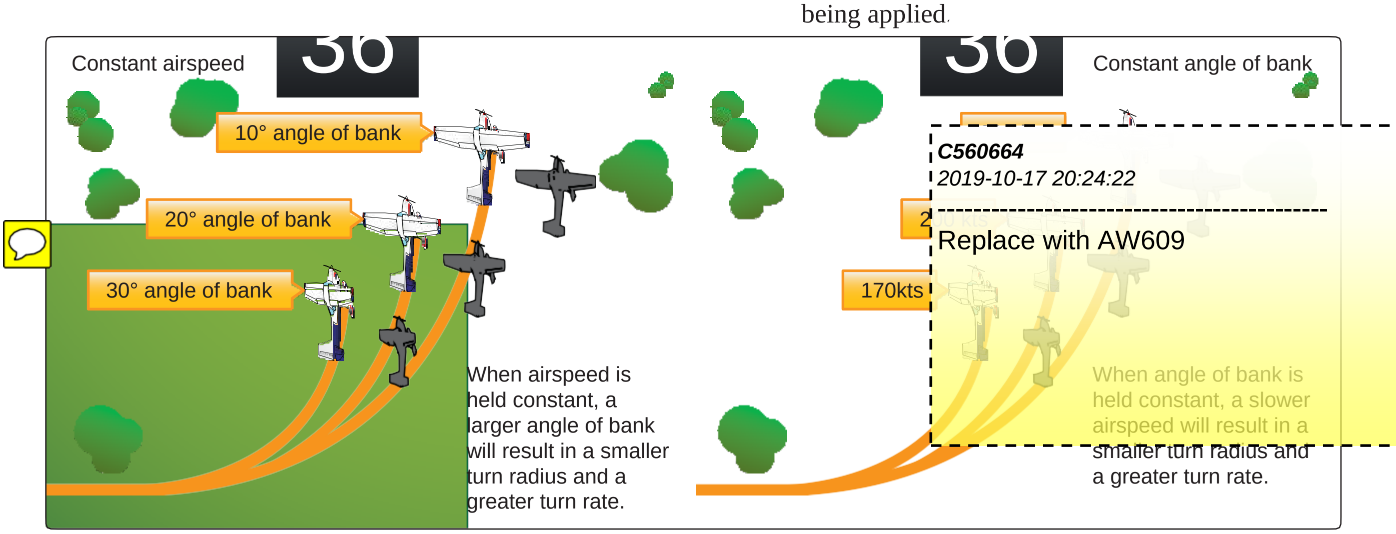

Figure 10-10. *Angle of bank and airspeed regulate rate and radius of turn.*

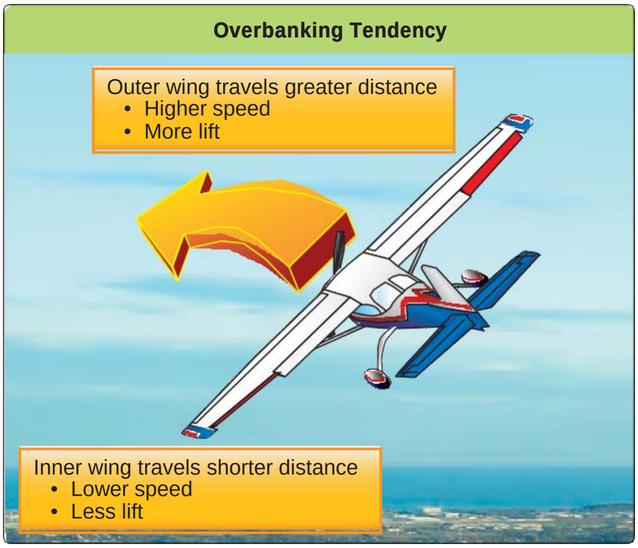

Figure 10-11. *Overbanking tendency.*

After the bank has been established, all flight control pressures applied to the flaperons and yaw control inputs may be relaxed or adjusted, depending on the established bank angle, to compensate for the aircraft's inherent stability or overbanking tendencies. The aircraft should remain at the desired bank angle with the proper application of flaperon pressures. If the desired bank angle is shallow, the pilot needs to maintain a small amount of flaperon pressure into the direction of bank including rudder to compensate for yaw effects. For medium bank angles, the flaperons and yaw control should be neutralized. Steep bank angles require opposite aileron and rudder to prevent the bank from steepening.

Back pressure on the elevator should not be relaxed as the vertical component of lift must be maintained if altitude is to be maintained. Throughout the turn, the pilot should reference the natural horizon, scan for aircraft traffic, and occasionally cross-check the flight instruments to verify performance. A reduction in airspeed is the result of increased drag but is generally not significant for shallow bank angles. In steeper turns, additional power may be required to maintain airspeed. If altitude is not being maintained during the turn, the pitch attitude should be corrected in relation to the natural horizon and cross-checked with the flight instruments to verify performance.

Steep turns require accurate, smooth, and timely flight control inputs. Minor corrections for pitch attitude are accomplished with proportional elevator back pressure while the bank angle is held constant with the flaperons. However, during steep turns, it is not uncommon for a pilot to allow the nose to get excessively low, resulting in a significant loss in altitude in a very short period of time. The recovery sequence requires that the pilot first reduce the angle of bank with coordinated use of opposite flaperon and yaw control, and then increase the pitch attitude by increasing elevator back pressure. If recovery from an excessively nose-low, steep bank condition is attempted by use of the elevator only, it only causes a steepening of the bank and unnecessary stress on the aircraft. Steep turn performance can be improved by an appropriate application of power to overcome the increase in drag and trimming additional elevator back pressure as the bank angle goes beyond 30°. This tends to reduce the demands for large control inputs from the pilot during the turn.

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Since the aircraft continues turning as long as there is any bank, the rollout from the turn must be started before reaching the desired heading. The amount of lead required to rollout on the desired heading depends on the degree of bank used in the turn. A rule of thumb is to lead by one-half the angle of bank. For example, if the bank is 30°, lead the rollout by 15°. The rollout from a turn is similar to the roll-in except the flight controls are applied in the opposite direction. Flaperon and yaw control are applied in the direction of the rollout or toward the high wing. As the angle of bank decreases, the elevator pressure should be relaxed as necessary to maintain altitude. As the wings become level, the flight control pressures should

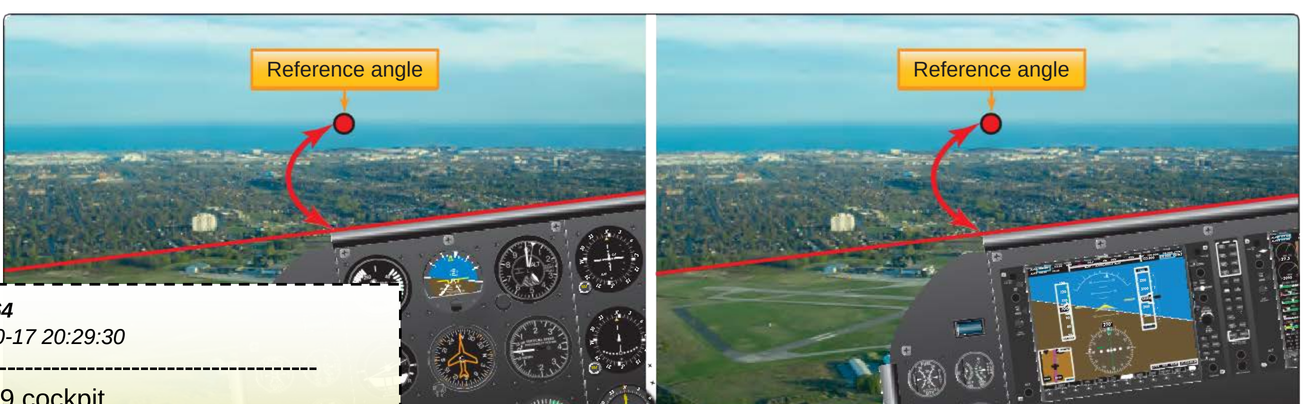

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Figure 10-12. *Visual reference for angle of bank.*

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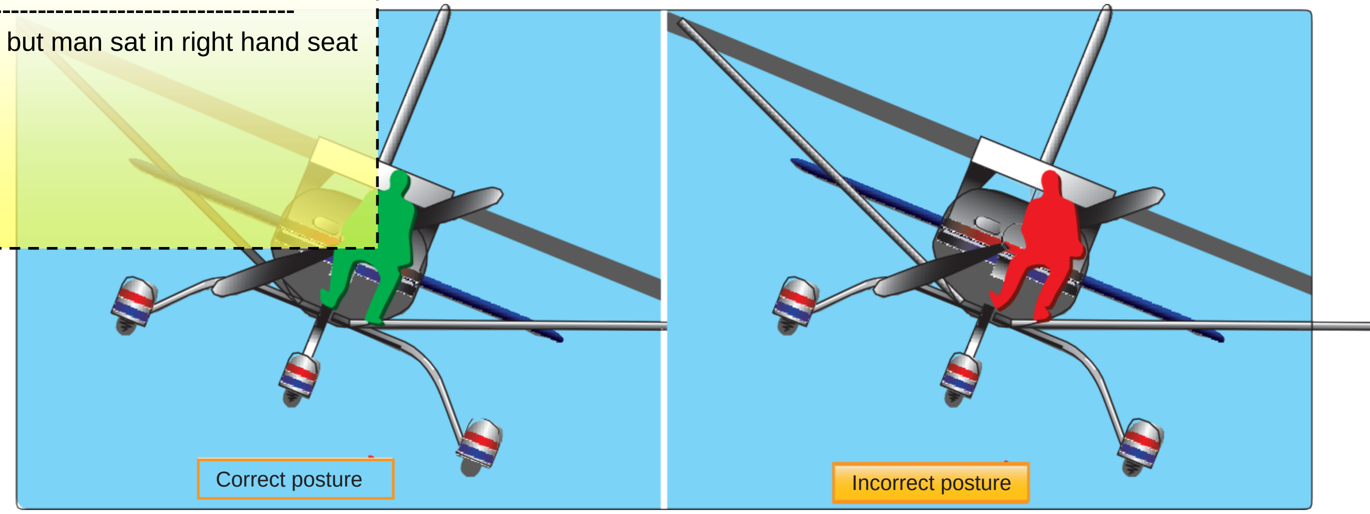

Figure 10-13. *Proper seat posture is essential.*

be smoothly relaxed so that the controls are neutralized as the airplane returns to straight-and-level flight. If trim was used, such as during a steep turn, forward elevator pressure may be required until the trim can be adjusted. As the rollout is being completed, attention should be given to outside visual references, as well as the flight instruments to determine that the wings are being leveled and the turn stopped.

For outside references, select the horizon and another point ahead. If those two points stay in alignment, the aircraft is tracking to that point as long as there is not a crosswind requiring a crab angle. It would also be a good idea to include VFR references for heading as well and pitch. A pilot holds course in VFR by tracking to a point in front of the compass, with only glances at the compass to ensure he or she is still on course. This reliance on a surface point does not work when flying over water or flat snow covered surfaces. In these conditions, the pilot must rely on the compass or gyro-heading indicator.

Because the elevator and flaperons are on one control, practice is required to ensure that only the intended pressure is applied to the intended flight control. For example, a beginner pilot is likely to unintentionally add pressure to the pitch control when only bank was intended. This cross-coupling may be diminished or enhanced by the design of the flight controls; however, practice is the appropriate measure for smooth, precise, and accurate flight control inputs. For example, diving when turning right and climbing when turning left is common with center stick controls, because the arm tends to rotate from the elbow joint, which induces a secondary arc control motion if the pilot is not extremely careful. Likewise, lowering the nose is likely to induce a right turn, and raising the nose to climb tends to induce a left turn. These actions would apply for a pilot using the right hand to move the stick. In any case, the pilot must retain the proper sight picture of the nose following the horizon, whether up, down, left or right and isolate undesired motion. It is essential that flight control coordination be developed because it is the very basis of all fundamental flight maneuvers.

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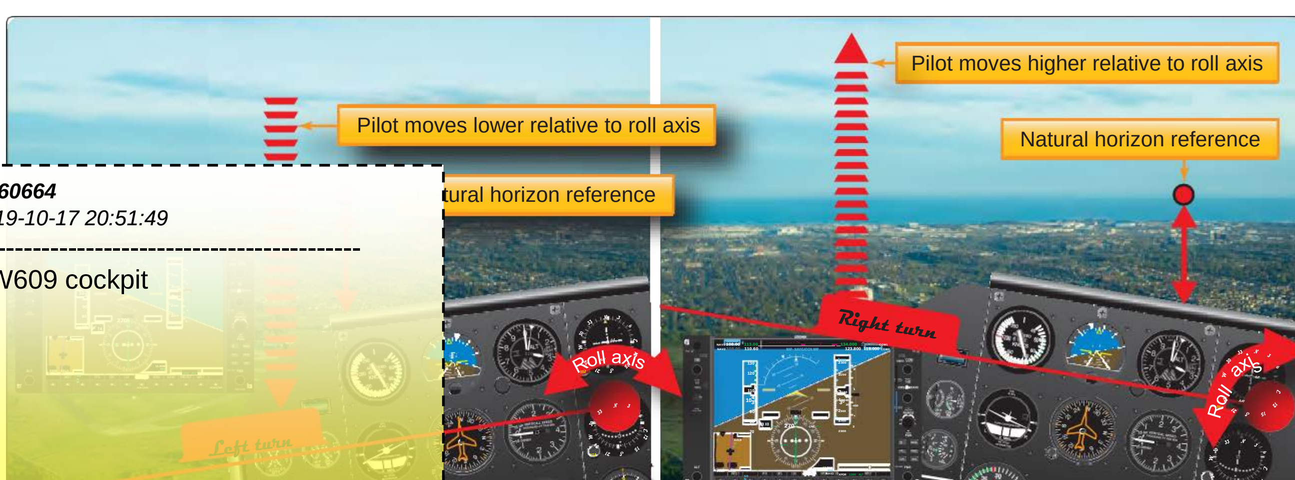

Figure 10-14. *Parallax view.*

Common errors in level turns are:

- Failure to adequately clear in the direction of turn for aircraft traffic.
- Gaining or losing altitude during the turn.
- Not holding the desired bank angle constant.
- Attempting to execute the turn solely by instrument reference.
- Leaning away from the direction of the turn while seated.
- Insufficient feel for the aircraft as evidenced by the inability to detect slips or skids without reference to flight instruments.
- Attempting to maintain a constant bank angle by referencing only the aircraft's nose.
- Making skidding flat turns to avoid banking the aircraft.
- Holding excessive yaw control in the direction of turn.
- Gaining proficiency in turns in only one direction.
- Failure to coordinate the controls.

Climbs and Climbing Turns

When an aircraft enters a climb, it changes its flightpath from level flight to a climb attitude. In a climb, weight no longer acts in a direction solely perpendicular to the flightpath. When an airplane enters a climb, excess lift must be developed to overcome the weight or gravity. This requirement to develop more lift results in more induced drag, which either results in decreased airspeed and/or an increased power setting to maintain a minimum airspeed in the climb. An aircraft can only sustain a climb when there is sufficient thrust to offset increased drag; therefore, climb rate is limited by the excess thrust available.

The pilot should know the powerplant power settings, natural horizon pitch attitudes, and flight instrument indications that produce the following types of climb:

Normal climb—performed at an airspeed recommended by the aircraft manufacturer. Normal climb speed is generally higher than the aircraft's best rate of climb. The additional airspeed provides for better powerplant cooling, greater control authority, and better visibility over the nose of the aircraft. Normal climb is sometimes referred to as cruise climb.

Best rate of climb (V_Y)—produces the most altitude gained over a given amount of time. This airspeed is typically used when initially departing a runway without obstructions until it is safe to transition to a normal or cruise climb configuration. Best angle of climb (V_X)—performed at an airspeed that produces the most altitude gain over a given horizontal distance. The best angle of climb results in a steeper climb, although the aircraft takes more time to reach the same altitude than it would at best rate of climb airspeed. The best angle of climb is used to clear obstacles, such as a strand of trees, after takeoff. *[Figure 3-19]*

It should be noted that as altitude increases, the airspeed for best angle of climb increases and the airspeed for best rate of climb decreases. Performance charts contained in the aircraft Flight Manual or Pilot's Operating Handbook

Figure 3-19. *Best angle of climb verses best rate of climb.*

must be consulted to ensure that the correct airspeed is used for the desired climb profile at the given environmental conditions. There is a point at which the best angle of climb airspeed and the best rate of climb airspeed intersect. This occurs at the absolute ceiling at which the airplane is incapable of climbing any higher. *[Figure 3-20]*

Establishing a Climb

A straight climb is entered by gently increasing back pressure on the elevator flight control to the pitch attitude referencing the aircraft's nose to the natural horizon while simultaneously increasing engine power to the climb power setting. The wingtips should be referenced in maintaining the climb attitude while cross-checking the flight instruments to verify performance. In many aircraft, as power is increased, an increase in slipstream over the horizontal stabilizer causes the aircraft's pitch attitude to increase greater than desired. The pilot should be prepared for slipstream effects but also for the effect of changing airspeed and changes in lift. The pilot should be prepared to use the required flight control pressures to achieve the desired pitch attitude.

If a climb is started from cruise flight, the airspeed gradually decreases as the aircraft enters a stabilized climb attitude. The thrust required to maintain straight-and-level flight at a given airspeed is not sufficient to maintain the same airspeed in a climb. Increased drag in a climb stems from increased lift demands made upon the wing to increase altitude. Climbing requires an excess of lift over that necessary to maintain level flight. Increased lift will generate more induced drag. That increase in induced drag is why more power is needed and why a sustained climb requires an excess of thrust.

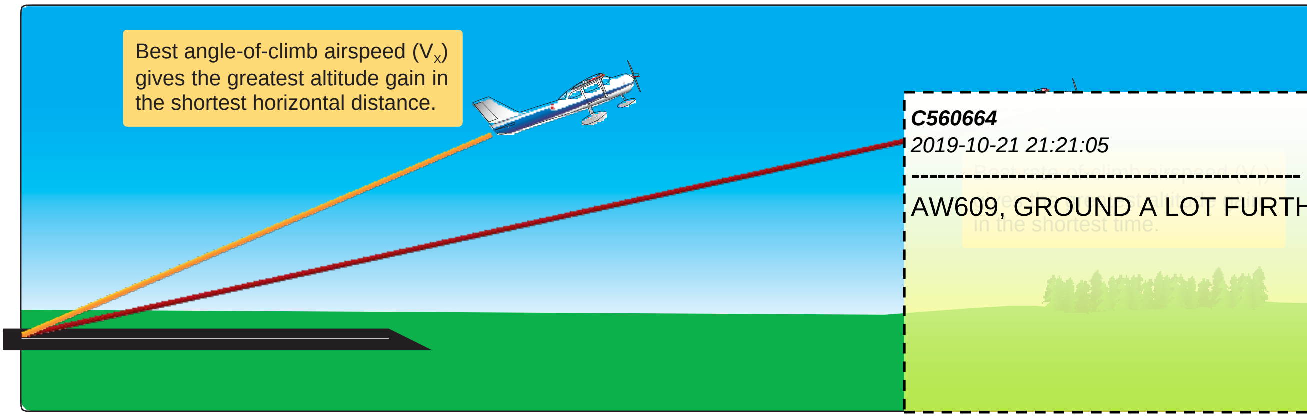

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Figure 10-15. *Various climb profiles are available.*

For practical purposes, gravity or weight is a constant. Even using a vector diagram to show where more lift is necessary because the lift vector from the wings is no longer perpendicular to the wings, therefore more lift is needed from the wings which requires more thrust from the powerplant.

The power should be advanced to the recommended climb power.

Engines that are normally aspirated experience a reduction of power as altitude is gained. As altitude increases, air density decreases, which results in a reduction of power. The indications show an increase in powerplant temperatures for a given amount of thrust produced. The pilot should reference the engine instruments to ensure that climb power is being maintained and that pressures and temperatures are within the manufacturer's limits. As powerplant efficiency decreases in the climb, the pilot must continually advance the power lever to maintain specified climb settings.

As the airspeed decreases during the climb's establishment, the aircraft's pitch attitude tends to lower unless the pilot increases the elevator flight control pressure. Nose-up elevator trim should be used so that the pitch attitude can be maintained without the pilot holding back elevator pressure. Throughout the climb, since the power should be fixed at the climb power setting, airspeed is controlled by the use of elevator pressure. The pitch attitude to the natural horizon determines if the pitch attitude is correct and should be cross-checked to the flight instruments to verify climb performance. *[Figure 3-21]*

To return to straight-and-level flight from a climb, it is necessary to begin leveling-off prior to reaching the desired altitude. Level-off should begin at approximately 10 percent of the rate of climb. For example, if the aircraft is climbing at 500 feet per minute (fpm), leveling off should begin 50 feet prior to reaching the desired altitude. The pitch attitude must be decreased smoothly and slowly to allow for the airspeed to increase; otherwise, a loss of altitude results if the pitch attitude is changed too rapidly without allowing the airspeed to increase proportionately.

Climbing Turns

In the performance of climbing turns, the following factors should be considered.

- With a constant power setting, the same pitch attitude and airspeed cannot be maintained in a bank as in a straight climb due to the increase in the total lift required.
- The degree of bank should not be too steep. A steep bank significantly decreases the rate of climb. The bank should always remain constant.
- It is necessary to maintain a constant airspeed and constant rate of turn in both right and left turns. The coordination of all flight controls is a primary factor.
- At a constant power setting, the aircraft climbs at a slightly shallower climb angle because some of the lift is being used to turn the airplane.

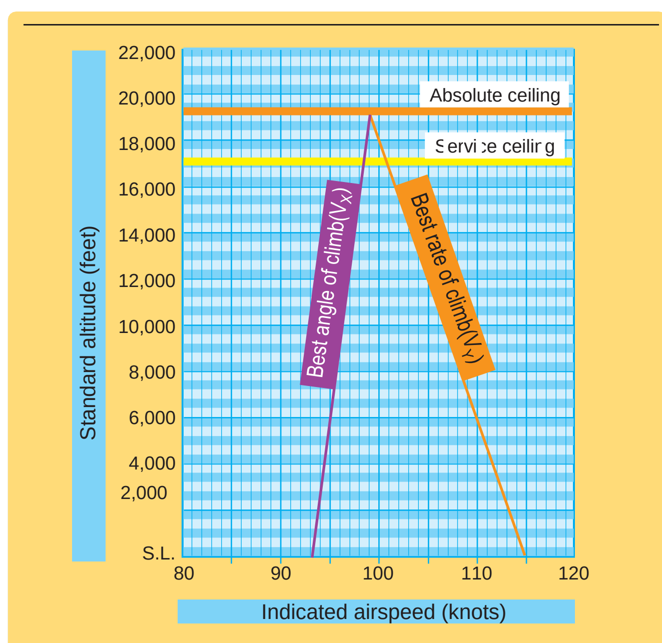

Figure 10-16. *Absolute ceiling.*

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Figure 10-17. *Climb Indications*

After the aircraft is established in level flight at a constant altitude, climb power should be retained temporarily so that the aircraft accelerates to the cruise airspeed. When the airspeed reaches the desired cruise airspeed, the power should be set to the cruise power setting and the aircraft re-trimmed.

Climbing turns may be established by entering the climb first and then banking into the turn or climbing and turning simultaneously. During climbing turns, as in any turn, the loss of vertical lift must be compensated by an increase in pitch attitude. When a turn is coupled with a climb, the additional drag and reduction in the vertical component of lift must be further compensated for by an additional increase in elevator back pressure. When turns are simultaneous with a climb, it is most effective to limit the turns to shallow bank angles. This provides for an efficient rate of climb. If a medium or steep banked turn is used, climb performance is degraded or possibly non-existent.

Common errors in the performance of climbs and climbing turns are:

- Attempting to establish climb pitch attitude by primarily referencing the airspeed indicator resulting in the pilot chasing the airspeed.
- Applying elevator pressure too aggressively resulting in an excessive climb angle.
- Inadequate or inappropriate yaw control pressure during climbing turns.
- Allowing the aircraft to yaw during climbs.
- Fixation on the aircraft's nose during straight climbs, resulting in climbing with one wing low.
- Failure to properly initiate a climbing turn with a coordinated use of the flight controls, resulting in no turn but rather a climb with one wing low.
- Improper coordination resulting in a slip that counteracts the rate of climb, resulting in little or no altitude gain.
- Inability to keep pitch and bank attitude constant during climbing turns.
- Attempting to exceed the aircraft's climb capability.
- Applying forward elevator pressure too aggressively during level-off resulting in a loss of altitude or G-force substantially less than one G.

Descents and Descending Turns

When an aircraft enters a descent, it changes its flightpath from level flight to a descent attitude. *[Figure 10-22]* In a descent, weight no longer acts solely perpendicular to the flightpath. Since induced drag is decreased as lift is reduced in order to descend, excess thrust will provide higher airspeeds. The weight/gravity force is about the same. This causes a thrust imbalance, and a power reduction is required to balance the forces if airspeed is to be maintained.

The pilot should know the engine power settings, natural horizon pitch attitudes, and flight instrument indications that produce the following types of descents:

Partial power descent—the normal method of losing altitude is to descend with partial power. This is often termed cruise or en route descent. The airspeed and power setting recommended by the flight manual for prolonged descent should be used. The target descent rate should be 500 fpm. The desired airspeed, pitch attitude, and power combination should be preselected and kept constant.

Emergency descent—some aircraft have a specific procedure for rapidly losing altitude. The flight manual specifies the procedure. Emergency descent maneuvers often include turns, and further detail is provided in Chapter 15.

Figure 10-18. *Descent Indications*

Chapter Summary

Regardless of mode of flight, the four fundamental maneuvers of straight-and-level flight, turns, climbs, and descents are the foundation of basic airmanship. Effort and continued practice are required to master the fundamentals. It is important that a pilot consider the six motions of flight: bank, pitch, yaw and horizontal, vertical, and lateral displacement. In order for an aircraft to fly from one location to another, it pitches, banks, and yaws while it moves over and above, in relationship to the ground, to reach its destination. The aircraft must be treated as an aerodynamic vehicle that is subject to rigid aerodynamic laws. A pilot must understand and apply the principles of flight in order to control an aircraft with the greatest margin of mastery and safety.

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Traffic Patterns

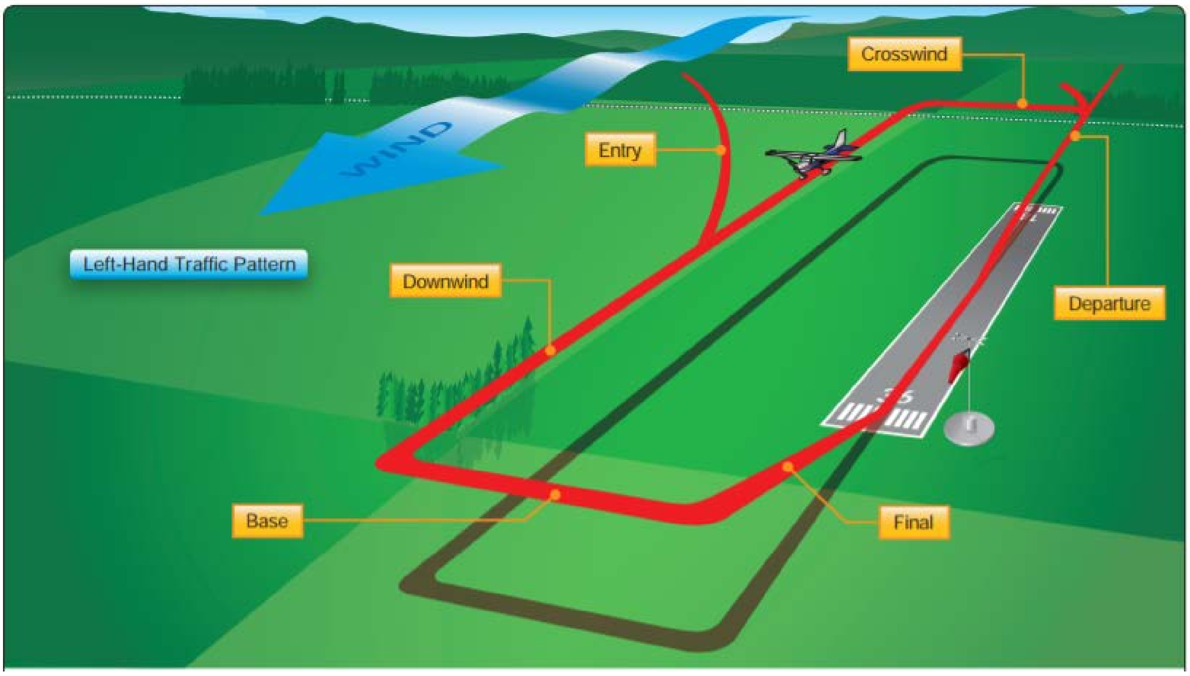
Airport traffic patterns are developed to ensure that air traffic is flown into and out of an airport safely. Each airport traffic pattern is established based on the local conditions, including the direction and placement of the pattern, the altitude at which it is to be flown, and the procedures for entering and exiting the pattern. It is imperative that pilots are taught correct traffic pattern procedures and exercise constant vigilance in the vicinity of airports when entering and exiting the traffic pattern. Information regarding the procedures for a specific airport can be found in the Chart Supplements. Additional information on airport operations and traffic patterns can be found in the Aeronautical Information Manual (AIM).

A traffic pattern is useful to control the flow of traffic, particularly at airports without operating control towers. It affords a measure of safety, separation, protection, and administrative control over arriving, departing, and circling aircraft. Due to specialized operating characteristics, airplanes and helicopters do not mix well in the same traffic environment. The tilt-rotor aircraft has the ability to configure to fly in either traffic pattern At multiple-use airports, when operating in Conversion mode, you routinely must avoid the flow of fixed-wing traffic. To do this, you need to be familiar with the patterns and you should learn how to fly these patterns in case air traffic control (ATC) requests that you fly a fixed-wing traffic pattern or you are operating in APLN mode.

When operating at an airport with an operating control tower, the pilot receives a clearance to approach or depart, as well as pertinent information about the traffic pattern by radio. If there is not a control tower, it is the pilot's responsibility to determine the direction of the traffic pattern, to comply with the appropriate traffic rules, and to display common courtesy toward other pilots operating in the area.

A normal traffic pattern is rectangular, has five named legs, and a designated altitudes, dependent on the aircraft type. For helicopters 500 feet AGL, for light fixed wing, usually 600 to 1,000 feet AGL and for multiengine fixed wing 1500 feet AGL. The Tilt-rotor will generally be flown at either 500 feet AGL in conversion mode and 1500 feet AGL in APLN mode.

A pattern in which all turns are to the left is called a standard pattern. [Figure 9-18] The takeoff leg (item 1) normally consists of the aircraft's flight path after takeoff. This leg is also called the upwind leg. You should turn to the crosswind leg (item 2), after passing the departure end of the runway when you are at a safe altitude. Fly the downwind leg (item 3) parallel to the runway at the designated traffic pattern altitude and distance from the runway. Begin the base leg (item 4) at a point selected according to other traffic and wind conditions. If the wind is very strong, begin the turn sooner than normal. If the wind is light, delay the turn to base. The final approach (item 5) is the path the aircraft flies immediately prior to touchdown.



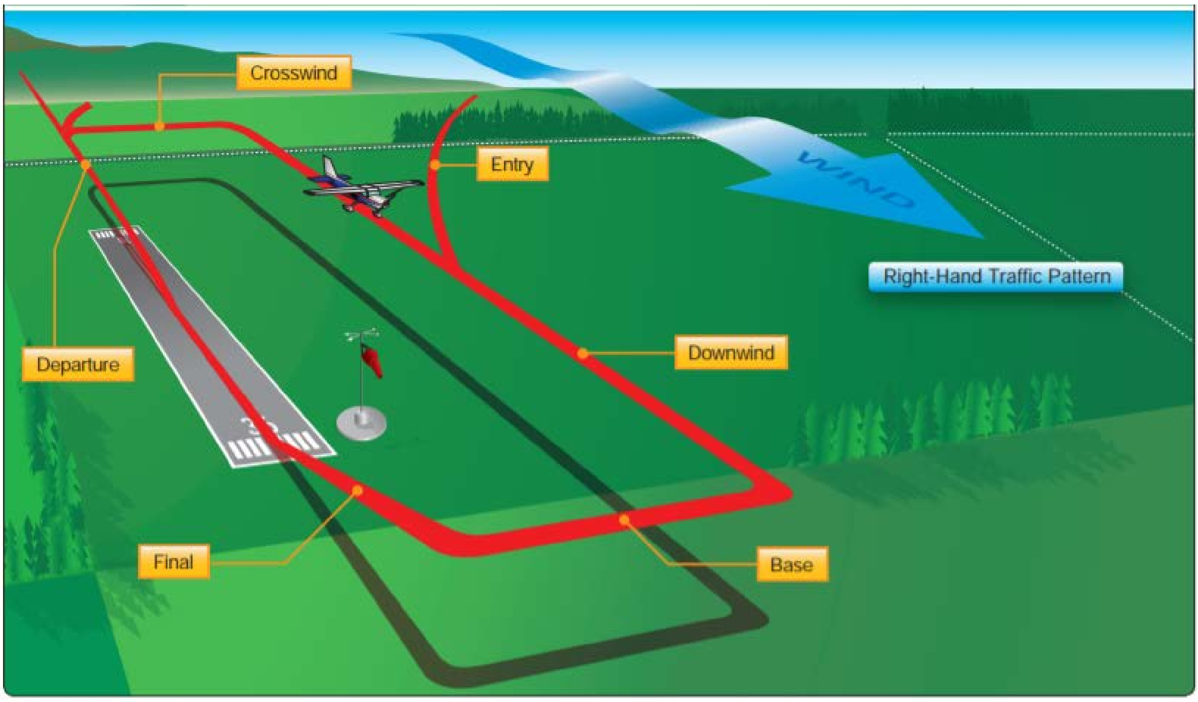


Figure 7-1. *Traffic patterns*

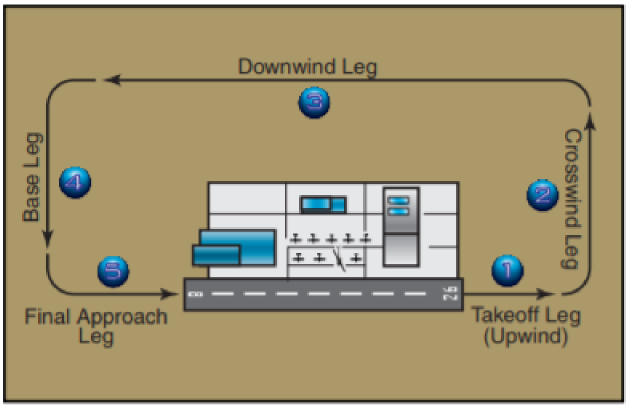


Figure 9-18. A standard traffic pattern has turns to left and five designated legs.

You may find variations at different localities and at airports with operating control towers. For example, a right-hand pattern may be designated to expedite the flow of traffic when obstacles or highly populated areas make the use of a left-hand pattern undesirable.

Compliance with the basic rectangular traffic pattern reduces the possibility of conflicts at airports without an operating control tower. It is imperative that a pilot form the habit of exercising constant vigilance in the vicinity of airports even when the air traffic appears to be light. Midair collisions usually occur on clear days with unlimited visibility. Never assume you have found all of the air traffic and stop scanning.

When approaching an airport with an operating control tower in conversion mode, it is possible to expedite traffic by stating your intentions, for example:
1. (Call sign of aircraft) Agusta 609.
2. (Position) 10 miles west.
3. (Request) for landing J/G intersection

In order to avoid the flow of fixed-wing traffic, the tower will often clear you direct to an approach point or to a particular runway intersection nearest your destination point. At uncontrolled airports, if at all possible, you should adhere to standard practices and patterns. Traffic pattern entry procedures at airports with an operating control tower are specified by the controller.

When entering the traffic pattern at an airport without an operating control tower, inbound pilots are expected to observe other aircraft already in the pattern and to conform to the traffic pattern in use. If there are no other aircraft present, the pilot should check traffic indicators on the ground and wind indicators to determine which runway and traffic pattern direction to use. [Figure 7-2]

Many airports have L-shaped traffic pattern indicators displayed with a segmented circle adjacent to the runway. The short member of the L shows the direction in which the traffic pattern turns are made when using the runway parallel to the long member. The pilot should check the indicators from a distance or altitude well away from any other airplanes that may be flying in the traffic pattern. Upon identifying the proper traffic pattern, the pilot should enter into the traffic pattern at a point well clear of the other airplanes.

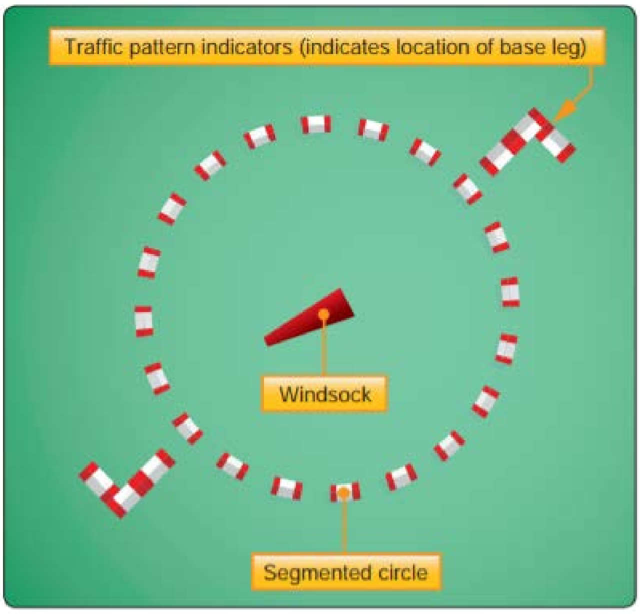


Figure 7-2. *Traffic pattern indicators.*

When approaching an airport for landing, the traffic pattern is normally entered at a 45° angle to the downwind leg, headed toward a point abeam the midpoint of the runway to be used for landing. When arriving, the pilot should be aware of the proper traffic pattern altitude before entering the pattern and remain clear of the traffic flow until established on the entry leg. Entries into traffic patterns while descending create specific collision hazards and should always be avoided.

For information concerning traffic pattern and landing direction, you should utilize airport advisory service or UNICOM, when available.

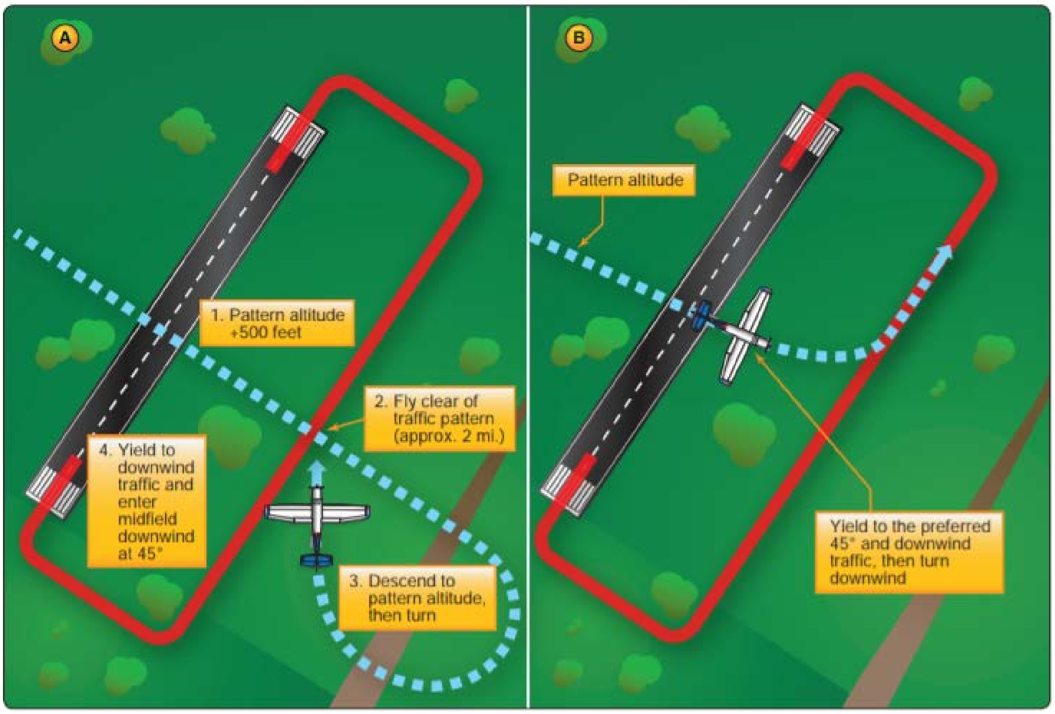


Figure 7-4. *Preferred entry from upwind leg side of airport (A). Alternate midfield entry from upwind leg side of airport (B).*

The standard departure procedure, when using the fixed-wing traffic pattern, is usually straight-out, downwind or a right-hand departure. When a control tower is in operation, you can request the type of departure you desire. In most cases, conversion mode departures are made into the wind unless obstacles or traffic dictate otherwise.

At airports without an operating control tower, you must comply with the departure procedures established for that airport.

Circuit Pattern in CONV Mode

The CONV pattern begins at the completion of the transition to forward flight and is flown at an altitude compatible with rotorcraft in the pattern, and at a speed that maintains separation and proper spacing between traffic.

The maneuver originates from the hover, but may be flown from a rolling takeoff, if desired.
Depending on the particular circuit size, pilots may be able to climb on departure heading to 500 feet. At smaller airfields or with hazards ahead, you may have to execute the crosswind turn once above 200 feet AGL.

Anticipate reaching pattern altitude and adjust power to level off at 500 feet AGL or circuit altitude. Remember Power, Attitude, Trim (PAT), and accelerate to the desired speed.

Maintain pattern altitude and speed on the downwind. Use power to control altitude and nacelles to maintain the desired airspeed. Adjust the downwind heading to counter the effects of crosswind.

Prior to the abeam position, complete the landing checks, ensuring the landing gear is down. As the landing point passes through the 5'oclock position (7'oclock for a Left hand pattern), enter a descending turn, decelerating and converting if required, to arrive at the 90º position 300 feet AGL and 75 knots, utilizing approximately 300-400 feet per minute (FPM) rate of descent (ROD).

At the 90º position rotate the nacelles aft to begin decelerating the aircraft. At the 45º position, while descending and decelerating, rotate the nacelles further aft as necessary to control closure rate, maintaining a near level attitude. The nacelle setting required to decelerate depends upon aircraft gross weight and ambient conditions. Higher gross weights will necessitate more aft nacelle while headwinds will require more forward nacelle.

Allow the aircraft to decelerate and use power lever to control glideslope to arrive on final at 150 feet AGL, 50 knot ground speed (GS), 0.3 nm of straightaway. As the aircraft intercepts the glideslope the groundspeed should be around 35-40 knots. If in a safe position to continue the approach, follow the procedures outlined in the approaches section of this handbook.

Circuit Pattern in APLN Mode

To assure that air traffic flows into and out of an airport in an orderly manner, an airport traffic pattern is established based on the local conditions, to include the direction and altitude of the pattern and the procedures for entering and leaving the pattern. Unless the airport displays approved visual markings indicating that turns should be made to the right, the pilot should make all turns in the pattern to the left.

When operating in the traffic pattern at an airport without an operating control tower, the pilot should maintain an airspeed of no more than 200 knots (230 miles per hour (mph)) as required by Title 14 of the Code of Federal Regulations (14 CFR) part 91. In any case, the pilot should adjust the airspeed, when necessary, so that it is compatible with the airspeed of the other airplanes/aircraft in the pattern.

The APLN mode cruise pattern begins after the transition to APLN mode and is flown at a minimum of 1500 feet AGL and at a speed appropriate to the traffic pattern, but never slower than VS +15 Kts. After departure, maintain departure heading straight ahead to 700ft AGL before executing the crosswind turn. If sufficient space is available, climb straight ahead to pattern altitude while accelerating and transitioning to desired speed.

Use appropriate angle of bank for the wind conditions to turn to the downwind at pattern altitude. Continue accelerating and transitioning to the desired speed, if not already established. Aim to fly the downwind offset the runway by approximately 1.2-1.5 nm.

Once abeam the intended landing spot, smoothly lower the nose and simultaneously reduce power to initiate a descent without accelerating. With a stabilized rate of descent established (approximately 600-700 FPM), begin a decelerating, descending, converting turn to arrive at the 90º position at 500 feet AGL, approximately 120-130 KIAS.

At a suitable point the pilot flying (PF) should ensure the pre-landing checks are completed and the landing gear (if fitted) is confirmed down.

Allow the aircraft to continue decelerating while turning onto final. Some aircraft are fitted with conversion protection which prevents the nacelles from moving until the aircraft is within defined speed parameters. If aircraft speed activates conversion protection and inhibits further conversion, it may be necessary to further reduce power and establish a nose high attitude to allow the aircraft to decelerate. This technique will decelerate the aircraft, allowing movement of the nacelles. Pilots may need to allow a moment for the deceleration to take place before attempting to move nacelles as the effect is not immediate. Once back within conversion parameters, anticipate the need to adjust power and reset nacelles to recapture a normal approach closure rate and glideslope.

Roll wings level on finals and continue a descending/decelerating profile to arrive at 0.3 nm at 150 feet AGL and 50 knots GS. If in a safe position to continue the approach, follow the procedures outlined in the approaches section of this handbook.

Common Errors

- Over-controling with the cyclic, nose low or high attitudes, rather than using the nacelles.
- Poor trim technique.
- Poor or innapropriate marker selection before or during the circuit.
- Staring at the instruments with poor lookout, reducing situational awareness (SA) in the circuit, especially in regard to other traffic in the pattern.
- While transitioning to high-speed cruise mode, a severe turn with insufficient power may place the aircraft near or in stall conditions.
- Carrying too much speed while on long finals and using aft cyclic for speed correction.
- Excessive aft nacelle or aft cyclic during the approach and landing short of the intended point.
- Failure to anticipate the power requied as the aircraft slows.

Approaches and Landings

Introduction

There is a saying that while takeoff is optional, landing is mandatory. Unfortunately, a review of accident statistics indicates that over 45 percent of all general aviation accidents occur during the approach and landing phases of a flight. A closer look shows that the cause of over 90 percent of those cases was pilot related and loss of control was also a major contributing factor in 33 percent of the cases. While the requirement to maneuver close to the ground cannot be eliminated, pilots can develop the skills and follow established procedures to reduce the likelihood of an accident or mishap. This chapter focuses on the approach to landing, factors that affect landings, types of landings, and aspects of faulty landings.

Approaches

A normal approach and landing involves the use of procedures for what is considered a normal situation; that is, when engine power is available, the wind is light, or the final approach is made directly into the wind, the final approach path has no obstacles and the landing surface is firm and of ample length to gradually bring the aircraft to a hover, no-hover or running landing, as required.

The factors involved and the procedures described for the normal approach and landing also have applications to the other-than-normal approaches and landings and are discussed later in this chapter. This being the case, the principles of normal operations are explained first and must be understood before proceeding to the more complex operations. To help the pilot better understand the factors that influence judgment and procedures, the last part of the approach pattern and the actual landing is divided into four phases:

1. the base leg
2. the final approach
3. the touchdown

It must be remembered that the manufacturer's recommended procedures, including aircraft configuration and airspeeds, and other information relevant to approaches and landings in a specific make and model aircraft are contained in the Federal Aviation Administration (FAA)-approved aircraft Flight Manual and/or Pilot's Operating Handbook (AFM/RFM/POH) for that aircraft. If any of the information in this chapter differs from the aircraft manufacturer's recommendations as contained in the AFM/POH, the aircraft manufacturer's recommendations take precedence

Base Leg

The placement of the base leg is one of the more important judgments made by the pilot in any landing approach. [Figure 8-1] The pilot must accurately judge the altitude and distance from which a gradual, stabilized descent results in landing at the desired spot. In tiltrotors, the distance depends on the altitude of the base leg, the effect of wind, and the aircraft nacelle setting. When there is a strong wind on final approach or a steep angle of descent is required, the base leg must be positioned closer to the approach end of the runway than would be required with a light wind or shallower approach. Normally, the landing gear is extended and the before-landing check completed prior to reaching the base leg.

In tiltrotors, allow the aircraft to continues to descend and decelerate. The nacelles will be moving rearwards, towards the landing configuration, maintain a speed above safe single engine speed throughout. The base leg is continued to the point where a medium to shallow-banked turn aligns the aircraft's path directly with the centerline of the landing runway. This descending turn is completed at a safe altitude and dependent upon the height of the terrain and any obstructions along the ground track. The turn to the final

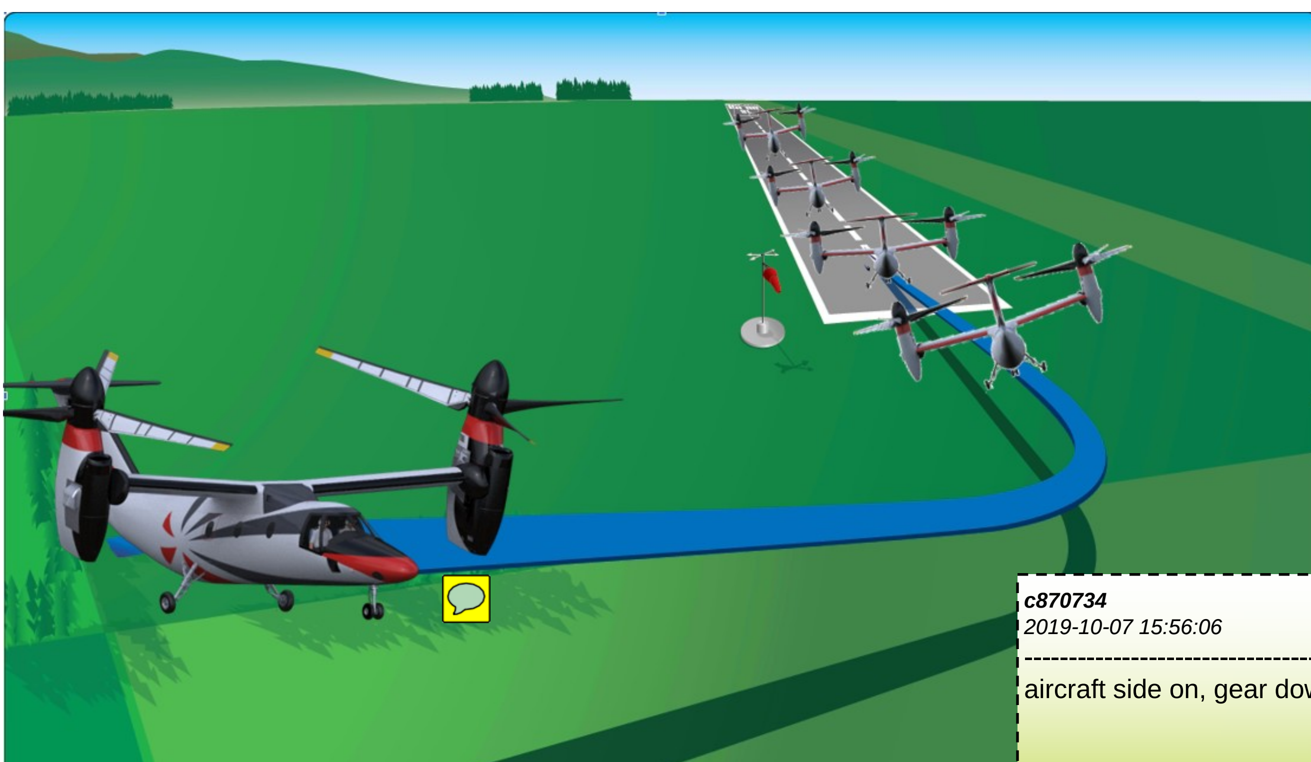


Figure 12-1. *Base leg and final approach.*

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aircraft side on, gear down

approach is sufficiently above the landing site elevation to permit a final approach long enough to accurately estimate the resultant point of touchdown while maintaining the proper approach airspeed.

This requires careful planning as to the starting point and the radius of the turn. Since the base-to-final turn is made at a relatively low altitude, it is important that an unwanted descent does not occur at this point. If an extremely steep bank is needed to prevent overshooting the proper final approach path, it is advisable to discontinue the approach, go around, and plan to start the turn earlier on the next approach rather than risk a hazardous situation.

Final

After the turn to final approach completed, the longitudinal axis of the aircraft is aligned with the centerline of the runway or landing surface so that any drift is recognized immediately. Assuming no wind drift, the longitudinal axis is kept aligned with the runway centerline throughout the approach and landing.

After aligning the aircraft with the extended landing site or runway centerline, set the recommended landing nacelle. Maintaining a level pitch attitude, adjust power as required for the required rate of descent. Slight adjustments in pitch and power may be necessary to maintain the descent attitude and the recommended approach airspeed. It is recommended to keep the airspeed at or above the safe single engine speed long as possible as this will reduce any height loss should a power plant failure occur.

A stabilized descent angle is controlled throughout the approach so that the aircraft lands in the center of the first third of the runway. The descent angle is affected by all four fundamental forces that act on an aircraft (lift, drag, thrust, and weight). If all forces are held constant, the descent angle also remains constant in a no-wind condition. After setting the recommended landing nacelle, the pilot controls the forces acting on the aircraft by adjusting nacelle, airspeed, aircraft attitude, and power.

During the approach, pilots can expect that for a given nacelle angle and pitch attitude, there is only one power setting for one airspeed and one wind condition. A change in any one of these variables requires an appropriate coordinated change in the other controllable variables. For example, if the pitch attitude is raised too high without an increase of power, the aircraft slows and touches down short of the desired spot. The proper angle of descent and airspeed is maintained by coordinating nacelle, pitch attitude and power changes.

The objective of a good, stabilized final approach is to descend at an angle and airspeed that permits the aircraft to reach the desired touchdown point at an airspeed that results in minimum floating during a running landing or descending vertically during an approach to the hover. just before touchdown. To accomplish this, it is essential that both the descent angle and the airspeed be accurately controlled. Power and pitch attitude are adjusted simultaneously as necessary to control the airspeed and the descent angle, or to attain the desired altitudes along the approach path. To correct for being too high during the approach, reduce the power to intercept the approach angle and adjust aircraft attitude and nacelle to maintain the desired speed.

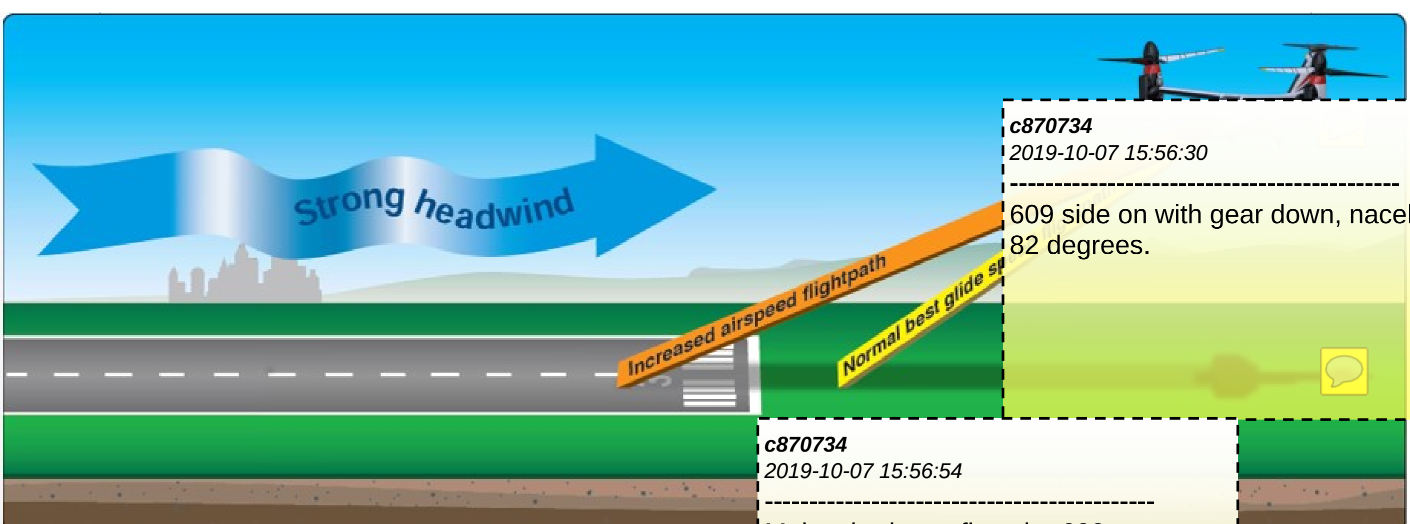

Figure 12-2. *Effect of headwind on final approach.*

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609 side on with gear down, nacelle at
82 degrees.

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Make shadow reflect the 609

Estimating Height and Movement

During the approach through the touchdown; vision is of prime importance. To provide a wide scope of vision and to foster good judgment of height and movement, the pilot's head should assume a natural, straight-ahead position. Visual focus is not fixed on any one side or any one spot ahead of the aircraft. Instead, it is changed slowly from a point just over the aircraft's nose to the desired touchdown zone and back again. This is done while maintaining a deliberate awareness of distance from either side of the runway using your peripheral field of vision. Accurate estimation of distance is, besides being a matter of practice, dependent upon how clearly objects are perceived.

Speed blurs objects at close range. For example, most everyone has noted this in an automobile moving at high speed. Nearby objects seem to merge together in a blur, while objects farther away stand out clearly. The driver subconsciously focuses the eyes sufficiently far ahead of the automobile to see objects distinctly.

The distance at which the pilot's vision is focused should be proportionate to the speed at which the aircraft is traveling over the ground. Thus, as speed is reduced during the final stages of the approach, the distance ahead of the aircraft at which it is possible to focus is brought closer accordingly.

If the pilot attempts to focus on a reference that is too close or looks directly down, the reference becomes blurred, [Figure 12-5] and the reaction is either too abrupt or too late. In this case, the pilot's tendency is to over-control, rounding out high during a running landing or unintetionally high during an approach to the hover. If the pilot focuses too far ahead, accuracy in judging the closeness of the ground is lost and the consequent reaction is too slow since there does not appear to be a necessity for action. During a running landing or very low during an approach to the hover, this may result in the aircraft flying into the ground nose first.

Figure 12-3. *Focusing too close blurs vision.*

The change of visual focus from a long distance to a short distance requires a definite time interval and, even though the time is brief, the aircraft's speed during this interval is such that the aircraft travels an appreciable distance, both forward and downward toward the ground.

If the focus is changed gradually, being brought progressively closer as speed is reduced, the time interval and the pilot's reaction are reduced and the whole landing process smoothed out.

Stabilized Approach Concept

A stabilized approach is one in which the pilot establishes and maintains a constant angle glide path towards a predetermined point on the landing runway. It is based on the pilot's judgment of certain visual clues and depends on the maintenance of a constant final descent airspeed and configuration.

An aircraft descending on final approach at a constant rate and airspeed is traveling in a straight line toward a spot on the ground ahead. During a running landing, this spot is not the spot on which the aircraft touches down because some float occurs as the ROD is reduced and the aircraft decelerates (Figure 12-9]

The point toward which the aircraft is progressing is termed the "aiming point." [Figure 12-9] It is the point on the ground at which, if the aircraft maintains a constant glide path and was not configured for landing, it would strike the ground. To a pilot moving straight ahead toward an object, it appears to be stationary. It does not appear to move under the nose of the aircraft and does not appear to move forward away from the aircraft. This is how the aiming point can be distinguished—it does not move. However, objects in front of and beyond the aiming point do appear to move as the distance is closed, and they appear to move in opposite directions.

During instruction in landings, one of the most important skills a pilot must acquire is how to use visual cues to accurately determine the true aiming point from any distance out on final approach. From this, the pilot is not only able to determine if the glide path results in either an under or overshoot but, taking into account float during the landing, the pilot is able to predict the touchdown point to within a few feet.

For a constant angle glide path, the distance between the horizon and the aiming point remains constant. If a final approach descent is established and the distance between the perceived aiming point and the horizon appears to increase (aiming point moving down away from the horizon), then the true aiming point, and subsequent touchdown point, is farther down the runway. If the distance between the perceived aiming point and the horizon decreases, meaning that the aiming point is moving up toward the horizon, the true aiming point is closer than perceived.

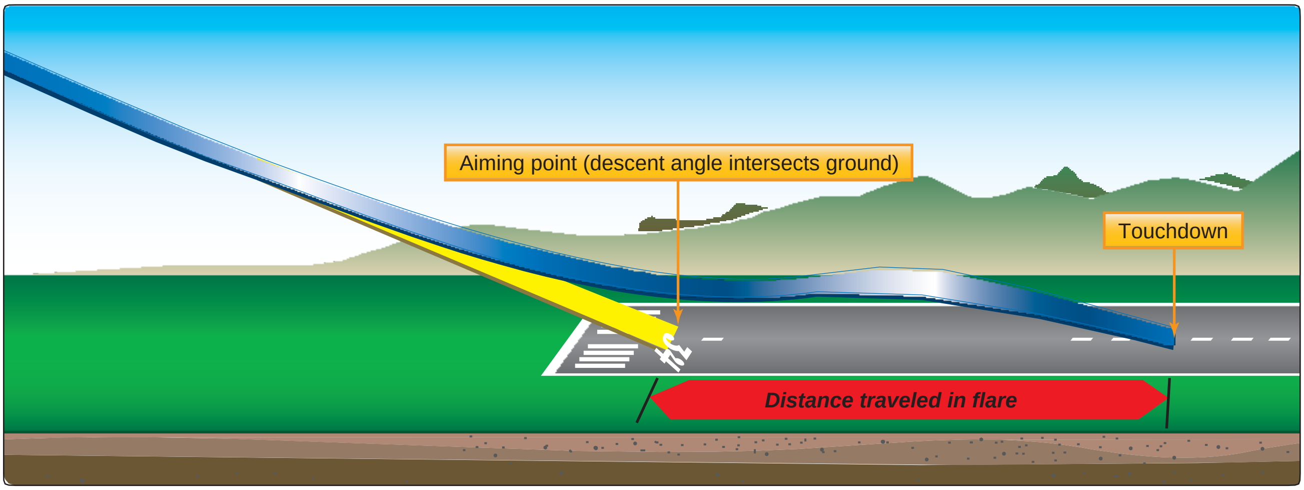

Figure 12-9. *Stabilized approach.*

When the aircraft is established on final approach, the shape of the runway image also presents clues as to what must be done to maintain a stabilized approach to a safe landing.

Obviously, runway is normally shaped in the form of an elongated rectangle. When viewed from the air during the approach, the phenomenon known as perspective causes the runway to assume the shape of a trapezoid with the far end looking narrower than the approach end and the edge lines converging ahead.

As an aircraft continues down the glide path at a constant angle (stabilized), the image the pilot sees is still trapezoidal but of proportionately larger dimensions. In other words, during a stabilized approach, the runway shape does not change. [Figure 8-10]

The objective of a stabilized approach is to select an appropriate touchdown point on the runway, and adjust the glide path so that the true aiming point and the desired touchdown point basically coincide. Immediately after rolling out on final approach, adjust the power, nacelle and attitude so that the aircraft is descending then decelerating directly toward the aiming point at the appropriate airspeed, in the landing configuration, and trimmed for “hands off” flight. With the approach set up in this manner, the pilot is free to devote full attention toward outside references. Do not stare at any one place, but rather scan from one point to another, such as from the aiming point to the horizon, to the trees and bushes along the runway, to an area well short of the runway, and back to the aiming point. This makes it easier to perceive a deviation from the desired glide path and determine if the aircraft is proceeding directly toward the aiming point.

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during a running landing.

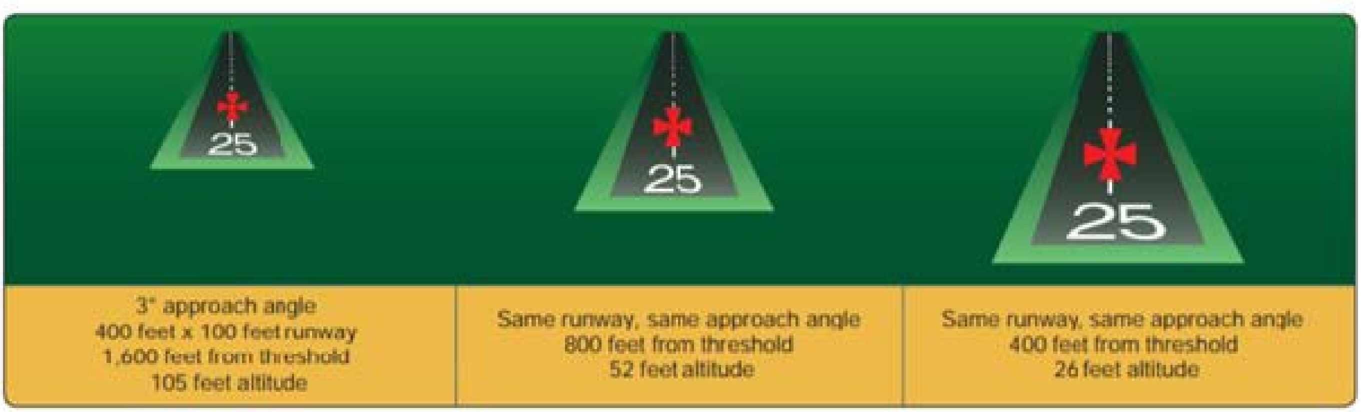


Figure 8-9. ***Runway shape during*** *Stabilized approach.*

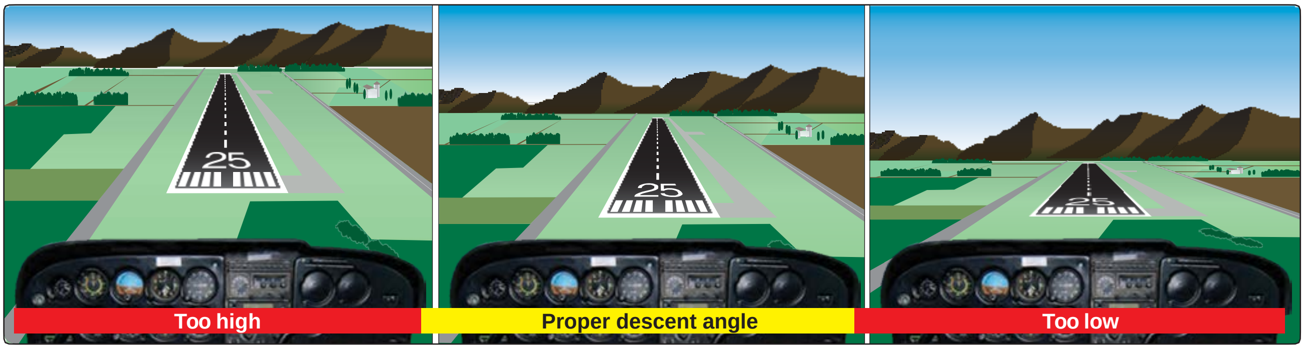


Figure 8-11. *Change in runway shape if approach becomes narrow or steep.*

If there is any indication that the aiming point on the runway is not where desired, an adjustment must be made to the glide path. This in turn moves the aiming point. For instance, if the aiming point is short of the desired touchdown point and results in an undershoot, an increase in power is warranted. Airspeed must be controlled through nacelle modulation and center stick. This results in a shallowing of the glide path with the aiming point moving towards the desired touchdown point. Conversely, if the aiming point is farther down the runway than the desired touchdown point resulting in an overshoot, the glide path is steepened by a decrease in power. Once again, the airspeed must be controlled. It is essential that deviations from the desired glide path be detected early so that only slight and infrequent adjustments to glide path are required.

The closer the aircraft gets to the runway, the larger and more frequent the required corrections become, resulting in an unstable approach.

Common errors:

1. Inadequate wind drift correction on the base leg.
2. Overshooting or undershooting the turn onto final approach resulting in too steep or too shallow a turn onto final approach.
3. Flat or skidding turns from base leg to final approach as a result of overshooting/inadequate wind drift correction.
4. Poor coordination during turn from base to final approach.
5. Over use of the center stick to control the speed.
6. Failure to complete the landing checklist in a timely manner.
7. Unstable approach.
8. Poor trim technique on final approach.
9. Touching down prior to attaining proper landing attitude.
10. Failure to hold sufficient back-center stick pressure after touchdown during a running landing.
11. Failure to position the nacelles fully aft after touchdownduring a running landing
12. Excessive/early use of brakes during a running landing.

Tranistion to Landing

The tranition to landing from the normal approach is made to a hover, to the surface or to running landing. Approaches are categorized according to the angle of descent as normal, steep, or shallow. A normal approach uses a descent profile of between 7° and 12°, a steep approach uses a descent profile of between 13° and 15°, a shallow approach is less than 7°.

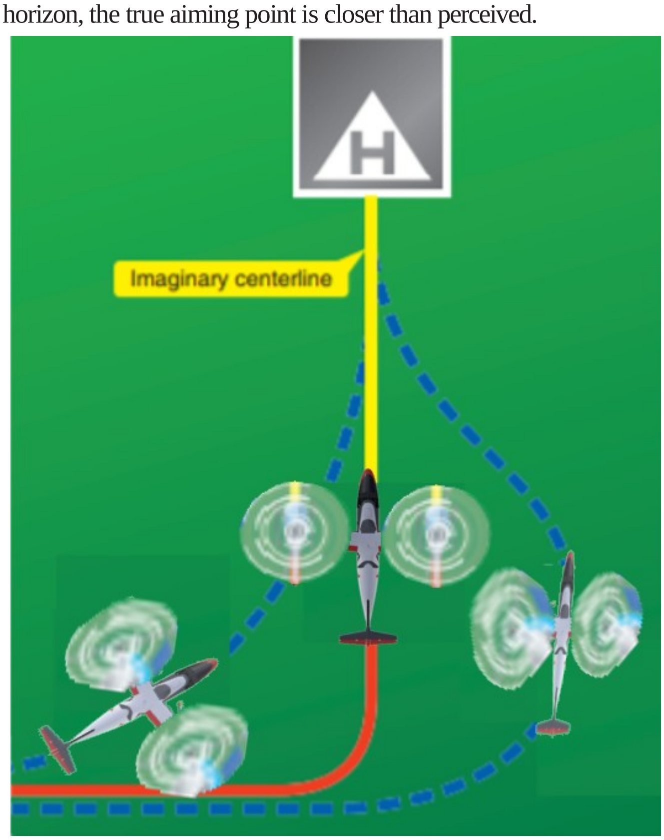
The selection of approach type will vary depending on factors such as obstacles on the approach, size and surface of the landing area, density altitude, aircraft weight, wind direction and speed. Regardless of the type of approach, it should always be made to a specific, predetermined landing site.

This section will focus on the normal visual approach.

Normal Approach to a Hover

From approximately 300-500 feet AGL, at the recommended approach airspeed and aircraft configuration, the aircraft should be on the correct ground track (or ground alignment) for the intended landing site. See Figure xxx.

For a constant angle glide path, the distance between the horizon and the aiming point remains constant. If a final approach descent is established and the distance between the perceived aiming point and the horizon appears to increase (aiming point moving down away from the horizon), then the true aiming point, and subsequent touchdown point, is farther down the runway. If the distance between the perceived aiming point and the horizon decreases, meaning that the aiming point is moving up toward the horizon, the true aiming point is closer than perceived.



As the aircraft intercepts the desired approach angle, reduce the power sufficiently to establish a descent and maintain the glideslope angle. With a power reduction, the nose tends to pitch down, requiring some aft center stick to maintain the recomended approach airspeed and attitude. Initially maintain the entry airspeed until the groundspeed and rate of closure begin to increase. At this point, for tiltrotor aircraft, begin decelerating with gradual aft nacelle (1º-2º increments), and smoothly reduce power to maintain the approach angle. With a level attitude, power controls the angle of approach, and nacelle position controls the rate of closure or how fast the aircraft is moving toward the touchdown point.

Pilots may visualize the angle from the landing point to the middle of the aircraft landing gear and should maneuver the aircraft down that imaginary slope until the aircraft is hovering or touching down centered on the landing point. The most important standard for a normal approach is maintaining a constant angle of approach to the termination point. As the aircraft approaches 100-50 feet AGL, align the aircraft and landing gear with the intended landing point.

As the aircraft slows, lift will increasingly be provided by the rotor system instead of the wing. At approximately 25 knots, depending on wind strength, the aircraft begins to lose effective translational lift. To compensate for loss of effective translational lift, increase the power to prevent sink and maintain the approach glideslope. The increase of power with an aft nacelle position tends to reduce the closure rate, usually requiring a minor nacelle adjustment and slight forward center stick to maintain the proper rate of closure.

Just prior to reaching the recommended hover altitude, set the nacelles for a zero ground speed hover and add power sufficiently to maintain the hover height. Aft center stick may be required to stop any forward movement while maintaining aircraft heading and alignment with the pedals. Once established over the arrival point, re-trim the aircraft for the IGE hover.

Common Errors

1. Starting the descent too early or late, resulting in a shallow or steep approach.
2. Improper use of power in controlling the angle of descent.
3. Not allowing the nacelles to take effect by adding aft center stick and slowing the aircraft too quickly.
4. Maintaining a constant groundspeed on final approach, resulting in a landing site overshoot.
5. Failing to simultaneously arrive at hovering altitude and attitude with zero groundspeed.
6. Improper nacelle setting upon reaching the hover at the end of the approach.
7. Using excessive center stick inputs to control airspeed.
8. Drifting in the hover, not re-trimming to the hover

Normal Approach to the Surface

A normal approach to the surface or a no-hover landing is often used if loose snow or dusty surface conditions exist or when the aircraft is operating at a high gross weight. These situations could cause a degraded visual environment (DVE), or the engine could possibly ingest debris when the aircraft comes to a hover.

The approach is the same as the normal approach to a hover; however, instead of terminating at a hover, continue the approach to touchdown. Touchdown should occur with a level attitude, at near zero forward groundspeed, no lateral drift, and a rate of descent approaching zero fpm.

As the aircraft enters ground effect, anticipate a small reduction in power required to avoid terminating in a low hover. Some aft center stick (1°-2°) can be used to reduce the speed towards zero, however, avoid excessive aft center stick application close to the ground. This could place the rear of the aircraft very close to the ground and may impact if low enough. It would be better to accept a very small run on (less than 5 knots groundspeed) than flaring the aircraft too low and striking the ground.

Just prior to landing, increase power as necessary to cushion and level the aircraft for landing with near zero forward movement. Once on the ground, smoothly reduce the power and centralize the flight controls, positioning the nacelles to vertical. Use the foot brakes to stop or prevent any forward movement.

Common Errors

1. Terminating to a hover and then making a vertical landing.
2. Touching down with too much forward movement.
3. Lateral drift during touchdown.
4. Approaching too slowly, requiring the use of excessive power and forward nacelle during the maneuver.
5. Approaching too fast, requiring excessive aft nacelle and/or center stick to arrest the closure rate.
6. Excessive aft center stick close to the ground
7. Not maintaining landing gear aligned with direction of travel at touchdown

Normal Approach to a Running Landing

In tilt-rotor a running landing is often used if a runway is available or aircraft gross weight, environmental factors, or an aircraft emergency preclude hover operations.

A normal approach to a running landing is a slow, smooth transition from the approach descent profile to a landing attitude, gradually rounding out the flight path to one that is parallel with, and within a very few inches above, the runway. When the aircraft, in a normal descent, approaches within what appears to be 10 to 20 feet above the ground, the power can be increased to bring the ROD towards zero. At the same time the aircraft attitude can be adjusted to ensure all wheels touchdown or even the rear wheels first. This will be achieved by applying aft center stick which allows the aircraft to continue settling slowly as forward speed decreases. The AOA is momentarily increased and this decreases the rate of descent.

Visual cues are important in applying power and decelerating at the proper altitude and maintaining the wheels a few inches above the runway until eventual touchdown. Deceleration or flare cues are primarily dependent on the angle at which the pilot's central vision intersects the ground (or runway) ahead and slightly to the side. Proper depth perception is a factor in a successful flare, but the visual cues used most are those related to changes in runway or terrain perspective and to changes in the size of familiar objects near the landing area, such as fences, bushes, trees, hangars, and even sod or runway texture. Focus direct central vision at a shallow downward angle from 10° to 15° toward the runway as the round out/flare is initiated. Maintaining the same viewing angle causes the point of visual interception with the runway to move progressively rearward as the aircraft loses altitude. This is an important visual cue in assessing the rate of altitude loss. Conversely, forward movement of the visual interception point indicates an increase in altitude and means that the pitch angle was increased too rapidly, resulting in an over flare. Location of the visual interception point in conjunction with assessment of flow velocity of nearby off-runway terrain, as well as the similarity of appearance of height above the runway ahead of the aircraft (in comparison to the way it looked when the aircraft was taxied prior to takeoff), is also used to judge when the wheels are just a few inches above the runway.

In some cases, it may be necessary to increase the power to prevent an excessive ROD, which may results in a hard, drop-in type landing.

It is extremely important that the touchdown occur with the aircraft's longitudinal axis exactly parallel to the direction in which the aircraft is moving along the runway. Failure to accomplish this imposes severe side loads on the landing gear. To avoid these side stresses, do not allow the aircraft to touch down while turned into the wind or drifting.

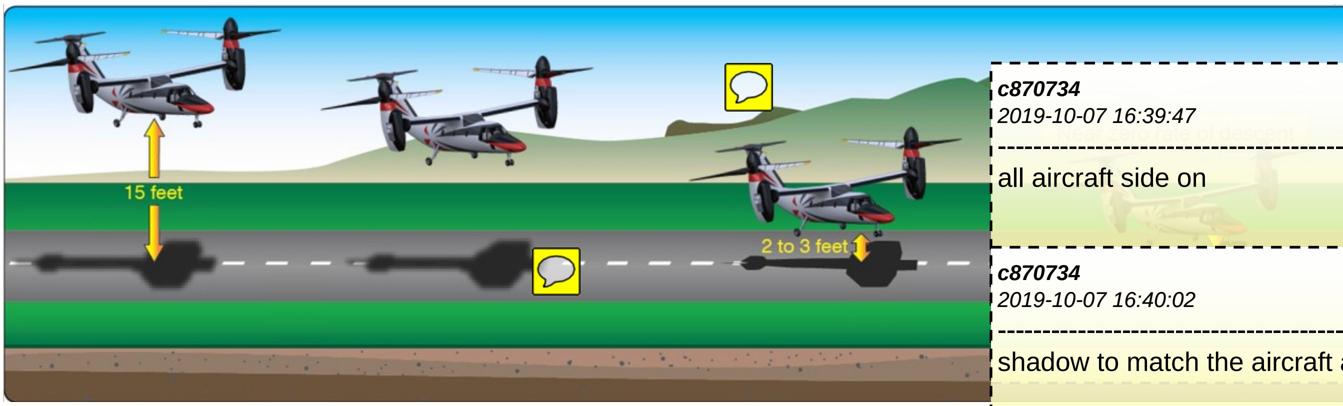


Figure 8-8. *A well-executed roundout results in attaining the proper landing attitude.*

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all aircraft side on

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shadow to match the aircraft above

Some pilots try to force or fly the aircraft onto the ground without establishing the proper landing attitude. The aircraft should never be flown on the runway with excessive speed or nose down attitude. A common technique to making a smooth touchdown is to actually focus on holding the wheels of the aircraft a few inches off the ground as long as possible using the center stick while the power is smoothly reduced. In most cases, when the wheels are within 2 or 3 feet off the ground, the aircraft is still settling too fast for a gentle touchdown; therefore, this descent must be retarded by increasing power. At the same time, the landing attitude should be maintained resulting in the main wheels touching down first so that little or no weight is on the nose wheel. [Figure 8-8]

After-Landing Roll

After the main wheels make initial contact with the ground, slowly reduce the back-center stick pressure allowing the nose wheel to settle onto the runway as the aircraft continues decelerates. Once the landing gear is in firm contact with the ground, reduce the power to zero and begin to rotate the nacelles to fully aft. Aircraft deceleration occurs primarily by rotating the nacelles to their aft-most setting. It also permits steering with the nose wheel, preventing floating or skipping and allows the full weight of the aircraft to rest on the wheels for better braking action.

The landing process must never be considered complete until the aircraft decelerates to the normal taxi speed during the landing roll or has been brought to a complete stop when clear of the landing area. Numerous accidents occur as a result of pilots abandoning their vigilance and failing to maintain positive control after getting the aircraft on the ground.

A pilot must be alert for directional control difficulties immediately upon and after touchdown due to the ground friction on the wheels. Loss of directional control may lead to a dynamic rollover. The combination of centrifugal force acting on the center of gravity (CG) and ground friction of the main wheels resisting it during the ground loop may cause the aircraft to tip or lean enough for the nacelle to contact the ground. This imposes a sideward force that could collapse the landing gear.

The pedals serve the same purpose on the ground as they did in the air— controlling the yawing of the aircraft. As the speed decreases and the nose wheel has been lowered to the ground, the pedals provide positive directional control.

As well as the nacelles, the brakes can also be used to reduce speed on the ground. They are also used as an aid in directional control when more positive control is required than could be obtained with nose wheel steering alone.

Putting maximum weight on the wheels after touchdown is an important factor in obtaining optimum braking performance. After touchdown, the nose wheel is lowered to the runway to maintain directional control. During excessive deceleration, the nose may pitch down by braking and the weight transferred to the nose wheel from the main wheels. This does not aid in braking action, so back pressure can be applied to the center stick, without lifting the nose wheel off the runway. This enables directional control while keeping weight on the main wheels.

Careful application of the brakes is initiated when the aircraft is below the braking speed and directional control is established. If the brakes are applied so hard that skidding takes place, braking becomes ineffective. Skidding is stopped by releasing the brake pressure. Braking effectiveness is not enhanced by alternately applying, releasing, and reapplying brake pressure. The brakes are applied firmly and smoothly as necessary.

During the ground roll, normal directional control is achieved through the pedals, however, the aircraft's direction of movement can be changed by carefully applying pressure on one brake or uneven pressures on each brake in the desired direction. Caution must be exercised when applying brakes to avoid overcontrolling.

During the after-landing roll, the center stick is used to keep the wings level. If a wing starts to rise, lateral center stick control is applied toward that wing to lower it, the amount required depends on the crosswind speed. Procedures for crosswind conditions are explained further in this chapter, in the Crosswind Approach and Landing section.

Once the aircraft has slowed sufficiently, configure the aircraft for taxi and clear the runway. Performing the after-landing checklist when able.

Crosswind during Approaches

Many runways or landing areas are such that landings must be made while the wind is blowing across rather than parallel to the landing direction. All pilots must be prepared to cope with these situations when they arise. The same basic principles and factors involved in a normal approach and landing apply to a crosswind approach and landing; therefore, only the additional procedures required for correcting for wind drift are discussed here.

Before starting a crosswind approach, check that the crosswind component is within the aircraft limits. Initially crab into the wind, then at approximately 100-50 feet AGL, use a slip to align the fuselage with the ground track. For tiltrotor aircraft, the proprotors are tilted into the wind with center stick pressure so the sideward movement of the aircraft and the wind drift counteract one another.

Crosswind landings are a little more difficult to perform than crosswind takeoffs, mainly due to different problems involved in maintaining accurate control of the aircraft while its speed is decreasing rather than increasing as on takeoff. Also, the difference in lift generated by the upwind and downwind proprotors adds a rolling motion that must be overcome with into wind center stick.

During crosswind approaches, ground track is always controlled by the center stick movement and heading is controlled by the pedals. Adjust power to control the approach angle. This technique can be used on any type of crosswind approach, whether it is a shallow, normal, or steep approach.

Crosswind Final Approach

The crab method is executed by establishing a heading (crab) toward the wind with the wings level so that the aircraft's ground track remains aligned with the centerline of the runway. [Figure 8-15] This crab angle is maintained until just prior to touchdown, when the longitudinal axis of the aircraft must be aligned with the runway to avoid sideward contact of the wheels with the runway. If a long final approach is being flown, one option is to use the crab method until just before the landing and then smoothly change to the wing-low method for the remainder of the landing.

To correct for strong crosswind, the slip into the wind is increased by lowering the upwind wing a considerable amount. As a consequence, this results in a greater tendency of the aircraft to turn. Since turning is not desired, considerable opposite pedal must be applied to keep the aircraft's longitudinal axis aligned with the runway. In some aircraft, there may not be sufficient rudder travel available to compensate for the strong turning tendency caused by the steep bank. The maximum crosswind allowance will be listed in the manufacturer's procedures, and should never be exceeded.

If the known wind strength is too great or the required bank is such that full opposite rudder does not prevent a turn, the wind is too strong to safely land the aircraft on that particular runway with those wind conditions. Since the aircraft's capability may be exceeded, it is imperative that the landing be made on a more favorable runway either at that airport or at an alternate airport.

Crosswind Touchdown

If the crab method is used throughout the final approach and landing the crab must be removed the instant before touchdown by applying pedal to align the aircraft's longitudinal axis with its direction of movement. This requires timely and accurate action. Failure to accomplish this, results in severe side loads being imposed on the landing gear.

If the wing-low method is used, the crosswind correction (center stick into the wind and opposite pedal) is maintained throughout the approach, and the touchdown made on the upwind main wheel. During gusty or high wind conditions, prompt adjustments must be made in the crosswind correction to assure that the aircraft does not drift as the aircraft touches down. As the forward momentum decreases after initial contact, the weight of the aircraft causes the downwind main wheel to gradually settle onto the runway.

In those aircraft having nose-wheel steering interconnected with the pedals, the nose wheel is not aligned with the runway as the wheels touch down because opposite pedal is being held in the crosswind correction. To prevent swerving in the direction the nose wheel is offset, the corrective pedal pressure must be promptly relaxed just as the nose wheel touches down.

Common errors:

1. Attempting to land in crosswinds that exceed the aircraft's maximum demonstrated crosswind component
2. Inadequate compensation for wind drift on the turn from base leg to final approach, resulting in undershooting or overshooting
3. Inadequate compensation for wind drift on final approach
4. Unstable approach
5. Touchdown while drifting
6. Excessive airspeed on touchdown
7. Failure to apply appropriate flight control inputs during landing
8. Failure to maintain direction control on landing
9. Excessive braking or braking above brake speed
10. Loss of aircraft control

Go-Around

Whenever landing conditions are not satisfactory, a go-around is warranted. There are many factors that can contribute to unsatisfactory landing conditions. Situations such as air traffic control (ATC) requirements, unexpected appearance of hazards on the runway, overtaking another aircraft, wind shear, wake turbulence, mechanical failure, and/or an unstable approach are all examples of reasons to discontinue a landing approach and make another approach under more favorable conditions.

The assumption that an aborted landing is invariably the consequence of a poor approach, which in turn is due to insufficient experience or skill, is a fallacy. The go-around is not strictly an emergency procedure. It is a normal maneuver that is also used in an emergency situation. Like any other normal maneuver, the go-around must be practiced and perfected. The flight instructor needs to emphasize early on, and the pilot must be made to understand, that the go-around maneuver is an alternative to any approach and/or landing.

Although the need to discontinue a landing may arise at any point in the landing process, the most critical go-around is one started when very close to the ground. The earlier a condition that warrants a go-around is recognized, the safer the go-around/rejected landing is. The go-around maneuver is not inherently dangerous in itself. It becomes dangerous only when delayed unduly or executed improperly. Delay in initiating the go-around normally stems from two sources:
Landing expectancy or set—the anticipatory belief that conditions are not as threatening as they are and that the approach is surely terminated with a safe landing,
Pride—the mistaken belief that the act of going around is an admission of failure—failure to execute the approach properly. The improper execution of the go-around maneuver stems from a lack of familiarity with the three cardinal principles of the procedure: power, attitude, and configuration

Power

Power is the pilot's first concern. The instant a pilot decides to go around, takeoff power must be applied smoothly and without hesitation and held until the aircraft is in a positive climb. Applying only partial power in a go-around is never appropriate. The pilot must be aware of the degree of inertia that must be overcome before an aircraft that is settling towards the ground can regain sufficient airspeed to become fully controllable and capable of climbing or turning safely. The application of power is smooth, as well as positive. Abrupt/harsh changes of power in some aircraft may cause the aircraft to over-temp/over-torque as well as undesirable yaw.

Attitude

Attitude is always critical when close to the ground, and when power is added, a deliberate effort on the part of the pilot is required to keep the aircraft level and prevent any speed deviations through pitch changes. As the power has been added, the attitude and nacelle setting is adjusted to achieve the safe single engine speed before any effort is made to execute a turn. Allowing the nose to raise too early could result in the aircraft decelerating, which will require more power to start and maintain the climb.

A concern for quickly regaining altitude during a go-around produces a natural tendency to pull the nose up with aft center stick. If below safe single engine speed, it is desirable to lower the nose briefly to gain airspeed. This can be done through forward center stick, forward nacelle or a combination of both. As soon as the appropriate climb configuration, airspeed and attitude are attained trim the aircraft to relieve any adverse control pressures.

Configuration

After establishing the proper climb attitude, nacelle and power settings and the aircraft is in a controlled climb start to think about the landing gear (if retractable). The landing gear can be raised if required to increase the ROC, or left down for a subsequent landing. Most modern tilt-rotor aircraft will have auto scheduling flaps, so there is no action required by the pilots.

Common errors:

1. Delayed recognition of a condition that warrants a rejected landing
2. Indecision
3. Delay in initiating a go-around
4. Failure to apply maximum allowable power in a timely manner
5. Abrupt/harsh power application
6. Uncontrolled Pitch and heading changes
7. Improper pitch attitude and nacelle setting for the required airspeed
8. Failure to configure the aircraft appropriately
9. Manuevering too early
10. Loss of aircraft control.

Chapter Summary

Accident statistics show that a pilot is at most risk for an accident during the approach and landing than any other phase of a flight. There are many factors that contribute to accidents in this phase, but an overwhelming percentage of accidents are caused from pilot's lack of proficiency. This chapter presents procedures that, when learned and practiced, are a key to attaining proficiency. Additional information on aerodynamics, aircraft performance, and other aspects affecting approaches and landings can be found in the Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-25, as revised). For information concerning risk assessment as a means of preventing accidents, refer to the Risk Management Handbook (FAA-H-8083-2).

Approaches

An approach is the transition from altitude to either a hover or to the surface. Approaches are categorized according to the angle of descent as normal, steep, or shallow. A normal approach uses a descent profile of between 7° and 12°, a steep approach uses a descent profile of between 13° and 15°, a shallow approach is less than 7°.

The selection of approach type will vary depending on factors such as obstacles on the approach, size and surface of the landing area, density altitude, aircraft weight, wind direction and speed. Regardless of the type of approach, it should always be made to a specific, predetermined landing spot.
This chapter will focus on the normal approach.

Normal Approach to a Hover

From approximately 300-500 feet AGL, at the recommended approach airspeed and aircraft configuration, the aircraft should be on the correct ground track (or ground alignment) for the intended landing site.

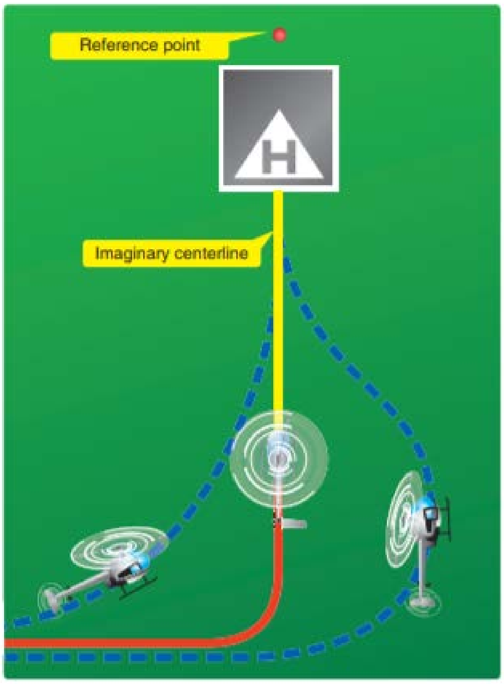


Figure 9-20. *Plan the turn to final so the helicopter rolls out on an imaginary extension of the centerline for the final approach path. This path should neither angle to the landing area, as shown by the helicopter on the left, nor require an S-turn, as shown by the helicopter on the right.*

As the aircraft intercepts the desired approach angle reduce the power sufficiently to get the aircraft begin the descent and maintain the glideslope angle. With the decrease in power, the nose tends to pitch down, requiring aft center stick to maintain the recommended approach airspeed and attitude. Initially maintain the entry airspeed until the apparent groundspeed and rate of closure appear to be increasing. At this point, begin decelerating with gradual aft nacelle (1^0-2^0 increments), and smoothly reduce power to maintain the approach angle. Power controls the angle of approach and nacelle modulation controls the rate of closure, or how fast the aircraft is moving toward the touchdown point.

Pilots may visualize the angle from the landing point to the middle of the aircraft landing gear and should maneuver the aircraft down that imaginary slope until the aircraft is hovering or touching down centered on the landing point. The most important standard for a normal approach is maintaining a consistent angle of approach to the termination point. As the aircraft approaches 50-100' AGL align the aircraft and landing gear with the intended landing point.

As the aircraft slows, lift will increasingly be provided by the proprotors instead of the wing. At approximately 25 knots, depending on wind strength, the aircraft begins to lose effective translational lift. To compensate for loss of effective translational lift, increase the power to prevent sink and maintain the approach glideslope. The increase of power with an aft nacelle position tends to reduce the closure rate, usually requiring a minor nacelle adjustment and slight forward center stick to maintain the proper rate of closure.

Just prior to reaching the recommended hover altitude and position set hover nacelle and begin to increase the power sufficiently to maintain the hover height. Aft center stick may be required to stop any forward movement while maintaining aircraft heading and alignment with the pedals. Once established over the arrival point, re-trim the aircraft for the IGE hover.

Common Errors

- Starting the descent too early, going shallow.
- Improper use of power in controlling the angle of descent.
- Not allowing the nacelles to take effect by adding aft center stick and slowing the aircraft too quickly.
- Maintaining a constant airspeed on final approach instead of an apparent brisk walk.
- Failing to simultaneously arrive at hovering altitude and attitude with zero groundspeed.
- Improper nacelle setting in transition to the hover at the end of the approach.
- Using excessive center stick inputs to control airspeed.
- Drifting in the hover, not re-trimming to the hover

Normal Approach to the Surface

A normal approach to the surface or a no-hover landing is often used if loose snow or dusty surface conditions exist or when the aircraft is operating at a high AUM. These situations could cause a degraded visual environment (DVE), or the engine could possibly ingest debris when the tilt-rotor comes to a hover.

The approach is the same as the normal approach to a hover; however, instead of terminating at a hover, continue the approach to touchdown. Touchdown should occur with a level attitude, zero groundspeed, and a rate of descent approaching zero.

As the aircraft enters ground effect, anticipate a small reduction in power required to avoid terminating in a low hover. Some aft center stick (1°-2°) can be used to reduce the speed towards zero, however, avoid excessive aft center stick application close to the ground. This will place the rear of the aircraft very close to the ground and may impact if low enough. It would be better to accept a very small run on than flaring the aircraft too low and striking the ground.

Just prior to landing, increase power as necessary to cushion.and level the aircraft for landing and with no forward movement. Once on the ground smoothly reduce the power to zero and centralize the flight controls, positioning the nacelles to vertical. Use the foot brakes to stop or prevent any forward movement.

Common Errors

- Terminating to a hover, and then making a vertical landing.
- Touching down with forward movement.
- Approaching too slowly, requiring the use of excessive power and forward nacelle during the maneuver.
- Approaching too fast, requiring excessive aft nacelle and / or center stick to arrest the closure rate.
- Aft center stick, close to the ground
- Not maintaining landing gear aligned with direction of travel at touchdown.

Crosswind during Approaches

Before starting a crosswind approach check that the crosswind elements are within the aircraft limits. Initially crab into the wind then at approximately 50-100 feet AGL, use a slip to align the fuselage with the ground track. The proprotors are tilted into the wind with center stick pressure so that the sideward movement of the tilt-rotor and the wind drift counteract one another.

Under crosswind approaches, ground track is always controlled by the center stick movement and heading is controlled by the pedals. Apply or reduce power to control the hover height. This technique should be used on any type of crosswind approach, whether it is a shallow, normal, or steep approach.

Go-Around

A go-around may be necessary when:

- Instructed by the control tower or instructor.
- Traffic conflict occurs.
- The aircraft is in a position from which it is not safe to continue the approach.
- Any time an approach feels uncomfortable, incorrect, or potentially dangerous.

The decision to execute a go-around should be positive and initiated before a critical situation develops. When the decision is made, carry it out without hesitation. In most cases, when initiating the go-around, power is at a low setting. Therefore, the first response is to apply takeoff power. This movement is coordinated with the center stick, and pedals to control the aircraft's flight vector. Then, establish a climb attitude, nacelle setting and speed to pattern altitude before attempting another approach.

Normal Approach and Running Landing

In tilt-rotor a running landing is often used if a runway is available or aircraft gross weight, environmental factors, or an aircraft emergency preclude hover operations.

A normal approach and landing involves the use of procedures for what is considered a normal situation; that is, when engine power is available, the wind is light, or the final approach is made directly into the wind, the final approach path has no obstacles and the landing surface is firm and of ample length to gradually bring the aircraft to a stop. The selected landing point is normally beyond the runway's approach threshold but within the first 1⁄3 portion of the runway.

The factors involved and the procedures described for the normal approach and landing also have applications to the other-than-normal approaches and landings and are discussed later in this chapter. This being the case, the principles of normal operations are explained first and must be understood before proceeding to the more complex operations. To help the pilot better understand the factors that influence judgment and procedures, the last part of the approach pattern and the actual landing is divided into four phases:

- the base leg
- the final approach
- the touchdown
- the after-landing roll.

It must be remembered that the manufacturer's recommended procedures, including aircraft configuration and airspeeds, and other information relevant to approaches and landings in a specific make and model aircraft are contained in the Federal Aviation Administration (FAA)-approved Aircraft Flight Manual and/or Pilot's Operating Handbook (AFM/POH) for that aircraft. If any of the information in this chapter differs from the aircraft manufacturer's recommendations as contained in the AFM/POH, the aircraft manufacturer's recommendations take precedence

Base Leg

The placement of the base leg is one of the more important judgments made by the pilot in any landing approach. [Figure 8-1] The pilot must accurately judge the altitude and distance from which a gradual, stabilized descent results in landing at the desired spot. The distance depends on the altitude of the base leg, the effect of wind, and the amount of wing flaps used. When there is a strong wind on final approach or a steep angle of descent is required, the base leg must be positioned closer to the approach end of the runway than would be required with a light wind or shallower approach. Normally, the landing gear is extended and the before-landing check completed prior to reaching the base leg.

The aircraft continues to descend and decelerate. The nacelles will be moving rearwards, towards the landing configuration, maintain a speed above safe single engine speed throughout. The base leg is continued to the point where a medium to shallow-banked turn aligns the aircraft's path directly with the centerline of the landing runway. This descending turn is completed at a safe altitude and dependent upon the height of the terrain and any obstructions along the ground track. The turn to the final approach is sufficiently above the airport elevation to permit a final approach long enough to accurately estimate the resultant point of touchdown while maintaining the proper approach airspeed.

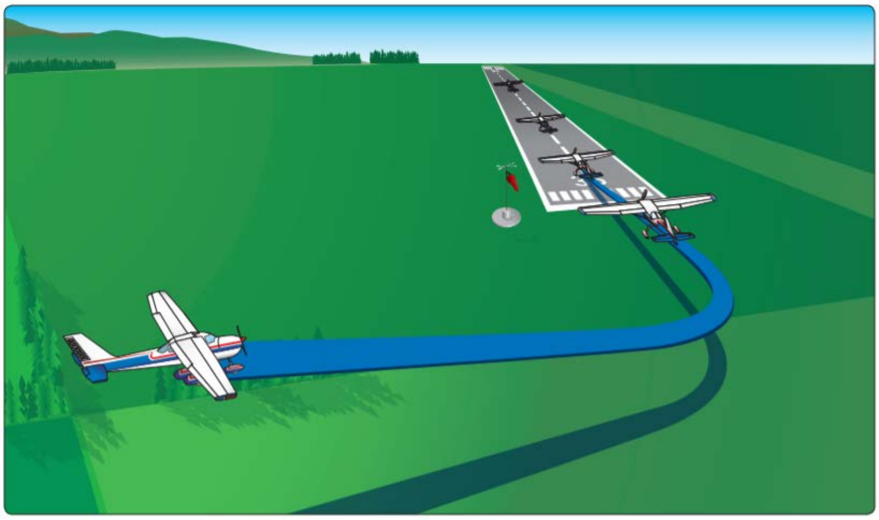


Figure 8-1. *Base leg and final approach.*

This requires careful planning as to the starting point and the radius of the turn. Normally, it is recommended that the angle of bank not exceed a medium bank because the steeper the angle of bank, the higher the airspeed at which the aircraft stalls and will require higher power settings. Since the base-to-final turn is made at a relatively low altitude, it is important that an unwanted descent occur at this point. If an extremely steep bank is needed to prevent overshooting the proper final approach path, it is advisable to discontinue the approach, go around, and plan to start the turn earlier on the next approach rather than risk a hazardous situation.
This approach is identical to the normal approach until the turn to final. In a running landing, the pilot maintains a calculated approach reference speed until the round out and flare, terminating in a rolling touchdown. Touchdown should occur with a level to slightly nose up attitude, and at a rate of descent approaching zero.

Final Approach

After the turn to final approach completed, the longitudinal axis of the aircraft is aligned with the centerline of the runway or landing surface so that any drift is recognized immediately. Assuming no wind drift, the longitudinal axis is kept aligned with the runway centerline throughout the approach and landing.

After aligning the aircraft with the runway centerline, set the recommended landing nacelle. Maintaining a level pitch attitude, adjust power as required for the required rate of descent. Slight adjustments in pitch and power may be necessary to maintain the descent attitude and the recommended approach airspeed. It is recommended to keep the airspeed at or above the safe single engine speed as this will reduce any height loss should a power plant failure occur.

A stabilized descent angle is controlled throughout the approach so that the aircraft lands in the center of the first third of the runway. The descent angle is affected by all four fundamental forces that act on an aircraft (lift, drag, thrust, and weight). If all forces are held constant, the descent angle also remains constant in a no-wind condition. After setting the recommended landing nacelle, the pilot controls the forces acting on the aircraft by adjusting nacelle, airspeed, aircraft attitude, and power.

During the approach, pilots can expect that for a given nacelle angle and pitch attitude, there is only one power setting for one airspeed and one wind condition. A change in any one of these variables requires an appropriate coordinated change in the other controllable variables. For example, if the pitch attitude is raised too high without an increase of power, the aircraft slows and touches down short of the desired spot. The proper angle of descent and airspeed is maintained by coordinating nacelle, pitch attitude and power changes.

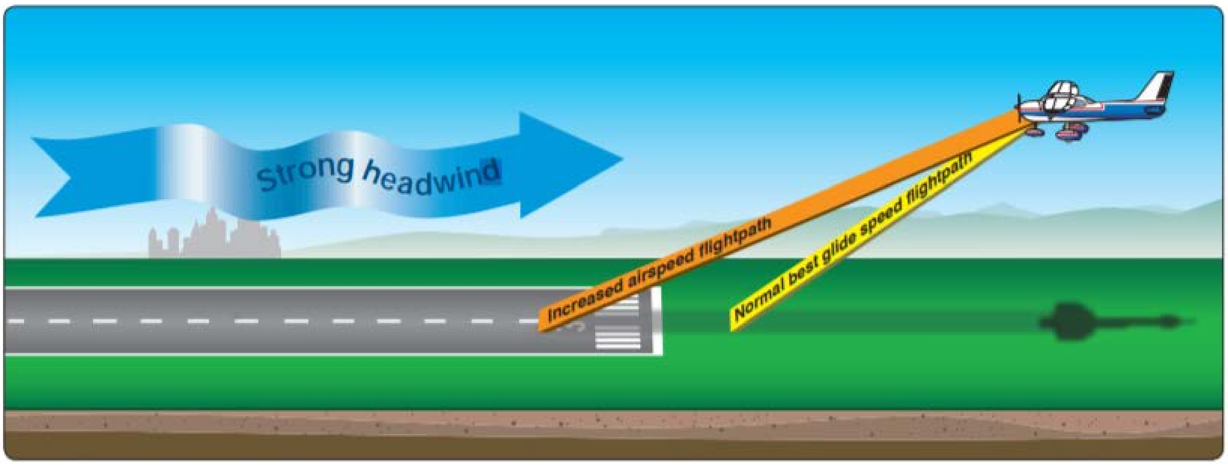


Figure 8-2. *Effect of headwind on final approach.*

The objective of a good, stabilized final approach is to descend at an angle and airspeed that permits the aircraft to reach the desired touchdown point at an airspeed that results in minimum floating just before touchdown. To accomplish this, it is essential that both the descent angle and the airspeed be accurately controlled. Power and pitch attitude are adjusted simultaneously as necessary to control the airspeed and the descent angle, or to attain the desired altitudes along the approach path. By lowering the nose and reducing power to keep approach airspeed constant, a descent at a higher rate can be made to correct for being too high in the approach.

Estimating Height and Movement

During the approach, round out, and touchdown; vision is of prime importance. To provide a wide scope of vision and to foster good judgment of height and movement, the pilot's head should assume a natural, straight-ahead position. Visual focus is not fixed on any one side or any one spot ahead of the aircraft. Instead, it is changed slowly from a point just over the aircraft's nose to the desired touchdown zone and back again. This is done while maintaining a deliberate awareness of distance from either side of the runway using your peripheral field of vision.
Accurate estimation of distance is, besides being a matter of practice, dependent upon how clearly objects are perceived.

Speed blurs objects at close range. For example, most everyone has noted this in an automobile moving at high speed. Nearby objects seem to merge together in a blur, while objects farther away stand out clearly. The driver subconsciously focuses the eyes sufficiently far ahead of the automobile to see objects distinctly.

The distance at which the pilot's vision is focused should be proportionate to the speed at which the aircraft is traveling over the ground. Thus, as speed is reduced during the round out, the distance ahead of the aircraft at which it is possible to focus is brought closer accordingly.

If the pilot attempts to focus on a reference that is too close or looks directly down, the reference becomes blurred, [Figure 8-5] and the reaction is either too abrupt or too late. In this case, the pilot's tendency is to over-control, round out high, and make full-stall, drop-in landings. If the pilot focuses too far ahead, accuracy in judging the closeness of the ground is lost and the consequent reaction is too slow since there does not appear to be a necessity for action. This results in the aircraft flying into the ground nose first. The change of visual focus from a long distance to a short distance requires a definite time interval and, even though the time is brief, the aircraft's speed during this interval is such that the aircraft travels an appreciable distance, both forward and downward toward the ground.

Figure 8-5. *Focusing too close blurs vision.*

If the focus is changed gradually, being brought progressively closer as speed is reduced, the time interval and the pilot's reaction are reduced and the whole landing process smoothed out.

Touchdown

The touchdown is a slow, smooth transition from a descent profile to a landing attitude, gradually rounding out the flight path to one that is parallel with, and within a very few inches above, the runway. When the aircraft, in a normal descent, approaches within what appears to be 10 to 20 feet above the ground, the power can be increased to bring the ROD towards zero. At the same time the aircraft attitude can be adjusted to ensure all wheels touchdown or even the rear wheels first. This will be achieved by applying aft center stick which allows the aircraft to continue settling slowly as forward speed decreases. The AOA is momentarily increased and this decreases the rate of descent.

The touchdown out is executed such that the landing nacelle is set, the proper landing attitude and the touchdown speed are attained simultaneously just as the wheels contact the landing surface.

Visual cues are important in applying power and decelerating at the proper altitude and maintaining the wheels a few inches above the runway until eventual touchdown. Deceleration or flare cues are primarily dependent on the angle at which the pilot's central vision intersects the ground (or runway) ahead and slightly to the side. Proper depth perception is a factor in a successful flare, but the visual cues used most are those related to changes in runway or terrain perspective and to changes in the size of familiar objects near the landing area, such as fences, bushes, trees, hangars, and even sod or runway texture. Focus direct central vision at a shallow downward angle from 10° to 15° toward the runway as the round out/flare is initiated. Maintaining the same viewing angle causes the point of visual interception with the runway to move progressively rearward as the aircraft loses altitude. This is an important visual cue in assessing the rate of altitude loss. Conversely, forward movement of the visual interception point indicates an increase in altitude and means that the pitch angle was increased too rapidly, resulting in an over flare. Location of the visual interception point in conjunction with assessment of flow velocity of nearby off-runway terrain, as well as the similarity of appearance of height above the runway ahead of the aircraft (in comparison to the way it looked when the aircraft was taxied prior to takeoff), is also used to judge when the wheels are just a few inches above the runway.

In some cases, it may be necessary to increase the power to prevent an excessive ROD, which may results in a hard, drop-in type landing.

It is extremely important that the touchdown occur with the aircraft's longitudinal axis exactly parallel to the direction in which the aircraft is moving along the runway. Failure to accomplish this imposes severe side loads on the landing gear. To avoid these side stresses, do not allow the aircraft to touch down while turned into the wind or drifting.

Some pilots try to force or fly the aircraft onto the ground without establishing the proper landing attitude. The aircraft should never be flown on the runway with excessive speed or nose down attitude. A common technique to making a smooth touchdown is to actually focus on holding the wheels of the aircraft a few inches off the ground as long as possible using the center stick while the power is smoothly reduced. In most cases, when the wheels are within 2 or 3 feet off the ground, the aircraft is still settling too fast for a gentle touchdown; therefore, this descent must be retarded by increasing power. At the same time, the landing attitude should be maintained resulting in the main wheels touching down first so that little or no weight is on the nose wheel. [Figure 8-8]

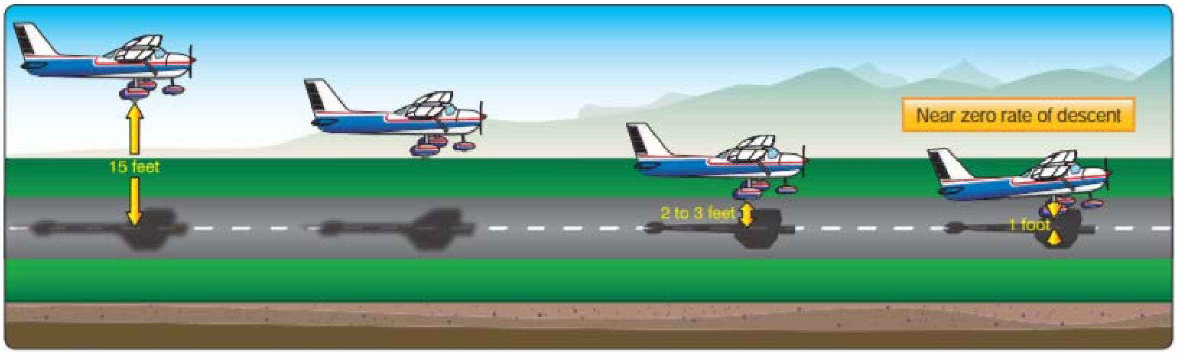


Figure 8-8. *A well-executed roundout results in attaining the proper landing attitude.*

After-Landing Roll

After the main wheels make initial contact with the ground, slowly reduce the back-center stick pressure allowing the nose wheel to settle onto the runway as the aircraft continues decelerates. Once the landing gear is in firm contact with the ground, reduce the power to zero and begin to rotate the nacelles to fully aft. Aircraft deceleration occurs primarily by rotating the nacelles to their aft-most setting. It also permits steering with the nose wheel, preventing floating or skipping and allows the full weight of the aircraft to rest on the wheels for better braking action.

The landing process must never be considered complete until the aircraft decelerates to the normal taxi speed during the landing roll or has been brought to a complete stop when clear of the landing area. Numerous accidents occur as a result of pilots abandoning their vigilance and failing to maintain positive control after getting the aircraft on the ground.

A pilot must be alert for directional control difficulties immediately upon and after touchdown due to the ground friction on the wheels. Loss of directional control may lead to a dynamic rollover. The combination of centrifugal force acting on the center of gravity (CG) and ground friction of the main wheels resisting it during the ground loop may cause the aircraft to tip or lean enough for the nacelle to contact the ground. This imposes a sideward force that could collapse the landing gear.

The pedals serve the same purpose on the ground as they did in the air— controlling the yawing of the aircraft. As the speed decreases and the nose wheel has been lowered to the ground, the pedals provide positive directional control.

As well as the nacelles, the brakes can also be used to reduce speed on the ground. They are also used as an aid in directional control when more positive control is required than could be obtained with nose wheel steering alone.

Putting maximum weight on the wheels after touchdown is an important factor in obtaining optimum braking performance. After touchdown, the nose wheel is lowered to the runway to maintain directional control. During excessive deceleration, the nose may pitch down by braking and the weight transferred to the nose wheel from the main wheels. This does not aid in braking action, so back pressure can be applied to the center stick, without lifting the nose wheel off the runway. This enables directional control while keeping weight on the main wheels.

Careful application of the brakes is initiated when the aircraft is below the braking speed and directional control is established. If the brakes are applied so hard that skidding takes place, braking becomes ineffective. Skidding is stopped by releasing the brake pressure. Braking effectiveness is not enhanced by alternately applying, releasing, and reapplying brake pressure. The brakes are applied firmly and smoothly as necessary.

During the ground roll, normal directional control is achieved through the pedals, however, the aircraft's direction of movement can be changed by carefully applying pressure on one brake or uneven pressures on each brake in the desired direction. Caution must be exercised when applying brakes to avoid overcontrolling.

During the after-landing roll, the center stick is used to keep the wings level. If a wing starts to rise, lateral center stick control is applied toward that wing to lower it, the amount required depends on the crosswind speed. Procedures for crosswind conditions are explained further in this chapter, in the Crosswind Approach and Landing section.

Once the aircraft has slowed sufficiently, configure the aircraft for taxi and clear the runway. Performing the after-landing checklist when able.

Stabilized Approach Concept

A stabilized approach is one in which the pilot establishes and maintains a constant angle glide path towards a predetermined point on the landing runway. It is based on the pilot's judgment of certain visual clues and depends on the maintenance of a constant final descent airspeed and configuration.

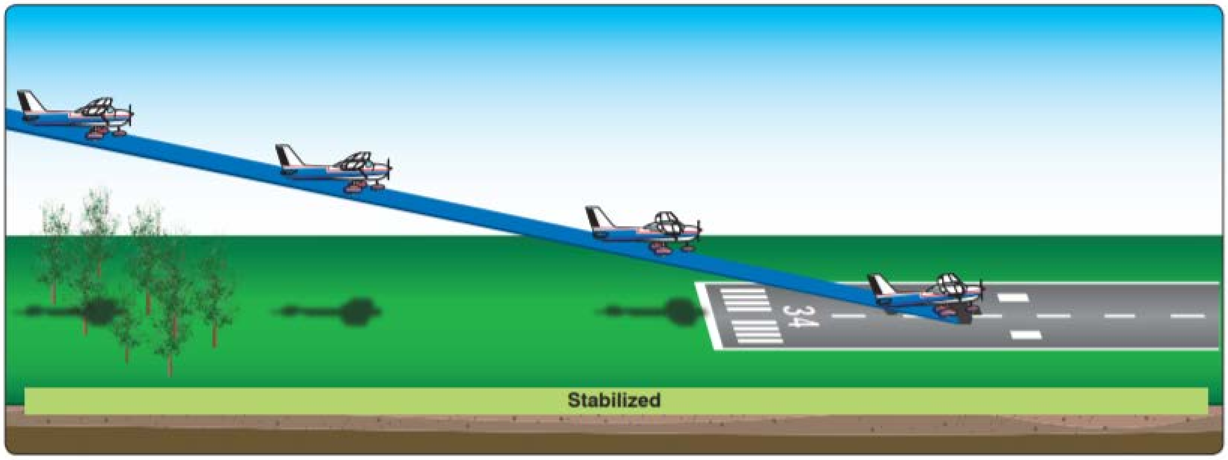


Figure 8-22. *Stabilized approach.*

An aircraft descending on final approach at a constant rate and airspeed is traveling in a straight line toward a spot on the ground ahead. This spot is not the spot on which the aircraft touches down because some float occurs prior to the touchdown as the ROD is reduced and the aircraft decelerates(Figure 8-9]

The point toward which the aircraft is progressing is termed the “aiming point.” [Figure 8-9] It is the point on the ground at which, if the aircraft maintains a constant glide path and was not configured for landing, it would strike the ground. To a pilot moving straight ahead toward an object, it appears to be stationary. It does not appear to move under the nose of the aircraft and does not appear to move forward away from the aircraft. This is how the aiming point can be distinguished—it does not move. However, objects in front of and beyond the aiming point do appear to move as the distance is closed, and they appear to move in opposite directions. During instruction in landings, one of the most important skills a pilot must acquire is how to use visual cues to accurately determine the true aiming point from any distance out on final approach. From this, the pilot is not only able to determine if the glide path results in either an under or overshoot but, taking into account float during the landing, the pilot is able to predict the touchdown point to within a few feet.

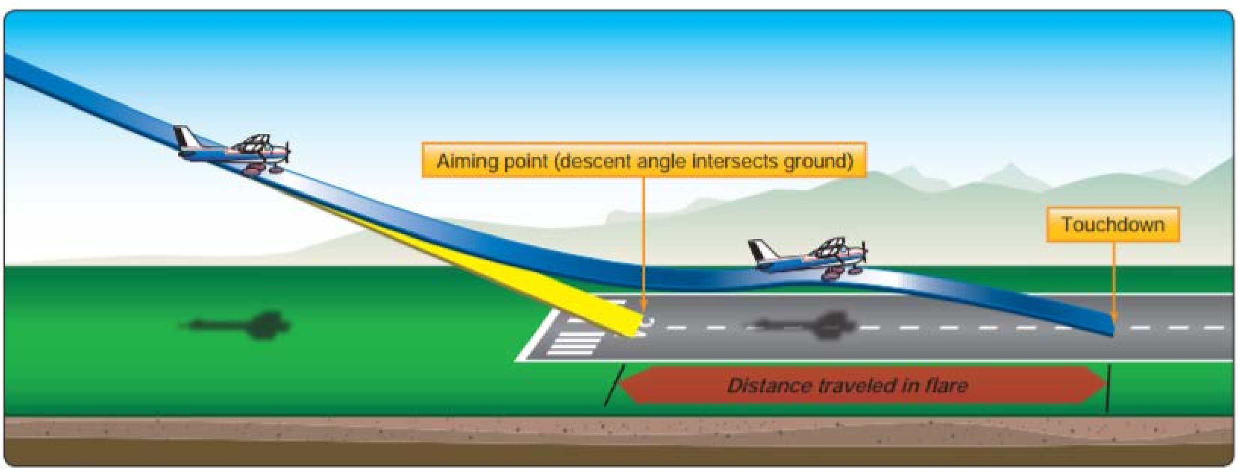


Figure 8-9. *Stabilized approach.*

For a constant angle glide path, the distance between the horizon and the aiming point remains constant. If a final approach descent is established and the distance between the perceived aiming point and the horizon appears to increase (aiming point moving down away from the horizon), then the true aiming point, and subsequent touchdown point, is farther down the runway. If the distance between the perceived aiming point and the horizon decreases, meaning that the aiming point is moving up toward the horizon, the true aiming point is closer than perceived.

When the aircraft is established on final approach, the shape of the runway image also presents clues as to what must be done to maintain a stabilized approach to a safe landing.

Obviously, runway is normally shaped in the form of an elongated rectangle. When viewed from the air during the approach, the phenomenon known as perspective causes the runway to assume the shape of a trapezoid with the far end looking narrower than the approach end and the edge lines converging ahead.

As an aircraft continues down the glide path at a constant angle (stabilized), the image the pilot sees is still trapezoidal but of proportionately larger dimensions. In other words, during a stabilized approach, the runway shape does not change. [Figure 8-10]

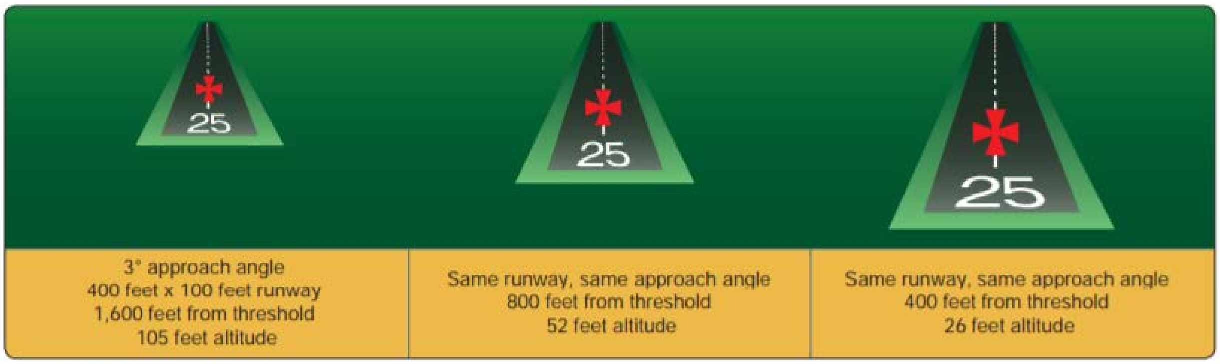


Figure 8-10. *Runway shape during stabilized approach.*

If the approach becomes shallow, the runway appears to shorten and become wider. Conversely, if the approach is steepened, the runway appears to become longer and narrower. [Figure 8-11].

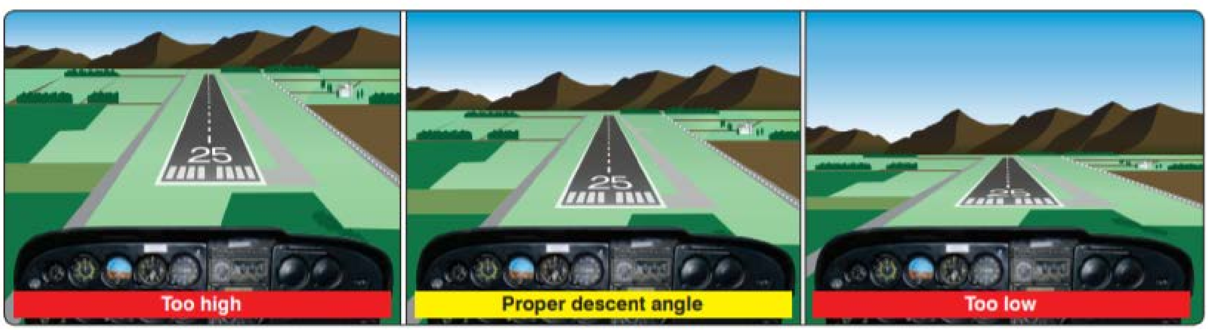


Figure 8-11. *Change in runway shape if approach becomes narrow or steep.*

The objective of a stabilized approach is to select an appropriate touchdown point on the runway, and adjust the glide path so that the true aiming point and the desired touchdown point basically coincide. Immediately after rolling out on final approach, adjust the power, nacelle and attitude so that the aircraft is descending then decelerating directly toward the aiming point at the appropriate airspeed, in the landing configuration, and trimmed for "hands off" flight. With the approach set up in this manner, the pilot is free to devote full attention toward outside references. Do not stare at any one place, but rather scan from one point to another, such as from the aiming point to the horizon, to the trees and bushes along the runway, to an area well short of the runway, and back to the aiming point. This makes it easier to perceive a deviation from the desired glide path and determine if the aircraft is proceeding directly toward the aiming point.

If there is any indication that the aiming point on the runway is not where desired, an adjustment must be made to the glide path. This in turn moves the aiming point. For instance, if the aiming point is short of the desired touchdown point and results in an undershoot, an increase in power is warranted. Airspeed must be controlled through nacelle modulation and center stick. This results in a shallowing of the glide path with the aiming point moving towards the desired touchdown point. Conversely, if the aiming point is farther down the runway than the desired touchdown point resulting in an overshoot, the glide path is steepened by a decrease in power. Once again, the airspeed must be controlledi. It is essential that deviations from the desired glide path be detected early so that only slight and infrequent adjustments to glide path are required.

The closer the aircraft gets to the runway, the larger and more frequent the required corrections become, resulting in an unstable approach.

Common Errors

- Inadequate wind drift correction on the base leg.
- Overshooting or undershooting the turn onto final approach resulting in too steep or too shallow a turn onto final approach.
- Flat or skidding turns from base leg to final approach as a result of overshooting/inadequate wind drift correction.
- Poor coordination during turn from base to final approach.
- Over use of the center stick to control the speed.
- Failure to complete the landing checklist in a timely manner.
- Unstable approach.
- Poor trim technique on final approach.
- Touching down prior to attaining proper landing attitude.
- Failure to hold sufficient back-center stick pressure after touchdown.
- Failure to position the nacelles fully aft after touchdown
- Excessive/early use of brakes.
- Loss of aircraft control during touchdown and ground roll.

Go-Arounds (Rejected Landings)

Whenever landing conditions are not satisfactory, a go-around is warranted. There are many factors that can contribute to unsatisfactory landing conditions. Situations such as air traffic control (ATC) requirements, unexpected appearance of hazards on the runway, overtaking another aircraft, wind shear, wake turbulence, mechanical failure, and/or an unstable approach are all examples of reasons to discontinue a landing approach and make another approach under more favorable conditions.

The assumption that an aborted landing is invariably the consequence of a poor approach, which in turn is due to insufficient experience or skill, is a fallacy. The go-around is not strictly an emergency procedure. It is a normal maneuver that is also used in an emergency situation. Like any other normal maneuver, the go-around must be practiced and perfected. The flight instructor needs to emphasize early on, and the pilot must be made to understand, that the go-around maneuver is an alternative to any approach and/or landing.

Although the need to discontinue a landing may arise at any point in the landing process, the most critical go-around is one started when very close to the ground. The earlier a condition that warrants a go-around is recognized, the safer the go-around/rejected landing is. The go-around maneuver is not inherently dangerous in itself. It becomes dangerous only when delayed unduly or executed improperly. Delay in initiating the go-around normally stems from two sources:
Landing expectancy or set—the anticipatory belief that conditions are not as threatening as they are and that the approach is surely terminated with a safe landing,
Pride—the mistaken belief that the act of going around is an admission of failure—failure to execute the approach properly. The improper execution of the go-around maneuver stems from a lack of familiarity with the three cardinal principles of the procedure: power, attitude, and configuration.

Power

Power is the pilot’s first concern. The instant a pilot decides to go around, takeoff power must be applied smoothly and without hesitation and held until the aircraft is in a positive climb. Applying only partial power in a go-around is never appropriate. The pilot must be aware of the degree of inertia that must be overcome before an aircraft that is settling towards the ground can regain sufficient airspeed to become fully controllable and capable of climbing or turning safely. The application of power is smooth, as well as positive. Abrupt/harsh changes of power in some aircraft may cause the aircraft to over-temp/over-torque as well as undesirable yaw.

Attitude

Attitude is always critical when close to the ground, and when power is added, a deliberate effort on the part of the pilot is required to keep the aircraft level and prevent any speed deviations through pitch changes. As the power has been added, the attitude and nacelle setting is adjusted to achieve the safe single engine speed before any effort is made to execute a turn. Allowing the nose to raise too early could result in the aircraft decelerating, which will require more power to start and maintain the climb.

A concern for quickly regaining altitude during a go-around produces a natural tendency to pull the nose up with aft center stick. If below safe single engine speed, it is desirable to lower the nose briefly to gain airspeed. This can be done through forward center stick, forward nacelle or a combination of both. As soon as the appropriate climb configuration, airspeed and attitude are attained trim the aircraft to relieve any adverse control pressures.

Configuration

After establishing the proper climb attitude, nacelle and power settings and the aircraft is in a controlled climb start to think about the landing gear (if retractable). The landing gear can be raised if required to increase the ROC, or left down for a subsequent landing. Most modern tilt-rotor aircraft will have auto scheduling flaps, so there is no action required by the pilots.

Common Errors

- Failure to recognize a condition that warrants a rejected landing
- Indecision
- Delay in initiating a go-around
- Failure to apply maximum allowable power in a timely manner
- Abrupt/harsh power application
- Uncontrolled Pitch and heading changes
- Improper pitch attitude and nacelle setting for the required airspeed
- Failure to configure the aircraft appropriately
- Manuevering too early
- Loss of aircraft control.

Crosswind Approach and Landing

Many runways or landing areas are such that landings must be made while the wind is blowing across rather than parallel to the landing direction. All pilots must be prepared to cope with these situations when they arise. The same basic principles and factors involved in a normal approach and landing apply to a crosswind approach and landing; therefore, only the additional procedures required for correcting for wind drift are discussed here.

Crosswind landings are a little more difficult to perform than crosswind takeoffs, mainly due to different problems involved in maintaining accurate control of the aircraft while its speed is decreasing rather than increasing as on takeoff. Also, the difference in lift generated by the upwind and downwind proprotors adds a rolling motion that must be overcome with into wind center stick.

There are two usual methods of accomplishing a crosswind approach and landing—the crab method and the wing-low (sideslip) method. Although the crab method may be easier for the pilot to maintain during final approach, it requires a high degree of judgment and timing in removing the crab immediately prior to touchdown. The wing-low method is recommended in most cases, although a combination of both methods may be used.

Crosswind Final Approach

The crab method is executed by establishing a heading (crab) toward the wind with the wings level so that the aircraft's ground track remains aligned with the centerline of the runway. [Figure 8-15] This crab angle is maintained until just prior to touchdown, when the longitudinal axis of the aircraft must be aligned with the runway to avoid sideward contact of the wheels with the runway. If a long final approach is being flown, one option is to use the crab method until just before the landing and then smoothly change to the wing-low method for the remainder of the landing.

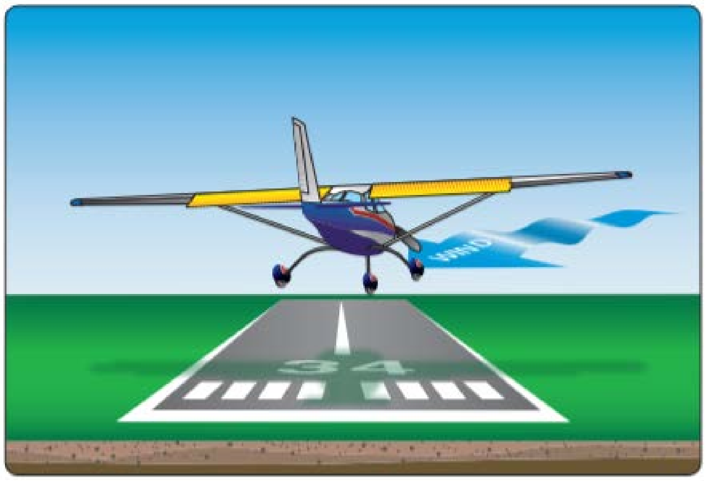


Figure 8-15. *Crabbed approach.*

Figure 8-16. *Sideslip approach.*

To correct for strong crosswind, the slip into the wind is increased by lowering the upwind wing a considerable amount. As a consequence, this results in a greater tendency of the aircraft to turn. Since turning is not desired, considerable opposite pedal must be applied to keep the aircraft's longitudinal axis aligned with the runway. In some aircraft, there may not be sufficient rudder travel available to compensate for the strong turning tendency caused by the steep bank. The maximum crosswind allowance will be listed in the AFM and should never be exceeded.

If the known wind strength is too great or the required bank is such that full opposite rudder does not prevent a turn, the wind is too strong to safely land the aircraft on that particular runway with those wind conditions. Since the aircraft's capability may be exceeded, it is imperative that the landing be made on a more favorable runway either at that airport or at an alternate airport.

Crosswind Touchdown

If the crab method is used throughout the final approach and landing the crab must be removed the instant before touchdown by applying pedal to align the aircraft's longitudinal axis with its direction of movement. This requires timely and accurate action. Failure to accomplish this, results in severe side loads being imposed on the landing gear.

If the wing-low method is used, the crosswind correction (center stick into the wind and opposite pedal) is maintained throughout the approach, and the touchdown made on the upwind main wheel. During gusty or high wind conditions, prompt adjustments must be made in the crosswind correction to assure that the aircraft does not drift as the aircraft touches down. As the forward momentum decreases after initial contact, the weight of the aircraft causes the downwind main wheel to gradually settle onto the runway.

In those aircraft having nose-wheel steering interconnected with the pedals, the nose wheel is not aligned with the runway as the wheels touch down because opposite pedal is being held in the crosswind correction. To prevent swerving in the direction the nose wheel is offset, the corrective pedal pressure must be promptly relaxed just as the nose wheel touches down.

Crosswind After-Landing Roll

Particularly during the after-landing roll, special attention must be given to maintaining directional control by the use of the pedals or nose-wheel steering, while keeping the upwind wing from rising by the use of center stick. When an aircraft is airborne, it moves with the air mass in which it is flying regardless of the aircraft's heading and speed. When an aircraft is on the ground, it is unable to move with the air mass (crosswind) because of the resistance created by ground friction on the wheels.

Characteristically, an aircraft has a greater profile or side area behind the main landing gear than forward of the gear. With the main wheels acting as a pivot point and the greater surface area exposed to the crosswind behind that pivot point, the aircraft tends to turn or weathervane into the wind.

Wind acting on an aircraft during crosswind landings is the result of two factors. One is the natural wind, which acts in the direction the air mass is traveling, while the other is induced by the forward movement of the aircraft and acts parallel to the direction of movement. Consequently, a crosswind has a headwind component acting along the aircraft's ground track and a crosswind component acting 90° to its track. The resultant or relative wind is somewhere between the two components. As the aircraft's forward speed decreases during the after landing roll, the headwind component decreases and the relative wind has more of a crosswind component. The greater the crosswind component, the more difficult it is to prevent weathervaning.

Maintaining control on the ground is a critical part of the after-landing roll because of the weathervaning effect of the wind on the aircraft. Additionally, tire side load from runway contact while drifting could generate roll-overs in tricycle-geared aircraft or damage to the undercarriage. The basic factors involved are cornering angle and side load.

Cornering angle is the angular difference between the heading of a tire and its path. Whenever a load bearing tire's path and heading diverge, a side load is created. It is accompanied by tire distortion. Although side load differs in varying tires and air pressures, it is completely independent of speed, and through a considerable range, is directly proportional to the cornering angle and the weight supported by the tire. As little as 10° of cornering angle creates a side load equal to half the supported weight; after 20°, the side load does not increase with increasing cornering angle. For each high-wing, tricycle-geared aircraft, there is a cornering angle at which roll-over is inevitable. The roll-over axis is the line linking the nose and main wheels. At lesser angles, the roll-over may be avoided by use of the center stick, pedal, or steerable nose wheel but not brakes.

While the aircraft is decelerating during the after-landing roll, more and more center stick is applied to keep the upwind wing from rising. Since the aircraft is slowing down, there is less airflow around the ailerons and they become less effective, with all the lift being generated by the proprotor. At the same time, the relative wind becomes more of a crosswind and exerting a greater lifting force on the upwind proprotor. When the aircraft is coming to a stop, the center stick control must be held fully toward the wind.

Maximum Safe Crosswind Velocities

The headwind component and the crosswind component for a given situation is determined by reference to a crosswind component chart in the AFM/QRH. [Figure 8-19] It is imperative that pilots determine the maximum crosswind component of each aircraft they fly and avoid operations in wind conditions that exceed the capability of the aircraft.

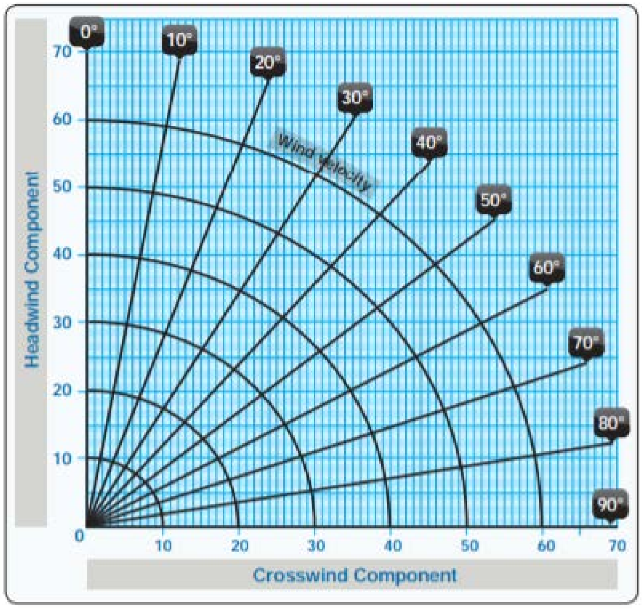


Figure 8-19. *Crosswind component chart.*

Takeoffs and landings outside the stated crosswind limits are prohibited and dangerous. If the crosswind is great enough to warrant an extreme drift correction, a hazardous landing condition may result. Therefore, the takeoff and landing capabilities with respect to the reported surface wind conditions and the available landing directions must be considered.

Common Errors

- Attempting to land in crosswinds that exceed the aircraft's maximum demonstrated crosswind component
- Inadequate compensation for wind drift on the turn from base leg to final approach, resulting in undershooting or overshooting
- Inadequate compensation for wind drift on final approach
- Unstable approach
- Touchdown while drifting
- Excessive airspeed on touchdown
- Failure to apply appropriate flight control inputs during landing
- Failure to maintain direction control on landing
- Excessive braking or braking above brake speed
- Loss of aircraft control

Wheel Barrowing

When a pilot permits the aircraft weight to become concentrated about the nose wheel during the takeoff or landing roll, a condition known as wheel barrowing occurs. Wheel barrowing may cause loss of directional control during the landing roll and the aircraft tends to swerve or pivot on the nose wheel, particularly in crosswind conditions. One of the most common causes of wheel barrowing during the landing roll is a simultaneous touchdown of the main and nose wheel, with forward pressure on the center stick control. Usually, the situation can be corrected by smoothly applying aft center stick and gradually lowering the front wheel to the ground.

Hard Landing

When the aircraft contacts the ground during landings, its vertical speed is instantly reduced to zero. Unless provisions are made to slow this vertical speed and cushion the impact of touchdown, the force of contact with the ground may be so great it could cause structural damage to the aircraft. The purpose of pneumatic tires, shock absorbing landing gear, and other devices is to cushion the impact and to increase the time in which the aircraft's vertical descent is stopped. The importance of this cushion may be understood from the computation that a 6-inch free fall on landing is roughly equal to a 340 fpm descent. Within a fraction of a second, the aircraft must be slowed from this rate of vertical descent to zero without damage.

During this time, the landing gear, together with an appropriate increase in power, must supply whatever force is needed to counteract the force of the aircraft's inertia and weight. The lift decreases rapidly as the aircraft's forward speed is decreased, translational lift is reduced, and the force on the landing gear increases by the impact of touchdown. As the power is removed, the lift is practically zero, leaving the landing gear alone to carry both the aircraft's weight and inertia force. The load imposed at the instant of touchdown may easily be three or four times the actual weight of the aircraft depending on the severity of contact.

Touchdown in a Drift or Crab

At times, it is necessary to correct for wind drift by crabbing on the final approach. If the round out and touchdown are made while the aircraft is drifting or in a crab, it contacts the ground while moving sideways. This imposes extreme side loads on the landing gear and, if severe enough, may cause structural failure.

The most effective method to prevent drift is the wing-low method. This technique keeps the longitudinal axis of the aircraft aligned with both the runway and the direction of motion throughout the approach and touchdown.

There are three factors that cause the longitudinal axis and the direction of motion to be misaligned during touchdown: drifting, crabbing, or a combination of both.

If the pilot does not take adequate corrective action to avoid drift during a crosswind landing, the main wheels' tire tread offers resistance to the aircraft's sideward movement in respect to the ground. Consequently, any sidewise velocity of the aircraft is abruptly decelerated, resulting in the aircraft being shifted to the right due to the inertia force which is shown in Figure 8-38. This creates a moment around the main wheel when it contacts the ground, tending to overturn or tip the aircraft. If the windward wingtip and proprotor is raised by the action of this moment, all the weight and shock of landing is borne by one main wheel. This could cause structural damage as well as the danger of the downwind nacelle striking the ground Not only are the same factors present that are attempting to raise a wing, but the crosswind is also acting on the fuselage surface behind the main wheels, tending to yaw (weathervane) the aircraft into the wind.

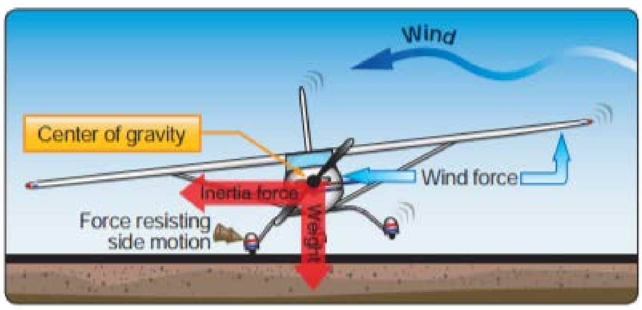


Figure 8-38. *Drifting during touchdown.*

Hydroplaning

Hydroplaning is a condition that can exist when an airplane has landed on a runway surface contaminated with standing water, slush, and/or wet snow. Hydroplaning can have serious adverse effects on ground controllability and braking efficiency. The three basic types of hydroplaning are dynamic hydroplaning, reverted rubber hydroplaning, and viscous hydroplaning. Any one of the three can render an aircraft partially or totally uncontrollable anytime during the landing roll.

Dynamic Hydroplaning

Dynamic hydroplaning is a relatively high-speed phenomenon that occurs when there is a film of water on the runway that is at least one-tenth of an inch deep. As the speed of the airplane and the depth of the water increase, the water layer builds up an increasing resistance to displacement, resulting in the formation of a wedge of water beneath the tire.

Dynamic hydroplaning is related to tire inflation pressure. Data obtained during hydroplaning tests have shown the minimum dynamic hydroplaning speed (Vp) of a tire to be 8.6 times the square root of the tire pressure in pounds per square inch (PSI). For an airplane with a main tire pressure of 24 pounds, the calculated hydroplaning speed would be approximately 42 knots. It is important to note that the calculated speed referred to above is for the start of dynamic hydroplaning. Once hydroplaning has started, it may persist to a significantly slower speed depending on the type being experienced.

Reverted Rubber

Hydroplaning Reverted rubber (steam) hydroplaning occurs during heavy braking that results in a prolonged locked-wheel skid. Only a thin film of water on the runway is required to facilitate this type of hydroplaning. The tire skidding generates enough heat to cause the rubber in contact with the runway to revert to its original uncured state. The reverted rubber acts as a seal between the tire and the runway and delays water exit from the tire footprint area. The water heats and is converted to steam, which supports the tire off the runway.

Reverted rubber hydroplaning frequently follows an encounter with dynamic hydroplaning, during which time the pilot may have the brakes locked in an attempt to slow the airplane. Eventually the airplane slows enough to where the tires make contact with the runway surface and the airplane begins to skid. The remedy for this type of hydroplane is to release the brakes and allow the wheels to spin up and apply moderate braking. Reverted rubber hydroplaning is insidious in that the pilot may not know when it begins, and it can persist to very slow ground speeds (20 knots or less).

Viscous Hydroplaning

Viscous hydroplaning is due to the viscous properties of water. A thin film of fluid no more than one thousandth of an inch in depth is all that is needed. The tire cannot penetrate the fluid and the tire rolls on top of the film. This can occur at a much lower speed than dynamic hydroplane, but requires a smooth or smooth acting surface, such as asphalt or a touchdown area coated with the accumulated rubber of past landings. Such a surface can have the same friction coefficient as wet ice.

When confronted with the possibility of hydroplaning, it is best to land on a grooved runway (if available). Touchdown speed should be as slow as possible consistent with safety. After the nose wheel is lowered to the runway, moderate braking is applied. If deceleration is not detected and hydroplaning is suspected, raise the nose and use aerodynamic drag to decelerate to a point where the brakes do become effective.

Proper braking technique is essential. The brakes should only be applied below the brake speed listed in the AFM and are applied firmly until reaching a point just short of a skid. At the first sign of a skid, release brake pressure and allow the wheels to spin up. Directional control is maintained as far as possible with the rudder. Remember that in a crosswind, if hydroplaning occurs, the crosswind causes the aircraft to simultaneously weathervane into the wind, as well as slide downwind.

Chapter Summary

Accident statistics show that a pilot is at most risk for an accident during the approach and landing than any other phase of a flight. There are many factors that contribute to accidents in this phase, but an overwhelming percentage of accidents are caused from pilot’s lack of proficiency. This chapter presents procedures that, when learned and practiced, are a key to attaining proficiency. Additional information on aerodynamics, aircraft performance, and other aspects affecting approaches and landings can be found in the Pilot’s Handbook of Aeronautical Knowledge (FAA-H-8083-25, as revised). For information concerning risk assessment as a means of preventing accidents, refer to the Risk Management Handbook (FAA-H-8083-2). Both of these publications are available at www.faa.gov/library/manuals/aviation.

Out of Ground Effect (OGE) Hover

The benefit of placing the aircraft near the ground is lost above IGE altitude. Above this altitude, the power required to hover remains nearly constant, given similar conditions (such as wind). Induced flow velocity is increased, resulting in a decrease in AOA and a decrease in lift.

A higher blade pitch angle is required to maintain the same AOA as in IGE hover. The increased pitch angle also creates more drag. This increased pitch angle and drag requires more power to hover OGE than IGE.

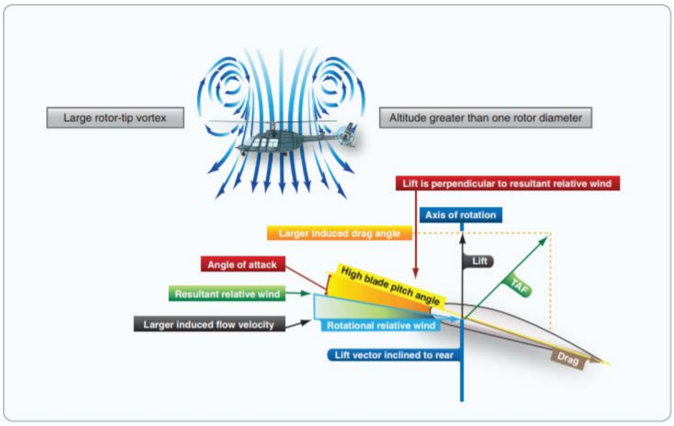


Figure 2-21. *Out of ground effect (OGE).*

Commented [WA1]: Change for tiltrotor

If aircraft performance will allow the aircraft can simply be climbed vertically to a height outside of ground effect

From any aircraft configuration in forward flight and at a height at or above 100 feet AGL, begin to decelerate the aircraft by reducing power and rotating the nacelles aft toward hover nacelle, applying aft center stick to maintain altitude.

Throughout the maneuver, monitor the Barometric altimeter, Radar Altimeter (if equipped) and vertical speed indicator (VSI). As the airspeed reduces to below 30 KIAS, anticipate the loss of translational lift and increase power as required to control the rate of descent. Expect to use about 5/10% more power than that required for an IGE hover. Anticipating the increase in power will ensure that a rate of descent (ROD) does not develop that cannot be arrested.

As airspeed further decreases, primarily monitor ground speed as the indicated airspeed (IAS) is inaccurate at low speeds. Picking external markers will make it easier to maintain a ground position and assess any sideways or backwards drift. As the ground speed reduces to 0 knots, monitor the VSI very closely.

Do not allow a ROD to exceed 500 feet per minute (FPM). If an excessive ROD develops, the aircraft is in danger of entering vortex ring state (VRS). Smoothly abort the hover, freeze or slightly decrease power, and rotate nacelles forward with a nose down attitude to increase airspeed to execute a go-around.

Note

VRS will only occur in one of the rotor systems; therefore, the high ROD will be accompanied by an uncommanded roll. This will be discussed in greater detail in Chapter XX.

The power required to OGE hover will be between 5-10% more than in an IGE hover. Required hover nacelle setting may vary depending on density altitude, wind, turbulence, etc.

To maintain the hover, trim all the flight controls by momentarily depressing the force trim release then make small, refined adjustments with the four-way trim switch to maintain the desired ground position. Establish forward and lateral visual markers to maintain ground position, cross checked by scanning the instruments regularly to assess GS, position, and vertical speed.

To fly the aircraft away once the exercise is complete, lower the nose to an accelerative attitude and rotate the nacelles forward. Simultaneously raise the power lever to maintain height and accelerate the aircraft above V_{TOSS}.

Common Errors

1. Failing to anticipate the increased power requirements (up to +10%) as the aircraft loses translational lift.
2. Slow reaction or incorrect response (such as increasing power) to any signs of a high ROD or VRS.
3. Failure to establish forward and lateral markers to maintain ground position.
4. Over controlling, especially when depressing or holding in the force trim release, generating pilot induced oscillations.

Rapid Deceleration or Quick Stop

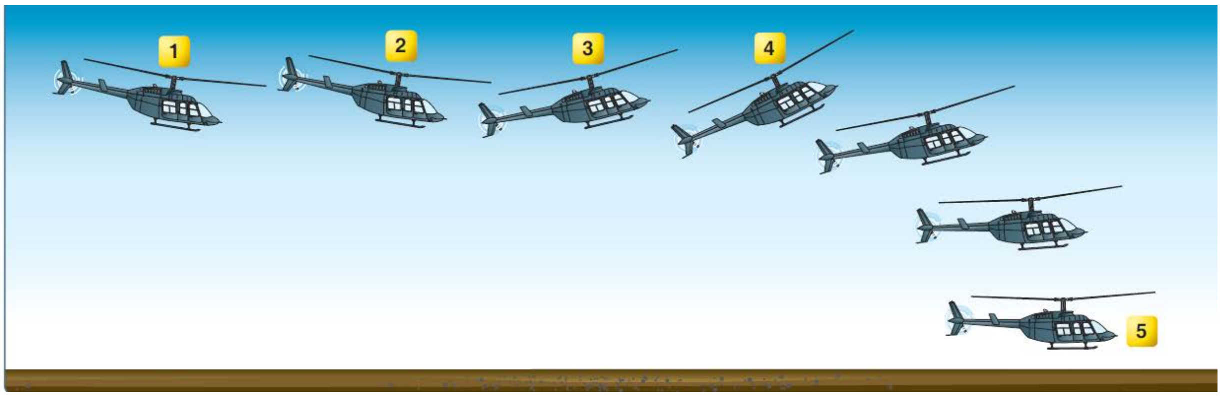
This maneuver is used to decelerate from forward flight to a hover. It is often used to abort takeoffs, to stop if something blocks the aircraft flight path, or simply to terminate a VTOL air taxi maneuver, as discussed in chapter xx. A quick stop is usually practiced on a runway, taxiway, or over a large grassy area away from other traffic or obstacles.

Technique

The maneuver requires a high degree of coordination of all controls. It is practiced at an altitude that permits a safe clearance from all obstacles throughout the maneuver, being conscious of aircraft clearances (tail and nacelle). The altitude at completion should be no higher than the maximum safe hovering altitude prescribed by that particular aircraft's manufacturer. In selecting an altitude at which to begin the maneuver, take into account the overall length of the aircraft, to avoid danger to the tail and nacelles, and staying out of the hazardous areas of the height velocity diagram throughout the maneuver. In addition, this altitude should be low enough that the aircraft can be brought to an IGE hover during the recovery.

Even though the maneuver is called a rapid deceleration or quick stop, it is performed slowly and smoothly with the primary emphasis on coordination.

During training, always perform this maneuver into the wind *[Figure 10-3, position 1]*. Level off at an altitude between 25 and 40 feet, depending upon the manufacturer's recommendations. Using an appropriate forward nacelle setting, accelerate to the desired entry speed, approximately 45 knots for most aircraft (position 2).



At position 3, initiate the deceleration by simultaneously moving nacelles full aft while applying aft center stick to reduce forward groundspeed. Avoid excessive aft center stick, as this will decrease forward visibility and shift the C of G very quickly. Simultaneously, lower the collective, as necessary, to counteract any climbing tendency. The control applications must be coordinated, if slow or too little power is taken out for the rate of aft conversion and the amount of aft center stick applied, the aircraft will climb. If too quick or too much power is removed, the aircraft will descend.

After attaining the desired speed (position 4), initiate the recovery by lowering the nose and setting the appropriate nacelle angle to achieve a level attitude. Allow the aircraft to descend to a normal hover altitude in level flight and zero groundspeed (position 5). During the recovery, increase the power, as necessary to stop the aircraft at normal hovering altitude, whilst maintaining heading with the pedals. Re-trim the aircraft to hover attitude.

Common Errors

- Initiating the maneuver by lowering the collective without aft nacelle / center stick pressure to maintain altitude.
- Initially applying aft nacelle/center stick too rapidly, causing the aircraft to balloon (climb).
- Failing to effectively control the rate of deceleration to accomplish the desired results.
- Allowing the aircraft to stop forward motion in a tail-low attitude.
- Allowing a high ROD to develop with low IAS, VRS.

- Failing to maintain a safe clearance over the terrain.
- Failing to maintain heading.
- Using an excessively nose-high attitude.

Speed Sweep Maneuver

This maneuver is used to rapidly decelerate from APLN mode forward flight to a desired CONV mode nacelle angle's minimum airspeed (V_{min}). It is often used to stop if something blocks the aircraft flight path, or simply as a training maneuver to enhance understanding of the aircraft's handling qualities, transition/conversion characteristics, and limitations. A speed sweep is usually practiced in isolated airspace, away from other traffic or obstacles at a minimum altitude of 1000' AGL.

Technique

The maneuver requires a high degree of coordination of all controls. Select a training area and altitude that permits a safe clearance from all obstacles throughout the maneuver. During training, always perform this maneuver into the wind.

Level off at an altitude at or above 1000' AGL at normal APLN mode cruise airspeed. Smoothly reduce power to near idle (approximately 20-25% power). Increase pitch as required to maintain altitude, allowing airspeed to reduce. Many tilt-rotor aircraft reduce N_R in APLN mode to allow for smoother flight and higher airspeeds. In these aircraft the pilot should set 100% N_R upon passing through the manufacturer's upper airspeed limit, as this will increase the rate of deceleration. It will also produce a climbing tendency as the NR is increased.

Begin converting the aircraft at the maximum rate, in accordance with the manufacturer's recommended conversion envelope. Recognize that raising the nacelles will cause the aircraft to want to climb. Pilots should counter this tendency by adjusting power and pitch to maintain altitude and allow further deceleration.

Continue nacelle conversion until at the desired setting, using a nose high attitude to continue decelerating. As the aircraft decelerates, hold and maintain this attitude and apply power to maintain altitude until establishing V_{min} for the current configuration.

Once stabilized and established at V_{min}, smoothly begin transitioning the nacelles forward, using slightly forward center stick and simultaneously applying power to accelerate. Ensure the rate of transition/airspeed remains within the manufacturer's recommendations, while continuously lowering the nacelles and adding power. Expect to adopt a progressively higher pitch attitude to counter the aircraft's tendency to descend.

Continue acceleration and nacelle transition until at 0º nacelle. Once on the down stops, set N_R (as required) for APLN mode cruise, and continue to accelerate to desired cruise speed.

Common Errors

- Initiating the maneuver by lowering the collective without sufficient aft nacelle / center stick pressure to maintain altitude.
- Initially applying aft nacelle/center stick too rapidly, causing the aircraft to balloon (climb).
- Failing to effectively control the rate of deceleration to accomplish the desired results.
- Allowing a high ROD to develop with low IAS, VRS.
- Allowing the aircraft to descend upon transition back to APLN mode.
- Failing to maintain a safe clearance over the terrain.
- Failing to maintain heading.
- Using excessive pitch attitudes.

Steep Approach

A steep approach is used primarily when there are obstacles in the approach path that are too high and too close to allow a normal approach to be flown. An approach angle of greater than 8° is considered a steep approach and will permit entry into most confined areas. The technique can also be used to avoid areas of turbulence around a pinnacle, remaining in the up-drafting /rising airflow.

Prior to commencing a steep approach, especially into a confined area, an appropriate high and low recce should be conducted. This will ensure the site is suitable for the aircraft, selection of approach and departure headings as well as external and internal markers to ensure aircraft clearance and landing point identification.

Caution must be exercised to avoid the parameters for VRS (20–100 percent of available power applied, airspeed of less than 10 knots, and a rate of descent greater than 300 fpm). For additional information on settling with power, refer to Chapter XX, Tiltrotor Emergencies and Hazards.

Technique

On final approach, maintain track with the intended touchdown point, using external markers and heading reference, into the wind as much as possible at the recommended approach airspeed (position 1). When intercepting an approach angle of 8° to 15°, begin the approach by decreasing power sufficiently to start a descent and decelerate using a nacelle setting slightly aft of hover nacelle (position 2). Since this angle is steeper than a normal approach angle, expect to reduce power more than that required for a normal approach. Maintaining a nacelle setting slightly aft of hover nacelle, continue to decelerate with slight aft center stick and smoothly manage power to maintain the approach angle.

During the approach the recce will continue and if the pilot determines that the area chosen is safe to land in, the approach can be continued or if unsure conduct a go-around. The intended touchdown point may not always be visible throughout the approach, therefore appropriate selection of external and internal markers will aid in positive aircraft placement. If a decision is made to complete the approach, terminate the landing to a hover in order to check the landing point carefully before lowering the aircraft to the surface. Under certain conditions, such as high AUM, it may be desirable to continue the approach to the surface

One technique to increase visibility during the steep approach is the nose low steep approach. Here the nacelles are placed fully aft at the start of the descent. The aircraft would want to stop, however forward center stick and a nose down attitude drives the aircraft forward, power lever is used to control the ROD. In this technique the aircraft nose will be lower than normal and the landing site can remain in view for longer. At a suitable height the nacelles will be reset to landing nacelle and the aircraft leveled, to continue for a normal steep approach.

Insert diagram

Constant management of approach angle and airspeed is essential to any approach. An early aft nacelle setting is required to decelerate sooner than a normal approach, and the rate of closure becomes apparent at a higher altitude. Maintain the approach angle and rate of descent with power, rate of closure with a combination of nacelle and center stick, and ground track with the pedals.

The aircraft should be trimmed just prior to loss of effective translational lift (approximately 16 knots) and the decision to land or go around should be made prior to decelerating below effective translational lift (ETL), or before descending below the barriers surrounding the confined area. Loss of effective translational lift occurs higher in a steep approach, requiring an increase in power to prevent settling, and more forward center stick to achieve the proper rate of closure.

Below 100' AGL, the pedals should be adjusted to align the aircraft with the intended touchdown point. Visualize the location of the rear of the aircraft, assisted with use of markers and fly the aircraft to 20 feet above the intended landing point. In small confined areas, the pilot must precisely position the aircraft over the intended landing area. therefore, use of internal markers is key.

Once the intended landing area is reached, smoothly establish hover nacelle setting, and terminate the approach to a hover with zero groundspeed (position 4). If the approach has been executed properly, the aircraft will come to a halt in an IGE hover approximately 20 feet over the intended landing point to avoid lateral darting.

Insert diagram here

The pilot must aware that the wind effect may be altered or lost entirely once the aircraft descends below the barriers surrounding a confined area, causing the aircraft to settle more quickly. Additional power may be needed to arrest closure and ROD under a strong wind condition.

Common Errors

- Rushing/poor recce.
- High ROD/low airspeed-VRS.
- Poor ground track during the approach.
- Slowing airspeed excessively, becoming vertical
- Failing to anticipate when effective translational lift is lost.
- Failing to arrive at hovering altitude and attitude, and zero groundspeed almost simultaneously.
- Maintaining nacelles too far aft when transitioning to the hover at the end of the approach.
- Using too much aft center stick close to the surface.
- Failure to align landing gear with direction of travel.

Slope Operations

Due to the varied operations that the aircraft may perform, it will not always be possible to land at an airport/helipad landing site, it may be necessary to land at an unprepared site. In this situation, it is imperative that a suitable reconnaissance (recce) of the area be conducted and checked for suitability, hazards and slope limitations.

Suitable “recce” techniques include using the Five S Recce model:

1. Size: Is the area big enough for all aircraft clearances?
2. Shape: What is the shape of the landing area? How can you best use this shape in relation to the wind strength and direction?
3. Surroundings: What is the area surrounded by? Will it be a hazard (i.e. hanging trees, loose articles, foreign object damage (FOD), etc.)?
4. Surface: What is the condition/type of surface that you are going to land on? Could the aircraft sink/slip/roll, etc.?
5. Slope: What is the gradient of the slope? Is it inside the aircraft limitations?

Once you have conducted a recce, an initial approach can be made and a closer inspection can be conducted prior to landing. The aircraft can be landed nose up slope, nose down slope, left/right gear up slope, or to a compound slope.

The risks associated with slope take-offs and landings include:

- Wheel or gear damage. Taking off and landing front gear first will produce aircraft damage.
- Damage can also occur if lateral drift is present during the landing. You must also ensure the area immediately below the aircraft has been checked for suitability, especially if landing off site.
- Dynamic Rollover. Be aware of dynamic rollover potential on slopes and even during operations on flat ground. Any lateral drift during touchdown can result in a dynamic rollover situation, and exasterbated when a reject is performed (i.e. if the aircraft lifted too quickly back into the hover).
- Nacelle strike/damage for lateral/cross slope landings. Powered lift aircraft with below wing mounted nacelles are especially suseptable due to reduced nacelle clearance.

Nose Up/Down Slope Landing

The technique for landing a tilt-rotor aircraft is the same for nose up or down slope.

Establish a hover above the landing area and complete the Five S Recce to assess the gradient of the slope. Maintain the IGE hover and conduct the before landing checks, ensuring the parking brake is applied.

Match the gradient of the slope with the selection of a nacelle to adopt a fuselage attitude that is parallel to the slope, maintaining ground position with the centerstick, trimming the aircraft, but avoiding overuse of the force trim release (FTR).
Once the appropriate nacelle angle is established, slowly reduce power to begin a gradual decent to the ground. Ensure the nacelles have been positioned to allow the main gear to touch first or all the wheels to touch down simultaneously, as contact is made with the ground. Maintain constant heading and do not allow any drift to develop.

After initial ground contact, ensure proper wheel contact is made, then continue to reduce power with coordinated center stick input to ensure no skid and zero GS landing.

Placeholder for diagram/figure

Nose Up/down Slope Takeoff

The technique for landing a tilt-rotor aircraft is the same for nose up or down slope.

Ensure the parking brake is applied and conduct the before takeoff checks.

Set the nacelles to the same setting as was required for the previous landing. If this is not available, use the attitude indicator (AI) to judge the slope and set the nacelles to give a fuselage attitude that is parallel to the slope for takeoff.

Look well ahead of the aircraft and select a marker to aid in maintaining heading while smoothly increasing power and simultaneously moving the center stick to achieve the proper takeoff attitude. The front gear should lift off just prior to main gear or all wheels simultaneously during takeoff to avoid any potential front undercarriage damage.

Maintain ground position and the desired heading to establish a hover sufficiently high above the takeoff surface then reset the nacelles to hover nacelle and adopt an aircraft level attitude. Retrim the aircraft and complete after-takeoff checks. Maneuver clear of the area or fly away as required. When safe to do so, release the parking brake.

Placeholder for diagram/figure

Placeholder for diagram/figure

Lateral Slope Landing

Establish a hover above the landing area and complete the Five S Recce to assess the gradient of the slope. Maintain the hover and conduct the before landing checks ensuring the parking brake is applied.

Before landing, it is essential to ensure sufficient clearance between the up slope aircraft/nacelle, the ground and surrounding objects. Assess the slope angle during the landing phase using the AI as required to ensure no limitations are exceeded. If you are aware that the slope limitation will be exceeded, reject the landing, re-establish the aircraft in the hover, and select another landing location that will not exceed any AFM limitations.

Smoothly reduce power to allow the uphill gear to come in contact with the ground. As you continue to reduce power and descend, avoid pivoting around the uphill gear. Maintain heading with a combination of pedal and into the slope center stick until the uphill gear comes in contact with the ground.

After uphill gear touches and aircraft is stable (heading, drift, decent rate), continue to reduce power and allow the front and downslope gear to contact the ground. Apply center stick pressure into the slope during the landing to avoid any skid or drift down the slope.

With no skid or drift down the slope and the aircraft within limitations, reduce power to idle while centering the other flight controls. Once centered re trim by depressing the FTR once.

Placeholder for diagram/figure

Lateral Slope Takeoff

Complete the before takeoff checks and set hover nacelle. With the force trim (FT) depressed, smoothly increase power while applying sufficient up slope center stick to maintain ground position. Maintain heading with pedals and use of an external reference point.

As the down slope gear comes clear of the ground, level the aircraft with center stick and hold the aircraft momentarily on the up slope gear, release the FT.

Continue to increase power until the aircraft comes clear of the ground and continue to slightly higher than normal hover height. Re-trim to a hover attitude.

Placeholder for diagram/figure

Throughout all the maneuvers, use external markers to maintain heading and ground position with a cross reference against the internal instruments. A systematic scan is required in a cycle. Remember “Lookout, attitude, instruments.”

Common Errors

- Staring internally at the instruments, with poor lookout.
- Overuse of the FT, especially when in close proximity to the ground.
- Rushing the maneuver. Lifting the aircraft off the ground or landing too quickly has the associated danger of nacelle contact, dynamic rollover and aircraft damage.
- Exceeding aircraft slope limitations.

Confined Area Operations

A confined area is an area where the flight of the tilt-rotor is limited in some direction by terrain or the presence of obstructions, natural or manmade. For example, a clearing in the woods, a city street, a road, a building roof, etc., can each be regarded as a confined area.

Reconnaissance Procedures

When planning to land or take off at an unfamiliar site or confined area, gather as much information as possible about the area. Reconnaissance techniques are ways of gathering this information.

High Reconnaissance

The purpose of conducting a high reconnaissance is to determine direction and speed of the wind, a touchdown point, suitability of the landing area, approach and departure axes, and obstacles for both the approach and departure. The pilot should also give particular consideration to forced landing areas in case of an emergency.

Altitude, airspeed, and flight pattern for a high reconnaissance are governed by wind and terrain features. It is important to strike a balance between a reconnaissance conducted too high and one too low. It should not be flown so low that a pilot must divide attention between studying the area and avoiding obstructions to flight. A high reconnaissance should be flown at an altitude of 300 to 500 feet above the surface. A general rule to follow is to ensure that sufficient altitude is available at all times to land or fly away into the wind in case of engine failure. In addition, a 45° angle of observation generally allows the best estimate of the height of barriers, the presence of obstacles, the size of the area, and the slope of the terrain. Always maintain safe altitudes and airspeeds, and keep a forced landing area within reach whenever possible.

During the high reconnaissance, the pilot needs to formulate a takeoff plan as well. The heights of obstacles need to be determined. It is not good practice to land in an area and then determine there is insufficient power exists to depart. Generally, more power is required to take off than to land, so the takeoff criteria is most crucial.

During the recce, select external and internal markers to ensure aircraft clearance during the approach. Fixing the approach and departure heading on the compass to ensure that the pilot is able to find the CA when aligned on the approach heading and take off over the preselected departure path when it is not visible while sitting in the confined area.

Low Reconnaissance

A low reconnaissance is accomplished during the approach to the landing area. When flying the approach, verify what was observed in the high reconnaissance, and check for anything new that may have been missed at a higher altitude, such as wires and their supporting structures (poles, towers, etc.), slopes, and small crevices. If the pilot determines that the area chosen is safe to land in, the approach can be continued. However, the decision to land or go around must be made prior to decelerating below effective translational lift (ETL), or before descending below the barriers surrounding the confined area.

If a decision is made to complete the approach, terminate the landing to a hover in order to check the landing point carefully before lowering the aircraft to the surface. Under certain conditions, it may be desirable to continue the approach to the surface. Once the aircraft is on the ground, maintain operating NR until the stability of the aircraft has been checked to be sure it is in a secure and safe position.

There are several things to consider when operating in confined areas. One of the most important is maintaining a clearance between the proprotors and obstacles forming the confined area. This not only applies while making the approach, but also while hovering. Another consideration is that wires are especially difficult to see; however, their supporting devices, such as poles or towers, serve as an indication of their presence and approximate height. If any wind is present, expect some turbulence.

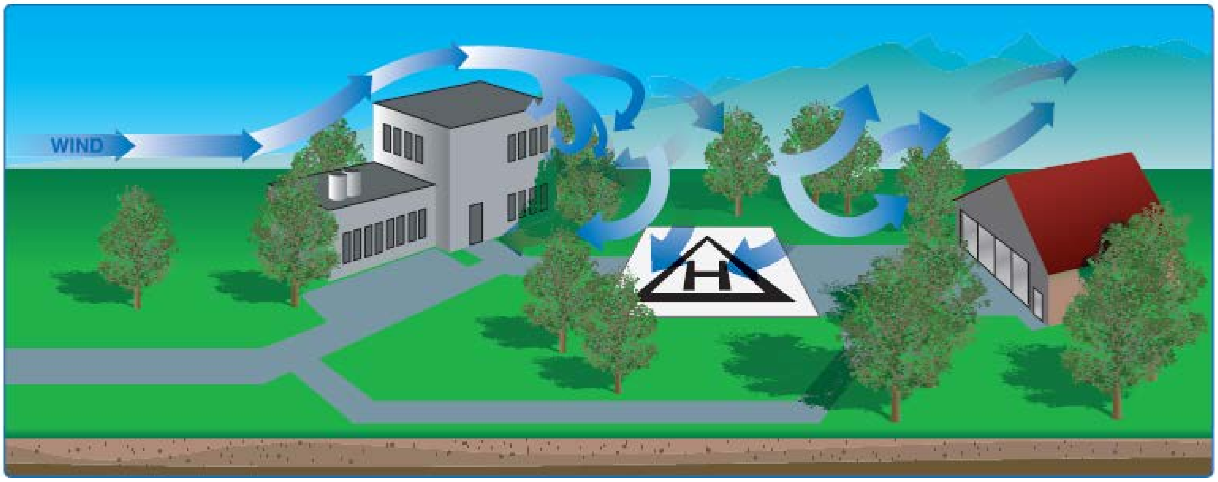


Figure XX-X.

Something else to consider is the availability of forced landing areas during the planned approach. Think about the possibility of flying from one alternate landing area to another throughout the approach, while avoiding unfavorable areas. Always leave a way out in case the landing cannot be completed or a go-around is necessary.

Approach

After completing a suitable recce start the approach phase using the wind and speed to the best possible advantage. Keep in mind areas suitable for a forced landing. It may be necessary to choose a crosswind approach that is over an open area, over one directly into the wind that is over trees. If these conditions exist, consider the possibility of making the initial phase of the approach crosswind over the open area and then turning into the wind for the final portion of the approach.

Always operate the aircraft as close to its normal capabilities as possible, taking into consideration the situation at hand. In all confined area operations, with the exception of the pinnacle operation, the angle of descent should be no steeper than necessary to clear any barrier with the rear of the aircraft in the approach path and still land on the selected spot.

The angle of climb on takeoff should be normal, or not steeper than necessary to clear any barrier. Clearing a barrier by a few feet and maintaining normal engine operating limits, with perhaps a reserve of power, is better than clearing a barrier by a wide margin but at engine limits and no power reserve.

Always make the landing to a specific point and not to some general area. This point should be located well forward, away from the approach end of the area. The more confined the area is, the more essential it is that the aircraft land precisely at a definite point. Use of the preselected markers will allow the aircraft to be aligned and clear of obstacles, even if the landing site is out of sight form the pilot. When flying the aircraft near obstacles, always consider proprotor diameter and aircraft tail clearance. After coming to a hover, initially maintain heading to ensure aircraft clearance. If required to maneuver, clear the aircraft in all directions, prior to commencing a turn or slide.

Takeoff

Some things to consider while formulating a takeoff plan are the aircraft load, height of obstacles, the shape of the area, direction of the wind, and surface conditions. Surface conditions can consist of dust, sand and snow, as well as mud and rocks. Dust landings and snow landings can lead to a brownout or whiteout condition, which is the loss of the horizon reference. Disorientation may occur, leading to ground contact, often with fatal results. Taking off or landing on uneven terrain, mud, or rocks can cause the aircraft to strike the surface or if the landing gear get caught can lead to dynamic rollover.

If the aircraft is heavily loaded, determine if there is sufficient power to clear the obstacles. Sometimes it is better to pick a path over shorter obstacles than to take off directly into the wind. Also evaluate the shape of the area so that a path can be chosen that will provide you the most room to maneuver and abort the takeoff if necessary. Positioning the aircraft to the most downwind portion of the confined area gives the pilot the most distance to clear obstacles.

Wind analysis also helps determine the route of takeoff. The prevailing wind can be altered by obstructions on the departure path and can significantly affect aircraft performance. There are several ways to check the wind direction before taking off. One technique is to watch the tops of the trees; another is to look for any smoke in the area. If there is a body of water in the area, look to see which way the water is rippling. If wind direction is still in question revert back to the last report that was received by either ATIS or airport tower.

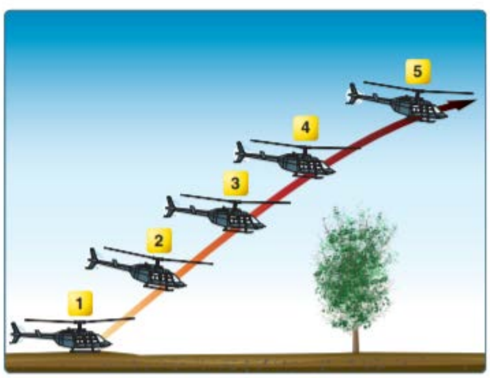
A confined area takeoff is used to climb at a steep or vertical angle to clear barriers in the flight path. It can be used when taking off from small areas surrounded by high obstacles. Allow for a vertical takeoff, if obstruction clearance could be in doubt. Before attempting a maximum performance takeoff, know thoroughly the capabilities and limitations of the equipment. Also consider the wind velocity, temperature, density altitude, gross weight, center of gravity (CG) location, and other factors affecting pilot technique and the performance of the aircraft.

To accomplish this type of takeoff safely, there must be enough power to hover OGE in order to prevent the helicopter from sinking back to the surface after becoming airborne. A hover power check can be used to determine if there is sufficient power available to accomplish this maneuver.

A confined area takeoff is considered an altitude over airspeed maneuver where altitude gain is more important than airspeed gain. Before takeoff, make a reconnaissance from the ground or cockpit to determine the type of takeoff to be performed, the point from which the takeoff should be initiated to ensure the maximum amount of available area, and finally, how to maneuver the aircraft from the landing point to the proposed takeoff position.

The aircraft can depart a confined area using two techniques:

1. Begin the takeoff by getting the helicopter light on the skids (position 1). Pause and neutralize all aircraft movement. Slowly increase the collective and position the cyclic to lift off in a 40 knot attitude. This is approximately the same attitude as when the helicopter is light on the skids. Continue to increase the collective slowly until the maximum power available is reached (takeoff power is normally 10 percent above power required for hover). This large collective movement requires a substantial increase in pedal pressure to maintain heading (position 2). Use the cyclic, as necessary, to control movement toward the desired flightpath and, therefore, climb angle during the maneuver (position 3). Maintain rotor rpm at its maximum, and do not allow it to decrease since you would probably need to lower the collective to regain it. Maintain these inputs until the helicopter clears the obstacle, or until reaching 50 feet for demonstration purposes (position 4). Then, establish a normal climb attitude and power setting (position 5). As in any maximum performance maneuver, the techniques used affect the actual results. Smooth, coordinated inputs coupled with precise control allow the helicopter to attain its maximum performance.



2. The vertical takeoff technique allows the pilot to descend vertically back into the confined area if the aircraft does not have the performance to clear the surrounding obstacles. During this maneuver, the aircraft must climb vertically and not be allowed to accelerate forward until the surrounding obstacles have been cleared. If not, a situation may develop where the aircraft does not have sufficient climb performance to

avoid obstructions and may not have power to descend back to the takeoff point. The vertical takeoff might not be as efficient as the climbing profile, but is much easier to abort from a vertical position directly over the landing point. This maneuver requires hover OGE power to accomplish.

Insert diagram here

Regardless of the technique used, after clearing the obstacle, maintain the power setting and accelerate to the normal climb speed. Then, reduce power to the normal climb power setting.

Common Errors

- Failure to perform, or improper performance of, a high or low reconnaissance.
- Approach angle that is too steep or too shallow for the existing conditions.
- Failure to consider emergency landing areas.
- Failure to select a specific landing spot.
- Failure to consider how wind and turbulence could affect the approach.
- Improper takeoff and climb technique for existing conditions.
- Failure to maintain safe clearance distance from obstructions.

Max Gross Weight (MGW) Takeoff from a Hover

The Max Gross Weight (MGW) takeoff in a tilt-rotor is employed when conditions of load and/or density altitude prevent a sustained hover at normal hovering altitude, and the takeoff location is unsuitable for a rolling takeoff. Consider reducing aircraft gross weight or wait for more favorable environmental conditions if there is insufficient power to IGE hover.

To accomplish a MGW takeoff, the intended takeoff area must be of sufficient length, and the flight path must be free of any barriers that could interfere with a shallow climb.

Technique

Refer to Figure XX-1. To begin the maneuver, first align the aircraft to the takeoff path, being conscious of wind direction. Next, increase power smoothly until the aircraft is established in a hover IGE (position 1). While in a stable hover, verify that the power required to hover is at or below the level calculated in preflight planning. Then, move the nacelles slightly forward of the hover nacelle position ($1\text{-}2^0$) to initiate forward flight (position 2).

To simulate a MGW condition during practice the evaluator may limit power available to IGE hover power +5%. Maintain a straight ground track with the center stick, and heading with the pedals.

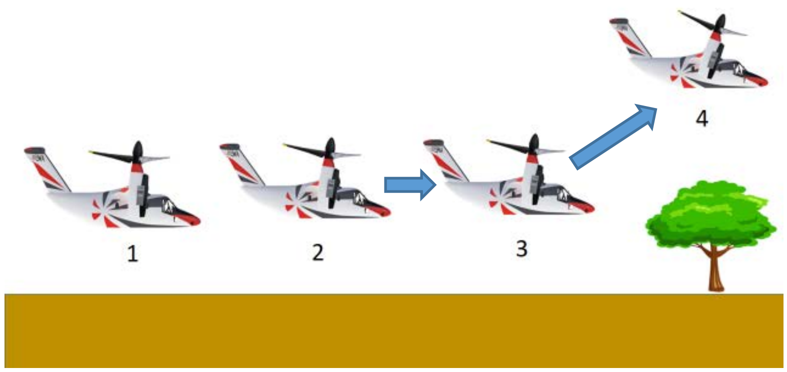


Figure XX-1. MGW Takeoff

Maintain an altitude to take advantage of ground effect, and slowly continue the transition toward CONV mode and normal climb speed once through ETL. Effective translational lift is achieved with increasing airspeed, and lift will begin to be provided by the aircraft wing rather than the proprotors (position 3).

Once at the recommended airspeed, follow a climb profile that takes the aircraft through the clear area of the height/velocity diagram (position 4).

During practice maneuvers, after having climbed to an altitude of 50 feet or at the instructor's direction, establish the normal climb power setting and attitude.

Note

It should be remembered that if a MGW takeoff is necessary, the aircraft is very close to, or has exceeded the maximum operating weight for the environmental conditions (i.e., temperature and altitude). Height/velocity parameters should be respected at all times. The aircraft should be flown to a suitable altitude to allow a safe acceleration in accordance with the height/velocity diagram.

Common Errors

- Failing to align heading and ground track with the winds to minimize power required.
- Attempting to climb OGE before obtaining effective translational lift.
- Using excessive forward center stick during the IGE acceleration.
- Lowering the nacelles too rapidly IGE, resulting in the aicraft settling back to the surface.

- Failing to remain IGE until airspeed approaches normal climb speed.

Category A Procedures

The purpose of category A procedures (CAT A) is to operate the aircraft in such a manner that, if one engine fails at any time after takeoff or during landing, the aircraft can;

- Land safely and stop in the takeoff area.
- Climb out from the point of failure and attain stabilized single engine forward flight.

In simple terms, aircraft certificated under CAT A standards can guarantee that in the event of a powerplant failure, the flight can continue safely. CAT A provides the most rigid rules, requiring independent engines, fuel systems and electrical systems. Additionally, it requires that no single failure in these areas can cause the simultaneous loss of two or more engines.

CAT A capable aircraft are certified to conduct the procedure in a manner to achieve the required performance by incorporating certain decision points and speeds.

The Takeoff Decision Point (TDP) is the first point in the Take-Off path from which a continued takeoff (CTO) capability is assured and the last point from which a rejected takeoff (RTO) is assured, within the rejected take off distance.

The TDP will be determined with the use of AFM data, and be at least 35 ft above either the:

- The take-off surface.
- A level height defined by the highest obstacle in the take-off distance required.

If obstacle height requires an increase in TDP during departure, the term TDP_E (Extended) is used. The maximum value for TDP_E will be listed in the CAT A procedures in the AFM. e.g. With a 50ft building in your departure path, the pilot must add 50ft to the TDP to ensure obstacle clearance in case of an engine failure. TDP_E= 35ft + 50ft= 85ft.

The departure procedure's Take off Path is defined as the commencement of the takeoff procedure to the point at which the aircraft reaches 1500ft. This procedure comprises three distinct segments: Lift/take off, Path 1 and Path 2.

1. The first segment covers the departure, TDP and acceleration to V_{TOSS}. The CTO is defined as the horizontal distance required from the takeoff commencement to a point at least 35ft AGL where Take Off Safety Speed (V_{TOSS}) and a positive rate of climb are attained following an engine failure at or after TDP. V_{TOSS} is the airspeed at which the required OEI climb gradient can be achieved.

2. Path 1: The end of the CTO distance to a height of 400ft AGL during a One Engine Inoperative (OEI), 2 min power climb at V_{TOSS} which achieves a minimum ROC of 100 fpm.

3. Path 2: The segment between 400ft AGL and 1500ft AGL during an OEI maximum continuous power (MCP) climb at V_Y and for a minimum ROC of 150 fpm.

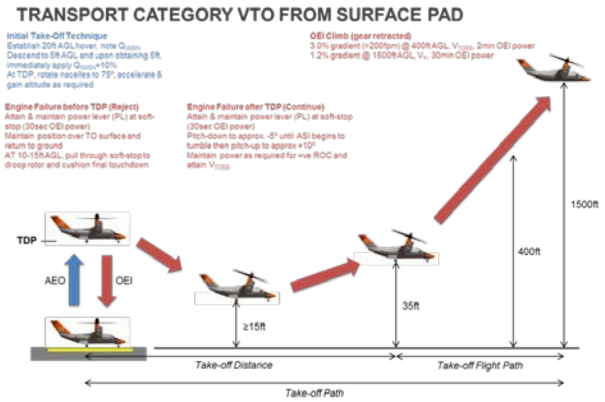
Insert diagram here

Category A procedures are constructed to allow various Take-off sites and aircraft operations i.e. Oil and Gas, VIP and EMS. Individual aircraft AFMs will detail what procedures an aircraft is certified to conduct. The AFM will also list the required power settings, speeds and heights for each maneuver. These must be checked and briefed prior to each departure.

Due to the varied applications of powered lift there may be many CAT A procedures listed in the AFM which are not covered in this document. The following techniques represent examples that will allow pilots to conduct a safe CAT A departure.

Ground Level or Elevated Heliport/Helideck Vertical Technique

In this procedure the aircraft climbs vertically from the IGE hover by smoothly and briskly increasing power to the AFM required figure, while maintaining ground position and heading. Upon passing TDP, the aircraft accelerates to forward flight by establishing either a nose down attitude, rotating the nacelles forward, or a combination of both. Continue acceleration until the aircraft reaches V_{TOSS}, then achieve and maintain V_Y. Climb at V_Y to 1500ft AGL, adjusting power as necessary to achieve the required ROC.



If the aircraft experiences an engine failure before TDP, descend vertically to the takeoff point. This is achieved by initially decreasing power to initiate a ROD to maintain N_R, which will decay if the power is not reduced. Maintain ground position with the center stick and heading with the pedals. The nacelles will already be set for the hover as they have not been moved yet. The touchdown will be cushioned by increasing power, drooping the N_R as required to ensure a safe landing. The aircraft parking brakes should remain on to prevent any roll on during landing.

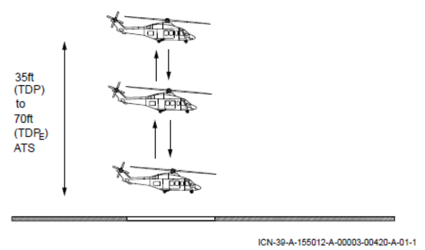


Figure 3A-1 Ground Level, Elevated Heliport/Helideck Engine Failure before TDP

If an engine failure occurs after TDP, then a CTO will be flown and the aircraft will be accelerated to V_{TOSS}, increasing the power to the aircraft's 30 second power limit. The N_R may decay, but this may be required to achieve V_{TOSS}. At V_{TOSS}, reduce power to no more than the 2 minute limit. This power reduction recovers the N_R to normal operating limits. Continue climbing once V_Y is achieved.

SINGLE ENGINE FAILURE RECOGNIZED AT OR AFTER TDP (CONTINUED TAKE-OFF)

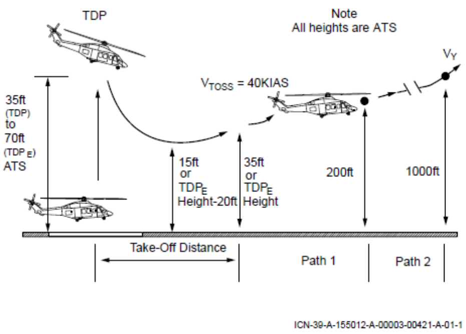
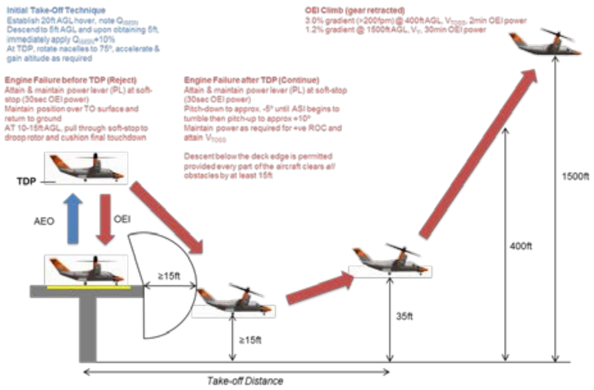


Figure 3A-2 Ground Level, Elevated Heliport/Helideck Engine Failure at/after TDP

This procedure can also be applied to an elevated helideck such as those used in the oil and gas industry. The technique is very similar, however the aircraft may descend below the helideck altitude if OEI occurs after reaching TDP which assure a 15ft deck edge clearance.



Common Errors

- Slow application of power for the vertical climb.
- Slow acceleration to V_{TOSS}.
- Staring at instrument with a poor outside scan.
- Incorrect decision before or after TDP with OEI conditions.
- Increasing the power too high above the ground during a Vertical Reject, decaying N_R.

- Failure to maintain ground position on a vertical climb or descent.
- Failure to increase the power sufficiently upon OEI conditions after TDP.

Rolling (RTO) Takeoff technique

This technique requires a prepared surface i.e. runway and may be used for high gross weight operations, IFR departures or when carrying passengers to provide a smoother takeoff. Takeoff distance varies with changing environmental conditions and aircraft gross weight. Pilots must calculate the required runway length using the appropriate performance charts in the AFM.

In addition to the takeoff distance calculations, pilots must calculate stopping distance to produce a total runway distance required.

Ensure all checks are completed and attain ATC clearance before taxing onto the runway and aligning the aircraft with the centerline. Rotate the nacelles forward to the recommended RTO setting and allow the aircraft to accelerate. Maintain runway alignment with the pedals and use the center stick to keep the wings level.

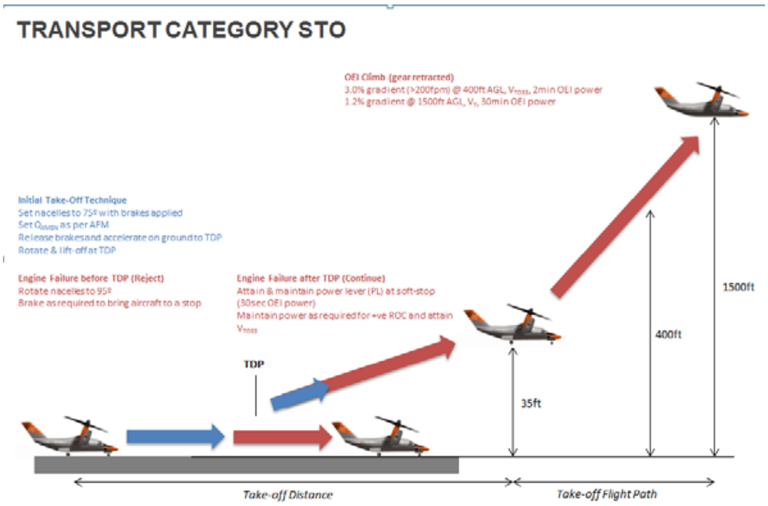
As the aircraft accelerates there will be a tendency to prematurely lift from the runway as translational lift increases and the wing becomes more effective. Apply forward center stick to prevent the aircraft from lifting off the runway as it continues to accelerate towards TDP.

In some aircraft TDP may also be the same value as V_{TOSS}. This ensures the aircraft does not lift from the ground until the safest possible moment. The aircraft will be in safe single engine flight conditions before liftoff.

Upon reaching TDP, increase power to the predetermined limit and establish a climb. There will be a tendency for the aircraft nose to drop on liftoff, which must be countered with aft center stick to maintain a level attitude. With a positive ROC established, allow the aircraft to continue acceleration to achieve and maintain V_Y until the completion of path 2 at 1500ft AGL.

If the engine fails prior to TDP, immediately reduce power to idle and rotate the nacelles fully aft to provide a rear thrust vector. At the speed listed in the AFM, apply maximum braking to bring the aircraft to a stop or suitable speed to taxi clear of the runway.

If an engine failure occurs after TDP, increase power to the 30 second limit and allow the aircraft to accelerate to V_Y. At the discretion of the pilot in command, and if sufficient runway remains, a running landing back to the surface may be conducted.



Common Errors

- Failure to maintain a proper aircraft attitude.
- Failure to maintain runway center line.
- Lifting off the surface prematurely.
- Allowing the nose to drop on lift off.
- Slow or insufficient application of power.
- Improper power setting during acceleration or climb.
- Failure to trim to the required attitude.

Category A Approach

The approach is flown with a reasonably steep vertical path and the pilot should continuously verify that speed and height over ground matches the appropriate profile as listed in the AFM.

Due to the steeper than normal approach it may be preferential to choose lateral markers abeam the landing site. These will assist in maintaining the landing site position even when it goes below the nose of the aircraft. Finding an additional marker, at the 12 o'clock position and aligned with the approach heading, will ensure the aircraft maintains a track towards the landing site.

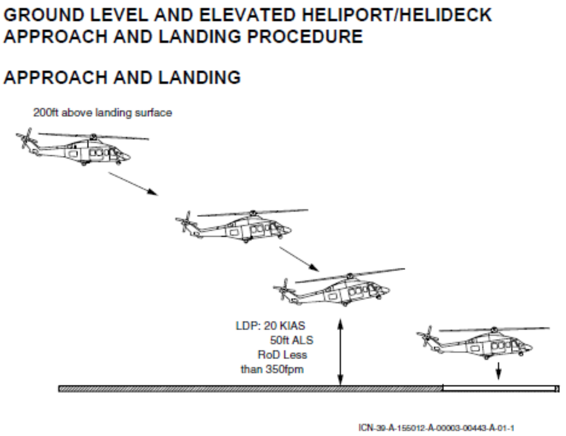


Figure 2G-1 Normal Landing Profile (Normal LDP)

Balked Landing Safety Speed (VBLSS) is the airspeed at which the scheduled climb gradient OEI can be achieved. Pilots must maintain at or above V_{BLSS} to the Landing Decision Point (LDP). The Landing Decision Point (LDP) is the last point in the approach landing path from which it is possible to land on a predetermined area or accomplish a Balked landing. LDP is generally about 50ft AGL at around 20 KIAS.

The manufacturer will provide the maximum ROD at particular speeds during the approach. These speeds account for the ROD in the event of an engine failure, and the potential danger of VRS conditions.

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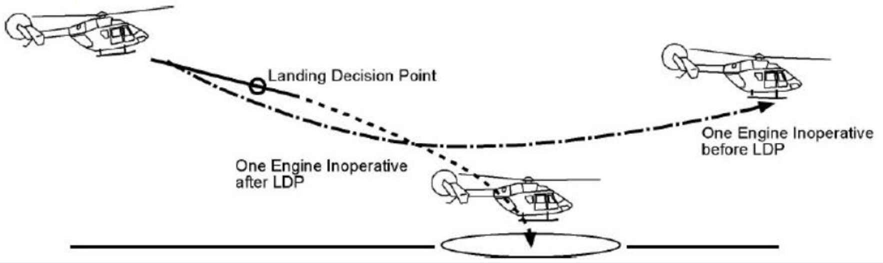
CAT-A Landing

OEI Approach Profile



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If a single engine failure occurs before the LDP, the emergency procedure is to set power to the 30 second OEI limit. This may droop the N_R in order to arrest the descent and start a climb.

Rotate the nacelles forward, lower the aircraft nose, or use a combination of both to increase forward speed to VTOSS, and then continue to accelerate to V_Y. Reduce the set power to MCP OEI limits to achieve the required ROC and recover the N_R to normal operating limits.

EMERGENCY PROCEDURES FOR ENGINE FAILURE DURING LANDING APPROACH

SINGLE ENGINE FAILURE DURING LANDING PRIOR TO LDP (BALKED LANDING)

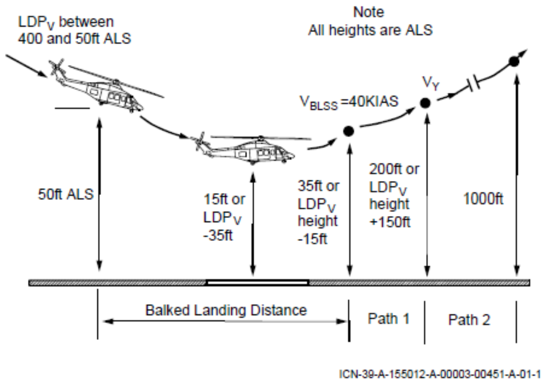

Figure 3G-1 Ground Level, Elevated Heliport/Helideck Engine Failure Prior to LDP

If an engine failure occurs after the LDP, the procedure is to initially maintain the flight profile, as the aircraft will be configured appropriately for the speed and height. Subsequently, to reduce forward speed, move the nacelles rearwards, towards the landing nacelle setting. Pilots may also be required to apply aft center stick and flare the aircraft slightly. The power can be increased to control the ROD and can use up to the 30 second limit to cushion the touchdown.

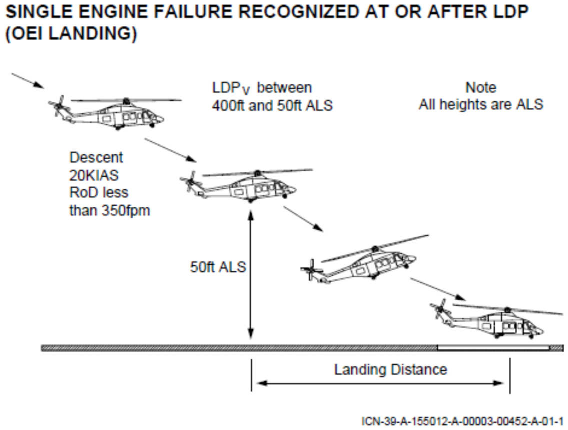

Figure 3G-2 Ground Level, Elevated Heliport/Helideck Engine Failure at/after LDP

Once the aircraft has all the landing gear on the ground remove the power, maintaining heading and ground position. Any checklist items can then be conducted and the failed engine secured.

Common Errors

- Flying the approach excessively slow or shallow.
- Yawing the aircraft to maintain view of the landing point
- Slowing the aircraft too early and landing short of intended landing point when OEI.
- Increasing power too quickly/early resulting in NR decay when OEI.
- Allowing the aircraft to yaw on touchdown when OEI.

Chapter 14

Maintaining Aircraft Control: Upset Prevention and Recovery Training

Introduction

A pilot's fundamental responsibility is to prevent a loss of control (LOC). Loss of control in-flight (LOC-I) is the leading cause of fatal general aviation accidents in the U.S. and commercial aviation worldwide. LOC-I is defined as a significant deviation of an aircraft from the intended flightpath and it often results from an aircraft upset. Maneuvering is the most common phase of flight for general aviation LOC-I accidents to occur; however, LOC-I accidents occur in all phases of flight.

To prevent LOC-I accidents, it is important for pilots to recognize and maintain a heightened awareness of situations that increase the risk of loss of control. Those situations include: uncoordinated flight, equipment malfunctions, pilot complacency, distraction, turbulence, and poor risk management – like attempting to fly in instrument meteorological conditions (IMC) when the pilot is not qualified or proficient. Sadly, there are also LOC-I accidents resulting from intentional disregard or recklessness.

To maintain aircraft control when faced with these or other contributing factors, the pilot must be aware of situations where LOC-I can occur, recognize when an aircraft is approaching a stall, has stalled, or is in an upset condition, and understand and execute the correct procedures to recover the aircraft.

Defining an Aircraft Upset

The term "upset" was formally introduced by an industry working group in 2004 in the "Pilot Guide to Airplane Upset Recovery," which is one part of the "Airplane Upset Recovery Training Aid." The working group was primarily focused on large transport aircraft and sought to come up with one term to describe an "unusual attitude" or "loss of control," for example, and to generally describe specific parameters as part of its definition. Consistent with the Guide, the FAA has defined an upset as an event that unintentionally exceeds the parameters normally experienced in flight or training. These parameters are:

- Pitch attitude greater than 25°, nose up
- Pitch attitude greater than 10°, nose down
- Bank angle greater than 45°
- Within the above parameters, but flying at airspeeds inappropriate for the conditions.

The reference to inappropriate airspeeds describes a number of undesired aircraft states, including stalls. However, stalls are directly related to angle of attack (AOA), not airspeed.

To develop the crucial skills to prevent LOC-I, a pilot must receive upset prevention and recovery training (UPRT), which should include: slow flight, stalls, spins, and unusual attitudes.

Upset training has placed more focus on prevention—understanding what can lead to an upset so a pilot does not find himself or herself in such a situation. If an upset does occur, however, upset training also reinforces proper recovery techniques. A more detailed discussion of UPRT to include its core concepts, what the training should include, and what aircraft or kinds of simulation can be used for the training can be found later in this chapter.

Coordinated Flight

Coordinated flight occurs whenever the pilot is proactively correcting for yaw effects associated with power application, flaperon inputs, how an aircraft reacts when turning, and aircraft rigging. The aircraft is in coordinated flight when the aircraft's nose is yawed directly into the relative wind and the ball is centered in the slip/skid indicator. *[Figure 14-1]*

A pilot should develop a sensitivity to side loads that indicate the nose is not yawed into the relative wind, and the aircraft

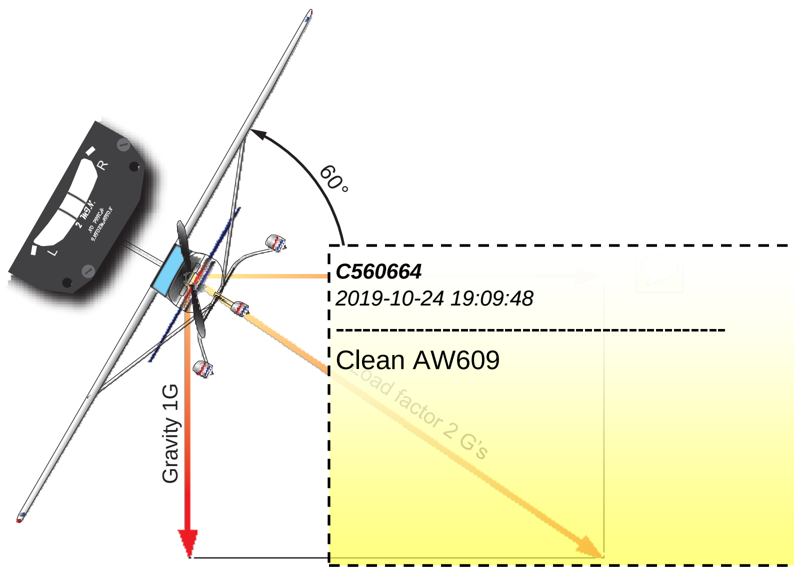

Figure 14-1. *Coordinated flight in a turn.*

is not slipping or skidding. A correction should be made by applying yaw control pressure on the side toward which one feels a leaning sensation. This will be the same side to which the ball in the slip/skid indicator has slewed (i.e., the old saying "step on the ball").

Angle of Attack

The angle of attack (AOA) is the angle at which the chord of the wing meets the relative wind. The chord is a straight line from the leading edge to the trailing edge. At low angles of attack, the airflow over the top of the wing flows smoothly and produces lift with a relatively small amount of drag. As the AOA increases, lift as well as drag increases; however, above a wing's critical AOA, the flow of air separates from the upper surface and backfills, burbles and eddies, which reduces lift and increases drag. This condition is a stall, which can lead to loss of control if the AOA is not reduced.

It is important for the pilot to understand that a stall is the result of exceeding the critical AOA, not of insufficient airspeed. The term "stalling speed" can be misleading, as this speed is often discussed when assuming 1G flight at a particular weight and configuration. Increased load factor directly affects stall speed (as well as do other factors such as gross weight, center of gravity, and flap setting). Therefore, it is possible to stall the wing at any airspeed, at any flight attitude, and at any power setting. For example, if a pilot maintains airspeed and rolls into a coordinated, level 60° banked turn, the load factor is 2Gs, and the aircraft will stall at a speed that is 40 percent higher than the straight-and-level stall speed. In that 2G level turn, the pilot has to increase AOA to increase the lift required to maintain altitude. At this condition, the pilot is closer to the critical AOA than during level flight and therefore closer to the higher speed that the aircraft will stall at. Because "stalling speed" is not a constant number, pilots must understand the underlying factors that affect it in order to maintain aircraft control in all circumstances.

Slow Flight

Slow flight is when the aircraft AOA is just under the AOA which will cause an aerodynamic buffet or a warning from a stall warning device if equipped with one. A small increase in AOA may result in an impending stall, which increases the risk of an actual stall. In most normal flight operations the aircraft would not be flown close to the stall-warning AOA or critical AOA, but because the aircraft is flown at higher AOAs, and thus reduced speeds in the takeoff/departure and approach/landing phases of flight, learning to fly at reduced airspeeds is essential. In these phases of flight, the aircraft's close proximity to the ground would make loss of control catastrophic; therefore, the pilot must be proficient in slow flight.

The objective of maneuvering in slow flight is to understand the flight characteristics and how the aircraft's flight controls feel near its aerodynamic buffet or stall-warning. It also helps to develop the pilot's recognition of how the aircraft feels, sounds, and looks when a stall is impending. These characteristics include, degraded response to control inputs and difficulty maintaining altitude. Practicing slow flight will help pilots recognize an imminent stall not only from the feel of the controls, but also from visual cues, aural indications, and instrument indications.

For pilot training and testing purposes, slow flight includes two main elements:

1. Slowing to, maneuvering at, and recovering from an airspeed at which the aircraft is still capable of maintaining controlled flight without activating the stall warning—5 to 10 knots above the 1G stall speed is a good target; and
2. Performing slow flight in configurations appropriate to takeoffs, climbs, descents, approaches to landing, and go-arounds.

Slow flight should be introduced with the airspeed sufficiently above the stall to permit safe maneuvering, but close enough to the stall warning for the pilot to experience the characteristics of flight at a very low airspeed. One way to determine the target airspeed is to slow the aircraft to the stall warning when in the desired slow flight configuration, pitch the nose down slightly to eliminate the stall warning, add power to maintain altitude and note the airspeed.

When practicing slow flight, a pilot learns to divide attention between aircraft control and other demands. How the aircraft feels at the slower airspeeds aids the pilot in learning that as airspeed decreases, control effectiveness decreases. For instance, reducing airspeed from 30 knots to 20 knots above the stalling speed will result in a certain loss of effectiveness of flight control inputs because of less airflow over the control surfaces. As airspeed is further reduced, the control effectiveness is further reduced and the reduced airflow over the control surfaces results in larger control movements being required to create the same response. Pilots sometimes refer to the feel of this reduced effectiveness as "sloppy" or "mushy" controls.

When flying above minimum drag speed (L/D_{MAX}), even a small increase in power will increase the speed of the aircraft. When flying at speeds below L/D_{MAX}, also referred to as flying on the back side of the power curve, larger inputs in power or reducing the AOA will be required for the aircraft to be able to accelerate. Since slow flight will be performed well below L/D_{MAX}, the pilot must be aware that large power inputs or a reduction in AOA will be required to prevent the aircraft from decelerating. It is important to note that when flying on the backside of the power curve, as the AOA increases toward the critical AOA and the aircraft's speed continues to decrease, small changes in the pitch control result in disproportionally large changes in induced drag and therefore changes in airspeed. As a result, pitch becomes a more effective control of airspeed when flying below L/D_{MAX} and power is an effective control of the altitude profile (i.e., climbs, descents, or level flight)

It is also important to note that an aircraft flying below L / D_{MAX}, exhibits a characteristic known as "speed instability" and the airspeed will continue to decay without appropriate pilot action. For example, if the aircraft is disturbed by turbulence and the airspeed decreases, the airspeed may continue to decrease without the appropriate pilot action of reducing the AOA or adding power. *[Figure 14-2]*

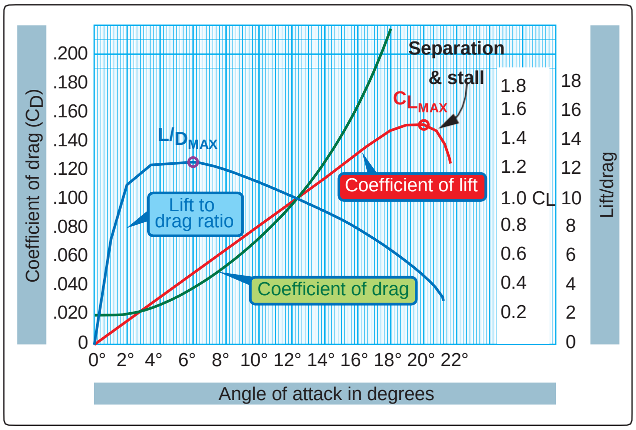

Figure 14-2. *Angle-of-attack in degrees.*

Performing the Slow Flight Maneuver

Slow flight should be practiced in straight-and-level flight, straight-ahead climbs and climbing medium-banked (approximately 20 degrees) turns, and straight-ahead power-off gliding descents and descending turns. Slow flight training should include slowing the aircraft smoothly and promptly from cruising to slow flight speeds without changes in altitude or heading, and understanding the required power and trim settings to maintain slow flight. Slow flight should be conducted so the maneuver can be completed no lower than 1,500 feet AGL, or higher, if recommended by the manufacturer. In all cases, practicing slow flight should be conducted at an adequate height above the ground for recovery should the aircraft inadvertently stall.

To begin the slow flight maneuver, clear the area and gradually reduce thrust from cruise power and adjust the pitch to allow the airspeed to decrease while maintaining altitude. As the speed of the aircraft decreases, note a change in the sound of the airflow around the aircraft. As the speed approaches the target slow flight speed, which is an airspeed just above the stall warning in the desired configuration (i.e., approximately 5–10 knots above the stall speed for that flight condition), additional power will be required to maintain altitude. During these changing flight conditions, it is important to trim the aircraft to compensate for changes in control pressures. If the aircraft remains trimmed for cruising speed (a lower AOA), strong aft (back) control pressure is needed on the elevator, which makes precise control difficult unless the aircraft is retrimmed.

In traditional aircraft, slow flight is typically performed and evaluated in the landing configuration. In tiltrotors, this is uncecessary as the likelihood of a stall while configured for landing is highly unlikely when in VTOL/CONV mode for approach and landing. Tiltrotors are much more likely to approach a stall when initiating a climb during takeoff or cruise, or during an APLN mode descent. Practicing this maneuver in other configurations, such as a with the gear down, is not recommended as slow flight speeds are often near or in excess of an aircraft's V_{LE}/V_{LO}.

With an AOA just under the AOA which may cause an aerodynamic buffet or stall warning, the flight controls are less effective. *[Figure 14-3]* The elevator control is less responsive, and larger control movements are necessary to retain control of the aircraft. In some aircraft, torque, slipstream effect, and other factors may produce a strong

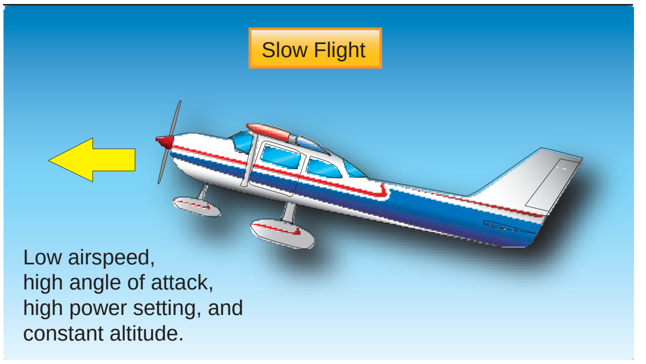

Figure 14-3. *Slow flight—low airspeed, high angle of attack, high power, and constant altitude.*

yawing tendency, which requires yaw control input to maintain coordinated flight. The closer the aircraft is to the 1G stall, the greater the amount of yaw control pressure required.

Maneuvering in Slow Flight

When the desired pitch attitude and airspeed have been established in straight-and-level slow flight, the pilot must maintain awareness of outside references and continually cross-check the aircraft's instruments to maintain control. The pilot should note the feel of the flight controls, especially the airspeed changes caused by small pitch adjustments, and the altitude changes caused by power changes. The pilot should practice turns to determine the aircraft's controllability characteristics at this low speed. During the turns, it will be necessary to increase power to maintain altitude. Abrupt or rough control movements during slow flight may result in a stall. For instance, abruptly increasing pitch while in slow flight can cause the aircraft to stall.

The pilot should also practice climbs and descents by adjusting the power when stabilized in straight-and-level slow flight.

To exit the slow flight maneuver, follow the same procedure as for recovery from a stall: apply forward control pressure to reduce the AOA, maintain coordinated flight and level the wings, and apply power as necessary to return to the desired flightpath. As airspeed increases, clean up the aircraft by retracting flaps and landing gear if they were extended. A pilot should anticipate the changes to the AOA as the landing gear and flaps are retracted to avoid a stall.

Common errors in the performance of slow flight are:

- Failure to adequately clear the area
- Inadequate back-elevator pressure as power is reduced, resulting in altitude loss

- Excessive back-elevator pressure as power is reduced, resulting in a climb followed by a rapid reduction in airspeed
- Insufficient heading control.
- Fixation on the flight instruments
- Failure to anticipate changes in AOA as flaps are extended or retracted
- Inadequate power management
- Inability to adequately divide attention between aircraft control and orientation
- Failure to properly trim the aircraft
- Failure to respond to a stall warning

Stalls

A stall is an aerodynamic condition which occurs when smooth airflow over the aircraft's wings is disrupted, resulting in loss of lift. Specifically, a stall occurs when the AOA—the angle between the chord line of the wing and the relative wind—exceeds the wing's critical AOA. It is possible to exceed the critical AOA at any airspeed, at any attitude, and at any power setting. *[Figure 14-4]*

For these reasons, it is important to understand factors and situations that can lead to a stall, and develop proficiency in stall recognition and recovery. Performing intentional stalls will familiarize the pilot with the conditions that result in a stall, assist in recognition of an impending stall, and develop the proper corrective response if a stall occurs. Stalls are practiced to two different levels:

- Impending Stall—an impending stall occurs when the AOA causes a stall warning, but has not yet reached the critical AOA. Indications of an impending stall can include buffeting, stick shaker, or aural warning.
- Full Stall—a full stall occurs when the critical AOA is exceeded. Indications of a full stall are typically that an uncommanded nose-down pitch cannot be readily arrested, and this may be accompanied by an uncommanded rolling motion. For aircraft equipped with stick pushers, its activation is also a full stall indication.

Although it depends on the degree to which a stall has progressed, some loss of altitude is expected during recovery. The longer it takes for the pilot to recognize an impending stall, the more likely it is that a full stall will result. Intentional stalls should therefore be performed at an altitude that provides adequate height above the ground for recovery and return to normal level flight.

Stall Recognition

A pilot must recognize the flight conditions that are conducive to stalls and know how to apply the necessary corrective action. This level of proficiency requires learning to recognize an impending stall by sight, sound, and feel.

Stalls are usually accompanied by a continuous stall warning for aircraft equipped with stall warning devices. These devices may include an aural alert, lights, or a stick shaker all which alert the pilot when approaching the critical AOA. Certification standards permit manufacturers to provide the required stall warning either through the inherent aerodynamic qualities of the aircraft or through a stall warning device that gives a clear indication of the impending stall.

Other sensory cues for the pilot include:

- Feel—the pilot will feel control pressures change as speed is reduced. With progressively less resistance on the control surfaces, the pilot must use larger control movements to get the desired aircraft response. The pilot will notice the aircraft's reaction time to control movement increases. Just before the stall occurs, buffeting, uncommanded rolling, or vibrations may begin to occur.

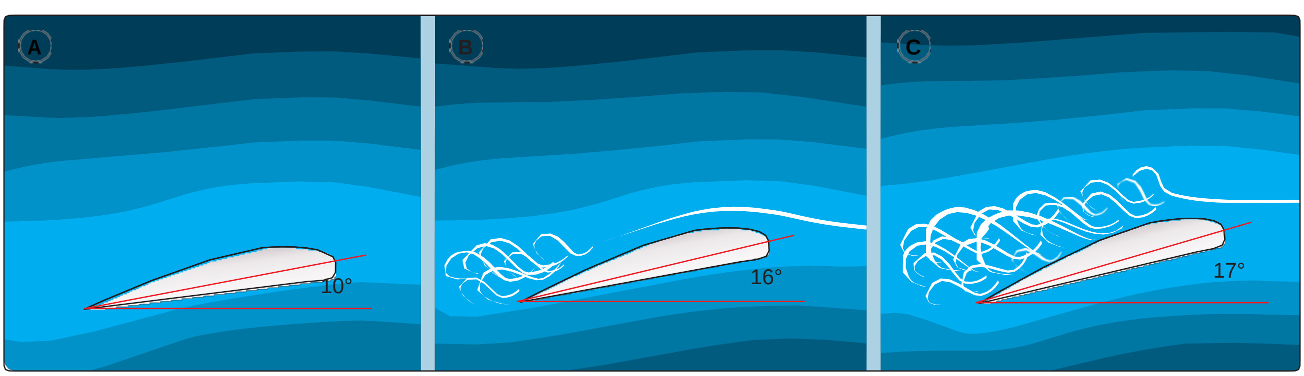

Figure 14-4. *Critical angle of attack and stall.*

- Vision—since the aircraft can be stalled in any attitude, vision is not a foolproof indicator of an impending stall. However, maintaining pitch awareness is important.
- Hearing—as speed decreases, the pilot should notice a change in sound made by the air flowing along the aircraft structure.
- Kinesthesia—the physical sensation (sometimes referred to as "seat of the pants" sensations) of changes in direction or speed is an important indicator to the trained and experienced pilot in visual flight. If this sensitivity is properly developed, it can warn the pilot of an impending stall.

Pilots in training must remember that a level-flight 1G stalling speed is valid only:

- In unaccelerated 1G flight
- In coordinated flight (slip-skid indicator centered)
- At one weight (typically maximum gross weight)
- At a particular center of gravity (CG) (typically maximum forward CG)

Angle of Attack Indicators

Learning to recognize stalls without relying on stall warning devices is important. However, aircraft can be equipped with AOA indicators that can provide a visual indication of the aircraft's proximity to the critical AOA. There are several different kinds of AOA indicators with varying methods for calculating AOA, therefore proper installation and training on the use of these devices is important. AOA indicators measure several parameters simultaneously, determine the current AOA, and provide a visual image of the proximity to the critical AOA. *[Figure 14-5]* Some AOA indicators also provide aural indications, which can provide awareness to a change in AOA that is trending towards the critical AOA prior to installed stall warning systems. It's important to note that some indicators take flap position into consideration, but not all do.

Understanding what type of AOA indicator is installed on an aircraft, how the particular device determines AOA, what the display is indicating and when the critical AOA is reached, and what the appropriate response is to those indications are all important components to AOA indicator training. It is also encouraged to conduct in-flight training to see the indications throughout various maneuvers, like slow flight, stalls, takeoffs, and landings, and to practice the appropriate responses to those indications. It is also important to note that some items may limit the effectiveness of an AOA indicator (e.g., calibration techniques, wing contamination, unheated probes/vanes). Pilots flying an aircraft equipped with an AOA indicator should refer to the pilot handbook information or contact the manufacturer for specific limitations applicable to that indicator type.

Stall Characteristics

Different aircraft designs can result in different stall characteristics. The pilot should know the stall characteristics of the aircraft being flown and the manufacturer's recommended recovery procedures. Factors that can affect the stall characteristics of an aircraft include its geometry, CG, wing design, and high-lift devices. Engineering design variations make it impossible to specifically describe the stall characteristics for all aircraft; however, there are enough similarities in aircraft to offer broad guidelines.

Most traditional aircraft are designed so that the wings stall progressively outward from the wing roots (where the wing attaches to the fuselage) to the wingtips. Some wings are

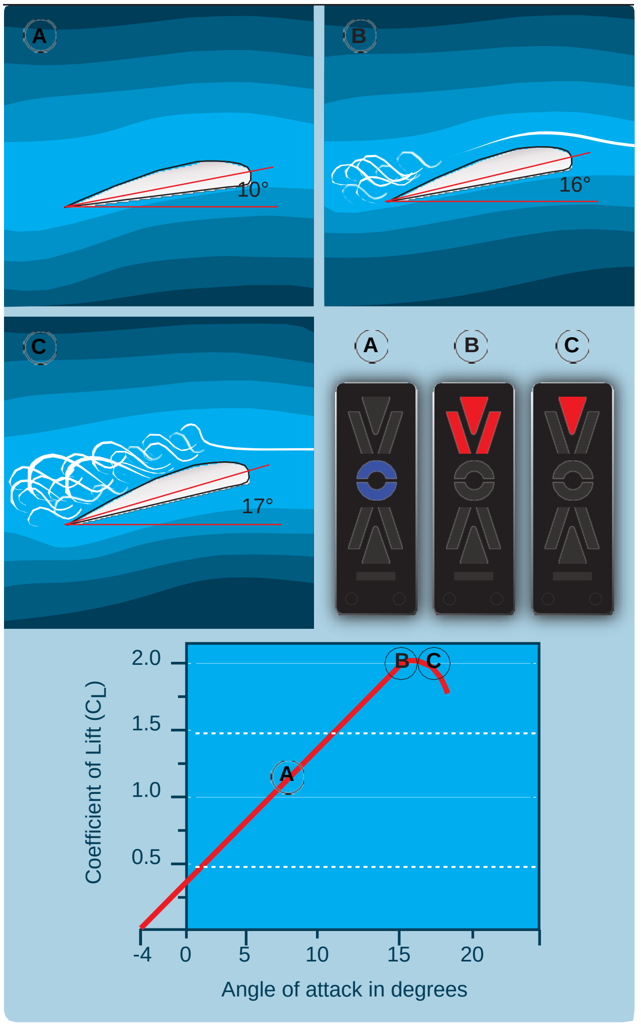

Figure 14-5. *A conceptual representation of an AOA indicator. It is important to become familiar with the equipment installed in a specific aircraft.*

manufactured with a certain amount of twist, known as washout, resulting in the outboard portion of the wings having a slightly lower AOA than the wing roots. This design feature causes the wingtips to have a smaller AOA during flight than the wing roots. Thus, the wing roots of an aircraft exceed the critical AOA before the wingtips, meaning the wing roots stall first. Therefore, when the aircraft is in a stalled condition, the flaperons should still have a degree of control effectiveness until/unless stalled airflow migrates outward along the wings. Although airflow may still be attached at the wingtips, a pilot should exercise caution using the flaperons prior to the reduction of the AOA because it can exacerbate the stalled condition. For example, if the aircraft rolls left at the stall ("rolls-off"), and the pilot applies right flaperon to try to level the wing, the downward-deflected flaperon on the left wing produces a greater AOA (and more induced drag), and a more complete stall at the tip as the critical AOA is exceeded. This can cause the wing to roll even more to the left, which is why it is important to first reduce the AOA before attempting to roll the aircraft.

The pilot must also understand how the factors that affect stalls are interrelated. In a power-off stall, for instance, the cues (buffeting, shaking) are less noticeable than in the power-on stall. In the power-off, 1G stall, the predominant cue may be the elevator control position (full up elevator against the stops) and a high descent rate.

Fundamentals of Stall Recovery

Depending on the complexity of the aircraft, stall recovery could consist of as many as six steps. Even so, the pilot should remember the most important action to an impending stall or a full stall is to reduce the AOA. There have been numerous situations where pilots did not first reduce AOA, and instead prioritized power and maintaining altitude, which resulted in a loss of control. This section provides a generic stall recovery procedure and can be adjusted appropriately for the aircraft used. *[Figure 14-6]* However, a pilot should always follow the aircraft-specific manufacturer's recommended procedures if published and current.

The recovery actions should be made in a procedural manner; they can be summarized in *Figure 14-6.* The following discussion explains each of the six steps:

1. Disconnect the wing leveler or autopilot (if equipped). Manual control is essential to recovery in all situations. Disconnecting this equipment should be done immediately and allow the pilot to move to the next crucial step quickly. Leaving the wing leveler or autopilot connected may result in inadvertent changes or adjustments to the flight controls or trim that may not be easily recognized or appropriate, especially during high workload situations.
2. a) Pitch nose-down control. Reducing the AOA is crucial for all stall recoveries. Push forward on the flight controls to reduce the AOA below the critical AOA until the impending stall indications are eliminated before proceeding to the next step.

   b) Trim nose-down pitch. If the elevator does not provide the needed response, pitch trim may be necessary. However, excessive use of pitch trim may aggravate the condition, or may result in loss of control or high structural loads.
3. Roll wings level. This orients the lift vector properly for an effective recovery. It is important not to be tempted to control the bank angle prior to reducing AOA. Both roll stability and roll control will improve considerably after getting the wings flying again. It is also imperative for the pilot to proactively cancel yaw with proper use of the yaw control to prevent a stall from progressing into a spin.
4. Add thrust/power. Power should be added as needed, as stalls can occur at high power or low power settings, or at high airspeeds or low airspeeds. Increase the

Stall Recovery Template	
1. Wing leveler or autopilot	1. Disconnect
2. a) Pitch nose-down	2. a) Apply until impending stall indications are eliminated
b) Trim nose-down pitch	b) As needed
3. Bank	3. Wings Level
4. Thrust/Power	4. As needed
5. If unable to recover:	5. Max rate conversion to VTOL/CONV mode.
6. Return to the desired flight path	

Figure 14-6. *Stall recovery template.*

power promptly, but smoothly, as needed while using yaw control and elevator controls to stop any yawing motion and prevent any undesirable pitching motion. Adding power typically reduces the loss of altitude during a stall recovery, but it does not eliminate a stall. The reduction in AOA is imperative. For propeller-driven aircraft, power application increases the airflow around the wing, assisting in stall recovery.

5. If unable to recover from the stall in a tiltrotor aircraft, begin a maxmum rate conversion to VTOL/ CONV mode.
6. Return to the desired flightpath. Apply smooth and coordinated flight control movements to return the aircraft to the desired flightpath being careful to avoid a secondary stall. The pilot should, however, be situationally aware of the proximity to terrain during the recovery and take the necessary flight control action to avoid contact with it.

The above procedure can be adapted for the type of aircraft flown. For example, an aircraft without an autopilot would likely only use four of the six steps. The first step is not needed therefore reduction of the AOA until the stall warning is eliminated is first. Use of pitch trim is less of a concern because most pilots can overpower the trim in these aircraft and any mistrim can be corrected when returning to the desired flightpath. The next step is rolling the wings level followed by the addition of power as needed all while maintaining coordinated flight. Conclude the recovery by returning to the desired flightpath.

Stall Training

Practice in both power-on and power-off stalls is important because it simulates stall conditions that could occur during normal flight maneuvers. It is important for pilots to understand the possible flight scenarios in which a stall could occur. Stall accidents usually result from an inadvertent stall at a low altitude, with the recovery not completed prior to ground contact. For example, power-on stalls are practiced to develop the pilot's awareness of what could happen if the aircraft is pitched to an excessively nose-high attitude immediately after takeoff, during a climbing turn, or when trying to clear an obstacle. Power-off turning stalls develop the pilot's awareness of what could happen if the controls are improperly used during a turn or descent. The power-off straight-ahead stall simulates the stall that could occur when trying to stretch a glide after the engines have failed.

As in all maneuvers that involve significant changes in altitude or direction, the pilot must ensure that the area is clear of other air traffic at and below their altitude and that sufficient altitude is available for a recovery before executing the maneuver. It is recommended that stalls be practiced at an altitude that allows recovery no lower than 3,000 feet AGL , or higher if recommended by the AFM/POH. Losing altitude during recovery from a stall is to be expected.

Approaches to Stalls (Impending Stalls), Power-On or Power-Off

An impending stall occurs when the aircraft is approaching, but does not exceed the critical AOA. The purpose of practicing impending stalls is to learn to retain or regain full control of the aircraft immediately upon recognizing that it is nearing a stall, or that a stall is likely to occur if the pilot does not take appropriate action. Pilot training should emphasize teaching the same recovery technique for impending stalls and full stalls.

The practice of impending stalls is of particular value in developing the pilot's sense of feel for executing maneuvers in which maximum aircraft performance is required. These maneuvers require flight in which the aircraft approaches a stall, but the pilot initiates recovery at the first indication, such as by a stall warning device activation.

Impending stalls may be entered and performed in the same attitudes and configurations as the full stalls or other maneuvers described in this chapter. However, instead of allowing the aircraft to reach the critical AOA, the pilot must immediately reduce AOA once the stall warning device goes off, if installed, or recognizes other cues such as buffeting. Hold the nose down control input as required to eliminate the stall warning. Then level the wings maintain coordinated flight, and then apply whatever additional power is necessary to return to the desired flightpath. The pilot will have recovered once the aircraft has returned to the desired flightpath with sufficient airspeed and adequate flight control effectiveness and no stall warning. Performance of the impending stall maneuver is unsatisfactory if a full stall occurs, if an excessively low pitch attitude is attained, or if the pilot fails to take timely action to avoid excessive airspeed, excessive loss of altitude, or a spin.

Full Stalls, Power-Off

The practice of power-off stalls in tiltrotors is usually performed with normal cruise conditions to simulate an accidental stall occurring during cruise or in a descent or turn. However, power-off stalls may be practiced in other configurations to ensure familiarity with handling arising from mechanical failures, icing, or other abnormal situations. Excessive airspeed should not be carried into a stall entry since it could result in an abnormally nose-high attitude.

To set up the entry for a straight-ahead power-off stall, establish the APLN mode cruise configuration. Retarding the power to idle, hold the aircraft at a constant altitude in level flight until the airspeed decelerates 5-10% above calculated stall speed.

When the approach attitude and airspeed have stabilized, the pilot should smoothly raise the aircraft's nose to an attitude that induces a stall. Directional control should be maintained and wings held level by coordinated use of the flaperons and yaw control. Once the aircraft reaches an attitude that will lead to a stall, the pitch attitude is maintained with the elevator until the stall occurs. The stall is recognized by the full-stall cues previously described.

Recovery from the stall is accomplished by reducing the AOA, applying as much nose-down control input as required to eliminate the stall warning, leveling the wings, maintaining coordinated flight, and then applying power as needed. Yaw control pressure may be necessary to maintain heading as power is advanced and the nose is lowered. *[Figure 14-7]* With increasing airspeed, establish a positive rate of climb.

Recovery from power-off stalls should also be practiced from shallow banked turns to simulate an inadvertent stall during a turn. During the practice of these stalls, take care to ensure that the aircraft remains coordinated and the turn continues at a constant bank angle until the full stall occurs. If the aircraft is allowed to develop a slip, the outer wing may stall first and move downward abruptly. The recovery procedure is the same, regardless of whether one wing rolls off first. The pilot must apply as much nose down control input as necessary to eliminate the stall warning, level the wings with flaperons, coordinate with yaw control, and add power as needed. In the practice of turning stalls, no attempt should be made to stall or recover the aircraft on a predetermined heading. However, the stall normally should be made to occur within a heading change of approximately 90°.

Full Stalls, Power-On

Power-on stall recoveries are practiced from straight climbs and climbing turns (15° to 20° bank) to help the pilot recognize the potential for an accidental stall during takeoff, go around, climb, or when trying to clear an obstacle. Power-on stalls should be practiced with the aircraft in a clean configuration. Power for practicing the takeoff stall recovery should be maximum power, although for some aircraft it may be reduced to a setting that will prevent an excessively high pitch attitude.

To set up the entry for power-on stalls, establish the aircraft in the APLN mode climb configuration. Trim the aircraft to normal climb speed while continuing to clear the area of other traffic. Upon reaching the desired speed, set takeoff power or the recommended climb power for the power-on stall (often referred to as a departure stall) while establishing a climbing attitude. Carefully monitor airspeed to avoid an excessively steep nose-up attitude for a long period before the aircraft stalls.

After establishing the climb attitude, smoothly raise the nose to increase the AOA, and hold that attitude until the full stall

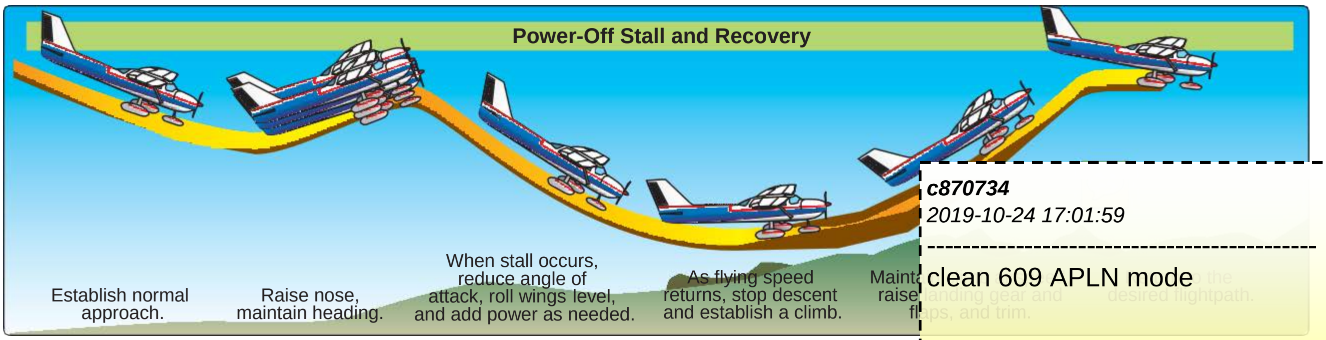

Figure 14-7. *Power-off stall and recovery.*

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clean 609 APLN mode

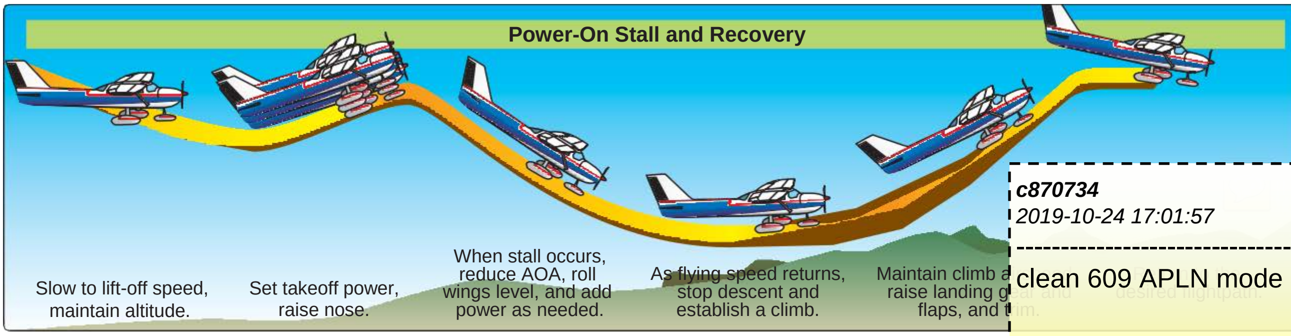

Figure 14-8. *Power-on stall.*

occurs. As described in connection with the stall characteristics discussion, continual adjustments must be made to flaperon pressure, elevator pressure, and yaw control pressure to maintain coordinated flight while holding the attitude until the full stall occurs. In most aircraft, as the airspeed decreases the pilot must move the elevator control progressively further back while simultaneously adding right yaw control and maintaining the climb attitude until reaching the full stall.

The pilot must promptly recognize when the stall has occurred and take action to prevent a prolonged stalled condition. The pilot should recover from the stall by immediately reducing the AOA and applying as much nose-down control input as required to eliminate the stall warning, level the wings with flaperons, coordinate with yaw control, and smoothly advance the power as needed. Since the power is already at the climb power setting, this step may simply mean confirming the proper power setting. *[Figure 14-8]*

The final step is to return the aircraft to the desired flightpath (e.g., straight and level or departure/climb attitude). With sufficient airspeed and control effectiveness, reset the appropriate power setting.

Secondary Stall

A secondary stall is so named because it occurs after recovery from a preceding stall. It is typically caused by abrupt control inputs or attempting to return to the desired flightpath too quickly and the critical AOA is exceeded a second time. It can also occur when the pilot does not sufficiently reduce the AOA by lowering the pitch attitude or attempts to break the stall by using power only. *[Figure 14-9]*

When a secondary stall occurs, the pilot should again perform the stall recovery procedures by applying nose-down elevator pressure as required to eliminate the stall warning, level the wings with flaperons, coordinate with yaw control, and adjust power as needed. When the aircraft is no longer in a stalled condition, the pilot can return the aircraft to the desired flightpath. For pilot certification, this is a demonstration-only maneuver; only flight instructor applicants may be required to perform it on a practical test.

Accelerated Stalls

The objectives of demonstrating an accelerated stall are to determine the stall characteristics of the aircraft, experience stalls at speeds greater than the +1G stall speed, and develop the ability to instinctively recover at the onset of such stalls. This is a maneuver only commercial pilot and flight instructor applicants may be required to perform or demonstrate on a practical test. However, all pilots should be familiar with the situations that can cause an accelerated stall, how to recognize it, and the appropriate recovery action should one occur.

At the same gross weight, aircraft configuration, CG location, power setting, and environmental conditions,

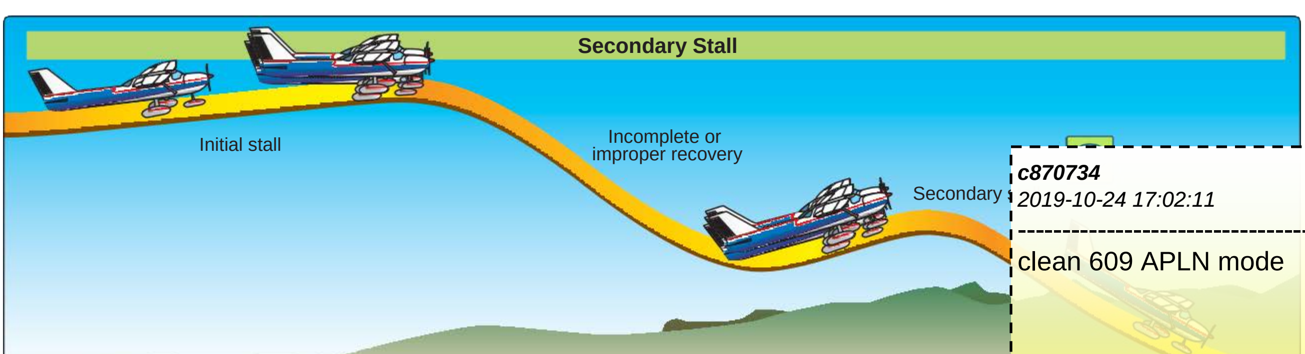

Figure 4-9. *Secondary stall.*

a given aircraft consistently stalls at the same indicated airspeed provided the aircraft is at +1G (i.e., steady-state unaccelerated flight). However, the aircraft can also stall at a higher indicated airspeed when the aircraft is subject to an acceleration greater than +1G, such as when turning, pulling up, or other abrupt changes in flightpath. Stalls encountered any time the G-load exceeds +1G are called "accelerated maneuver stalls". The accelerated stall would most frequently occur inadvertently during improperly executed turns, stall and spin recoveries, pullouts from steep dives, or when overshooting a base to final turn. An accelerated stall is typically demonstrated during steep turns.

A pilot should never practice accelerated stalls with wing flaps in the extended position due to the lower design G-load limitations in that configuration. Accelerated stalls should be performed with a bank of approximately 45°, and in no case at a speed greater than the aircraft manufacturer's recommended airspeed or the specified design maneuvering speed (V_A).

It is important to be familiar with V_A, how it relates to accelerated stalls, and how it changes depending on the aircraft's weight. V_A is the maximum speed at which the maximum positive design load limit can be imposed either by gusts or full one-sided deflection with one control surface without causing structural damage. Performing accelerated stalls at or below V_A allows the aircraft to reach the critical AOA, which unloads the wing before it reaches the load limit. At speeds above V_A, the wing can reach the design load limit at an AOA less than the critical AOA. This means it is possible to damage the aircraft before reaching the critical AOA and an accelerated stall. Knowing what V_A is for the weight of the aircraft being flown is critical to prevent exceeding the load limit of the aircraft during the maneuver.

There are two methods for performing an accelerated stall. The most common accelerated stall procedure starts from straight-and-level flight at an airspeed at or below V_A. Roll the aircraft into a coordinated, level-flight 45° turn and then smoothly, firmly, and progressively increase the AOA through back elevator pressure until a stall occurs. Alternatively, roll the aircraft into a coordinated, level-flight 45° turn at an airspeed above V_A. After the airspeed reaches V_A, or at an airspeed 5 to 10 percent faster than the unaccelerated stall speed, progressively increase the AOA through back elevator pressure until a stall occurs. The increased back elevator pressure increases the AOA, which increases the lift and thus the G load. The G load pushes the pilot's body down in the seat. The increased lift also increases drag, which may cause the airspeed to decrease. It is recommended that you know the published stall speed for 45° of bank, flaps up, before performing the maneuver. This speed is typically published in the aircraft flight manual.

An aircraft typically stalls during a level, coordinated turn similar to the way it does in wings level flight, except that the stall buffet can be sharper. If the turn is coordinated at the time of the stall, the aircraft's nose pitches away from the pilot just as it does in a wings level stall since both wings will tend to stall nearly simultaneously. If the aircraft is not properly coordinated at the time of stall, the stall behavior may include a change in bank angle until the AOA has been reduced. It is important to take recovery action at the first indication of a stall (if impending stall training/checking) or immediately after the stall has fully developed (if full stall training/checking) by applying forward elevator pressure as required to reduce the AOA and to eliminate the stall warning, level the wings using flaperons, coordinate with yaw control, and adjust power as necessary. Stalls that result from abrupt maneuvers tend to be more aggressive than unaccelerated, +1G stalls. Because they occur at higher-than-normal airspeeds or may occur at lower-than-anticipated pitch attitudes, they can surprise an inexperienced pilot. A prolonged accelerated stall should never be allowed. Failure to take immediate steps toward recovery may result in a spin or other departure from controlled flight.

Cross-Control Stall

The objective of the cross-control stall demonstration is to show the effects of uncoordinated flight on stall behavior and to emphasize the importance of maintaining coordinated flight while making turns. This is a demonstration-only maneuver; only flight instructor applicants may be required to perform it on a practical test. However, all pilots should be familiar with the situations that can lead to a cross-control stall, how to recognize it, and the appropriate recovery action should one occur.

The aerodynamic effects of the uncoordinated, cross-control stall can surprise the unwary pilot because it can occur with very little warning and can be deadly if it occurs close to the ground. The nose may pitch down, the bank angle may suddenly change, and the aircraft may continue to roll to an inverted position, which is usually the beginning of a spin. It is therefore essential for the pilot to follow the stall recovery procedure by reducing the AOA until the stall warning has been eliminated, then roll wings level using flaperons, and coordinate with yaw control inputs before the aircraft enters a spiral or spin.

A cross-control stall occurs when the critical AOA is exceeded with flaperon pressure applied in one direction and yaw control pressure in the opposite direction, causing uncoordinated flight.

Common Errors

Common errors in the performance of intentional stalls are:

- Failure to adequately clear the area
- Over-reliance on the airspeed indicator and slip-skid indicator while excluding other cues
- Inadvertent accelerated stall by pulling too fast on the controls during a power-off or power on stall entry
- Inability to recognize an impending stall condition
- Failure to take timely action to prevent a full stall during the conduct of impending stalls
- Failure to maintain a constant bank angle during turning stalls
- Failure to maintain proper coordination with the yaw control throughout the stall and recovery
- Recovering before reaching the critical AOA when practicing the full stall maneuver
- Not disconnecting the wing leveler or autopilot, if equipped, prior to reducing AOA
- Recovery is attempted without recognizing the importance of pitch control and AOA
- Not maintaining a nose down control input until the stall warning is eliminated
- Pilot attempts to level the wings before reducing AOA
- Pilot attempts to recover with power before reducing AOA
- Failure to roll wings level after AOA reduction and stall warning is eliminated
- Inadvertent secondary stall during recovery
- Excessive forward-elevator pressure during recovery resulting in low or negative G load
- Excessive airspeed buildup during recovery
- Losing situational awareness and failing to return to desired flightpath or follow ATC instructions after recovery.

Spin Awareness

A spin is an aggravated stall that typically occurs from a full stall occurring with the aircraft in a yawed state and results in the aircraft following a downward corkscrew path. As the aircraft rotates around a vertical axis, the outboard wing is less stalled than the inboard wing, which creates a rolling, yawing, and pitching motion. The aircraft is basically descending due to gravity, rolling, yawing, and pitching in a spiral path. *[Figure 14-10]* The rotation results from an unequal AOA on the aircraft's wings. The less-stalled rising wing has a decreasing AOA, where the relative lift increases and the drag decreases. Meanwhile, the descending wing has an increasing AOA, which results in decreasing relative lift and increasing drag.

A spin occurs when the aircraft's wings exceed their critical AOA (stall) with a sideslip or yaw acting on the aircraft at, or beyond, the actual stall. An aircraft will yaw not only because of incorrect yaw control application but because of adverse yaw created by flaperon deflection; engine/prop effects, including p-factor, torque, spiraling slipstream, and gyroscopic precession; and wind shear, including wake turbulence. If the yaw had been created by the pilot because of incorrect

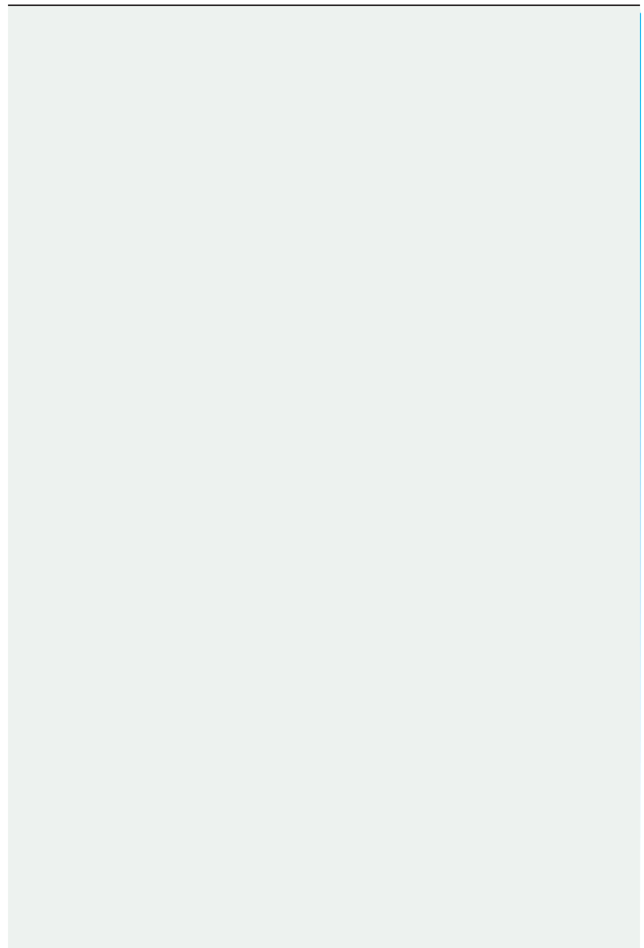

Figure 14-10. *Spin—an aggravated stall and autorotation.*

yaw control use, the pilot may not be aware that a critical AOA has been exceeded until the aircraft yaws out of control toward the lowering wing. A stall that occurs while the aircraft is in a slipping or skidding turn can result in a spin entry and rotation in the direction of yaw control application, regardless of which wingtip is raised. If the pilot does not immediately initiate stall recovery, the aircraft may enter a spin.
Maintaining directional control and not allowing the nose to yaw before stall recovery is initiated is key to averting a spin. The pilot must apply the correct amount of yaw control to keep the nose from yawing and the wings from banking.

Modern aircraft tend to be more reluctant to spin compared to older designs, however it is not impossible for them to spin. Mishandling the controls in turns, stalls, and flight at minimum controllable airspeeds can put even the most reluctant aircraft into an accidental spin. Proficiency in avoiding conditions that could lead to an accidental stall/spin situation, and in promptly taking the correct actions to recover to normal flight, is essential. An aircraft must be stalled and yawed in order to enter a spin; therefore, continued practice in stall recognition and recovery helps the pilot develop a more instinctive and prompt reaction in recognizing an approaching spin. Upon recognition of a spin or approaching spin, the pilot should immediately execute spin recovery procedures.

Spin Procedures

The first rule for spin demonstration is to ensure that the aircraft is approved for spins. Please note that this discussion addresses generic spin procedures; it does not cover special spin procedures or techniques required for a particular aircraft. Safety dictates careful review of the aircraft flight manual and regulations before attempting spins in any aircraft. The review should include the following items:

- The aircraft's limitations section, placards, or type certification data to determine if the aircraft is approved for spins
- Weight and balance limitations
- Recommended entry and recovery procedures
- The current 14 CFR Part 91 parachute requirements

Also essential is a thorough aircraft preflight inspection, with special emphasis on excess or loose items that may affect the weight, center of gravity, and controllability of the aircraft. It is also important to ensure that the aircraft is within any CG limitations as determined by the manufacturer.

Prior to beginning spin training, clear the flight area above and below the aircraft for other traffic. This task may be accomplished while slowing the aircraft for the spin entry. In addition, all spin training should be initiated at an altitude high enough to complete recovery at or above 1,500 feet AGL.

It may be appropriate to introduce spin training by first practicing both power-on and power-off stalls in a clean configuration. This practice helps familiarize the pilot with the aircraft's specific stall and recovery characteristics. In all phases of training, the pilot should take care with handling of the power according to the manufacturer's recommendations.

There are four phases of a spin: entry, incipient, developed, and recovery. *[Figure 14-12]*

Entry Phase

In the entry phase, the pilot intentionally or accidentally provides the necessary elements for the spin. The entry procedure for demonstrating a spin is similar to a power-off stall. During the entry, the pilot should slowly reduce power to idle, while simultaneously raising the nose to a pitch attitude that ensures a stall. As the aircraft approaches a stall, smoothly apply full yaw control in the direction of the desired spin rotation while applying full back (up) elevator to the limit of travel. Always maintain the flaperons in the neutral position during the spin procedure unless the manufacturer's procedures specify otherwise.

Incipient Phase

The incipient phase occurs from the time the aircraft stalls and starts rotating until the spin has fully developed. This phase may take two to four turns for most aircraft. In this phase, the aerodynamic and inertial forces have not achieved a balance. As the incipient phase develops, the indicated airspeed will generally stabilize at a low and constant airspeed and the symbolic aircraft of the turn indicator should indicate the direction of the spin. The slip/skid ball is unreliable when spinning.

The pilot should initiate incipient spin recovery procedures prior to completing 360° of rotation. The pilot should apply full yaw control opposite the direction of rotation. The turn indicator shows a deflection in the direction of rotation if disoriented.

Incipient spins that are not allowed to develop into a steady-state spin are the most commonly used maneuver in initial spin training and recovery techniques.

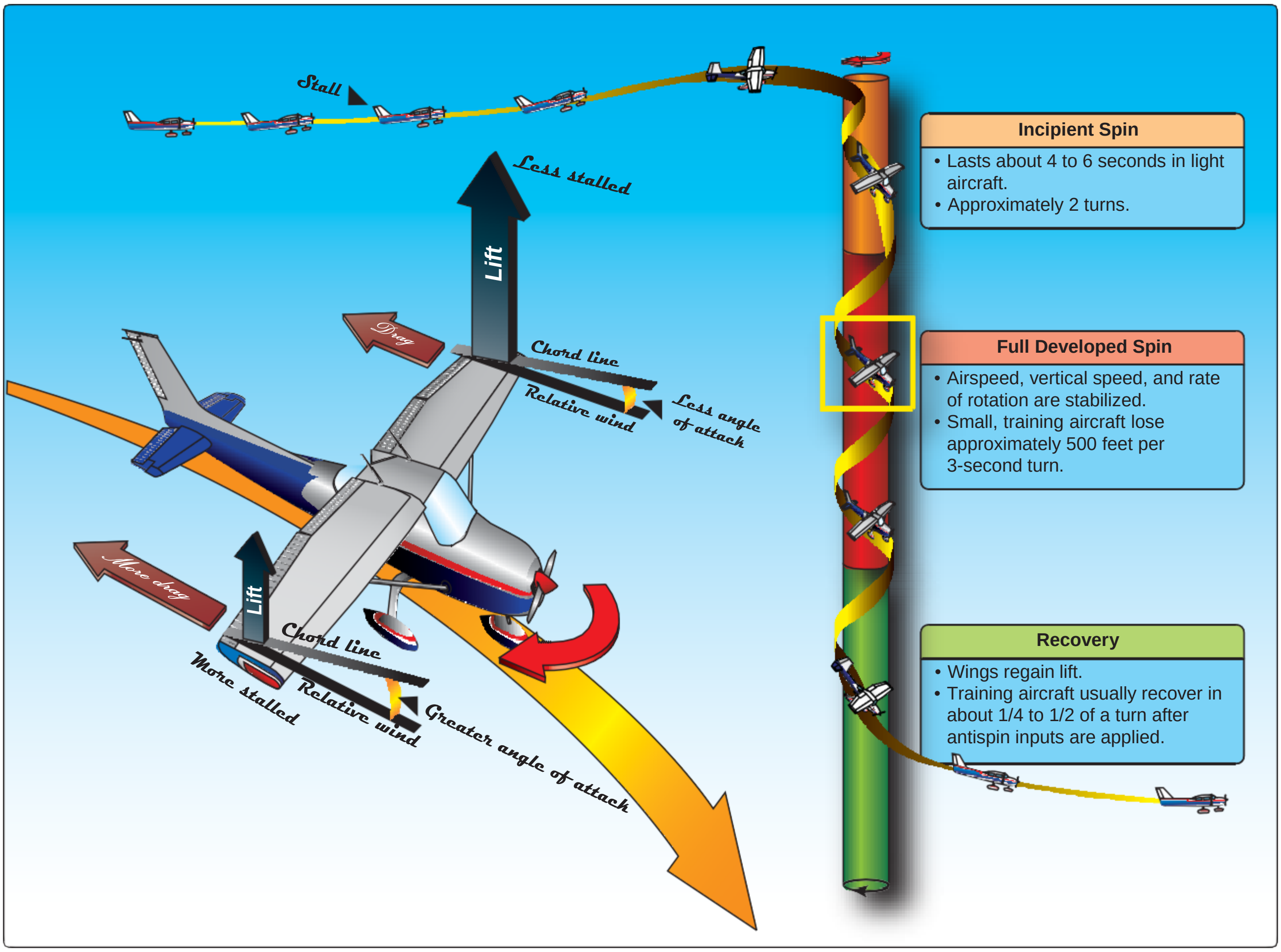

Figure 14-11. *Spin entry and recovery.*

Developed Phase

The developed phase occurs when the aircraft's angular rotation rate, airspeed, and vertical speed are stabilized in a flightpath that is nearly vertical. In the developed phase, aerodynamic forces and inertial forces are in balance, and the aircraft's attitude, angles, and self-sustaining motions about the vertical axis are constant or repetitive, or nearly so. The spin is in equilibrium. It is important to note that some training aircraft will not enter into the developed phase but could transition unexpectedly from the incipient phase into a spiral dive. In a spiral dive the aircraft will not be in equilibrium but instead will be accelerating and G load can rapidly increase as a result.

Recovery Phase

The recovery phase occurs when rotation ceases and the AOA of the wings is decreased below the critical AOA. This phase may last for as little as a quarter turn or up to several turns depending upon the aircraft and the type of spin.

To recover, the pilot applies control inputs to disrupt the spin equilibrium by stopping the rotation and unstalling the wing. To accomplish spin recovery, always follow the manufacturer's recommended procedures. In the absence of the manufacturer's recommended spin recovery procedures and techniques, use the spin recovery procedures in *Figure 14-12*. If the flaps and/or retractable landing gear are extended prior to the spin, they should be retracted as soon as practicable after spin entry.

1. Reduce the Power to Idle
2. Position the flaperons to Neutral
3. Apply Full Opposite yaw control against the Rotation
4. Apply Positive, Brisk, and Straight Forward Elevator (Forward of Neutral)
5. Neutralize the yaw control After Spin Rotation Stops
6. Apply Back Elevator Pressure to Return to Level Flight

Spin Recovery Template
1. Reduce the power (throttle) to idle
2. Position the flaperons to neutral
3. Apply full opposite yaw control against the rotation
4. Apply positive, brisk, and straight forward elevator (forward of neutral)
5. Neutralize the yaw control after spin rotation stops
6. Apply back elevator pressure to return to level flight

Figure 14-12. *Spin recovery template.*

The following discussion explains each of the six steps:

1. Reduce the Power to Idle. Power aggravates spin characteristics. It can result in a flatter spin attitude and usually increases the rate of rotation.
2. Position the flaperons to Neutral. flaperons may have an adverse effect on spin recovery. Flaperon control in the direction of the spin may accelerate the rate of rotation, steepen the spin attitude and delay the recovery. Flaperon control opposite the direction of the spin may cause flattening of the spin attitude and delayed recovery; or may even be responsible for causing an unrecoverable spin. The best procedure is to ensure that the flaperons are neutral.
3. Apply Full Opposite yaw control against the Rotation. Apply and hold full opposite yaw control until rotation stops. yaw control tends to be the most important control for recovery in typical, single-engine aircraft, and its application should be brisk and full opposite to the direction of rotation. Avoid slow and overly cautious opposite yaw control movement during spin recovery, which can allow the aircraft to spin indefinitely, even with anti-spin inputs. A brisk and positive technique results in a more positive spin recovery.
4. Apply Positive, Brisk, and Straight Forward Elevator (Forward of Neutral). This step should be taken immediately after full yaw control application. Do not wait for the rotation to stop before performing this step. The forceful movement of the elevator decreases the AOA and drives the aircraft toward unstalled flight. In some cases, full forward elevator may be required for recovery. Hold the controls firmly in these positions until the spinning stops. (Note: If the airspeed is increasing, the aircraft is no longer in a spin. In a spin, the aircraft is stalled, and the indicated airspeed should therefore be relatively low and constant and not be accelerating.)
5. Neutralize the yaw control After Spin Rotation Stops. Failure to neutralize the yaw control at this time, when airspeed is increasing, causes a yawing or sideslipping effect.
6. Apply Back Elevator Pressure to Return to Level Flight. Be careful not to apply excessive back elevator pressure after the rotation stops and the yaw control has been neutralized. Excessive back elevator pressure can cause a secondary stall and may result in another spin. The pilot must also avoid exceeding the G-load limits and airspeed limitations during the pull out.

Again, it is important to remember that the spin recovery procedures and techniques described above are recommended for use only in the absence of the manufacturer's procedures. The pilot must always be familiar with the manufacturer's procedures for spin recovery.

Intentional Spins

If the manufacturer does not specifically approve an aircraft for spins, intentional spins are not authorized by the CFRs or by this handbook. The official sources for determining whether the spin maneuver is approved are:

- Type Certificate Data Sheets or the Aircraft Specifications
- The limitation section of the FAA-approved AFM/POH. The limitation section may provide additional specific requirements for spin authorization, such as limiting gross weight, CG range, and amount of fuel.
- On a placard located in clear view of the pilot in the aircraft (e.g., "NO ACROBATIC MANEUVERS INCLUDING SPINS APPROVED"). In aircraft placarded against spins, there is no assurance that recovery from a fully developed spin is possible.

Unfortunately, accident records show occurrences in which pilots intentionally ignored spin restrictions. Despite the installation of placards prohibiting intentional spins in these aircraft, some pilots and even some flight instructors attempt to justify the maneuver, rationalizing that the spin restriction results from a "technicality" in the airworthiness standards. They believe that if the aircraft was spin tested during its certification process, no problem should result from demonstrating or practicing spins.

Such pilots overlook the fact that certification of a normal category aircraft only requires the aircraft to recover from a one-turn spin in not more than one additional turn or three seconds, whichever takes longer. In other words, the aircraft may never be in a fully developed spin. Therefore, in aircraft placarded against spins, there is absolutely no assurance that recovery from a fully developed spin is possible under any circumstances. The pilot of an aircraft placarded against intentional spins should assume that the aircraft could become uncontrollable in a spin.

Weight and Balance Requirements Related to Spins

In aircraft that are approved for spins, compliance with weight and balance requirements is important for safe performance and recovery from the spin maneuver. Pilots must be aware that even minor weight or balance changes can affect the aircraft's spin recovery characteristics. Such changes can either degrade or enhance the spin maneuver and/or recovery characteristics. For example, the addition of weight in the aft baggage compartment, or additional fuel, may still permit the aircraft to be operated within CG, but could seriously affect the spin and recovery characteristics. An aircraft that may be difficult to spin intentionally in the utility category (restricted aft CG and reduced weight) could have less resistance to spin entry in the normal category (less restricted aft CG and increased weight). This situation arises from the aircraft's ability to generate a higher AOA. An aircraft that is approved for spins in the utility category but loaded in accordance with the normal category may not recover from a spin that is allowed to progress beyond one turn.

Common Errors

Common errors in the performance of intentional spins are:

- Failure to apply full yaw control pressure (to the stops) in the desired spin direction during spin entry
- Failure to apply and maintain full up-elevator pressure during spin entry, resulting in a spiral
- Failure to achieve a fully-stalled condition prior to spin entry
- Failure to apply full yaw control (to the stops) briskly against the spin during recovery
- Failure to apply sufficient forward-elevator during recovery
- Waiting for rotation to stop before applying forward elevator
- Failure to neutralize the yaw control after rotation stops, possibly resulting in a secondary spin
- Slow and overly cautious control movements during recovery
- Excessive back elevator pressure after rotation stops, possibly resulting in secondary stall
- Insufficient back elevator pressure during recovery resulting in excessive airspeed

Upset Prevention and Recovery

Unusual Attitudes Versus Upsets

An unusual attitude is commonly referenced as an unintended or unexpected attitude in instrument flight. These unusual attitudes are introduced to a pilot during student pilot training as part of basic attitude instrument flying and continue to be trained and tested as part of certification for an instrument rating, aircraft type rating, and an airline transport pilot certificate. A pilot is taught the conditions or situations that could cause an unusual attitude, with focus on how to recognize one, and how to recover from one.

As discussed at the beginning of this chapter, the term "upset" is inclusive of unusual attitudes. An upset is defined as an event that unintentionally exceeds the parameters normally experienced in flight or training. These parameters are:

- Pitch attitude greater than 25°, nose up
- Pitch attitude greater than 10°, nose down
- Bank angle greater than 45°
- Within the above parameters, but flying at airspeeds inappropriate for the conditions.

(Note: The reference to inappropriate airspeeds describes a number of undesired aircraft states, including stalls. However, stalls are directly related to AOA, not airspeed.)

Given the upset definition, there are a few key distinctions between an unusual attitude and an upset. First, an upset includes stall events where unusual attitude training typically does not. Second, an upset can include overspeeds or other inappropriate speeds for a given flight condition, which is also not considered part of unusual attitude training. Finally, an upset has defined parameters; an unusual attitude does not. For example, for training purposes an instructor could place the aircraft in a 30° bank with a nose up pitch attitude of 15° and ask the student to recover and that would be considered an unusual attitude, but would not meet the upset parameters. While the information that follows in this section could apply to unusual attitudes, the focus will be on UPRT.

The top four causal and contributing factors that have led to an upset and resulted in LOC-I accidents are:

1. Environmental factors
2. Mechanical factors
3. Human factors
4. Stall-related factors

With the exception of stall-related factors, which were covered in the previous section, the remaining causal and contributing factors to LOC-I accidents will be discussed further below.

Environmental Factors

Turbulence, or a large variation in wind velocity over a short distance, can cause upset and LOC-I. Maintain awareness of conditions that can lead to various types of turbulence, such as clear air turbulence, mountain waves, wind shear, and thunderstorms or microbursts. In addition to environmentally-induced turbulence, wake turbulence from other aircraft can lead to upset and LOC-I.

Icing can destroy the smooth flow of air over the airfoil and increase drag while decreasing the ability of the airfoil to create lift. Therefore, it can significantly degrade aircraft performance, resulting in a stall if not handled correctly.

Mechanical Factors

Modern aircraft and equipment are very reliable, but anomalies do occur. Some of these mechanical failures can directly cause a departure from normal flight, such as malfunctioning or binding flight controls, and runaway trim.

Upsets can also occur if there is a malfunction or misuse of the autoflight system. Advanced automation may tend to mask the cause of the anomaly. Disengaging the autopilot allows the pilot to directly control the aircraft and possibly eliminate the cause of the problem. For these reasons the pilot must maintain proficiency to manually fly the aircraft in all flight conditions without the use of the autopilot.

Although these and other inflight anomalies may not be preventable, knowledge of systems and the manufacturer's recommended procedures helps the pilot minimize their impact and prevent an upset. In the case of instrument failures, avoiding an upset and subsequent LOC-I may depend on the pilot’s proficiency in the use of secondary instrumentation and partial panel operations.

Human Factors

VMC to IMC

Unfortunately, accident reports indicate that continued VFR flight from visual meteorological conditions (VMC) into marginal VMC and IMC is a factor contributing to LOC I. A loss of the natural horizon substantially increases the chances of encountering vertigo or spatial disorientation, which can lead to upset.

IMC

When operating in IMC, maintain awareness of conditions and use the fundamental instrument skills—cross-check, interpretation, and control—to prevent an upset.

Diversion of Attention

In addition to its direct impact, an inflight anomaly or malfunction can also lead to an upset if it diverts the pilot’s attention from basic aircraft control responsibilities. Failing to monitor the automated systems, over-reliance on those systems, or incomplete knowledge and experience with those systems can lead to an upset. Diversion of attention can also occur simply from the pilot’s efforts to set avionics or navigation equipment while flying the aircraft.

Task Saturation

The margin of safety is the difference between task requirements and pilot capabilities. An upset and eventual LOC-I can occur whenever requirements exceed capabilities. For example, an aircraft upset event that requires rolling an aircraft from a near-inverted to an upright attitude may demand piloting skills beyond those learned during primary training. In another example, a fatigued pilot who inadvertently encounters IMC at night coupled with an avionics failure, or a pilot fails to engage pitot heat while flying in IMC, could become disoriented and lose control of the aircraft due to the demands of extended—and unpracticed—partial panel flight. Additionally, unnecessary low-altitude flying and impromptu demonstrations for friends or others on the ground often lead pilots to exceed their capabilities, with fatal results.

Sensory Overload/Deprivation

A pilot’s ability to adequately correlate warnings, annunciations, instrument indications, and other cues from the aircraft during an upset can be limited. Pilots faced with upset situations can be rapidly confronted with multiple or simultaneous visual, auditory, and tactile warnings. Conversely, sometimes expected warnings are not provided when they should be; this situation can distract a pilot as much as multiple warnings can.

The ability to separate time-critical information from distractions takes practice, experience and knowledge of the aircraft and its systems. Cross-checks are necessary not only to corroborate other information that has been presented, but also to determine if information might be missing or invalid. For example, a stall warning system may fail and therefore not warn a pilot of close proximity to a stall, other cues must be used to avert a stall and possible LOC-I. These cues include aerodynamic buffet, loss of roll authority, or inability to arrest a descent.

Spatial Disorientation

Spatial disorientation has been a significant factor in many aircraft upset accidents. Accident data from 2008 to 2013 shows nearly 200 accidents associated with spatial disorientation with more than 70% of those being fatal. All pilots are susceptible to false sensory illusions while flying at night or in certain weather conditions. These illusions can lead to a conflict between actual attitude indications and what the pilot senses is the correct attitude. Disoriented pilots may not always be aware of their orientation error. Many aircraft upsets occur while the pilot is engaged in some task that takes attention away from the flight instruments or outside references. Others perceive a conflict between bodily senses and the flight instruments, and allow the aircraft to divert from the desired flightpath because they cannot resolve the conflict.

A pilot may experience spatial disorientation or perceive the situation in one of three ways:

1. Recognized spatial disorientation: the pilot recognizes the developing upset or the upset condition and is able to safely correct the situation.
2. Unrecognized spatial disorientation: the pilot is unaware that an upset event is developing, or has occurred, and fails to make essential decisions or take any corrective action to prevent LOC-I.
3. Incapacitating spatial disorientation: the pilot is unable to affect a recovery due to some combination of: (a) not understanding the events as they are unfolding, (b) lacking the skills required to alleviate or correct the situation, or (c) exceeding psychological or physiological ability to cope with what is happening.

For detailed information regarding causal factors of spatial disorientation, refer to Aerospace Medicine Spatial Disorientation and Aerospace Medicine Reference Collection, which provides spatial disorientation videos. This collection can be found online at: www.faa.gov/about/office_org/ headquarters_offices/avs/offices/aam/cami/library/online_libraries/aerospace_medicine/sd/videos/.

Startle Response

Startle is an uncontrollable, automatic muscle reflex, raised heart rate, blood pressure, etc., elicited by exposure to a sudden, intense event that violates a pilot's expectations.

Surprise Response

Surprise is an unexpected event that violates a pilot's expectations and can affect the mental processes used to respond to the event.

This human response to unexpected events has traditionally been underestimated or even ignored during flight training. The reality is that untrained pilots often experience a state of surprise or a startle response to an aircraft upset event. Startle may or may not lead to surprise. Pilots can protect themselves against a debilitating surprise reaction or startle response through scenario-based training, and in such training, instructors can incorporate realistic distractions to help provoke startle or surprise. To be effective the controlled training scenarios must have a perception of risk or threat of consequences sufficient to elevate the pilot's stress levels. Such scenarios can help prepare a pilot to mitigate psychological/physiological reactions to an actual upset.

Upset Prevention and Recovery Training (UPRT)

Upsets are not intentional flight maneuvers, except in maneuver-based training; therefore, they are often unexpected. The reaction of an inexperienced or inadequately trained pilot to an unexpected abnormal flight attitude is usually instinctive rather than intelligent and deliberate. Such a pilot often reacts with abrupt muscular effort, which is without purpose and even hazardous in turbulent conditions, at excessive speeds, or at low altitudes.

Without proper upset recovery training on interpretation and aircraft control, the pilot can quickly aggravate an abnormal flight attitude into a potentially fatal LOC-I accident. Consequently, UPRT is intended to focus education and training on the prevention of upsets, and on recovering from these events if they occur. *[Figure 14-14]*

- Upset prevention refers to pilot actions to avoid a divergence from the desired aircraft state. Awareness and prevention training serve to avoid incidents; early recognition of an upset scenario coupled with appropriate preventive action often can mitigate a situation that could otherwise escalate into a LOC-I accident.

Figure 14-13. *Maneuvers that better prepare a pilot for understanding unusual attitudes and situations are representative of upset training.*

- Recovery refers to pilot actions that return an aircraft that is diverging in altitude, airspeed, or attitude to a desired state from a developing or fully developed upset. Learn to initiate recovery to a normal flight mode immediately upon recognition of the developing upset condition. Ensure that control inputs and power adjustments applied to counter an upset are in direct proportion to the amount and rates of change of roll, yaw, pitch, or airspeed so as to avoid overstressing the aircraft unless ground contact is imminent. Recovery training serves to reduce accidents as a result of an unavoidable or inadvertently encountered upset event.

UPRT Core Concepts

Aircraft upsets are by nature time-critical events; they can also place pilots in unusual and unfamiliar attitudes that sometimes require counterintuitive control movements. Upsets have the potential to put a pilot into a life-threatening situation compounded by panic, diminished mental capacity, and potentially incapacitating spatial disorientation. Because real-world upset situations often provide very little time to react, exposure to such events during training is essential for pilots to reduce surprise and it mitigates confusion during unexpected upsets. The goal is to equip the pilot to promptly recognize an escalating threat pattern or sensory overload and quickly identify and correct an impending upset.

UPRT stresses that the first step is recognizing any time the aircraft begins to diverge from the intended flightpath or airspeed. Pilots must identify and determine what, if any, action must be taken. As a general rule, any time visual cues or instrument indications differ from basic flight maneuver expectations, the pilot should assume an upset and cross-check to confirm the attitude, instrument error or instrument malfunction.

To achieve maximum effect, it is crucial for UPRT concepts to be conveyed accurately and in a non-threatening manner. Reinforcing concepts through positive experiences significantly improves a pilot's depth of understanding, retention of skills, and desire for continued training. Also, training in a carefully structured environment allows for exposure to these events and can help the pilot react more quickly, decisively, and calmly when the unexpected occurs during flight. However, like many other skills, the skills needed for upset prevention and recovery are perishable and thus require continuous reinforcement through training.

UPRT in the aircraft and flight simulation training device (FSTD) should be conducted in both visual and simulated instrument conditions to allow pilots to practice recognition and recovery under both situations. UPRT should allow them to experience and recognize some of the physiological factors related to each, such as the confusion and disorientation that can result from visual cues in an upset event. Training that includes recovery from bank angles exceeding 90 degrees could further add to a pilot's overall knowledge and skills for upset recognition and recovery. For such training, additional measures should be taken to ensure the suitability of the aircraft or FSTD and that instructors are appropriately qualified.

Upset prevention and recovery training is different from aerobatic training. *[Figure 14-14]* In aerobatic training, the pilot knows and expects the maneuver, so effects of startle or surprise are missing. The main goal of aerobatic training is to teach pilots how to intentionally and precisely maneuver an aerobatic-capable aircraft in three dimensions. The primary goal of UPRT is to help pilots overcome sudden onsets of stress to avoid, prevent, and recover from unplanned excursions that could lead to LOC-I.

Aerobatics vs. UPRT Flight Training Methods		
ASPECT OF TRAINING	**AEROBATICS**	**UPSET PREVENTION AND RECOVERY TRAINING**
Primary Objective	Precision maneuvering capability	Safe, effective recovery from aircraft upsets
Secondary Outcome	Improved manual aircraft handling skills	Improved manual aircraft handling skills
Aerobatic Maneuvering	Primary mode of training	Supporting mode of training
Academics	Supporting role	Fundamental component
Training Resources Utilized	Aircraft (few exceptions)	Aircraft or a full-flight simulator

Figure 14-14. *Some differences between aerobatic training and upset prevention and recovery training.*

Comprehensive UPRT builds on three mutually supportive components: academics, aircraft-based training and, typically at the transport category type-rating training level, use of FSTDs. Each has unique benefits and limitations but, when implemented cohesively and comprehensively throughout a pilot's career, the components can offer maximum preparation for upset awareness, prevention, recognition, and recovery.

Academic Material (Knowledge and Risk Management)

Academics establish the foundation for development of situational awareness, insight, knowledge, and skills. As in practical skill development, academic preparation should move from the general to specific while emphasizing the significance of each basic concept. Although academic preparation is crucial and does offer a level of mitigation of the LOC-I threat, long-term retention of knowledge is best achieved when applied and correlated with practical hands-on experience.

The academic material needs to build awareness in the pilot by providing the concepts, principles, techniques, and procedures for understanding upset hazards and mitigating strategies. Awareness of the relationship between AOA, G-load, lift, energy management, and the consequences of their mismanagement, is essential for assessing hazards, mitigating the risks, and acquiring and employing prevention skills. Training maneuvers should be designed to provide awareness of situations that could lead to an upset or LOC. With regard to the top four causal and contributing factors to LOC-I accidents presented earlier in this chapter, training should include scenarios that place the aircraft and pilot in a simulated situation/environment that can lead to an upset.

The academics portion of UPRT should also address the prevention concepts surrounding Aeronautical Decision Making (ADM) and risk management (RM), and proportional counter response.

Prevention Through ADM and Risk Management

This element of prevention routinely occurs in a time-scale of minutes or hours, revolving around the concept of effective ADM and risk management through analysis, awareness, resource management, and interrupting the error chain through basic airmanship skills and sound judgment. For instance, imagine a situation in which a pilot assesses conditions at an airport prior to descent and recognizes those conditions as being too severe to safely land the aircraft. Using situational awareness to avert a potentially threatening flight condition is an example of prevention of a LOC-I situation through effective risk management. Pilots should evaluate the circumstances for each flight (including the equipment and environment), looking specifically for scenarios that may require a higher level of risk management. These include situations which could result in low-altitude maneuvering, steep turns in the pattern, uncoordinated flight, or increased load factors.

Another part of ADM is crew resource management (CRM) or Single Pilot Resource Management (SRM). Both are relevant to the UPRT environment. When available, a coordinated crew response to potential and developing upsets can provide added benefits such as increased situational awareness, mutual support, and an improved margin of safety. Since an untrained crewmember can be the most unpredictable element in an upset scenario, initial UPRT for crew operations should be mastered individually before being integrated into a multi-crew, CRM environment. A crew must be able to accomplish the following:

- Communicate and confirm the situation clearly and concisely;
- Transfer control to the most situationally aware crewmember;
- Using standardized interactions, work as a team to enhance awareness, manage stress, and mitigate fear.

Prevention through Proportional Counter-Response

In simple terms, proportional counter response is the timely manipulation of flight controls and thrust, either as the sole pilot or crew as the situation dictates, to manage an aircraft flight attitude or flight envelope excursion that was unintended or not commanded by the pilot.

The time-scale of this element of prevention typically occurs on the order of seconds or fractions of seconds, with the goal being able to recognize a developing upset and take proportionally appropriate avoidance actions to preclude the aircraft entering a fully developed upset. Due to the sudden, surprising nature of this level of developing upset, there exists a high risk for panic and overreaction to ensue and aggravate the situation.

Recovery

Last but not least, the academics portion lays the foundation for development of UPRT skills by instilling the knowledge, procedures, and techniques required to accomplish a safe recovery. The aircraft and FSTD-based training elements presented below serve to translate the academic material into structured practice. This can start with classroom visualization of recovery procedures and continue with repetitive skill practiced in an aircraft, and then potentially further developed in the simulated environment.

In the event looking outside does not provide enough situational awareness of the aircraft attitude, a pilot can use the flight instruments to recognize and recover from an upset. To recover from nose-high and nose-low attitudes, the pilot should follow the procedures recommended in the aircraft flight manual. In general, upset recovery procedures are summarized in *Figure 14-15.*

Upset Recovery Template
1. Disconnect the wing leveler or autopilot
2. Apply forward column or stick pressure to unload the aircraft
3. Aggressively roll the wings to the nearest horizon
4. Adjust power as necessary by monitoring airspeed
5. Return to level flight

Figure 14-15. *Upset recovery template.*

Common Errors

Common errors associated with upset recoveries include the following:

- Incorrect assessment of what kind of upset the aircraft is in
- Failure to disconnect the wing leveler or autopilot
- Failure to unload the aircraft, if necessary
- Failure to roll in the correct direction
- Inappropriate management of the airspeed during the recovery

Roles of FSTDs and aircraft in UPRT

Training devices range from aviation training devices (e.g., basic and advanced) to FSTDs (e.g., flight training devices (FTD) and full flight simulators (FFS)) and have a broad range of capabilities. While all of these devices have limitations relative to actual flight, only the higher fidelity devices (i.e., Level C and D FFS) are a satisfactory substitution for developing UPRT skills in the actual aircraft. Except for these higher fidelity devices, initial skill development should be accomplished in a suitable aircraft, and the accompanying training device should be used to build upon these skills. *[Figure 14-17]*

Aircraft-Based UPRT

Ultimately, the more realistic the training scenario, the more indelible the learning experience. Although creating a visual scene of a 110° banked attitude with the nose 30° below the horizon may not be technically difficult in a modern simulator, the learning achieved while viewing that scene from the security of the simulator is not as complete as when viewing the same scene in an aircraft. Maximum learning is achieved when the pilot is placed in the controlled, yet adrenaline-enhanced, environment of upsets experienced

Figure 14-16. *A Level D full-flight simulator could be used for UPRT.*

while in flight. For these reasons, aircraft-based UPRT improves a pilot's ability to overcome fear in an aircraft upset event.

However, aircraft-based UPRT does have limitations. The level of upset training possible may be limited by the maneuvers approved for the particular aircraft, as well as by the flight instructor's own UPRT capabilities. For instance, UPRT conducted in the normal category by a typical CFI will necessarily be different from UPRT conducted in the aerobatic category by a CFI with expertise in aerobatics.

When considering upset training conducted in an aerobatic-capable aircraft in particular, the importance of employing instructors with specialized UPRT experience in those aircraft cannot be overemphasized. Just as instrument or tailwheel instruction requires specific skill sets for those operations, UPRT demands that instructors possess the competence to oversee trainee progress, and the ability to intervene as necessary with consistency and professionalism. As in any area of training, the improper delivery of stall, spin and upset recovery training often results in negative learning, which could have severe consequences not only during the training itself, but in the skills and mindset pilots take with them into the cockpits of aircraft where the lives of others may be at stake.

All-Attitude/All-Envelope Flight Training Methods

Sound UPRT encompasses operation in a wide range of possible flight attitudes and covers the aircraft's limit flight envelope. This training is essential to prepare pilots for unexpected upsets. As stated at the outset, the primary focus of a comprehensive UPRT program is the avoidance of, and safe recovery from, upsets. Much like basic instrument skills, which can be applied to flying a vast array of aircraft, the majority of skills and techniques required for upset recovery are not aircraft specific. Just as basic instrument skills learned in lighter and lower performing aircraft are applied to more advanced aircraft, basic upset recovery techniques provide lessons that remain with pilots throughout their flying careers.

FSTD–based UPRT

UPRT can be effective in high fidelity devices (i.e. Level C and D FFS), however instructors and pilots must be mindful of the technical and physiological boundaries when using a particular FSTD for upset training. The FSTD must be qualified by the FAA National Simulator Program for UPRT; and, if the training is required for pilots by regulation, the course must also be FAA approved.

Spiral Dive

A spiral dive, a nose low upset, is a descending turn during which airspeed and G-load can increase rapidly and often results from a botched turn. In a spiral dive, the aircraft is flying very tight circles, in a nearly vertical attitude and will be accelerating because it is no longer stalled. Pilots typically get into a spiral dive during an inadvertent IMC encounter, most often when the pilot relies on kinesthetic sensations rather than on the flight instruments. A pilot distracted by other sensations can easily enter a slightly nose low, wing low, descending turn and, at least initially, fail to recognize this error. Especially in IMC, it may be only the sound of increasing speed that makes the pilot aware of the rapidly developing situation. Upon recognizing the steep nose down attitude and steep bank, the startled pilot may react by pulling back rapidly on the yoke while simultaneously rolling to wings level. This response can create aerodynamic loads capable of causing airframe structural damage and /or failure.

1. Reduce Power to Idle
2. Apply Some Forward Elevator
3. Roll Wings Level
4. Gently Raise the Nose to Level Flight
5. Increase Power to Climb Power

The following discussion explains each of the five steps:

1. Reduce Power to Idle. Immediately reduce power to idle to slow the rate of acceleration.
2. Apply Some Forward Elevator. Prior to rolling the wings level, it is important to unload the G-load on the aircraft ("unload the wing"). This is accomplished by applying some forward elevator pressure to return to about +1G. Apply just enough forward elevator to ensure that you are not aggravating the spiral with aft elevator. While generally a small input, this push has several benefits prior to rolling the wings level in the next step – the push reduces the AOA, reduces the G-load, and slows the turn rate while increasing the turn radius, and prevents a rolling pullout. The design limit of the aircraft is lower during a rolling pullout, so failure to reduce the G-load prior to rolling the wings level could result in structural damage or failure.
3. Roll Wings Level. Roll to wings level using coordinated flaperon and yaw control inputs. Even though the aircraft is in a nose-low attitude, continue the roll until the wings are completely level again before performing step four.
4. Gently Raise the Nose to Level Flight. It is possible that the aircraft in a spiral dive might be at or even beyond max operating V_{MO} or V_{NE} (never exceed speed) speed. Therefore, the pilot must make all control inputs slowly and gently at this point to prevent structural failure. Raise the nose to a climb attitude only after speed decreases to safe levels.

Spiral Dive Recovery Template
1. Reduce power to idle
2. Apply some forward elevator
3. Roll wings level
4. Gently raise the nose to level flight
5. Increase power to climb power

Figure 14-18. *Spiral dive recovery template.*

5. Increase Power to Climb Power. Once the airspeed has stabilized to V_Y, apply climb power and climb back to a safe altitude.

In general, spiral dive recovery procedures are summarized in *Figure 14-18.*

Common errors in the recovery from spiral dives are:

- Failure to reduce power first
- Mistakenly adding power
- Attempting to pull out of dive without rolling wings level
- Simultaneously pulling out of dive while rolling wings level
- Not unloading the Gs prior to rolling level
- Not adding power once climb is established

UPRT Summary

A significant point to note is that UPRT skills are both complex and perishable. Repetition is needed to establish the correct mental models, and recurrent practice/training is necessary as well. The context in which UPRT procedures are introduced and implemented is also an important consideration. The pilot must clearly understand, for example, whether a particular procedure has broad applicability, or is type-specific. To attain the highest levels of learning possible, the best approach starts with the broadest form of a given procedure, then narrows it down to type-specific requirements.

Chapter Summary

A pilot's most fundamental and important responsibility is to maintain aircraft control. Initial flight training thus provides skills to operate an aircraft in a safe manner, generally within normal "expected" environments, with the addition of some instruction in upset and stall situations.

This chapter discussed the elements of basic aircraft control, with emphasis on AOA. It offered a discussion of circumstances and scenarios that can lead to LOC-I, including stalls and aircraft upsets. It discussed the importance of developing proficiency in slow flight, stalls, and stall recoveries, spin awareness and recovery, upset prevention and recovery, and spiral dive recovery.

Pilots need to understand that primary training cannot cover all possible contingencies that an aircraft or pilot may encounter, and therefore they should seek recurrent/additional training for their normal areas of operation, as well as to seek appropriate training that develops the aeronautical skill set beyond the requirements for initial certification.

Additional advisory circular (AC) guidance is available at www.faa.gov:

- AC 61-67 (as revised), Stall and Spin Awareness Training;
- AC 120-109 (as revised), Stall Prevention and Recovery Training; and
- AC 120-111 (as revised), Upset Prevention and Recovery Training.

Autorotation

Generally tiltrotor aircraft are multi-powerplant aircraft, and in such the probability of double engine failure occurring is very slight, however, this manuever should be practiced. Due to the design of tilt rotor aircraft and the inbuilt conversion protection, autorotations cannot be practiced in the real aircraft. The AEIO condition requires, conversion at maximum rate, which in normal flight would exceed the airspeed, nacelle angle limit. Autorotations are therefore practiced in FFS only and are carried out to a landing.

Tilt-rotor have the ability to glide like an aeroplane safely all the way to the surface, however, this could result in the blades striking the ground, dependant on design, causing major aircraft damage. The preferred technique is to convert, autorotate and land the aircraft in conversion as a helicopter and minimize any damage to aircraft and occupants.

Several factors affect the rate of descent in the glide and autorotation: density altitude, gross weight, rotor rpm, airspeed and aircraft configuration. The primary way to control the rate of descent is with airspeed. Higher or lower airspeed is obtained with the pitch control.

When landing from an autorotation, the only energy available to arrest the descent rate and ensure a soft landing is the kinetic energy stored in the proprotor blades. Tip weights can greatly increase this stored energy. A greater amount of rotor energy is required to stop an aircraft with a high rate of descent than is required to stop a aircraft that is descending more slowly. Tiltrotor also have the ability to generate wingborne lift with forward speed. This must also be considered in the selection of the speed in the descent.

Each type of aircraft has a specific airspeed and rotor rpm at which a power-off glide is most efficient. The specific airspeed is somewhat different for each type of aircratf, but certain factors affect all configurations in the same manner. In general, rotor rpm maintained in the low green area gives more distance in an autorotation. Many modern aircraft will have automatic NR control, governed by the flight control computers. For specific autorotation airspeeds and rotor rpm combinations for a particular aircraft, refer to the Federal Aviation Administration (FAA)-approved aircraft/rotorcraft flight manual (A/RFM).

Depending on the power, nacelle setting and airspeed at the time, a simultaneous engine failure will result in a large and very rapid drop in rotor speed (NR) requiring a large and rapid power adjustment in order to recover proprotor speed within the Power Off range. It is imperative that these control inputs are made quickly and decisively.

To enable identification of a suitable landing site, APLN mode glide can be used to dramatically extend the aircraft range if required.

The exercise will be strarted from a sequential or simultaneous failure of all engines that will require entry into autorotation from Cruise speed in APLN mode. On recognition of AEIO condition, lower the power lever to zero and enter the aircraft into a glide, adjusting the nose attitude for speed control achieving best glide speed. Continue glide in APLN mode towards your chosen landing site. With a landing assured begin a conversion to full aft nacelle at the maximum conversion rate.

Note

Aircraft with conversion protection will have this function removed during AEIO conditions, allowing maximum rate conversion regardless of airspeed.

Hold the recommended airspeed in the descent and monitor the nacelle angle. As the nacelles approach conversion setting, smoothly pull aft on the center stick to acheive around 15^0 nose up attitude. This is done in order to speed up the change in airflow direction from the front of the disc to the underside of the disc, assisting in the recovery of NR. As discussed in Chapter 4 xxx.

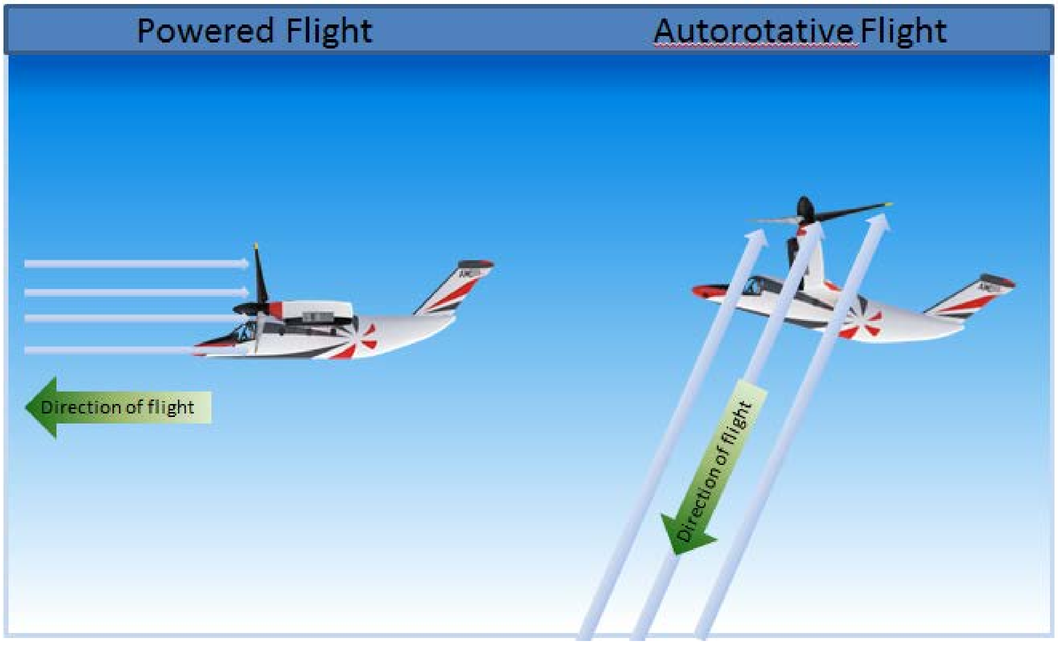

Figure 15-x *During an autorotation, the upward flow of relative wind permits the proprotors to rotate at their normal speed.*

Once established in Autorotative descent, slowly and smoothly push forward on the center stick to achieve and maintain the recommended speed for the descent in VTOL mode. It is key not to apply too harsh a nose forward movement as this will decay the NR rapidly. Maintain this airspeed and when able, lower the landing gear.

As the aircraft approaches 200 ft, start a gentle flare, position 1, with aft center stick upto 30^0 nose up, position 2. Modify the application of the flare dependant on the weight of the aircraft and the wind strength, looking to complete the flare by around 30 ft with the ROD reduced below 300 fpm.

AT 25-30 ft AGL, position 3, adopt a landing attitude, around 2^0 nose up, and simultaneously raise the power lever to cushion the touchdown. As the rear landing gear touch down, slowly reduce aft pressure on the center stick allowing the front landing gear to gently touch the ground, position 4. With all wheels firmly in contact with the ground you can now lower the power lever to zero and center the center stick. Refer fig 15-x

On the touchdown surface, maintain heading with use of the pedals, looking ahead to distance markers to keep the aircraft straight and allow the aircraft to slow. Once within brake limits, apply the foor brakes and bring the aircraft to a complete stop, resetting the nacelles to vertical.

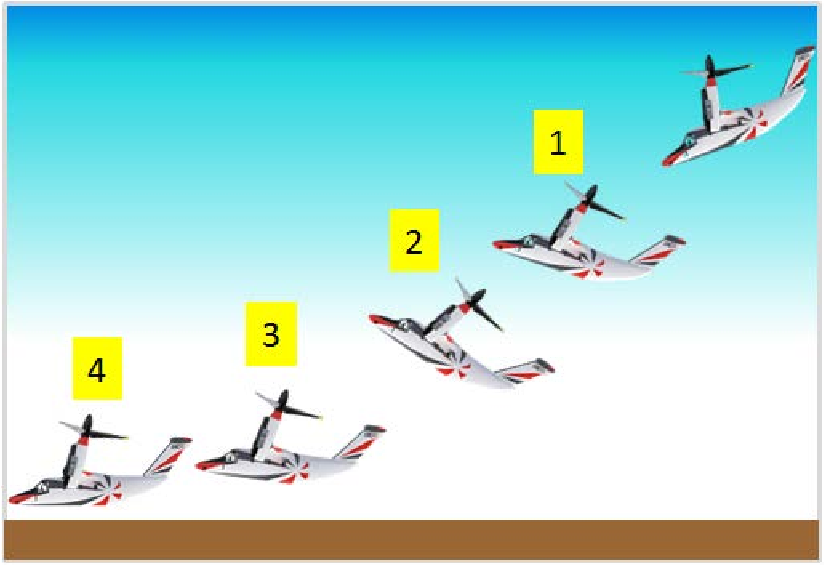

Figure 15-x. *Flare technique during straight autorotation.*

Common Errors

- Slow recognition and entry.
- Not using maximum rate nacelle transiton.
- Failling to recover the NR, not flaring sufficiently as the nacelles approach 650.
- Not maintaining heading or balance.
- Focussing inside rather than outside, instrument flying.
- Allowing the nose to drop as the power lever is lowered, allowing speed & ROD to increase.
- Poor judgement of level off height, not scanning to the side or using RADALT.
- Flaring & levelling too harshly (over controlling in pitch).
- Over rotating on level off and touching down front wheel first.
- Not maintaining direction control on touchdown.
- Applying brakes too early or too harshly.

Vortex Ring State

As described in Chapter 4 Para xx. VRS in a tiltrotor will most likely occur on only one proprotor system. It is a multi-staged phenomenon during which the aircraft experiences progressively degrading control characteristics and descent rate increases, leading to one of the proprotor systems entering vortex ring and rolling towards that side. During the" roll off" the aircraft may also begin to turn to that side

Recovery should be initiated at the first sign of VRS. For tiltrotor, this requires first rotating the nacelles forward, and applying forward center stick to increase acceleration. Power should be fixed (altitude permitting) until positive airspeed is established, followed by an appropriate unusual attitude recovery if roll off has occurred. [Figure 15-x]

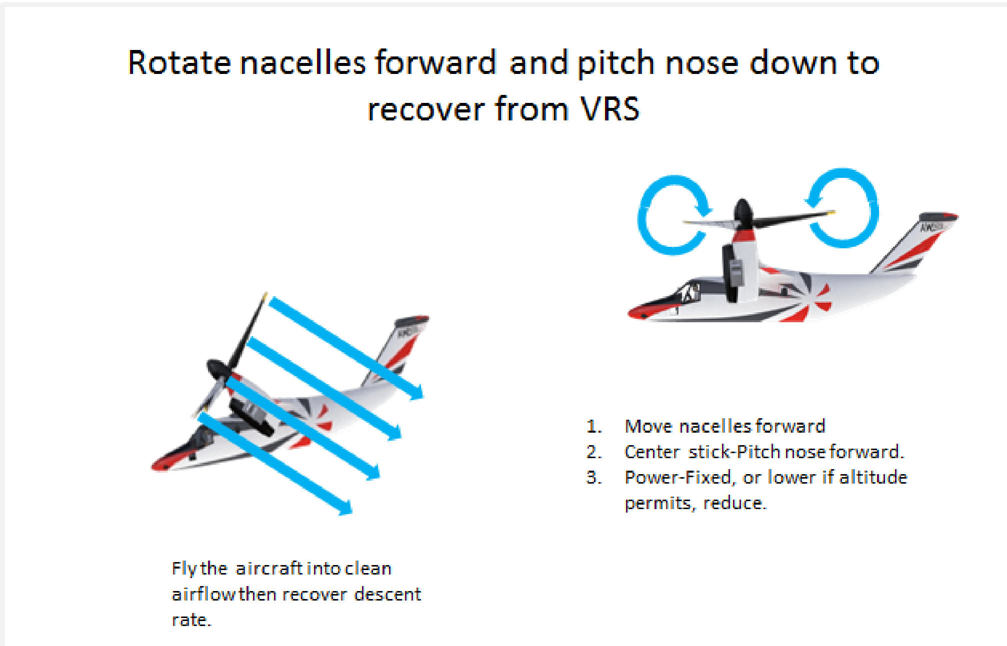

Figure 15-x *Recovery from VRS.*

Ground Resonance

Aircraft with articulating prop rotor systems, with lead-lag hinge,s (usually designs with three or more main rotor blades) are subject to ground resonance. Ground resonance is a destructive vibration phenomenon that occurs at certain rotor speeds when the aircraft is on the ground. Ground resonance is a mechanical design issue that results from the aircraft's airframe having a natural frequency that can be intensified by an out-of-balance proprotor. The unbalanced proprotor system vibrates at the same frequency or multiple of the airframe's resonant frequency and the harmonic oscillation increases because the power plant is adding power to the system, increasing the magnitude (or amplitude) of the vibrations until the structure or structures fail. This condition can cause an aircraft to self-destruct in a matter of seconds if left unchecked.

Hard contact with the ground on one corner (and usually with wheel-type landing gear) can send a shockwave to one or more of the prop rotor systems, resulting in the blades of a three-blade rotor system moving from their normal 120° relationship to each other. This movement occurs along the drag hinge and could result in something like 122°, 122°, and 116° between blades. [Figure 15-x] When one of the other landing gear strikes the surface, the unbalanced condition could be further aggravated. If the rpm is low, the only corrective action to stop ground resonance is to close the throttle immediately and fully lower the collective to place the blades in low pitch. If the rpm is in the normal operating range, fly the helicopter off the ground, and allow the blades to rephaze themselves automatically. Then, make a normal touchdown. If a pilot lifts off and allows the aircraft to firmly re-contact the surface before the blades are realigned, a second shock could move the blades again and aggravate the already unbalanced condition. This could lead to a violent, uncontrollable oscillation.

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Fig 15-x Ground Resonance

Ground resonance has not been "solved", and is still a big concern for anyone who flies an aircraft with a fully-articulated rotor system. Some aircraft designs have included weights and springs to damp out the oscillations. It is more likely in aircraft with improperly maintained landing gear (deflated oleo struts, for example).

Ground resonance does not occur in rigid or semi-rigid rotor systems because there is no drag hinge. In addition, skid-type landing gear is not as prone to ground resonance as wheeltype landing gear since the rubber tires are not present and change the rebound characteristics.

Dynamic Rollover

A tilt-rotor aircraft is susceptible to a lateral rolling tendency, called dynamic rollover, when the aircraft is in contact with the surface during takeoffs or landings. For dynamic rollover to occur, some factor must first cause the aircraft to roll or pivot around a skid or landing gear wheel, until its critical rollover angle is reached. (depending on the aircraft, winds, and loading) Then, beyond this point, prop rotor thrust continues the roll the aircraft and recovery is impossible.

After this angle is achieved, the center stick does not have sufficient range of control to eliminate the thrust component and convert it to lift. If the critical rollover angle is exceeded, the aircraft rolls on its side regardless of the center stick corrections made and will result in nacelle/aircraft damage.

Dynamic rollover can occur for a variety of reasons, including the failure to remove a tie down or skid-securing device, or if the skid or wheel contacts a fixed object while hovering sideward, or if the gear is stuck in ice, soft asphalt, or mud.. In all these conditions the lowest part of the aircraft will strike the ground first, usually the nacelle.

Dynamic rollover may also occur if you exceed aircraft limitations while performing slope operations. In this condition the lateral c of g will have been exceeded and as the aircraft attempts to take off or land the down slope landing gear becomes a pivot point, coupled with a rotor thrust assisted rolling motion, pivoting the aircraft beyond its critical angle.

Whatever the cause, if the gear or skid becomes a pivot point, dynamic rollover is possible if not using the proper corrective technique.

Once started, dynamic rollover cannot be stopped by application of opposite center stick alone. For example, the right skid contacts an object and becomes the pivot point while the aircraft starts rolling to the right. Even with full left center stick applied, the prop rotor thrust vector and its moment follows the aircraft as it continues rolling to the right. Quickly lowering the power lever is the most effective way to stop dynamic rollover from developing. Dynamic rollover can occur with any type of landing gear and all types of rotor systems.

It is important to remember rotor blades have a limited range of movement. If the tilt or roll of the aircraft exceeds that range the controls (center stick) can no longer command a vertical lift component and the thrust or lift becomes a lateral force that rolls the aircraft over. Pilots must remember that in order to remove thrust, the power lever must be lowered as this is the only recovery technique available.

Critical Conditions

Certain conditions reduce the critical rollover angle, thus increasing the possibility for dynamic rollover and reducing the chance for recovery. The rate of rolling motion is also a consideration because, as the roll rate increases, there is a reduction of the critical rollover angle at which recovery is still possible. Other critical conditions include operating at high gross weights with thrust (lift) approximately equal to the weight.

Refer to Figure xx. The following conditions are most critical for tilt-rotor aircraft

1. Exceeding slope limitations
2. Crosswinds.

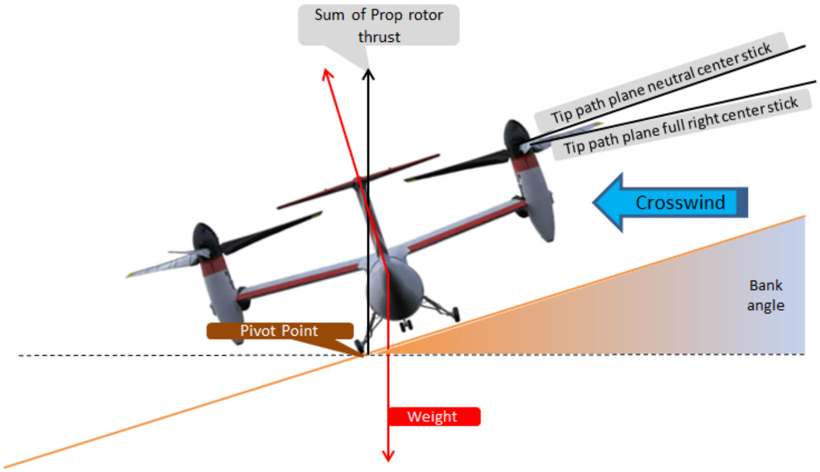

Figure X.X. *Forces acting on a tilt-rotor aircraft with left skid on the ground.*

Multi Powerplant Emergency Operations

Single-Engine Failure

When one engine has failed, the aircraft can often maintain altitude and airspeed until a suitable landing site can be selected. Whether or not this is possible becomes a function of such combined variables as aircraft weight, density altitude, height above ground, airspeed, phase of flight, single-engine capability, and environmental response time and control technique may be additional factors. In tiltrotor aircraft the phase of flight and aircraft configuration must also be taken into account. Caution must be exercised to correctly identify the malfunctioning engine since there is no telltale yawing as occurs in most multiengine airplanes. Shutting down the wrong engine could be disastrous!

Rejected Takeoff

Emergency or abnormal situations can occur during a takeoff that requires a pilot to reject the takeoff while still on the runway. Circumstances such as a malfunctioning powerplant, inadequate acceleration, runway incursion, or air traffic conflict may be reasons for a rejected takeoff.

Prior to takeoff, the pilot should identify a point along the runway at which the airplane should be airborne. If that point is reached and the airplane is not airborne, immediate action should be taken to discontinue the takeoff. Properly planned and executed, the airplane can be stopped on the remaining runway without using extraordinary measures, such as excessive braking that may result in loss of directional control, airplane damage, and/or personal injury.

In the event a takeoff is rejected on the runway surface, the power is reduced to idle, nacelles rotated fully aft and when within speed limits, maximum braking applied while maintaining directional control. If it is necessary to shut down the engine due to a fire, carry out any immediate memory items and always follow the manufacturer's emergency procedure as listed in the QRH/AFM.

Powerplant Failure after Liftoff

An emergency contingency plan and safety brief should be clearly understood well before the takeoff roll commences. An engine failure before a predetermined airspeed or point results in an aborted takeoff. An engine failure after a certain airspeed and point and climb performance assured result in a continued takeoff. With loss of an engine, it is paramount to maintain aircraft control and comply with the manufacturer's recommended emergency procedures. The altitude and runway remaining are in many ways, the controlling factor in the successful accomplishment of an emergency landing following a powerplant failure. Prior to departure the PIC should have calculated the TOLD data for the aircraft in the environmental conditions of the day. He will be aware of how much runway is required to accelerate and also to stop the aircraft.

During a rolling takeoff, if after liftoff, a power plant failure occurs the PIC has 2 options:

Continued Takeoff

If the aircraft has achieved V_{TOSS} the PIC could continue to climb using single engine maximum power available, accelerating to VY once above 200ft AGL. Once at a safe height and speed, the aircraft can be positioned in the traffic pattern to conduct an OEI landing as described below.

If the single-engine rate of climb is adequate, the procedures for continued flight should be followed. [Figure 15-x] There are four areas of concern: control, configuration, climb, and checklist.

Control

The first consideration following engine failure during takeoff is to maintain control of the aircraft. Maintaining directional control with pedal and pitch control (speed) with center stick. Power should initially be increased to maximum OEI power and the aircraft climbed clear of the ground and any obstructions. Due to the design of tiltrotor, there is no loss of thrust on the failed engine, due to drive form the working engine and therefore no change in yaw and heading control.

Configuration

The memory items from the Engine Failure After Takeoff checklist should be promptly executed to configure the aircraft for climb. [Figure 15-x] The specific procedures to follow are found in the AFM/QRH and checklist for the particular aircraft. Most direct the pilot to assume V_Y, set takeoff power, retract the flaps (if not auto scheduled) and landing gear.

Climb
As soon as the airplane is configured for climb, the bank angle should be reduced to that producing best climb performance. V_Y is maintained with pitch control and nacelle setting. As turning flight reduces climb performance, climb should be made straight ahead or with shallow turns to avoid obstacles to an altitude of at least 400 feet AGL before attempting a return to the airport.

Checklist
Having accomplished the memory items from the Engine Failure After Takeoff checklist, the printed copy should be reviewed as time permits. The Securing Failed Engine checklist should then be accomplished. Unless the pilot suspects an engine fire, the remaining items should be accomplished deliberately and without undue haste. Airplane control should never be sacrificed to execute the remaining checklists. The priority items have already been accomplished from memory. Aviate, Navigate, Communicate, always fly the aircraft as first priority.

There is a distinct possibility of actuating an incorrect switch or control if the procedure is rushed. The pilot should concentrate on flying the airplane and extracting maximum performance. If an ATC facility is available, an emergency should be declared.

Not all engine power losses are complete failures. Sometimes the failure mode is such that partial power may be available. In the case of partial governor rundown, the pilot may consider allowing it to continue to run until altitude and airspeed permit safe single-engine flight or if required for a safe landing, if this can be done without compromising safety. Attempts to save a malfunctioning engine can lead to a loss of the entire aircraft.

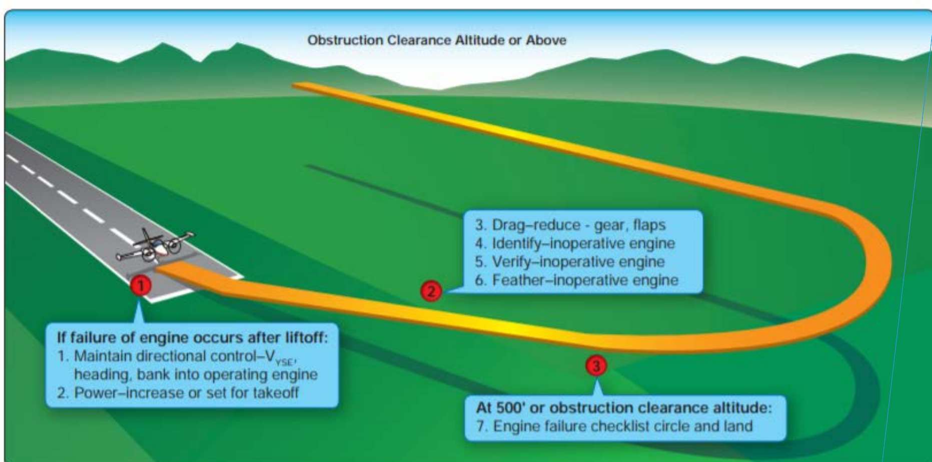

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Fig 15-x Adequate climb perforamance

Rejected Takeoff
Terminate the climb by reducing power, and pitch the nose up to a decelerative attitude i.e. 2-5^0 nose up and rotate the nacelles aft to rolling landing nacelle setting. From this position the aircraft can be descended back to the runway, with a ROD of around 300fpm allowing the rear gear or all the landing gear to touch. Avoid landing nose first as the front gear will “wheel barrow”. Once on the ground the nacelles can be rotated fully aft to assist braking and the aircraft can be taxied clear of the runway or shutdown in place if the emergency requires it.

Common Errors

- Slow decision to continue or reject the takeoff.
- Not applying maximum power during continued takeoff.
- Reducing power too much during a rejected take off, initiating high ROD.
- Too much aft center stick, nose high, decelerating the aircraft below $V_{TOSS.,}$during rejected takeoff.
- Rushing the maneuver.

Engine Failure in a Hover

From the hover the aircraft may be able to maintain height, dependent on the aircraft weight and the environmental conditions. The ability to hover in OEI conditions should have been calculated using the appropriate charts or through the aircrafts FMS. Pilots should be aware of the aircrafts performance and should note the power required to maintain an IGE hover. If the hover power is less than half of the single engine maximum power limit, then the aircraft should be able to hover with one engine.

If the aircraft is in the hover and suffers an engine failure the pilot should:

1. Maintain the aircraft ground position and prevent any drift. This will ensure the landing point, directly below the aircraft is clear.
2. Reduce power to initiate an ROD and recover NR, if it has dropped. No nacelle adjustment is required as hover nacelle is set.
3. Maintain heading with the pedals and an aircraft level attitude with center stick.
4. Cushion the touchdown by raising the power lever. Generally at the same rate the aircraft is sinking.
5. Apply the brakes to prevent any roll.
6. Complete emergency shutdown IAW AFM.

Note

The NR decay and aircraft sink will increase as the aircraft weight increases.

Common Errors

- Not maintaining ground position
- Reducing the power too much and initiating a high ROD.
- Cushion the touchdown too early/too much and getting airborne again.

Engine Failure during Flight

Engine failures well above the ground are handled differently than those occurring at lower speeds and altitudes. Cruise airspeed allows better airplane control and altitude, which may permit time for a possible diagnosis and remedy of the failure. Maintaining aircraft control, however, is still paramount. Aircraft have been lost at altitude due to apparent fixation on the engine problem to the detriment of flying the airplane.

Not all engine failures or malfunctions are catastrophic in nature (catastrophic meaning a major mechanical failure that damages the engine and precludes further engine operation). Many cases of power loss are related to fuel starvation, due to partial governor rundown, where restoration of power may be made by switching to manual throttle control. An orderly inventory of gauges and switches may reveal the problem. The affected engine may run smoothly at idle power setting.

Although it is a natural desire among pilots to save an ailing engine with a precautionary shutdown, the engine should be left running if there is any doubt as to needing it for further safe flight. Catastrophic failure accompanied by heavy vibration, smoke, blistering paint, or large trails of oil, on the other hand, indicate a critical situation. The affected engine should be Securing and the checklist completed. The pilot should divert to the nearest suitable airport and declare an emergency with ATC for priority handling.

Fuel crossfeed/transfer is a method of getting fuel from a tank on one side of the aircraft to an operating engine on the other. Crossfeed/transfer is used for extended single-engine operation. If a suitable airport is close at hand, there is no need to consider crossfeed/transfer. If prolonged flight on a single-engine is inevitable due to airport non-availability, then crossfeed/transfer allows use of fuel that would otherwise be unavailable to the operating engine. It also permits the pilot to balance the fuel consumption to avoid an out-of-balance wing heaviness.

The AFM/POH procedures for crossfeed/transfer vary widely. Thorough fuel system knowledge is essential if crossfeed/transfer is to be conducted. Fuel selector positions and fuel boost pump usage for crossfeed/transfer differ greatly among multiengine airplanes. Prior to landing, crossfeed/transfer should be terminated and the operating engine returned to its main tank fuel supply.

If an engine failure occurs during flight, the response will be determined by:
1. The configuration of the aircraft
2. The position of the aircraft in relation to airfields and other traffic
3. The weight of the aircraft (power available)
4. The environmental conditions.

With these factors in mind the Crew can make an informed decision for the best course of action.

In APLN mode a tilt rotor should be able to maintain normal flight parameters and retain the ability to climb. Therefore it would be safer to remain in APLN mode and fly to a suitable airfield to approach for a running landing. Whilst airborne the emergency can be dealt with IAW the QRH/AFM and the engine secured.

In CONV mode, the aircraft may not have the climb performance and therefore a transition to APLN mode may be required for onward flight. If however a suitable landing site is available, remain in CONV mode a position the aircraft for an OEI approach and landing.

Powerplant Inoperative Approach and Landing
The approach and landing with OEI is essentially the same as a two-engine approach and landing. The traffic pattern should be flown at similar altitudes, airspeeds, and key positions as a two-engine approach. The differences are the reduced power available and a higher-than-normal power setting is necessary on the operative engine.

In tilt rotor an OEI approach is the same profile flown as per a running landing with the aim to maintain the airspeed above $V_{BLSS/TOSS}$ (Single engine speed) until just prior to touchdown.
During the approach apply sufficient power to maintain the desired ROD, around 200-300 FPM.
With the nacelles in the required CONV mode/landing setting, hold around 2^0 nose up attitude. This will allow the rear wheels of the aircraft to touch down first and prevent the nose gear from “wheel barrowing”.

At around 5ft AGL smoothly apply power to cushion touchdown and on landing slowly lower the front gear onto the ground. With all the landing gear firmly on the ground reduce power to minimum and rotate the nacelles aft to stop the aircraft. Apply the footbrakes as required and either taxi clear of the runway or reset the nacelles to 90° and center the flying controls for a shutdown in place.

Common Errors
- Rushing the landing.
- Slowing too early with insufficient power.

Emergency Descents

An emergency descent is a maneuver for descending as rapidly as possible to a lower altitude or to the ground for an emergency landing. The need for this maneuver may result from an uncontrollable fire, a sudden loss of cabin pressurization, or any other situation demanding an immediate and rapid descent.

The objective is to descend the aircraft as expeditiously and rapidly as possible within the structural limitations of the aircraft. Simulated emergency descents should be made in a turn to check for other air traffic below and to look around for a possible emergency landing area. A radio call announcing descent intentions may be appropriate to alert other aircraft in the area.

When initiating the descent, rolling on a maximum bank angle which will be dependent on individual aircraft limitations, and maintaining positive load factors (G forces) on the aircraft.

Emergency descent training should be performed as recommended by the manufacturer, including the configuration and airspeeds. Except when prohibited by the manufacturer, the power should be reduced to idle, and the proprotor N_R control should be set for that will allow the aircraft to descend at the never-exceed speed (V_{NE}). Some aircraft will require the extension of the landing gear and flaperons (if available) to provide the maximum drag so that the descent can be made as rapidly as possible, without excessive airspeed, others may descend in a clean configuration due to lower V_{LO} speeds.

The pilot should not allow the aircraft's airspeed to pass (V_{NE}), the maximum landing gear extended speed (V_{LE}), or the maximum flap extended speed (V_{FE}), as applicable. In the case of an engine fire, a high airspeed descent could blow out the fire. However, the weakening of the aircraft structure is a major concern and descent at low airspeed would place less stress on the airframe.

If the descent is conducted in turbulent conditions, the pilot must also comply with the design maneuvering speed (V_A) limitations. The descent should be made at the maximum allowable airspeed consistent with the procedure used. Consideration may be given to increasing N_R to 100%, allowing the proprotors to act as a speed brake while descending at maximum maneuvering speed (V_A) This provides increased drag and, therefore, the loss of altitude as quickly as possible.

The recovery from an emergency descent should be initiated at a high enough altitude to ensure a safe recovery back to level flight or a precautionary landing. When the descent is established and stabilized during training and practice, the descent should be terminated.

Degraded Visual Environment

Degraded Visual Environment (DVE) is reduced visibility of potentially varying degrees, usually caused by darkness, snow, rain, blowing sand, dust, fog, smoke, clouds, or brownout conditions. In a DVE, situational awareness and aircraft control cannot be maintained as comprehensively as they are in normal visual meteorological conditions (VMC). DVEs often introduce misleading visual cues, leading to aircrew disorientation.

As visibility degrades, aviation operations become more dangerous, less effective, and often impossible or deadly. DVEs hamper operations, affect situational awareness, impact a crew's spatial orientation, result in diminished or even loss of aircraft control, and have contributed to a considerable number of accidents and incidents.

Figure X.X.

33

A Degraded Visual Environment (DVE) affects flight operations and safety on a daily basis. Weather, obscurants, or obstacles can be hazardous, and even deadly, in DVE.

Aircraft entering DVE conditions should treat the situation as if inadvertently entering IMC, and respond in the appropriate manner as visual references are lost. They should transfer their scan to the primary flight instruments and initiate a climb away from the ground and/or obstacles. Once clear of the hazardous environment they can reassess where they will land the aircraft.

One solution that has been developed to allow aircraft crews to mitigate and fly in DVE conditions is a Synthetic Vision Systems (SVS). A synthetic vision system (SVS) is an aircraft installation that combines three-dimensional data into intuitive displays to provide improved situational awareness to flight crews. This improved situational awareness can be expected from SVS regardless of weather or time of day. In addition the system facilitates a reduced pilot workload during complex situations and operationally demanding phases of flight, e.g. on approach. SVS merges a high resolution display(s) with databases of terrain and obstacle data, aeronautical information, data feeds from other aircraft, and GPS to show pilots where they are and what is in their immediate surrounding area. SVS displays a model of the real world, presenting information to the flight crew in a way that is easy to understand and can be rapidly assimilated. The picture presented on the SVS display(s) replaces conventional sky and ground depiction to include a 3D representation of the external environment with details of terrain, obstacles, weather, the approach path, runway and aerodrome maneuvering areas, and other traffic.

Chapter 16

Night Operations

Introduction

Pilots rely more on vision than on any other sense to orient themselves in flight. The following visual factors contribute to flying performance: good depth perception for safe landings, good visual acuity to identify terrain features and obstacles in the flightpath, and good color vision. Although vision is the most accurate and reliable sense, visual cues can be misleading, contributing to incidents occurring within the flight environment. Pilots must be aware of and know how to compensate effectively for the following:

- Physical deficiency or self-imposed stress, such as smoking, which limits night-vision capability
- Visual cue deficiencies
- Limitations in visual acuity, dark adaptation, and color and depth perception

For example, at night, the unaided eye has degraded visual acuity. For more information on night operations reference Chapter 16, pages 16-20 of the Pilots Handbook of Aeronautical Knowledge.

Visual Deficiencies

Night Myopia

At night, blue wavelengths of light prevail in the visible portion of the spectrum. Therefore, slightly nearsighted (myopic) individuals viewing blue-green light at night may experience blurred vision. Even pilots with perfect vision find that image sharpness decreases as pupil diameter increases. For individuals with mild refractive errors, these factors combine to make vision unacceptably blurred unless they wear corrective glasses. Another factor to consider is “dark focus.” When light levels decrease, the focusing mechanism of the eye may move toward a resting position and make the eye more myopic. These factors become important when pilots rely on terrain features during unaided night flights. Practicing good light discipline is very important and helps pilots to retain their night adaptation. Keeping the cockpit lighting on dim allows the pilot to better identify outside details, unmarked hazards such as towers less than 200' AGL, and unimproved landing sites with no hazard lighting.

A simple exercise that shows the difference in light contrast would be to go out to a very dark road and turn the dash board lights down very low or off and let your eyes adjust to the ambient light level. Then, turn the dash board lights up and note how the outside features disappear. The same concept applies to cockpit lighting and being able to see the surrounding terrain and obstacles. *[Figure 16-1]* Special corrective lenses can be prescribed to pilots who experience night myopia .

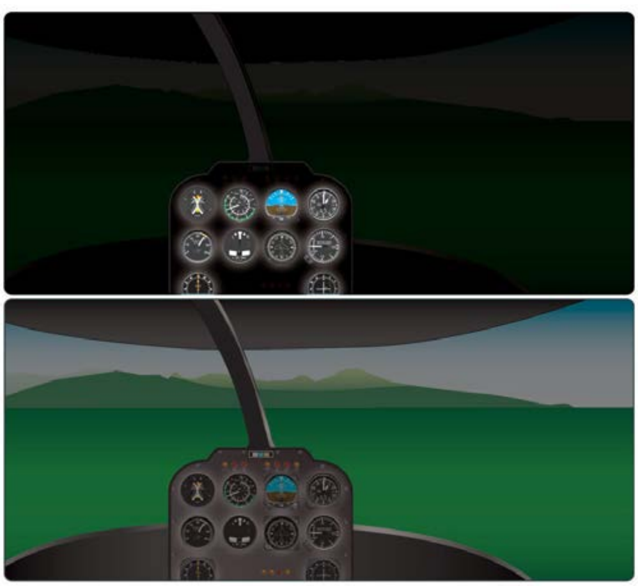

Figure 16-1. *Effects of dimming cockpit lighting during night flight to better see surrounding terrain.*

Hyperopia

Hyperopia is also caused by an error in refraction. In a hyperopic state, when a pilot views a near image, the actual focal point of the eye is behind the retinal plane (wall), causing blurred vision. Objects that are nearby are not seen clearly; only more distant objects are in focus. This problem, is referred to as farsightedness.

Astigmatism

An unequal curvature of the cornea or lens of the eye causes this condition. A ray of light is spread over a diffused area in one meridian. In normal vision, a ray of light is sharply focused on the retina. Astigmatism is the inability to focus different meridians simultaneously. If, for example, astigmatic individuals focus on power poles (vertical), the wires (horizontal) are out of focus for most of them. *[Figure 16-2]*

Presbyopia

This condition is part of the normal aging process, which causes the lens to harden. Beginning in the early teens, the human eye gradually loses the ability to accommodate for and focus on nearby objects. When people are about 40 years old, their eyes are unable to focus at normal reading distances without reading glasses. Reduced illumination interferes with focus depth and accommodation ability. Hardening of the lens may also result in clouding of the lens (cataract formation). Aviators with early cataracts may see a standard eye chart clearly under normal daylight but have difficulty seeing under bright light conditions. This problem is due to light scattering as it enters the eye. This glare sensitivity is disabling under certain circumstances. Glare disability, related to contrast sensitivity, is the ability to detect objects against varying shades of backgrounds. Other visual functions decline with age and affect the aircrew member’s performance:

- Dynamic acuity
- Recovery from glare
- Function under low illumination
- Information processing

Vision in Flight

The visual sense is especially important in collision avoidance and depth perception. A pilot’s vision sensors are the eyes, even though they are not perfect in the way they function. Due to the structure of the human eye, illusions and blindspots occur. The more pilots understand the eye and how it functions, the easier it is to compensate for these illusions and blindspots. *Figure 16-3* shows the basic anatomy of the

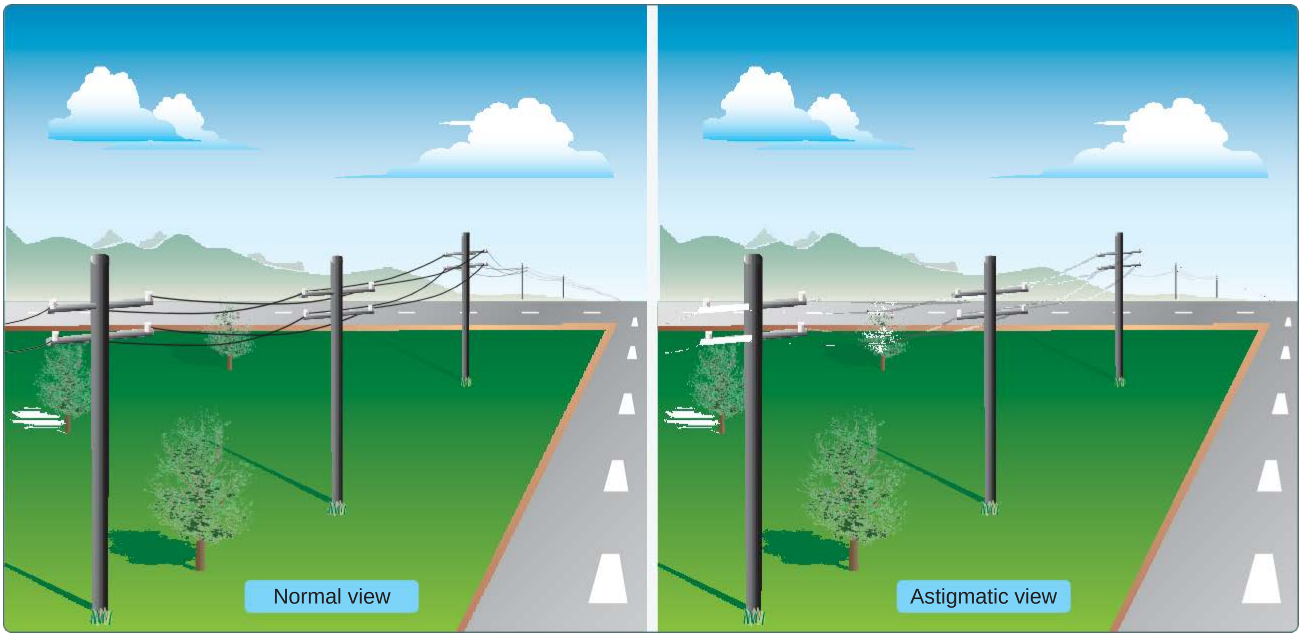

Figure 16-2. *Example of a view that might be experienced by someone with astigmatism.*

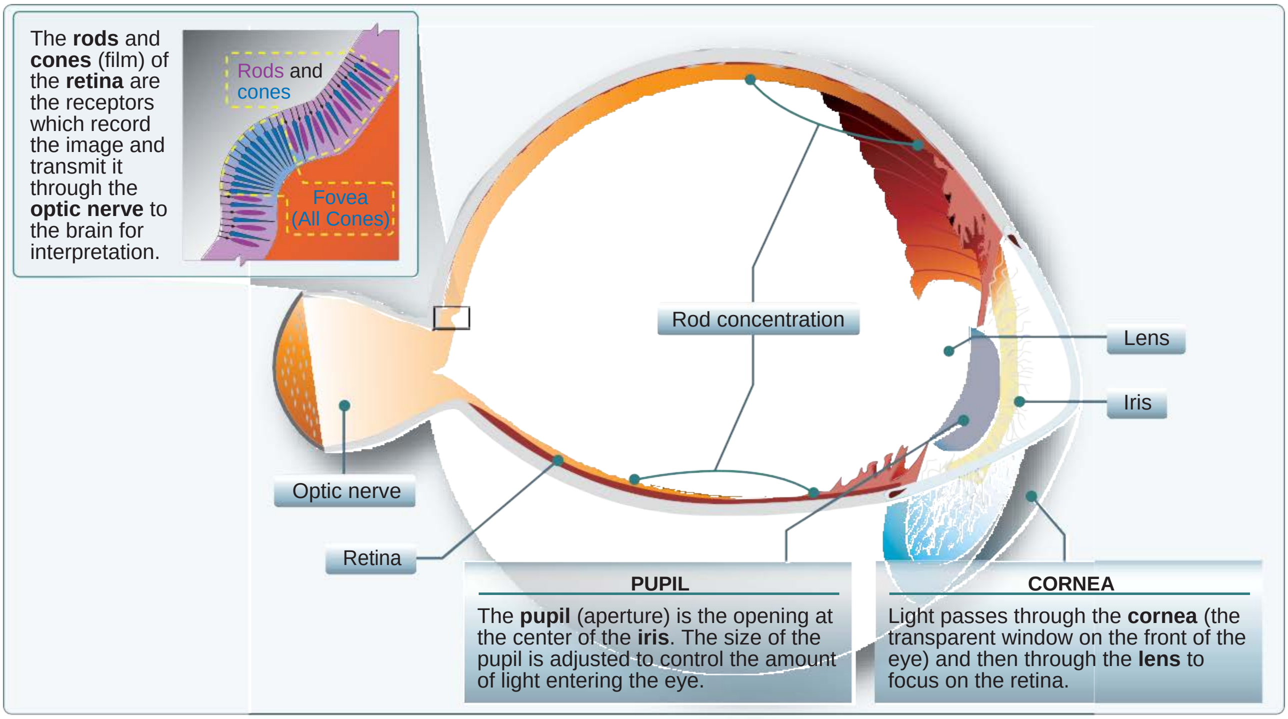

Figure 16-3. *The human eye.*

human eye and how it is like a camera. A camera is able to focus on near and far objects by changing the distance between the lens and the film. Objects can be seen clearly at various distances because the shape of the eye's lens is changed automatically by small muscles.

Visual Acuity

Normal visual acuity, or sharpness, is 20/20. A value of 20/80 indicates that an individual reads at 20 feet the letters that an individual with normal acuity (20/20) reads at 80 feet away. The human eye functions like a camera. It has an instantaneous field of view, which is oval and typically measures 120° vertically by 150° horizontally. When both eyes are used for viewing, the overall field of vision measures about 120° vertically by 200° horizontally.

The eye automatically adjusts for the light level experienced. During night flight, the cockpit and instrument lights should be as dim as possible. The eye can then adjust for the outside lighting conditions (ambient lighting) to see outside. The dimmer the inside lighting is, the better you can see outside.

The Eye

Vision is primarily the result of light striking a photosensitive layer, called the retina, at the back of the eye. The retina is composed of light-sensitive cones and rods. The cones in the eye perceive an image best when the light is bright, while the rods work best in low light. The pattern of light that strikes the cones and rods is transmitted as electrical impulses by the optic nerve to the brain where these signals are interpreted as an image.

Cones

Cones are concentrated around the center of the retina. They gradually diminish in number as the distance from the center increases. Cones allow color perception by sensing red, blue, and green light. Directly behind the lens, on the retina, is a small, notched area called the fovea. This area contains only a high concentration of cone receptors. The best vision in daylight is obtained by looking directly at the object. This focuses the image on the fovea, where detail is best seen. The cones, however, do not function well in darkness, which explains why color is not seen as vividly at night as it is during the day.

Rods

Concentrated outside the fovea area, the rods are the dim light and night receptors. The number of rods increases as the distance from the fovea increases. Rods sense images only in black and white. Because the rods are not located directly behind the pupil, they are responsible for most peripheral vision. Images that move are perceived more easily by the rod areas than by the cones in the fovea. If you have ever seen something move out of the corner of your eye, it was most likely detected by rod receptors.

In low light, the cones lose much of their function, while rods become more receptive. The eye sacrifices sharpness for sensitivity. The ability to see an object directly in front of you is reduced, and much depth perception is lost, as well as judgment of size. The concentration of cones in the fovea can make a night blindspot at the center of vision. How well a person sees at night is determined by the rods in the eyes, as well as the amount of light allowed into the eyes. The wider the pupil is open at night, the better night vision becomes.

Night Vision

Diet and general physical health have an impact on how well a person can see in the dark. Deficiencies in vitamins A and C have been shown to reduce night acuity. Other factors, such as carbon monoxide poisoning, smoking, alcohol, and certain drugs can greatly decrease night vision. Lack of oxygen can also decrease night vision as the eye requires more oxygen per weight than any other part of the body.

Night Scanning

Good night visual acuity is needed for collision avoidance. Night scanning, like day scanning, uses a series of short, regularly spaced eye movements in 10° sectors. Unlike day scanning, however, off-center viewing is used to focus objects on the rods rather than the fovea blindspot. *[Figure 16-4]* When looking at an object, avoid staring at it too long. If staring at an object without moving the eyes, the retina becomes accustomed to the light intensity and the image begins to fade. To keep it clearly visible, new areas in the retina must be exposed to the image. Small, circular eye movements help eliminate the fading. Also, move the eyes more slowly from sector to sector than during the day to prevent blurring.

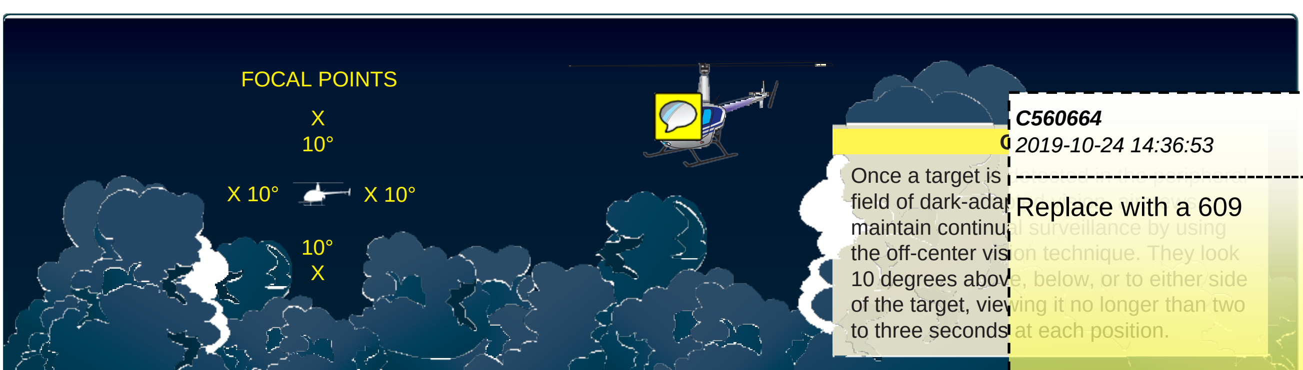

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Figure 16-4. *Off-center vision technique.*

During daylight, objects can be perceived at a great distance with good detail. At night, range is limited and detail is poor. Objects along the flight path can be more readily identified at night when pilots use the proper techniques to scan the terrain. To scan effectively, pilots look from right to left or left to right. They should begin scanning at the greatest distance at which an object can be perceived (top) and move inward toward the position of the aircraft (bottom). *Figure 16-5* shows this scanning pattern. Because the light-sensitive elements of the retina are unable to perceive images that are in motion, a stop-turn-stop-turn motion should be used. For each stop, an area about 30 degrees wide should be scanned. This viewing angle includes an area about 250 meters wide at a distance of 500 meters. The duration of each stop is based on the degree of detail that is required, but no stop should last more than two or three seconds. When moving from one viewing point to the next, pilots should overlap the previous field of view by 10 degrees. This scanning technique allows greater clarity in observing the periphery. Other scanning techniques, as illustrated in *Figure 16-6,* may be developed to fit the situation.

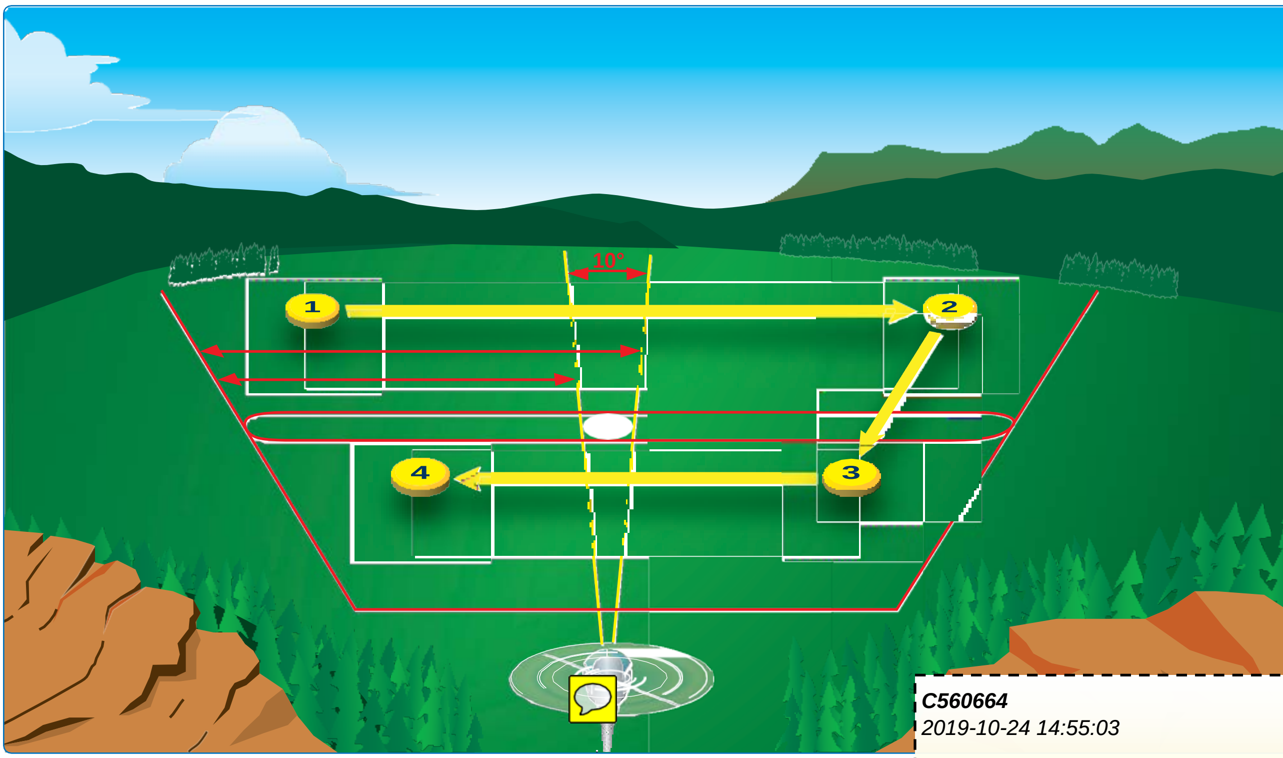

Figure 16-5. *Scanning pattern.*

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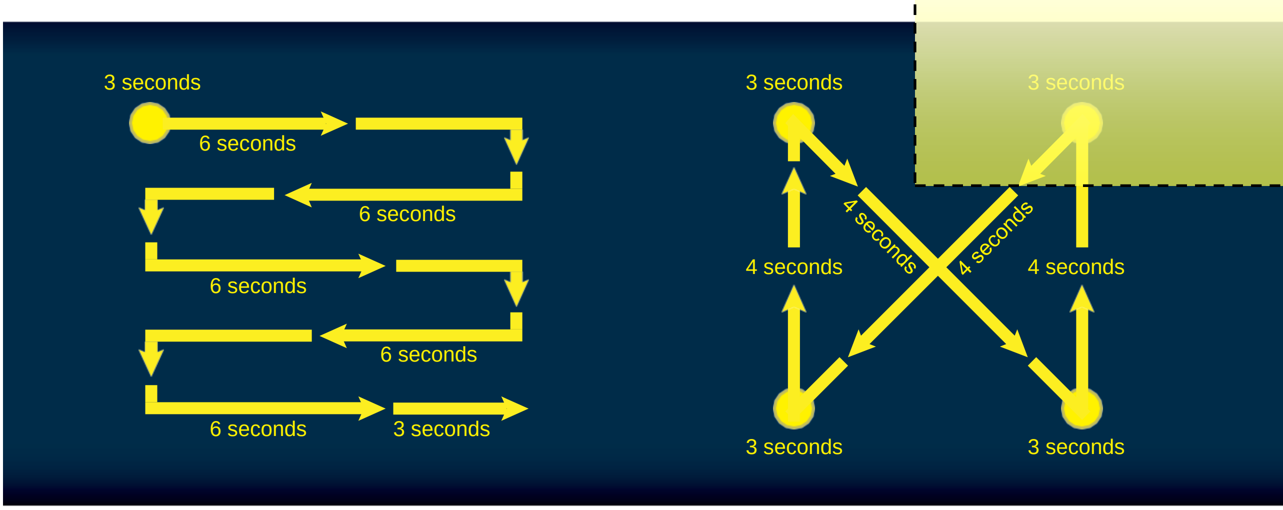

Figure 16-6. *Night vision.*

Obstruction Detection

Obstructions having poor reflective surfaces, such as wires and small tree limbs, are difficult to detect. The best way to locate wires is by looking for the support structures. However, pilots should review the most current hazard maps with known wire locations before night flights.

Aircraft Lighting

In order to see other aircraft more clearly, regulations require that all aircraft operating during the night hours have special lights and equipment. The requirements for operating at night are found in Title 14 of the Code of Federal Regulations (14 CFR) part 91. In addition to aircraft lighting, the regulations also provide a definition of night flight in accordance with 14 CFR part 91, currency requirements, fuel reserves, and necessary electrical systems.

Position lights enable a pilot to locate another aircraft, as well as help determine its direction of flight. The approved aircraft lights for night operations are a green light on the right cabin side or wingtip, a red light on the left cabin side or wingtip, and a white position light on the tail. In addition, flashing aviation red or white anticollision lights are required for night flights. These flashing lights can be in a number of locations, but are most commonly found on the top and bottom of the cabin.

Figure 16-7 shows examples of aircraft lighting. By interpreting the position lights on other aircraft, the pilot in aircraft 3 can determine whether the aircraft is flying in the opposite direction or is on a collision course. If a red position light is seen to the right of a green light, such as shown by aircraft 1, it is flying toward aircraft 3. A pilot should watch this aircraft closely and be ready to change course. Aircraft 2, on the other hand, is flying away from aircraft 3, as indicated by the white position light.

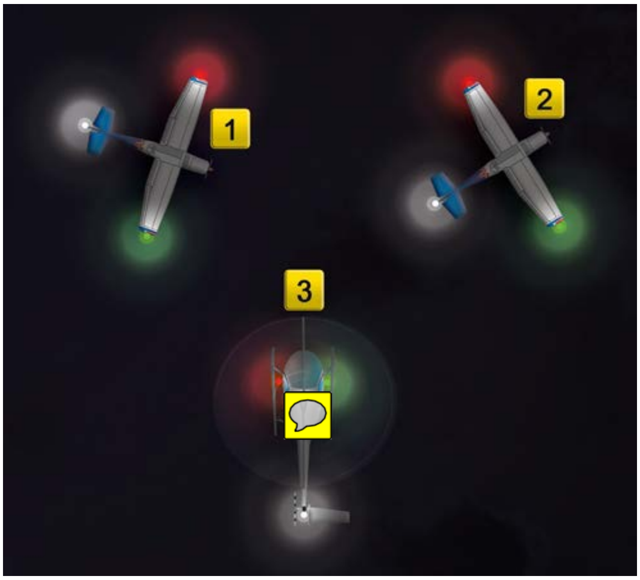

Figure 16-7. *Aircraft position lights.*

Visual Illusions

Illusions give false impressions or misconceptions of actual conditions; therefore, pilots must understand the type of illusions that can occur and the resulting disorientation. Although the visual system is the most reliable of the senses, some illusions can result from misinterpreting what is seen; what is perceived is not always accurate. Even with the references outside the cockpit and the display of instruments inside, pilots must be on guard to interpret information correctly.

Relative-Motion Illusion

Relative motion is the falsely perceived self-motion in relation to the motion of another object. The most common example is as follows. An individual in a car is stopped at a traffic light and another car pulls alongside. The individual that was stopped at the light perceives the forward motion of the second car as his or her own motion rearward. This results in the individual applying more pressure to the brakes unnecessarily. This illusion can be encountered during flight in situations such as formation flight, hover taxi, or hovering over water or tall grass.

Confusion With Ground Lights

Confusion with ground lights occurs when a pilot mistakes ground lights for stars. The pilot can place the aircraft in an extremely dangerous flight attitude if he or she aligns it with the wrong lights. In *Figure 16-8A*, the aircraft is aligned with a road and not with the horizon. Isolated ground lights can appear as stars and could lead to the illusion that the aircraft is in a nose-high attitude.

When no stars are visible because of overcast conditions, unlighted areas of terrain can blend with the dark overcast to create the illusion that the unlighted terrain is part of the sky in *Figure 16-8B*. In this illusion, the shoreline is mistaken for the horizon. In an attempt to correct for the apparent nose-high attitude, a pilot may lower the collective and attempt to fly "beneath the shore." This illusion can be avoided by referencing the flight instruments and establishing a true horizon and attitude.

Reversible Perspective Illusion

At night, an aircraft may appear to be flying away when it is actually approaching. If the pilot of each aircraft has the same assumption, and the rate of closure is significant by the time each pilot realizes his or her own error in assumption, it may be too late to avoid a mishap. This illusion is called reversible perspective, and is often experienced when a pilot observes another aircraft

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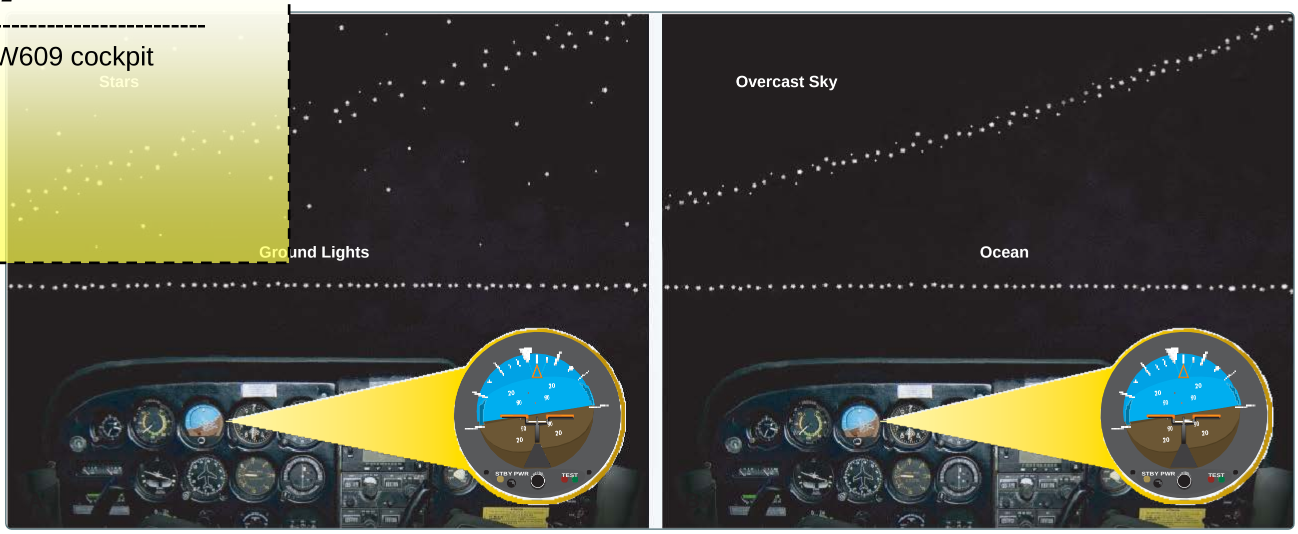

Figure 16-8. *At night, the horizon may be hard to discern due to dark terrain and misleading light patterns on the ground.*

flying a parallel course. To determine the direction of flight, the pilot should observe the other aircraft's position lights. Remember the following: red on right returning; that is, if an aircraft is seen with the red position light on the right and the green position light on the left, the observed aircraft is traveling in the opposite direction.

Flicker Vertigo

Flicker vertigo is technically not an illusion; however, as most people are aware from personal experience, viewing a flickering light can be both distracting and annoying. Flicker vertigo may be created by aircraft proprotors interrupting direct sunlight at a rate of 4 to 20 cycles per second. Flashing anticollision strobe lights, especially while the aircraft is in the clouds, can also produce this effect. One should also be aware that photic stimuli at certain frequencies could produce seizures in those rare individuals who are susceptible to flicker-induced epilepsy.

Night Flight

The night flying environment and the techniques used when flying at night, depend on outside conditions. Flying on a bright, clear, moonlit evening when the visibility is good and the wind is calm is not much different from flying during the day. However, if flying on an overcast night over a sparsely populated area, with few or no outside lights on the ground, the situation is quite different. Visibility is restricted, so be more alert in steering clear of obstructions and low clouds. Options are also limited in the event of an emergency, as it is more difficult to find a place to land and determine wind direction and speed. At night, rely more heavily on the aircraft systems, such as lights, flight instruments, and navigation equipment. As a precaution, if visibility is limited or outside references are inadequate, strongly consider delaying the flight until conditions improve, unless proper instrument flight training has been received and the aircraft has the appropriate instrumentation and equipment.

Preflight

Aircraft preflight inspection is a critical aspect of flight safety. It must comply with the appropriate flight manual. Preflight should be scheduled as early as possible in the flight planning sequence, preferably during daylight hours, allowing time for maintenance assistance and correction. If a night preflight is necessary, a flashlight with an unfiltered lens (white light) should be used to supplement lighting. Oil and hydraulic fluid levels and leaks are difficult to detect with a blue-green or red lens. Windscreens are checked ensuring they are clean and relatively free of scratches. Slight scratches are acceptable for day flight but may not be for night flight. The search light or landing light should be positioned for the best possible illumination during an emergency descent.

Careful attention must be paid to the aircraft electrical system. In aircraft equipped with fuses, a spare set is required by regulation, and common sense, so make sure they are on board. If the aircraft is equipped with circuit breakers, check to see that they are not tripped. A tripped circuit breaker may be an indication of an equipment malfunction and should be left for maintenance to troubleshoot.

All aircraft operating between sunset and sunrise are required to have operable navigation (position) lights. Turn these lights on during the preflight to inspect them visually for proper operation. Between sunset and sunrise, these lights must be on any time the aircraft is operating.

All recently manufactured aircraft certificated for night flight must have an anticollision light that makes the aircraft more visible to other pilots. This light is either a red or white flashing light and may be in the form of a rotating beacon or a strobe. While anticollision lights are required for night visual flight rules (VFR) flights, they may be turned off any time they create a distraction for the pilot.

One of the first steps in preparation for night flight is becoming thoroughly familiar with the aircraft's cockpit, instrumentation, and control layout. It is recommended that a pilot practice locating each instrument, control, and switch, both with and without cabin lights. Since the markings on some switches and circuit breaker panels may be difficult to read at night, pilots should be able to locate and use these devices, and read the markings in poor light conditions. Before starting the engine, make sure all necessary equipment and supplies needed for the flight, such as charts, notepads, and flashlights, are accessible and ready for use.

Cockpit Lights

Check all interior lights with special attention to the instrument and panel lights. The panel lighting can usually be controlled with a rheostat or dimmer switch, allowing the pilot to adjust the intensity. If a particular light is too bright or causes reflection or glare off the windshield, it should be adjusted or turned off. As ambient level decreases from twilight to darkness, intensity of the cockpit lights is reduced to a low, usable intensity level that reduces any glare or reflection off the windshield. The light level should be adjusted to as close to the ambient light level as possible. A flashlight, with red or blue-green lens filter, or map light can supplement the available light in the cockpit. Always carry a flashlight with fresh batteries to provide an alternate source of light if the interior lights malfunction. If an existing map/utility light is used, it should be hand held or remounted to a convenient location. In order to retain night adaptation use low level light when using your checklist. Brief you passengers on the importance of light discipline during night flight so the pilot is not blinded and loses dark adaptation.

Engine Starting and Propotor Engagement

Use extra caution when starting the engine and engaging the proprotors, especially in dark areas with little or no outside lights. In addition to the usual call of "clear," turn on the position and anticollision lights. If conditions permit, also turn the landing light on momentarily to help warn others that the engine is about to start and engage the proprotors.

Taxi Technique

Landing lights usually cast a beam that is narrow and concentrated ahead of the aircraft, so illumination to the side is minimal. Therefore, slow the taxi at night, especially in congested ramp and parking areas. Some aircraft have a taxi light in addition to a landing light, which illuminates a larger area under the aircraft.

When operating at an unfamiliar airport at night, ask for instructions or advice concerning local conditions, so as to avoid taxiing into areas of construction, or unlighted, unmarked obstructions. Ground controllers or UNICOM operators are usually cooperative in furnishing this type of information.

Takeoff

Before takeoff, make sure that there is a clear, unobstructed takeoff path. At airports, this is accomplished by taking off over a runway or taxi way, however, if operating off-airport, pay more attention to the surroundings. Obstructions may also be difficult to see if taking off from an unlighted area. Once a suitable takeoff path is chosen, select a point down the takeoff path to use for directional reference. The landing light should be positioned in order to illuminate the tallest obstacles in the takeoff path. During a night takeoff, notice a lack of reliable outside visual references after becoming airborne. This is particularly true at small airports and off-airport landing sites located in sparsely populated areas. To compensate for the lack of outside references, use the available flight instruments as an aid. Check the altimeter and the airspeed indicator to verify the proper climb attitude. Use the attitude indicator, to enhance attitude reference.

The first 500 feet of altitude after takeoff is considered to be the most critical period in transitioning from the comparatively well-lit airport or heliport into what sometimes appears to be total darkness. A takeoff at night is usually an "altitude over airspeed" maneuver, meaning a pilot most likely performs a nearly maximum performance takeoff. This improves the chances for obstacle clearance and enhances safety.

En Route Procedures

In order to provide a higher margin of safety, it is recommended that a cruising altitude somewhat higher than normal be selected. There are three reasons for this. First, a higher altitude gives more clearance between obstacles, especially those that are difficult to see at night, such as high tension wires and unlighted towers. Second, in the event of an engine failure, there is more time to set up for a landing and the greater gliding distance gives more options for a safe landing. Third, radio reception is improved, particularly if using radio aids for navigation.

During preflight planning, it is recommended that a route of flight that is within reach of an airport, or any safe landing site, be selected when possible. It is also recommended that pilots fly as close as possible to a populated or lighted area, such as a highway or town. Not only does this offer more options in the event of an emergency, but also makes navigation a lot easier. A course comprised of a series of slight zigzags to stay close to suitable landing sites and well-lit areas, only adds a little more time and distance to an otherwise straight course.

In the event of a forced landing at night, use the same procedure recommended for day time emergency landings. If available, turn on the landing light during the final descent to help in avoiding obstacles along the approach path.

Collision Avoidance at Night

Because the quantity and quality of outside visual references are greatly reduced, a pilot tends to focus on a single point or instrument, making him or her less aware of the other traffic around. Make a special effort to devote enough time to scan for traffic. As discussed previously in the chapter, effective scanning is accomplished with a series of short, regularly spaced eye movements that bring successive areas of the sky into the central visual field. Each movement should not exceed 10 degrees, and each area should be observed for at least 1 second to enable detection. If the pilot detects a dimly lit object in a certain direction, the pilot should not look directly at the object, but scan the area adjacent to it, called off-center viewing. This will decrease the chances of fixating on the light and allow focusing more on the objects (e.g., tower, aircraft, ground lights). Short stops of a few seconds in duration in each scan will help to detect the light and its movement. A pilot can determine another aircraft's direction of flight by interpreting the position and anticollision lights, as previously described. When scanning, pilots should also remember to move their heads, not just their eyes. Physical obstructions can cover a considerable amount of sky, and the area can easily be uncovered by a small head movement.

Approach and Landing

Night approaches and landings do have some advantages over daytime approaches, as the air is generally smoother and the disruptive effects of turbulence and excessive crosswinds are often absent. However, there are a few special considerations and techniques that apply to approaches at night. For example, when landing at night, especially at an unfamiliar airport, make the approach to a lighted runway and then use the taxiways to avoid unlighted obstructions or equipment.

Carefully controlled studies have revealed that pilots have a tendency to make lower approaches at night than during the day. This is potentially dangerous as there is a greater chance of hitting an obstacle, such as an overhead wire or fence, that is difficult to see. It is good practice to make steeper approaches at night, increasing the probability of clearing obstacles. Monitor altitude and rate of descent using the altimeter.

Another pilot tendency during night flight is to focus too much on the landing area and not pay enough attention to airspeed. If too much airspeed is lost is a descent, a vortex ring state condition may result. Maintain the proper attitude during the approach, and ensure that you keep some forward airspeed and movement until close to the ground. Outside visual references for airspeed and rate of closure may not be available, especially when landing in an unlit area, so pay special attention to the airspeed indicator.

Although the landing light is a helpful aid when making night approaches, there is an inherent disadvantage. The portion of the landing area illuminated by the landing light seems higher than the dark area surrounding it. This effect can cause a pilot to terminate the approach at an altitude that is too high, which may result in a settling-with-power condition and a hard landing.

Illusions Leading to Landing Errors

Various surface features and atmospheric conditions encountered in landing can create illusions of incorrect height above and distance from the runway threshold. Landing errors from these illusions can be prevented by anticipating them during approaches, conducting an aerial visual inspection of unfamiliar airports before landing, using electronic glideslope or VASI systems when available, and maintaining optimum proficiency in landing procedures.

Featureless Terrain Illusion

An absence of ground features, as when landing over water, darkened areas, and terrain made featureless by snow, can create the illusion that the aircraft is at a higher altitude than it actually is. The pilot who does not recognize this illusion will fly a lower approach.

Atmospheric Illusions

Rain on the windscreen can create the illusion of greater height, and atmospheric haze can create the illusion of being at a greater distance from the runway. The pilot who does not recognize these illusions flies a lower approach. Penetration of fog can create the illusion of pitching up. The pilot who does not recognize this illusion steepens the approach, often quite abruptly.

Ground Lighting Illusions

Lights along a straight path, such as a road, and even lights on moving trains can be mistaken for runway and approach lights. Bright runway and approach lighting systems, especially where few lights illuminate the surrounding terrain, may create the illusion of less distance to the runway.

The pilot who does not recognize this illusion flies a higher approach. Conversely, the pilot overflying terrain which has few lights to provide height cues may make a lower than normal approach.

Night VFR Operations

While ceiling and visibility significantly affect safety in night VFR operations, lighting conditions also have a profound effect on safety. Even in conditions in which visibility and ceiling are determined to be visual meteorological conditions, the ability to discern unlit or low contrast objects and terrain at night may be compromised. The ability to discern these objects and terrain is referred to as the "seeing condition," and is related to the amount of natural and manmade lighting available, and the contrast, reflectivity, and texture of surface terrain and obstruction features. In order to conduct operations safely, seeing conditions must be accounted for in the planning and execution of night VFR operations.

Night VFR seeing conditions can be described by identifying high lighting conditions and low lighting conditions.

High lighting conditions exist when one of two sets of conditions are present:

1. The sky cover is less than broken (less than $\frac{5}{8}$ cloud cover), the time is between the local moon rise and moon set, and the lunar disk is at least 50 percent illuminated; or
2. The aircraft is operated over surface lighting that, at least, provides lighting of prominent obstacles, the identification of terrain features (shorelines, valleys, hills, mountains, slopes) and a horizontal reference by which the pilot may control the aircraft. For example, this surface lighting may be the result of:
    a. Extensive cultural lighting (manmade, such as a built-up area of a city),
    b. Significant reflected cultural lighting (such as the illumination caused by the reflection of a major metropolitan area's lighting reflecting off a cloud ceiling), or
    c. Limited cultural lighting combined with a high level of natural reflectivity of celestial illumination, such as that provided by a surface covered by snow or a desert surface.

Low lighting conditions are those that do not meet the high lighting conditions requirements.

Some areas may be considered a high lighting environment only in specific circumstances. For example, some surfaces, such as a forest with limited cultural lighting, normally have little reflectivity, requiring dependence on significant moonlight to achieve a high lighting condition. However, when that same forest is covered with snow, its reflectivity may support a high lighting condition based only on starlight. Similarly, a desolate area, with little cultural lighting, such as a desert, may have such inherent natural reflectivity that it may be considered a high lighting conditions area regardless of season, provided the cloud cover does not prevent starlight from being reflected from the surface. Other surfaces, such as areas of open water, may never have enough reflectivity or cultural lighting to ever be characterized as a high lighting area.

Through the accumulation of night flying experience in a particular area, the pilot develops the ability to determine, prior to departure, which areas can be considered supporting high or low lighting conditions. Without that pilot experience, low lighting considerations should be applied by pilots for both preflight planning and operations until high lighting conditions are observed or determined to be regularly available.

Chapter Summary

Knowledge of the basic anatomy and physiology of the eye is helpful in the study of aircraft night operations. Adding to that knowledge a study of visual illusions gives the pilot ways to overcome those illusions. Techniques for preflight, engine start-up, collision avoidance, and night approach and landings help teach the pilot safer ways to conduct flight at night. More detailed information on the subjects discussed in this chapter is available in the Aeronautical Information Manual (AIM) and online at www.faa.gov.

Chapter 17

Effective Aeronautical Decision-Making

Introduction

The accident rate for helicopters has traditionally been higher than the accident rate of fixed-wing aircraft, probably due to the helicopter's unique capabilities to fly and land in more diverse situations than fixed-wing aircraft and pilot attempts to fly the helicopter beyond the limits of his or her abilities or beyond the capabilities of the helicopter. Powered-lift aircraft face the same challenges as helicopters, while also sharing some of the hazards of fixed-wing.

According to National Transportation Safety Board (NTSB) statistics, approximately 80 percent of all aviation accidents are caused by pilot error, the human factor. Many of these accidents are the result of the failure of instructors to incorporate single-pilot resource management (SRM) and risk management into flight training instruction of aeronautical decision-making (ADM).

SRM is defined as the art of managing all the resources (both on board the aircraft and from outside sources) available to a pilot prior to and during flight to ensure a successful flight. When properly applied, SRM is a key component of ADM. Additional discussion includes integral topics such as, the concepts of risk management, workload or task management, situational awareness, controlled flight into terrain (CFIT) awareness, and automation management.

ADM is all about learning how to gather information, analyze it, and make decisions. It helps the pilot accurately assess and manage risk and make accurate and timely decisions. Although the flight may be coordinated by a single person, the use of available resources, such as air traffic control (ATC) and flight service stations (FSS)/automated flight service stations (AFSS), replicates the principles of CRM.

References on CRM/SRM and ADM include:

- FAA-H-8083-2, Risk Management Handbook.
- Aeronautical Information Manual (AIM).
- Advisory Circular (AC) 60-22, Aeronautical Decision Making, which provides background information about ADM training in the general aviation (GA) environment.
- FAA-H-8083-25, Pilot's Handbook of Aeronautical Knowledge.

Aeronautical Decision-Making (ADM)

Making good choices sounds easy enough. However, there are a multitude of factors that come into play when these choices, and subsequent decisions, are made in the aeronautical world. Many tools are available for pilots to become more self aware and assess the options available, along with the impact of their decision. Yet, with all the available resources, accident rates are not being reduced. Poor decisions continue to be made, frequently resulting in lives being lost and/or aircraft damaged or destroyed. The Risk Management Handbook discusses ADM and CRM/SRM in detail and should be thoroughly read and understood.

While progress is continually being made in the advancement of pilot training methods, aircraft equipment and systems, and services for pilots, accidents still occur. Historically, the term "pilot error" has been used to describe the causes of these accidents. Pilot error means an action or decision made by the pilot was the cause of, or a contributing factor that led to, the accident. This definition also includes the pilot's failure to make a decision or take action. From a broader perspective, the phrase "human factors related" more aptly describes these accidents since it is usually not a single decision that leads to an accident, but a chain of events triggered by a number of factors. *[Figure 17-1]*

The poor judgment chain, sometimes referred to as the "error chain," is a term used to describe this concept of contributing factors in a human factors related accident. Breaking one link in the chain is often the only event necessary to change the outcome of the sequence of events. The following is an example of the type of scenario illustrating the poor judgment chain.

Scenario

An emergency medical services (EMS) aircraft pilot is nearing the end of his shift when he receives a request for a patient pickup at a roadside vehicle accident. The pilot has started to feel the onset of a cold; his thoughts are on getting home and getting a good night's sleep. After receiving the request, the pilot checks the accident location and required flightpath to determine if he has time to complete the flight to the scene, then on to the hospital before his shift expires. The pilot checks the weather and determines that, although thunderstorms are approaching, the flight can be completed prior to their arrival.

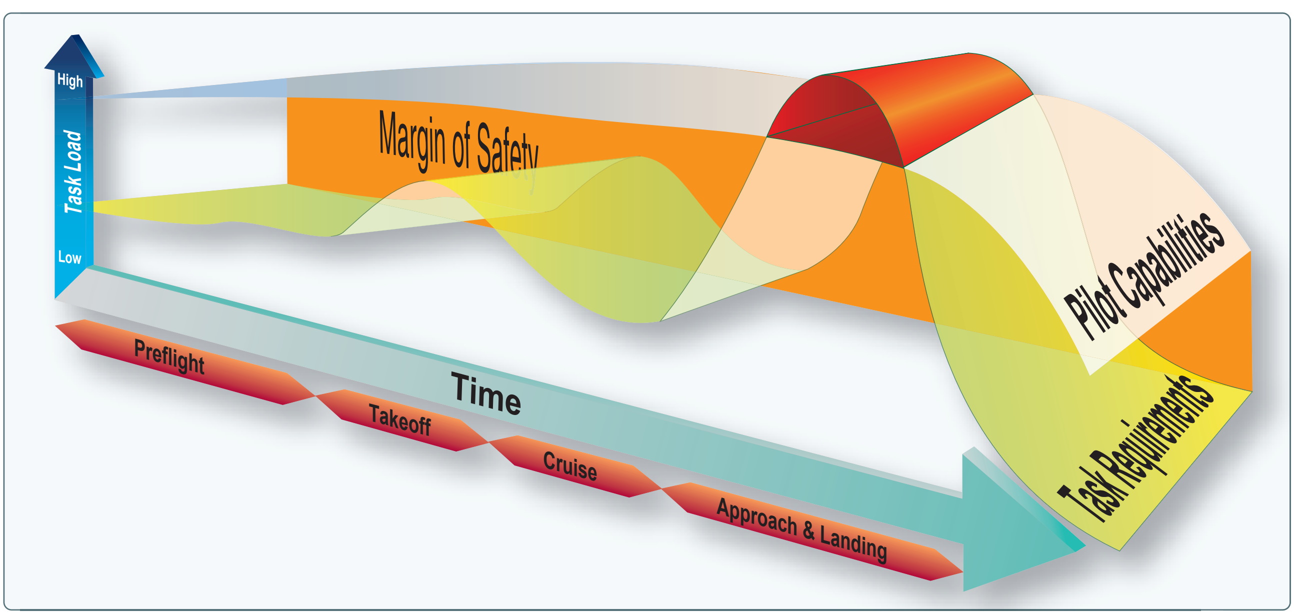

Figure 17-1. *The pilot has a limited capacity of doing work and handling tasks, meaning there is a point at which the tasking exceeds the pilot's capability. When this happens, either tasks are not done properly or some are not done at all.*

The pilot and on-board medical crews depart the home location and arrive overhead, at the scene of the vehicular accident. The pilot is not comfortable with the selected landing area due to tall trees in all quadrants of the confined area. The pilot searches for a secondary landing area. Unable to find one nearby, the pilot then returns to the initial landing area and decides he can make it work.

After successfully landing the aircraft, he is told that there will be a delay before the patient is loaded because more time is needed to extricate the patient from the wreckage. Knowing his shift is nearly over, the pilot begins to feel pressured to "hurry up" or he will require an extension for his duty day.

After 30 minutes, the patient is loaded and the pilot ensures everyone is secure. He notes that the storm is now nearby and that winds have picked up considerably. The pilot thinks, "No turning back now, the patient is on board and I'm running out of time." The pilot knows he must take off almost vertically to clear the obstacles, and chooses his departure path based on the observed wind during landing. Moments later, prior to clearing the obstacles, the aircraft begins an uncontrollable spin and augers back to the ground, seriously injuring all on board and destroying the aircraft.

What could the pilot have done differently to break this error chain? More important—what would you have done differently? By discussing the events that led to this accident, you should develop an understanding of how a series of judgmental errors contributed to the final outcome of this flight.

For example, the pilot's decision to fly the aircraft knowing that the effects of an illness were present was the initial contributing factor. The pilot was aware of his illness, but, was he aware of the impact of the symptoms—fatigue, general uneasy feeling due to a slight fever, perhaps?

Next, knowing the shift was about to end, the pilot based his time required to complete the flight on ideal conditions, and did not take into consideration the possibility of delays. This led to a feeling of being time limited.

Even after determining the landing area was unsuitable, the pilot forced the landing due to time constraints. At any time during this sequence, the pilot could have aborted the flight rather than risk crew lives. Instead, the pilot became blinded by a determination to continue.

After landing, and waiting 30 minutes longer than planned, the pilot observed the outer effects of the thunderstorm, yet still attempted to depart. The pilot dispelled any available options by thinking the only option was to go forward; however, it would have been safer to discontinue the flight

Using the same departure path selected under different wind conditions, the pilot took off and encountered winds that led to loss of aircraft control. Once again, faced with a self-imposed time constraint, the pilot improperly chose to depart the confined area. The end result: instead of one patient to transport by ground (had the pilot aborted the flight at any point), there were four patients to be transported.

On numerous occasions leading to and during the flight, the pilot could have made effective decisions that could have prevented this accident. However, as the chain of events unfolded, each poor decision left him with fewer options. Making sound decisions is the key to preventing accidents. Traditional pilot training emphasizes flying skills, knowledge of the aircraft, and familiarity with regulations. CRM/SRM and ADM training focus on the decision-making process and the factors that affect a pilot's ability to make effective choices.

Trescott Tips

Max Trescott, Master CFI and Master Ground Instructor and winner of the 2008 CFI of the year, has published numerous safety tips that every pilot should heed. He believes that the word "probably" should be purged from our flying vocabulary. Mr. Trescott contends that "probably" means we've done an informal assessment of the likelihood of an event occurring and have assigned a probability to it. He believes the term implies that we believe things are likely to work out, but there's some reasonable doubt in our mind. He further explains that if you ever think that your course of action will "probably work out," you need to choose a new option that you know will work out.

Another safety tip details the importance of accumulating flight hours in one specific airframe type. He explains that "statistics have shown that accidents are correlated more with the number of hours of experience a pilot has in a particular aircraft model and not with his or her total number of flight hours. Accidents tend to decrease after a pilot accumulates at least 100 hours of experience in the aircraft he or she is flying. Thus when learning to fly or transitioning into a new model, your goal should be to concentrate your flying hours in that model." He suggests waiting until you reach 100 hours of experience in one particular model before attempting a dual rating with another model. In addition, if you only fly a few hours per year, maximize your safety by concentrating those hours in just one aircraft model.

The third safety tip that is well worth mentioning is what Mr. Trescott calls "building experience from the armchair". Armchair flying is simply closing your eyes and mentally practicing exactly what you do in the aircraft. This is an excellent way to practice making radio calls, departures, approaches and even visualizing the parts and pieces of the aircraft. This type of flying does not cost a dime and will make you a better prepared and more proficient pilot.

All three of Max Trescott's safety tips incorporate the ADM process and emphasize the importance of how safety and good decision-making is essential to aviation.

The Decision-Making Process

An understanding of the decision-making process provides a pilot with a foundation for developing ADM skills. Some situations, such as engine failures, require a pilot to respond immediately using established procedures with little time for detailed analysis. Called automatic decision-making, it is based upon training, experience, and recognition. Traditionally, pilots have been well trained to react to emergencies, but are not as well prepared to make decisions that require a more reflective response when greater analysis is necessary. They often overlook the phase of decision-making that is accomplished on the ground: the preflight, flight planning, performance planning, weather briefing, and weight/center of gravity configurations. Thorough and proper completion of these tasks provides increased awareness and a base of knowledge available to the pilot prior to departure and once airborne. Typically during a flight, a pilot has time to examine any changes that occur, gather information, and assess risk before reaching a decision. The steps leading to this conclusion constitute the decision-making process.

Defining the Problem

Defining the problem is the first step in the decision-making process and begins with recognizing that a change has occurred or that an expected change did not occur. A problem is perceived first by the senses, then is distinguished through insight (self-awareness) and experience. Insight, experience, and objective analysis of all available information are used to determine the exact nature and severity of the problem. One critical error that can be made during the decision-making process is incorrectly defining the problem.

While going through the following example, keep in mind what errors lead up to the event. What planning could have been completed prior to departing that may have led to avoiding this situation? What instruction could the pilot have had during training that may have better prepared the pilot for this scenario? Could the pilot have assessed potential problems based on what the aircraft "felt like" at a hover? All these factors go into recognizing a change and the timely response.

While doing a hover check after picking up firefighter at the bottom of a canyon, a pilot realized that she was only 20 pounds under maximum gross weight. What she failed to realize was that the firefighter had stowed some of their heaviest gear in the baggage compartment, which shifted the center of gravity (CG) slightly behind the aft limits. Since weight and balance had never created any problems for her in the past, she did not bother to calculate CG and power required. She did try to estimate it by remembering the figures from earlier in the morning at the base camp. At a 5,000-foot density altitude (DA) and maximum gross weight, the performance charts indicated the aircraft had plenty of excess power. Unfortunately, the temperature was 93 °F and the pressure altitude at the pickup point was 6,200 feet (DA = 9,600 feet). Since there was enough power for the hover check, the pilot decided there was sufficient power to take off.

Even though the aircraft accelerated slowly during the takeoff, the distance between the aircraft and the ground continued to increase. However, when the pilot attempted to establish the best rate of climb speed, the nose tended to pitch up to a higher-than-normal attitude, and the pilot noticed that the helicopter was not gaining enough altitude in relation to the canyon wall approximately 200 yards ahead.

Choosing a Course of Action

After the problem has been identified, a pilot must evaluate the need to react to it and determine the actions to take to resolve the situation in the time available. The expected outcome of each possible action should be considered and the risks assessed before a pilot decides on a response to the situation.

The pilot's first thought was to pull up on the collective and pull back on the cyclic. After weighing the consequences of possibly losing rotor revolutions per minute (rpm) and not being able to maintain the climb rate sufficiently to clear the canyon wall, which is now only a hundred yards away, she realized the only course was to try to turn back to the landing zone on the canyon floor

Implementing the Decision and Evaluating the Outcome

Although a decision may be reached and a course of action implemented, the decision-making process is not complete. It is important to think ahead and determine how the decision could affect other phases of the flight. As the flight progresses, a pilot must continue to evaluate the outcome of the decision to ensure that it is producing the desired result.

As the pilot made the turn to the downwind, the airspeed dropped nearly to zero, and the aircraft became very difficult to control. At this point, the pilot must increase airspeed in order to maintain translational lift, but since the CG was aft of limits, she needed to apply more forward cyclic than usual. As she approached the landing zone with a high rate of descent, she realized that she would be in a potential settling-with-power situation if she tried to trade airspeed for altitude and lost effective translational lift (ETL). Therefore, it did not appear that she would be able to terminate the approach in a hover. The pilot decided to make the shallowest approach possible and perform a run-on landing.

Pilots sometimes have trouble not because of deficient basic skills or system knowledge, but because of faulty decision-making skills. Although aeronautical decisions may appear to be simple or routine, each individual decision in aviation often defines the options available for the next decision the pilot must make and the options (good or bad) it provides. Therefore, a poor decision early in a flight can compromise the safety of the flight at a later time. It is important to make accurate and decisive choices because good decision-making early in an emergency provide greater latitude for later options.

Decision-Making Models

The decision-making process normally consists of several steps before a pilot chooses a course of action. A variety of structured frameworks for decision-making provide assistance in organizing the decision process. These models include but are not limited to the 5P (Plan, Plane, Pilot, Passengers, Programming), the OODA Loop (Observation, Orientation, Decision, Action), and the DECIDE (Detect, Estimate, Choose, Identify, Do, and Evaluate) models. *[Figure 17-2]* All these models and their variations are discussed in detail in the Pilot's Handbook of Aeronautical Knowledge section covering aeronautical decision-making.

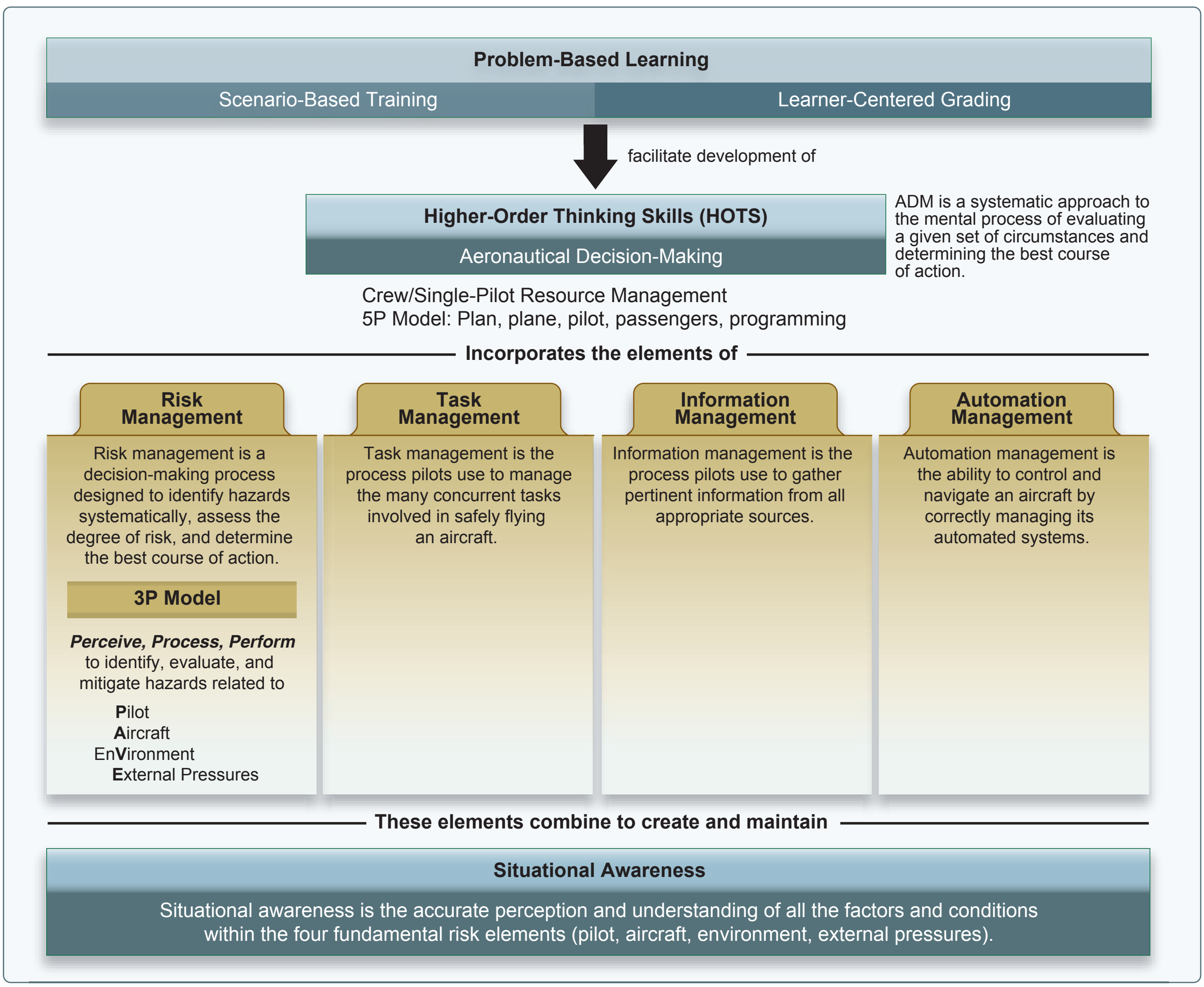

Figure 17-2. *Various models of decision-making are used in problem solving.*

Whatever model is used, the pilot learns how to define the problem, choose a course of action, implement the decision, and evaluate the outcome. Remember, there is no one right answer in this process; a pilot analyzes the situation in light of experience level, personal minimums, and current physical and mental readiness levels, and makes a decision.

Pilot Self-Assessment

The PIC of an aircraft is directly responsible for and is the final authority for the operation of that aircraft. The list of PIC responsibilities is long, and nothing should be overlooked. To exercise those responsibilities effectively and make effective decisions regarding the outcome of a flight, a pilot must have an understanding of personal limitations. Pilot performance from planning the flight to execution of the flight is affected by many factors, such as health, experience, knowledge, skill level, and attitude.

Exercising good judgment begins prior to taking the controls of an aircraft. Often, pilots thoroughly check their aircraft to determine airworthiness, yet do not evaluate their own fitness for flight. Just as a checklist is used when preflighting an aircraft, a personal checklist based on such factors as experience, currency, and comfort level can help determine if a pilot is prepared for a particular flight. Specifying when refresher training should be accomplished and designating weather minimums, which may be higher than those listed in Title 14 of the Code of Federal Regulations (14 CFR) part 91, are elements that may be included on a personal checklist. Over confidence can kill just as fast as inexperience. In addition to a review of personal limitations, a pilot should use the I'M SAFE checklist to further evaluate fitness for flight. *[Figure 17-3]*

Figure 17-3. *I'M SAFE checklist.*

Curiosity: Healthy or Harmful?

The roots of aviation are firmly based on curiosity. Where would we be today had it not been for the dreams of Leonardo da Vinci, the Wright Brothers, and Igor Sikorsky? They all were infatuated with flight, a curiosity that led to the origins of aviation. The tale of aviation is full of firsts: first flight, first tiltrotor, first trans-Atlantic flight, and so on. But, along the way there were many setbacks, fatalities, and lessons learned.
Today, we continue to learn and investigate the limits of aviation. We've been to the moon, and soon beyond. Our curiosity will continue to drive us to search for the next challenge.

However, curiosity can also have catastrophic consequences. Despite over 100 years of aviation practice, we still see accidents that are caused by impaired judgment formed from curious behavior. Pilots commonly seek to determine the limits of their ability as well as the limits of the aircraft. Unfortunately, too often this leads to mishaps with deadly results. Inquisitive behavior must be harnessed and displayed within personal and material limits.

Deadly curiosity may not seem as obvious to some as it is to others. Simple thoughts such as, "Is visibility really as bad as what the ATIS is reporting?" or "Will the 20 minute fuel light really indicate only 20 minutes worth of fuel?" can lead to poor decisions and disastrous outcomes.

Some aviators blatantly violate rules and aircraft limitations without thinking through the consequences. "What indications and change in flight characteristics will I see if I fly this aircraft above its maximum gross weight?" or "I've heard this aircraft can do aerobatic flight. Why is it prohibited?" are examples of extremely harmful curiosity. Even more astounding is their ignoring to the fact that the damage potentially done to the aircraft will probably manifest later in the aircraft's life, affecting other crews. Spontaneous excursions in aviation can be deadly.

Curiosity is natural, and promotes learning. Airmen should abide by established procedures until proper and complete hazard assessment and risk management can be completed.

The PAVE Checklist

As found in the Pilot's Handbook of Aeronautical Knowledge, the FAA has designed a personal minimums checklist. To help pilots with self-assessment, which in turn helps mitigate risk, the acronym PAVE divides the risks of flight into four categories. For each category, think of the applicability specific to powered-lift operations:

- Pilot (pilot in command)
  - Physical, emotional readiness.
  - Flight experience, recency, currency, total time in type.
- Aircraft
  - Is the aircraft capable of performing the task? -

  Can it carry the necessary fuel?
  - Does it provide adequate power margins for the task to be accomplished?
  - Can it carry the weight and remain within CG?
  - Will there be external loads?
- EnVironment
  - Aircraft are susceptible to the impact of changing weather conditions.
  - How will the change in moderating temperatures and DA affect performance?
  - Will controllability be jeopardized by winds, terrain, and turbulence?
- External pressures
  - Do not let the notion to accomplish "the mission" override good judgment and safety.
  - Many jobs include time lines. How often do we hear "time is money" or "time is wasting"? Don't sacrifice safety for an implied or actual need to meet the deadline!
  - Do not allow yourself to feel pressured by coworkers, family events, or friends.

Incorporated into preflight planning, the PAVE checklist provides the pilot with a simple way to remember each category to examine for risk prior to each flight. Once the pilot identifies the risks of a flight, he or she needs to decide whether the risk or combination of risks can be managed safely and successfully. Remember, the PIC is responsible for deciding about canceling the flight. If the pilot decides to continue with the flight, he or she should develop strategies to mitigate the risks.

One way to control risk is by setting personal minimums for items in each risk category. Remember, these are limits unique to an individual pilot's current level of experience and proficiency. They should be reevaluated periodically based upon experience and proficiency.

Resource Management

Defined as the art and science of managing all the resources (both on board the aircraft and from outside resources) available to a single pilot (prior to and during flight), CRM/SRM ensures the successful outcome of the flight. As mentioned earlier, this includes risk management, situational awareness, and CFIT awareness.

CRM/SRM training helps the pilot(s) maintain situational awareness by managing automation, associated control, and navigation tasks. This enables the pilot(s) to accurately assess hazards, manage resulting risk potential, and make good decisions.

To make informed decisions during flight operations, pilots must be aware of the resources found both inside and outside the cockpit. Since useful tools and sources of information may not always be readily apparent, learning to recognize these resources is an essential part of CRM/SRM training. Resources must not only be identified, but pilots must also develop the skills to evaluate whether he/she or they have the time to use a particular resource and the impact its use has upon the safety of flight.

If a pilot is flying into a confined area with no wind sock or access to a current wind report, should the PIC pick an approach path based on the direction of wind information received from an earlier weather brief? Making an approach into a confined area with a tailwind is a bad decision and can be avoided. Prior to landing, the pilot should use outside resources such a smoke, trees, and water on a pond to help him or her accurately determine which direction the winds are coming from. Pilots should never leave flying up to chance and hope for the best. Many accidents could and should be avoided by simply using the resources, internal and external that are available.

Internal resources are found in the cockpit during flight. Since some of the most valuable internal resources are ingenuity, knowledge, and skill, a pilot can expand cockpit resources immensely by improving these capabilities. This can be accomplished by frequently reviewing flight information publications, such as 14 CFR and the AIM, as well as by pursuing additional training.

No other internal resource is more important than the pilot's ability to control the situation, thereby controlling the aircraft. Pilots quickly learn that it is not possible to hover, single pilot, and pick up the checklist, a chart, or publication without endangering themselves, the aircraft, or those nearby.

Checklists are essential cockpit resources used to verify the aircraft instruments and systems are checked, set, and operating properly. They also ensure proper procedures are performed if there is a system malfunction or inflight emergency. Pilots at all levels of experience refer to checklists. The more advanced the aircraft is, the more crucial checklists are.

Therefore, have a plan on how to use the checklist (and other necessary publications) before you begin the flight. Always control the aircraft first. When hovering in an airport environment, the pilot can always land the aircraft to access the checklist or a publication, or have a passenger assist with holding items. There is nothing more unsettling than being in flight and not having a well thought-out plan for managing the necessary documents and data. This lack of planning often leads to confusion, distractions and aircraft mishaps.
Another way to avoid a potentially complex and confusing situation is to remove yourself from the situation. The following is an example of how proper resource management and removal from a situation are vital to safe flight

A single pilot is conducting a helicopter cross-country flight. He frequently goes to and is familiar with the final destination airport. Weather is briefed to be well above the minimum weather needed, but with isolated thunderstorms possible. For the pilot, this is a routine run-of-the-mill flight. He has done this many times before and has memorized the route, checkpoints, the frequencies, fuel required and knows exactly what to expect.

However, once within 30 miles of the destination airport the pilot observes that weather is deteriorating and a thunderstorm is nearby. The pilot assesses the situation and determines the best course of action is to reroute to another airport. The closest airport is an airport within Class C airspace. At this point, the pilot realizes the publications with the required alternate airport information are in the back of the helicopter out of reach. Now what?

The pilot continues toward the alternate airport while using the onboard equipment to access the information. He struggles to obtain the information because he or she is not thoroughly familiar with its operation. Finally, the information is acquired and the pilot dials in the appropriate alternate airfiel information. Upon initial contact ARTCC (Air Route Traffic Control Center) notifies the pilot that he has entered the airspace without the required clearance; in effect the pilot has violated airspace regulations.

Things have gone from bad to worse for him. When did the trouble begin for this pilot and what options were available?

Without a doubt, problems began during the planning phase, as the necessary resources were placed in the back of the aircraft, unavailable to the pilot during flight. Additional training with the available automated systems installed on the aircraft would have expedited access to the necessary information. What if they hadn't been installed or were inoperative?

Next, a poor decision to continue towards the Class C airspace was made. The pilot could have turned away from the Class C airspace, removing himself from the situation until the frequencies were entered and contact established. Remember, when possible, choose an option that gives more time to determine a course of action. Proper resource management could have negated this airspace violation.

The example also demonstrates the need to have a thorough understanding of all the equipment and systems in the aircraft. As is often the case, the technology available today is seldom used to its maximum capability. It is necessary to become as familiar as possible with this equipment to utilize all resources fully. For example, advanced navigation and autopilot systems are valuable resources. However, if pilots do not fully understand how to use this equipment, or they rely on it so much they become complacent, the equipment can become a detriment to safe flight

Another internal resource is the FAA-approved rotorcraft flight manual (RFM). *[Figure 17-4]* The RFM:

- Must be on board the aircraft.
- Is indispensable for accurate flight planning
- Plays a vital role in the resolution of inflight equipment malfunctions.

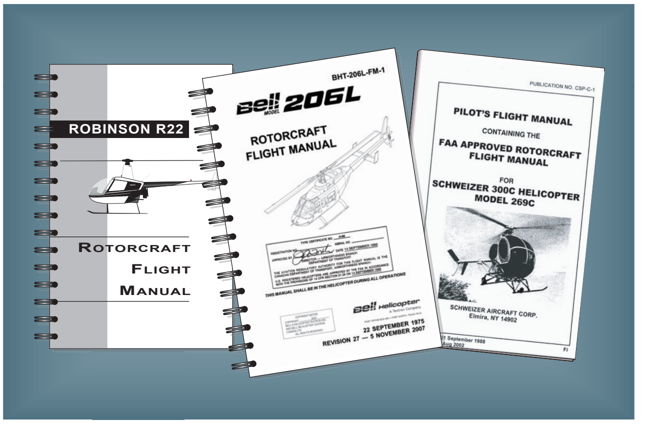

Figure 17-4. *FAA-approved Rotorcraft Flying Manual (RFM).*

Other valuable flight deck resources include current aeronautical charts and publications, such as the Airport/Facility Directory (A/FD).

As stated previously, passengers can also be a valuable resource. Passengers can help watch for traffic and may be able to provide information in an irregular situation, especially if they are familiar with flying. Crew briefs to passengers should always include some basic aircraft terminology. For example, explain that in the event you ask them if you are clear to hover to the right, their response should be either "yes, you are clear to hover to the right" or "no you are not clear." A simple yes or no answer can be ambiguous. A strange smell or sound may alert a passenger to a potential problem. As PIC, a pilot should brief passengers before the flight to make sure that they are comfortable voicing any concerns.

Instruction that integrates CRM/SRM into flight training teaches aspiring pilots how to be more aware of potential risks in flying, how to identify those risks clearly, and how to manage them successfully. The importance of integrating available resources and learning effective CRM/SRM skills cannot be overemphasized. Ignoring safety issues can have fatal results.

Risk Management

Risk management is a formalized way of dealing with hazards. It is the logical process of weighing the potential cost of risks from hazards against the possible benefits of allowing those risks from hazards to stand unmitigated. It is a decision-making process designed to identify hazards systematically, assess the degree of risk, and determine the best course of action. Once risks are identified, they must be assessed. The risk assessment determines the degree of risk (negligible, low, medium, or high) and whether the degree of risk is worth the outcome of the planned activity. If the degree of risk is "acceptable," the planned activity may then be undertaken. Once the planned activity is started, consideration must then be given whether to continue. Pilots must have preplanned, viable alternatives available in the event the original flight cannot be accomplished as planned.

Two defining elements of risk management are hazard and risk.

- A hazard is a present condition, event, object, or circumstance that could lead to or contribute to an unplanned or undesired event, such as an accident. It is a source of danger. For example, binding in the antitorque pedals represents a hazard.
- Risk is the future impact of a hazard that is not controlled or eliminated. It is the possibility of loss or injury. The level of risk is measured by the number of people or resources affected (exposure), the extent of possible loss (severity), and the likelihood of loss (probability).

A hazard can be a real or perceived condition, event, or circumstance that a pilot encounters. Learning how to identify hazards, assess the degree of risk they pose, and determine the best course of action is an important element of a safe flight.

Four Risk Elements

During each flight, decisions must be made regarding events that involve interactions between the four risk elements—the pilot in command (PIC), the aircraft, the environment, and the operation. The decision-making process involves an evaluation of each of these risk elements to achieve an accurate perception of the flight situation. *[Figure 17-5]*

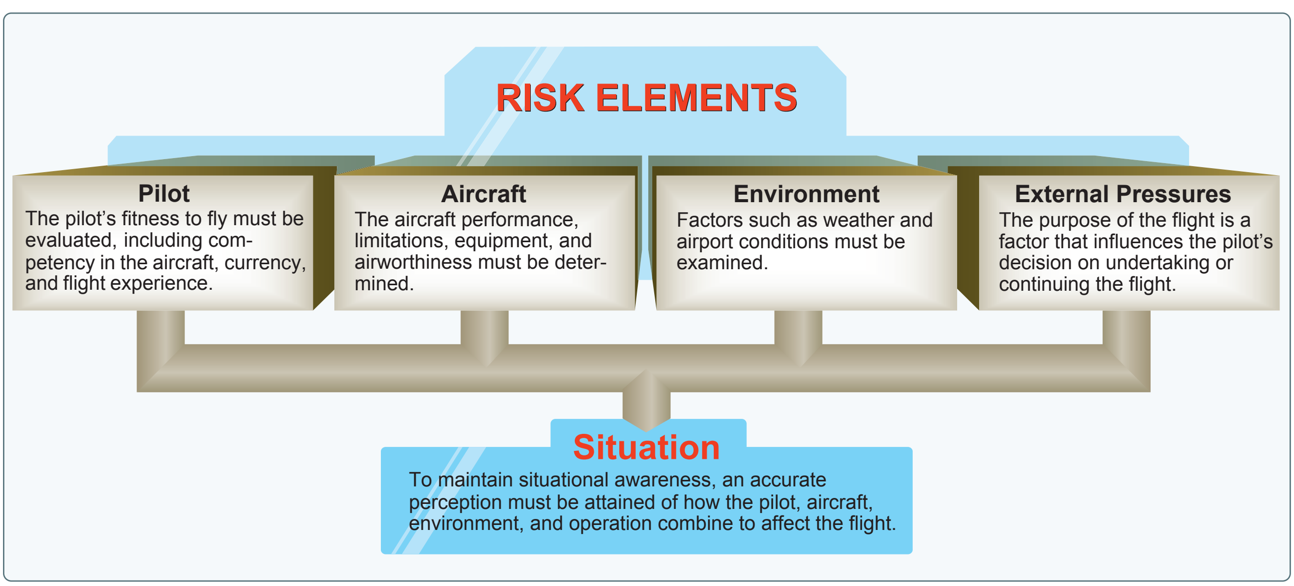

Figure 17-5. *Risk elements to evaluate in decision-making.*

One of the most important decisions that a PIC must make is the go/no-go decision. Evaluating each of these risk elements can help a pilot decide whether a flight should be conducted or continued. In the following situations, the four risk elements and how they affect decision-making are evaluated.

Pilot—A pilot must continually make decisions about personal competency, condition of health, mental and emotional state, level of fatigue, and many other variables. A situation to consider: a pilot is called early in the morning to make a long flight. With only a few hours of sleep and congestion that indicates the possible onset of a cold, is that pilot safe to fly

Aircraft—A pilot frequently bases decisions to fly on personal evaluations of the aircraft, such as its powerplant, performance, equipment, fuel state, or airworthiness. A situation to consider: en route to an oil rig an hour's flight from shore, having just passed the shoreline, the pilot notices the oil temperature at the high end of the caution range. Should the pilot continue out to sea or return to the nearest suitable heliport/airport?

Environment—This encompasses many elements unrelated to the pilot or aircraft. It can include such factors as weather, ATC, navigational aids (NAVAID), terrain, takeoff and landing areas, and surrounding obstacles. Weather is one element that can change drastically over time and distance. A situation to consider: a pilot is ferrying an aircraft cross-country and encounters unexpected low clouds and rain in an area of rising terrain. Does the pilot try to stay under them and scud run, or turn around, stay in the clear, and obtain current weather information?

External Pressures—The interaction between the pilot, the aircraft, and the environment is greatly influenced by the purpose of each flight operation. A pilot must evaluate the three previous areas to decide on the desirability of undertaking or continuing the flight as planned. It is worth asking why the flight is being made, how critical it is to maintain the schedule, and if the trip is worth the risks. A situation to consider: a pilot is tasked to take some technicians into rugged mountains for a routine survey in marginal weather. Would it be preferable to wait for better conditions to ensure a safe flight? How would the priorities change if a pilot were tasked to search for cross-country skiers who had become lost in deep snow and radioed for help?

Assessing Risk

It is important for a pilot to learn how to assess risk. Before a pilot can begin to assess risk, he or she must first perceive the hazard and attendant risk(s). In aviation, experience, training, and education help a pilot learn how to spot hazards quickly and accurately. During flight training, the instructor should point out the hazards and attendant risks to help the student pilot learn to recognize them.

Once a hazard is identified, determining the probability and severity of an accident (level of risk associated with it) becomes the next step. For example, the hazard of binding in the flight controls poses a risk only if the aircraft is flown. If the binding leads to a loss of directional control, the risk is high that it could cause catastrophic damage to the aircraft and the passengers. The pilot learns to identify hazards and how to deal with them when they are incorporated into the training program.

Every flight has hazards and some level of risk associated with it. It is critical that pilots be able to:

- Differentiate, in advance, between a low-risk fligh and a high-risk flight
- Establish a review process and develop risk mitigation strategies to address flights throughout that range

Examining NTSB reports and other accident research can help a pilot to assess risk more effectively. For example, the accident rate decreases by nearly 50 percent once a pilot obtains 100 hours, and continues to decrease until the 1,000 hour level. The data suggest that for the first 500 hours, pilots flying visual flight rules (VFR) at night should establish higher personal limitations than are required by the regulations and, if applicable, apply instrument flying skills in this environment.

Individuals training to be tiltrotor pilots should remember that the helicopter accident rate is 30 percent higher than the accident rate for fixed-wing aircraft, and consider that statistic when operating in VTOL/CONV mode. While many factors contribute to this, students must recognize the small margin of error that exists for tiltrotor and helicopter pilots in making critical decisions. In these aircraft, certain emergency actions require immediate action by the pilot. In the event of an engine malfunction, failure to immediately lower the collective results in rotor decay and failed autorotation. Fixed wing pilots may have slightly more time to react and establish a controllable descent. According to the General Aviation Joint Steering Committee, the leading causes of accidents in GA are CFIT, weather, runway incursions, pilot decision-making, and loss of control. These causes are referred to as pilot-error, or human factors related, accidents. CFIT, runway incursions, and loss of control type accidents typically occur when the pilot makes a series of bad judgments, which leads to these events. For example, when the pilot has not adequately planned the flight and the pilot subsequently fails to maintain adequate situational awareness to avoid the terrain, a CFIT accident occurs.

While the reasons for individual helicopter incidents vary, it can be argued that it is the aircraft's flight mode and operational complexity that directly contributes to each incident. By nature of its purpose, a tiltrotor or helicopter usually flies closer to terrain than does a fixed-wing aircraft. Subsequently, minimal time exists to avoid CFIT, weather related, or loss of control type incidents that require quick and accurate assessments. Fixed-wing and Tiltrotor aircraft normally fly at higher altitudes, and may be flown from prepared surface to prepared surface. Tiltrotors are also often operated in smaller, confined area-type environments and require continuous pilot control. Tiltrotor pilots must be aware of what proprotor downwash can do when landing to a dusty area or prior to starting where lose debris may come in contact with the proprotor blades.

Often, loss of control occurs when the pilot exceeds design or established operating standards, and the resulting situation exceeds pilot capability to handle it successfully. The FAA generally accepts these occurrences as resulting from poor judgment. Likewise, most weather-related accidents are not a result of the weather per se, but of a failure of the pilot to avoid a weather phenomenon for which the aircraft is not equipped, or the pilot is not trained to handle. That is, the pilot decides to fly or to continue into conditions beyond pilot capability, commonly considered bad judgment.

It cannot be emphasized enough that the tiltrotor's unique capabilities come with increased risk. Low-level maneuvering flight, including maneuvering for landing after an instrument approach, is one of the largest single categories of fatal accidents.

Fatal accidents that occur during approach often happen at night or in instrument flight rules (IFR) conditions. Takeoff/initial climb accidents are frequently due to the pilot's lack of awareness of the effects of density altitude on aircraft performance or other improper takeoff planning that results in loss of control during or shortly after takeoff. One of the most lethal types of GA flying is attempting VFR flight into instrument meteorological conditions (IMC). Accidents involving poor weather decision-making account for about 4 percent of the total accidents but 14 percent of the fatal mishaps. While weather forecast information has been gradually improving, weather should remain a high priority for every pilot assessing risk.

Using the 3P Model To Form Good Safety Habits

As discussed in the Pilot's Handbook of Aeronautical Knowledge, the Perceive, Process, Perform (3P) model helps a pilot assess and manage risk effectively in the real world. *[Figure 17-6]*

Figure 17-6. *3P Model.*

To use this model, the pilot will:

- Perceive hazards
- Process level of risk
- Perform risk management

Let's put this to use through a common scenario, involving a common task, such as a confined area approach. As is often the case, the continuous loop consists of several elements; each element must be addressed through the 3P process.

A tiltrotor pilot receives the task of flying four passengers into a remote area for a hunting expedition. The passengers have picked the location where they would like to be dropped off based on the likelihood of wildlife patterns for the area. The area has steep, rugged terrain in a series of valleys and canyons leading up to large mountains.

Upon arrival at the location, the pilot locates a somewhat large confined area near the base of one of the mountains. The pilot begins the 3P process by quickly noting (or perceiving) the hazards that affect the approach, landing, and takeoff. Through thorough assessment the pilot takes into consideration:

- Current aircraft weight/power available,
- Required approach angle to clear the trees for landing in the confined area
- Wind direction and velocity,
- Limited approach and departure paths (due to constricting terrain),

- Escape routes should the approach need to be terminated prior to landing,
- Possible hazards, such as wires or structures either around the landing site or inside of the confined area, and
- The condition of the terrain at the landing site. Mud, dust, and snow can be extreme hazards if the pilot is not properly trained to land in those particular conditions.

The pilot reviews the 3P process for each hazard. The pilot has perceived the risk associated for each of the bullets listed above. Now, the pilot assesses the risk level of each and what to do to manage or mitigate the risk.

The aircraft weight/power risk is assessed as low. While performing power checks, the pilot verified adequate out of ground effect (OGE) power exists. The pilot is also aware that, in this scenario, the departure DA (6,500 feet) is greater than the arrival location DA (6,000 feet) and that several hundred pounds of fuel have been burned off en route. Furthermore, once the passengers have disembarked, more power will be available for departure.

The pilot estimates that the highest obstacles along the approach path are 70–80 feet in height. With the size of the confined area, a normal approach angle can be maintained to clear these obstacles, giving this a low risk level. To further mitigate this risk the pilot has selected mental checkpoints along the approach path that will serve as go/no-go points should the pilot feel any assessed parameter is being exceeded.

Wind direction and velocity are assessed as a medium risk because (for this scenario) the direction of the wind is slightly offset from the chosen approach path, creating a 15–20° crosswind with a steady 10-knot wind. The pilot also takes into consideration that, due to the terrain, the wind direction and velocity may change during the approach. The pilot's experience and awareness of the complexity of mountain flow wind provide a management tool for risk reduction

From an approach and departure standpoint, the risk is assessed to be medium. There is only one viable approach and departure path. Given the size of the confined area and the wind direction, the approach and departure path is deemed acceptable.

The pilot assigns a medium risk level to the selection of an escape route. The pilot is aware of the constricting terrain on either side. Although adequate area exists for maneuvering, the pilot realizes there are physical boundaries and that they can affect the options available should the pilot need to conduct a go-around or abort the approach. Again, the pilot uses mental checkpoints to ensure an early decision is made to conduct a go-around, if needed. The selected go-around or escape route will be in line with the selected approach/departure path and generally into the wind.

As you may have noticed, one identified hazard and its correlating risk management action may have subsequent impact on other factors. This demonstrates the need for continuous assessment and evaluation of the impact of chosen courses of action.

The 3P model offers three good reasons for its use. First, it is fairly simple to remember. Second, it offers a structured, efficient, and systematic way to identify hazards, assess risk, and implement effective risk controls. Third, practicing risk management needs to be as automatic as basic aircraft control. As is true for other flying skills, risk management thinking habits are best developed through repetition and consistent adherence to specific procedures.

Once the pilot completes the 3P decision process and selects a course of action, the process begins anew as the set of circumstances brought about by the selected course of action requires new analysis. Thus, the decision-making process is a continuous loop of perceiving, processing, and performing.

Workload or Task Management

One component of CRM/SRM is workload or task management. Research shows that humans have a limited capacity for information. Once information flow exceeds the person's ability to mentally process the information, any additional information becomes unattended or displaces other tasks and information already being processed. Once this situation occurs, only two alternatives exist: shed the unimportant tasks or perform all tasks at a less than optimal level. Like an overloaded electrical circuit, either the consumption must be reduced or a circuit failure is experienced.

Effective workload management ensures essential operations are accomplished by planning and then placing them in a sequence that avoids work overload. As a pilot gains experience, he or she learns to recognize future workload requirements and can prepare for high workload periods during times of low workload.

Reviewing the appropriate chart and setting radio frequencies well in advance of need help reduce workload as a flight nears the airport. In addition, a pilot should listen to Automatic Terminal Information Service (ATIS), Automated Surface Observing System (ASOS), or Automated Weather Observing System (AWOS), if available, and then monitor the tower frequency or Common Traffic Advisory Frequency

(CTAF) to get a good idea of what traffic conditions to expect. Checklists should be performed well in advance so there is time to focus on traffic and ATC instructions. These procedures are especially important prior to entering a high-density traffic area, such as Class B airspace

To manage workload, items should be prioritized. For example, during any situation, and especially in an emergency, a pilot should remember the phrase "aviate, navigate, and communicate." This means that the first thing a pilot should do is make sure the aircraft is under control, then begin flying to an acceptable landing area. Only after the first two items are assured should a pilot try to communicate with anyone.

Another important part of managing workload is recognizing a work overload situation. The first effect of high workload is that a pilot begins to work faster. As workload increases, attention cannot be devoted to several tasks at one time, and a pilot may begin to focus on one item. When a pilot becomes task saturated, there is no awareness of additional inputs from various sources, so decisions may be made on incomplete information, and the possibility of error increases.

A very good example of this is inadvertent IMC. Once entering into bad weather, work overload becomes immediate. Mentally, the pilot must transition from flying outside of the aircraft to flying inside the aircraft. Losing all visual references can cause sensory overload and the ability to think rationally is gone. Instead of trusting the aircrafts instruments, pilots try to hang on to the little visual references that they have and forget all about the other factors surrounding them. Instead of slowing the aircraft down they increase airspeed. Because they are looking down for visual references they forget about the hazards in front of them and finally, because they are not looking at the flight instruments, the aircraft is not level. All of this can be avoided by proper training and proper planning. If going inadvertent IMC is your only course of action, pilots must commit to it and fly the aircraft using only the flight instruments and not trying to follow what little visual references they have.

When a work overload situation exists, a pilot needs to:

- Stop,
- Think,
- Slow down, and then
- Prioritize.

It is important for a pilot to understand how to decrease workload by:

- Placing a situation in the proper perspective,
- Remaining calm, and
- Thinking rationally.

These key elements reduce stress and increase the pilot's ability to fly safely. They depend upon the experience, discipline, and training that each safe flight earns. It is important to understand options available to decrease workload. For example, setting a radio frequency may be delegated to another pilot or passenger, freeing the pilot to perform higher priority tasks.

Situational Awareness

In addition to learning to make good aeronautical decisions, and learning to manage risk and flight workload, situation awareness (SA) is an important element of ADM. Situational awareness is the accurate perception and understanding of all the factors and conditions within the four fundamental risk elements (PAVE) that affect safety before, during, and after the flight. Situation awareness (SA) involves being aware of what is happening around you to understand how information, events, and your own actions will impact your goals and objectives, both now and in the near future. Lacking SA or having inadequate SA has been identified as one of the primary factors in accidents attributed to human error

Situational awareness in a tiltrotor can be quickly lost. Understanding the significance and impact of each risk factor independently and cumulatively aid in safe flight operations. It is possible, and all too likely, that we forget flying while at work. Our occupation, or work, may be conducting long line operations, maneuvering around city obstacles to allow a film crew access to news events, spraying crops, ferrying passengers or picking up a patient to be flown to a hospital. In each case we are flying a tiltrotor. The moment we fail to account for the aircraft systems, the environment, other aircraft, hazards, and ourselves, we lose situational awareness.

To maintain SA, all of the skills involved in CRM/SRM are used. For example, an accurate perception of pilot fitness can be achieved through self-assessment and recognition of hazardous attitudes. A clear assessment of the status of navigation equipment can be obtained through workload management, while establishing a productive relationship with ATC can be accomplished by effective resource use.

Obstacles to Maintaining Situational Awareness

What distractions interfere with our focus or train of thought? There are many. A few examples pertinent to aviation, and tiltrotors specifically, follow.

Fatigue, frequently associated with pilot error, is a threat to aviation safety because it impairs alertness and performance. *[Figure 17-7]* The term is used to describe a range of experiences from sleepy or tired to exhausted. Two major physiological phenomena create fatigue: circadian rhythm disruption and sleep loss.

Many aviation jobs require scheduling flexibility, frequently affecting the body's circadian rhythm. You may be flying a day flight Monday and then at night on Tuesday. Your awareness of how your body and mind react to this variation in schedule is vital to safety. This disruptive pattern may result in degradation of attention and concentration, impaired coordination, and decreased ability to communicate.

Physical fatigue results from sleep loss, exercise, or physical work. Factors such as stress and prolonged performance of cognitive work result in mental fatigue. Consecutive days of flying the maximum allowable flight time can fatigue a pilot, mentally and physically. It is important to take breaks within the workday, as well as days off when possible. When you find yourself in this situation, take an objective, honest assessment of your state of mind. If necessary, use rest periods to allow rejuvenation of the mind and body. *[Figure 17-8]*

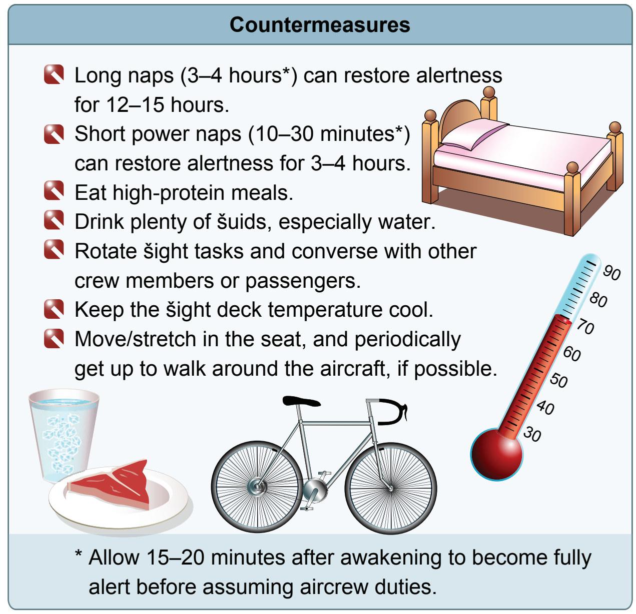

Figure 17-8. *Countermeasures to fatigue according to the FAA Civil Aerospace Medical Institute (CAMI).*

Fatigue also occurs under circumstances in which there is anticipation of flight followed by inactivity. For instance, a pilot is given a task requiring a specific takeoff time. In anticipation of the flight, the pilot's adrenaline kicks in and situational awareness is elevated. After a delay (weather, maintenance, or any other unforeseen delay), the pilot feels a let down, in effect, becoming fatigued. Then, upon resuming the flight, the pilot does not have that same level of attention.

Complacency presents another obstacle to maintaining situational awareness. Defined as overconfidence from repeated experience with a specific activity, complacency has been implicated as a contributing factor in numerous aviation accidents and incidents. When activities become routine, a pilot may have a tendency to relax and not put as much effort into performance. Like fatigue, complacency reduces a pilot's effectiveness on the flight deck. However, complacency is more difficult to recognize than fatigue, since everything seems to be progressing smoothly.

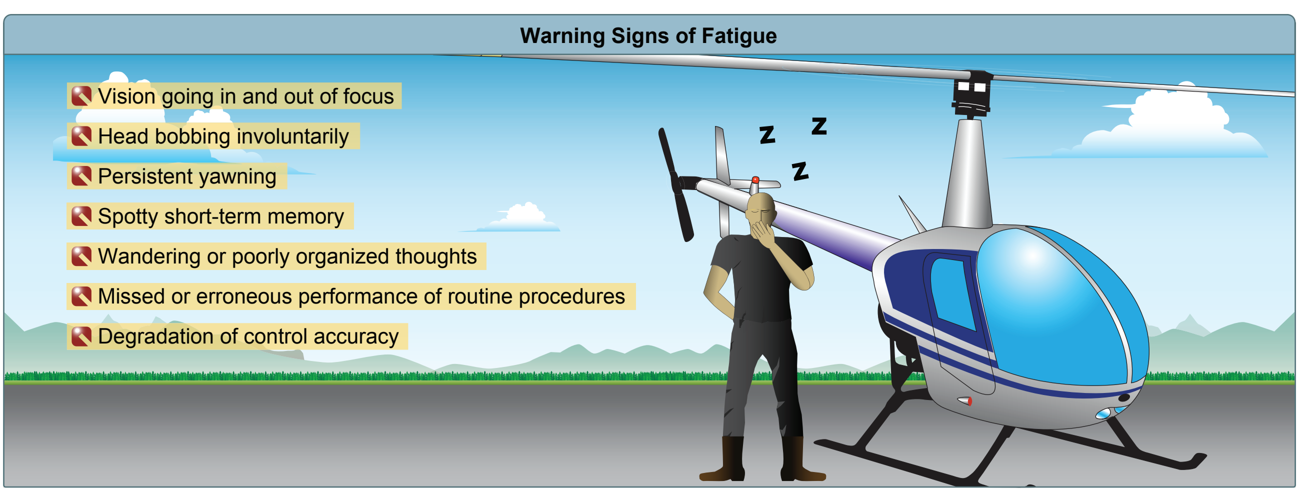

Figure 17-7. *Warning signs of fatigue according to the FAA Civil Aerospace Medical Institute (CAMI).*

Since complacency seems to creep into our routine without notice, ask what has changed. The minor changes that go unnoticed can be associated with the four fundamental risks we previously discussed: pilot, aircraft, environment, and external pressures.

As a pilot, am I still using checklists or have I become reliant on memory to complete my checks? Do I check NOTAMs before every flight or only when I think it is necessary? And the aircraft: did I feel that vibration before or is it new? Was there a log book entry for it? If so, has it been checked?

Complacent acceptance of common weather patterns can have huge impacts on safety. The forecast was for clearing after the rain shower, but what was the dew-point spread? The winds are greater than forecast. Will this create reduced visibility in dusty, snowy areas or exceed wind limitations?

While conducting crop spraying, a new agent is used. Does that change the weight? Does that change the flight profile and, if so, what new hazards might be encountered? When things are going smoothly, it is time to heighten your awareness and become more attentive to your flight activities.

Advanced avionics have created a high degree of redundancy and dependability in modern aircraft systems, which can promote complacency and inattention. Routine flight operations may lead to a sense of complacency, which can threaten flight safety by reducing situational awareness

Loss of situational awareness can be caused by a minor distraction that diverts the pilot's attention from monitoring the instruments or scanning outside the aircraft. For example, a gauge that is not reading correctly is a minor problem, but it can cause an accident if the pilot diverts attention to the perceived problem and neglects to control the aircraft properly.

Operational Pitfalls

There are numerous classic behavioral traps that can ensnare the unwary pilot. Pilots, particularly those with considerable experience, try to complete a flight as planned, please passengers, and meet schedules. This basic drive to achieve can have an adverse effect on safety and can impose an unrealistic assessment of piloting skills under stressful conditions. These tendencies ultimately may bring about practices that are dangerous and sometimes illegal, and may lead to a mishap. Pilots develop awareness and learn to avoid many of these operational pitfalls through effective CRM/SRM training. *[Figure 17-9]*

Controlled Flight Into Terrain (CFIT) Awareness

An emergency medical services (EMS) helicopter departed for a night flight to transport an 11-day-old infant patient from one hospital to another. No record was found indicating the pilot obtained a weather briefing before departure. The pilot had a choice of taking either a direct route that crossed a remote area of rugged mountainous terrain with maximum ground elevations of about 9,000 feet or a route that was about 10 minutes longer and followed an interstate highway with maximum ground elevations of about 6,000 feet. Radar data, which show about 4 minutes of the aircraft's flight before coverage was lost due to mountainous terrain, are consistent with the flight following the direct route.

A search was initiated about 4 hours after the aircraft did not arrive at the destination hospital, and the wreckage was located the following morning. Physical evidence observed at the accident site indicated that the aircraft was in level flight at impact and was consistent with CFIT. *[Figure 17-10]*

CFIT is a type of accident that continues to be a major safety concern, while at the same time difficult to explain because it involves a pilot controlling an airworthy aircraft that is flown into terrain (water or obstacles) with inadequate pilot awareness of the impending disaster.

One constant in CFIT accidents is that outside visibility is limited, or the accident occurs at night and the terrain is not seen easily until just prior to impact. Another commonality among CFIT accidents is lack of situational awareness. This includes not only horizontal awareness, knowing where the aircraft is over the ground, but also vertical awareness.

Training, planning, and preparation are a pilot's best defenses for avoiding CFIT accidents. For example, take some time before takeoff to become familiar with the proposed flight and the terrain. Avoidance of CFIT begins before the aircraft departs the home location. Proper planning, including applied risk mitigation must occur before the aircraft is even started. Thorough assessment of terrain, visibility, pilot experience and available contingencies must be conducted. If necessary, delay or postpone the flight while on the ground. The decision to abort the flight is much easier to make in the planning room than in the air. In case conditions deteriorate once in flight. Have contingency options available.

While many CFIT accidents and incidents occur during nonprecision approaches and landings, great measures have

Operational Pitfalls

Peer Pressure
It would be foolish and unsafe for a new pilot to attempt to compete with an older, more experienced pilot. The only safe competition should be completing the most safe flights with no one endangered or hurt and the aircraft returned to service. Efficiency comes with experience and on-the-job training.

Mind Set
A pilot should be taught to approach every day as something new.

Get-There-Itis
This disposition impairs pilot judgment through a fixation on the original goal or destination, combined with a disregard for any alternative course of action.

Duck-Under Syndrome
A pilot may be tempted to arrive at an airport by descending below minimums during an approach. There may be a belief that there is a built-in margin of error in every approach procedure, or the pilot may not want to admit that the landing cannot be completed and a missed approach must be initiated.

Scud Running
It is difficult for a pilot to estimate the distance from indistinct forms, such as clouds or fog formation.

Continuing Visual Flight Rules (VFR) Into Instrument Conditions
Spatial disorientation or collision with ground/obstacles may occur when a pilot continues VFR into instrument conditions. This can be even more dangerous if the pilot is not instrument rated or current.

Getting Behind the Aircraft
This pitfall can be caused by allowing events or the situation to control pilot actions. A constant state of surprise at what happens next may be exhibited when the pilot is "getting behind" the aircraft.

Loss of Positional or Situational Awareness
In extreme cases of a pilot getting behind the aircraft, a loss of positional or situational awareness may result. The pilot may not know the aircraft's geographical location, or may be unable to recognize deteriorating circumstances.

Operating Without Adequate Fuel Reserves
Pilots should use the last of the known fuel to make a safe landing. Bringing fuel to an aircraft is much less inconvenient than picking up the pieces of a crashed helicopter! Pilots should land prior to whenever their watch, fuel gauge, low-fuel warning system, or flight planning indicates fuel burnout. They should always be thinking of unforecast winds, richer-than-planned mixtures, unknown leaks, mis-servicing, and errors in planning. Newer pilots need to be wary of fuselage attitudes in low-fuel situations. Some helicopters can port air into the fuel system in low-fuel states, causing the engines to quit or surge.

Descent Below the Minimum En Route Altitude
The duck-under syndrome, as mentioned above, can also occur during the en route portion of an IFR flight.

Flying Outside the Envelope
The pilot must understand how to check the charts, understand the results, and fly accordingly.

Neglect of Flight Planning, Preflight Inspections, and Checklists
All pilots and operators must understand the complexity of the helicopter, the amazing number of parts, and why there are service times associated with certain parts. Pilots should understand material fatigue and maintenance requirements. Helicopters are unforgiving of disregarded maintenance requirements. Inspections and maintenance are in place for safety; something functioning improperly can be the first link in the error chain to an accident. In some cases, proper maintenance is a necessary condition for insurance converage.

Figure 17-9. *Operational pitfalls.*

been taken to improve instrument training, equipment and procedures. For the qualified pilot, instrument flight should not be avoided, but rather, trained as a viable option for safely recovering the aircraft. Like any other training, frequent instrument training builds confidence and reassurance

Good instrument procedures include studying approach charts before leaving cruise altitude. Key fixes and airport elevation must be noted and associated with terrain and obstacles along the approach path. Pilots should have a good understanding of both approach and departure design criteria

Figure 17-10. *Helicopter heading straight for mountain.*

to understand fully the obstacle clearance margins built into them. Some pilots have the false belief that ATC provides obstacle clearance while en route off airways. The pilot is ultimately responsible for obstacle clearance.

Altitude error is another common cause of CFIT. Cases of altitude error involve disorientation with respect to the NAVAID, improper transition on approach, selecting the wrong NAVAID, or just plain lack of horizontal situational awareness. Today's modern aircraft have sophisticated flight directors, autopilots, autothrottles, and flight management systems. These devices make significant contributions to the overall safety of flight, but they are only machines that follow instructions. They do whatever is asked of them, even if it is wrong. When commanded, they unerringly follow instructions—sometimes straight into the ground. The pilot must ensure that both vertical and horizontal modes are correct and engaged. Cross-check autopilots constantly.

When automated flight equipment is not available, great care must be taken to prepare properly for a night flight. CRM/SRM becomes more challenging under the cover of darkness and caution should be exercised when determining what artificial light source to use inside the aircraft. A light source that is too bright will blind the pilot from seeing outside obstacles or rising terrain. Certain colored lenses bleach out symbols and markings on a map. Conduct this planning on the ground, in a dark room if necessary, before the actual flight.

Pilots must be even more conservative with their decision-making and planning when flying at night. Flying becomes more difficult due to the degradation of our sensory perception and the lack of outside references. Beginning with preflight, looking over the aircraft with a flashlight can cause pilots to miss a discrepancy that they would easily see during the day. For example, failing to remove one or all if the tie downs and attempting to take off would probably result in a dynamic rollover accident. Whenever possible, preflight inspection should always be conducted during the day or in a lighted hangar. Depth perception is less acute; therefore, hover height should be increased to avoid contact with obstacles and hover speed should be reduced. Weather conditions can be very deceptive and difficult to detect in flight under night conditions. On a low-illumination night, it is easy to fly into clouds without realizing it before it is too late to correct.

Due to the number of recent CFIT night accidents, the NTSB issued a safety alert in 2008 about avoiding night CFIT accidents. That alert included the following information:

- Terrain familiarization is critical to safe visual operations at night. Use sectional charts or other topographic references to ensure the aircraft will safely clear terrain and obstructions all along the route.
- When planning a nighttime VFR flight, follow IFR practices, such as climbing on a known safe course until well above surrounding terrain. Choose a cruising altitude that provides terrain separation similar to IFR flights (2,000 feet above ground level in mountainous areas and 1,000 feet above the ground in other areas). Using this technique, known obstacles, such as towers, will be avoided.
- When receiving radar services, do not depend on ATC to warn of terrain hazards. Although controllers try to warn pilots if they notice a hazardous situation, they may not always recognize that a particular VFR aircraft is dangerously close to terrain.
- When ATC issues a heading with an instruction to "maintain VFR," be aware that the heading may not provide adequate terrain clearance. If any doubt exists about your ability to avoid terrain and obstacles visually, advise ATC immediately and take action to reach a safe altitude.
- For improved night vision, the FAA recommends the use of supplemental oxygen for flights above 5,000 feet.
- Obtain as much information about areas in which you will be flying and the routes to by utilizing hazard maps and satellite imagery.
- Before flying at night to unfamiliar remote areas or areas with hazardous terrain, try to arrange a day flight for familiarization.
- If a pilot flies at night, especially in remote or unlit areas, consider whether a global positioning system (GPS)-based terrain awareness unit would improve the safety of the flight

Of particular note in the 2008 safety alert is a comment regarding oxygen use above 5,000 feet. Most general aviation aircraft are neither required nor equipped for supplemental oxygen use at this altitude. Due to the physiological importance of oxygen in night vision, care should be taken to exercise light discipline. Interior lighting should be lowered to the lowest possible levels, but must allow adequate illumination of necessary systems and instruments. This, in turn, allows greater recognition of outside obstacles and terrain features.

Limited outside visibility is one constant in CFIT accidents. In the accident cited at the beginning of this section, it appears the pilot failed to obtain a weather briefing. If the pilot had obtained one, he would probably have learned of the cloud cover and light precipitation present along his planned route of flight. The limited outside visibility probably caused the CFIT accident since no evidence was found of any pre-impact mechanical discrepancies with the aircraft's airframe or systems that would have prevented normal operation.

Automation Management

Automation management is the control and navigation of an aircraft by means of the automated systems installed in the aircraft. One of the most important concepts of automation management is simply knowing when to use it and when not to use it.

Ideally, a pilot first learns to perform airman certification standards (ACS) maneuvers and procedures in the aircraft manually, or hand flying. After successfully demonstrating proficiency in the basic maneuvers, the pilot is then introduced to the available automation and/or the autopilot. Obviously, in some aircraft, not all automated systems may be disengaged for basic flight. The purpose of basic flight without automation is to ensure the pilot can hand fly the maneuver when necessary.

Advanced avionics offer multiple levels of automation, from strictly manual flight to highly automated flight. No one level of automation is appropriate for all flight situations, but to avoid potentially dangerous distractions when flying with advanced avionics, the pilot must know how to manage the course indicator, the navigation source, and the autopilot. It is important for a pilot to know the peculiarities of the particular automated system in use. This ensures the pilot knows what to expect, how to monitor for proper operation, and promptly take appropriate action if the system does not perform as expected.

At the most basic level, managing the autopilot means knowing at all times which modes are engaged and which modes are armed to engage. The pilot needs to verify that armed functions (e.g., navigation tracking or altitude capture) engage at the appropriate time. Automation management is a good place to practice the call-out technique, especially after arming the system to make a change in course or altitude.

Chapter Summary

This chapter focused on aeronautical decision-making, which includes CRM/SRM training, risk management, workload or task management, situational awareness, CFIT awareness, and automation management. Factors affecting a pilot's ability to make safe aeronautical decisions were also discussed. The importance of learning how to be aware of potential risks in flying, how to clearly identify those risks, and how to manage them successfully were also explored.

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