ACT ARC Recommendation 19-4

Energy Management

I. Submission

The recommendation(s) below were submitted by the Flight Path Management Workgroup (FPM WG) for consideration by the Air Carrier Training Aviation Rulemaking Committee (ACT ARC) Steering Committee at F2F–21, November 13-14, 2019. The ACT ARC Steering Committee adopted the recommendations, and they are submitted to the Federal Aviation Administration as ACT ARC Recommendation 19-4.

II. Statement of the Issue

The FPM WG was asked to evaluate the adequacy of the existing published Federal Aviation Administration (FAA) regulatory and guidance materials on the subject of Energy Management, including material related to pilot training and competency in this area, and make recommendations, where appropriate, to supplement the FAA materials. This tasking was based on a variety of factors, including:

a. Reports of pilot deviations such as missed altitude and/or speed constraints, particularly on Standard Instrument Departures (SID) and Standard Terminal Arrival Procedures (STAR);
b. Variations in the operating experience of pilots entering the workforce;
c. How NextGen technologies and airspace procedures impact the energy management component of Flight Path Management (FPM);
d. Common Energy Management "gotchas"[1] (*e.g.*, getting vectors off, then back on, a STAR during a "descend via" clearance; or low altitude level-offs).

Definitions

Flight Path Management is the planning, execution, and assurance of the guidance and control of aircraft trajectory and energy, in flight or on the ground.

Energy Management is the planning and control of airspeed (or groundspeed), altitude, thrust,[2] aerodynamic drag (speed brakes, slats/flaps, gear), and trajectory to achieve desired targets appropriate for the operational objectives.

Energy State is the combination and availability of airspeed, altitude, thrust, and aerodynamic drag at any given time.

Trajectory is the lateral and vertical flight path of an aircraft as it travels through a defined airspace.

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[1] Flight guidance and flight control system-behavioral challenges, and environmental/circumstantial traps that are known to lead to flight path-related errors are commonly referred to as "gotchas".
[2] In some documents, airspeed is referred to as kinetic energy, altitude as potential energy, and thrust as chemical energy.

III. Recommendation(s)

The ACT ARC proposes the following recommendations for FAA consideration:

1) The FAA has recently published regulatory and guidance material pertaining to Energy Management, including the training elements required as part of Title 14 Code of Federal Regulations (14 CFR) § 121.423 (Extended Envelope Training) and the recommendations contained in FAA Safety Alert for Operators 17007 (Manual Flight Operations Proficiency). Their effect may not be fully realized in air carrier operations at this time. The ACT ARC recommends the FAA monitor sources of data to determine the effectiveness of this guidance to assess the need for further guidance.
2) The ACT ARC recommends the FAA publish further guidance for industry stakeholders in the area of Energy Management. (See Attachments B and C.)
    a. Attachment B contains a list of FAA and industry documents reviewed for this task that, in part, address energy management.
    b. Attachment C contains recommended energy management training objectives and training scenarios that address perceived gaps in existing guidance.

IV. Rationale and Discussion

The ACT ARC previously submitted several recommendations that addressed, in part, training for the Energy Management aspect of Flight Path Management (FPM). A list of those recommendations is included in Attachment A to this document. Previous FPM recommendations did not include a detailed definition of Energy Management. To ensure a common understanding so that the FPM recommendations are consistently interpreted, Energy Management is defined above in Section II.

Pilot training should already include energy management, and a substantial body of guidance material on this topic already exists. For example, there are FAA and industry resources that provide information on how to integrate energy management into upset, extended envelope, and approach/landing training, and that also include some normal operating envelope scenarios. Some of these have only recently been implemented and effectiveness of the guidance is not yet known.

Energy management is needed in all phases of flight, but one identified area of concern has been the difficulty of complying with some SID/STAR restrictions. The perceived complexity of some terminal procedures,[3] coupled with variations in pilot operating experience and energy management “gotchas,” may increase the possibility of undesired flight path and energy states. Some of this difficulty may stem from mismanaged automation, and prior FPM recommendations address that area for both pilot and instructor. Current FAA and industry guidance may not sufficiently mitigate these issues. With the increased precision required on new and planned NextGen procedures[4] (*e.g.*, Trajectory Based Operations (TBO), Radius-to-Fix (RF) legs), pilot understanding and proper application of energy management continues to be necessary in all phases of flight. Although the FPM WG has identified SID/STAR compliance as a

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[3] See Chandra, Divya C., and Rebecca Markunas, Line Pilot Perspectives on Complexity of Terminal Instrument Flight Procedures, Volpe July 2017.
[4] FAA, Performance Based Navigation National Airspace System (PBN NAS) Navigation Strategy, 2016

key area of concern, additional training scenarios are provided in Attachment C to address other areas not sufficiently covered in FAA or industry documents.

V. Background Information

ACT ARC Recommendation 19-4 addresses item 5 in the FPM WG Scope of Work and Initiative #45 (see below):

<u>FPM WG Scope of Work:</u>

5) Recommend guidance for the knowledge and skills that air carrier pilots need for energy management as it relates to flight path management, during normal, non-normal, and rare normal conditions. When developing recommendations, the WG will initially answer the following questions:
   a) Based on operational data, where and when are pilots having difficulty with managing energy?
   b) What are current and recommended practices for pilot training of energy management?
   c) What are the recommended learning objectives for pilot energy management training, and what academic and training elements should be included, considering the following:
      i) How should pilots manage energy for executing airspace procedures (departures, arrivals, approaches)?
      ii) How should pilots manage energy in cruise and what are the risks/threats?
      iii) How and under what circumstances should energy management be included in briefings?
      iv) How should pilots determine whether an ATC clearance (including an amended clearance) can be met?
      v) How should pilots manage energy for stabilized approaches?
      vi) How should pilots manage energy during takeoffs and landings?
      vii) How should pilots manage energy during go-arounds/balked landings?
      viii) What are the energy management tasks that pilots need to prevent upsets and loss of control?
      ix) How should pilots use lift and drag devices to manage energy?
      x) What are common energy management "gotchas"?
   d) What new operations and NextGen technologies may change how pilots manage energy?

<u>ACT ARC Initiatives:</u>

Initiative #45: Examine what knowledge and skills pilots need for energy management

<u>Source Reports</u>

- See Attachment B

Attachment A: ACT ARC Recommendations containing, in part, training for Energy Management:

1. Recommendation 16-3: Operational Mode Awareness
    a. "Therefore, it is imperative that flight crews are thoroughly trained and understand the implications and relationships of each mode since the respective mode communicates the source of the aircraft flight path and energy. It is also imperative that both crew members, as a team, understand the current mode status and its controlling system to effectively manage flight path and energy."
    b. Recommendation to incorporate "…suggested tools/techniques for effective mode awareness/understanding that enhance flight path/energy management…"
    c. To incorporate a confirmation methodology where "Regardless of the form of the strategy, the objective is to ensure that everyone in the flight deck understands the active mode, the effects of the newly engaged mode, and skillfully reacts to ensure the aircraft trajectory and energy remains as desired."

2. Recommendation 16-4: Training Elements for Training the Pilot Monitoring
    a. "Every flight is vulnerable to distractions and interruptions, therefore pilots need training to understand how to protect the flight path and aircraft energy state, while managing distractions and interruptions."
    b. "Ensure pilots demonstrate a thorough understanding of combinations/levels of flight guidance and flight control automation (e.g., given a certain set of circumstances, what will happen next?)."
    c. "Train pilots to anticipate, recognize, and recover from known flight guidance (includes FMS) and flight control (includes autopilot and, autothrottles) system-behavioral challenges (e.g., subtle mode reversions), and environmental/ circumstantial traps that are known to lead to flight path-related errors (e.g., vectors off, then back on, a STAR during a "descend via" clearance)."
        i. Note: Pilots commonly refer to such examples as "gotchas.".
    d. Instructor knowledge to include "A thorough understanding of flight guidance and flight control systems, including a thorough understanding of what will happen 'next' given a certain set of flight circumstances, and the reasons why."

3. Recommendation 16-9: Manual Flight Operations
    a. Foundational knowledge and skill proficiency list
    b. "An incremental approach should be used so that pilots can build from refreshing basic maneuvers to managing a complex procedural non-precision approach (NPA) to Circle to Land, to exploring the extremities of the flight envelope (and associated Warnings) to eventually managing an aircraft that is in an undesired state and /or in situations beyond the scope of non-normal checklists."
    c. Attachment A: Proposed Content for Flight Path Management Policy and Procedures on Manual Flight Operations contains exercises that build on the foundational knowledge and skill proficiency list, to include Energy Management.

4. Recommendation 16-10: Flight Path Management Philosophy, Policy, and Procedures
    a. “Planning, executing and assuring the aircraft trajectory requires continuous vigilance and use of the appropriate tools at the appropriate time to ensure safe and efficient flight.”
    b. “Operators should provide guidance on the use of all tools (automated systems, manual flight, etc.). That guidance should provide detailed information on the operational application and utility of the respective tool(s) and consideration for combinations to best address the situation.”
    c. Operational Philosophy of Flight Path Management
        i. “Ensuring that the aircraft is on a safe flight path is the highest priority of each pilot on the flight crew” with the term “Flight Path” meaning the trajectory and energy state of the aircraft.

5. Recommendation 17-1: Manual Recovery of Unintended Autoflight States
    a. “For the purposes of this training, manual intervention consists of action taken by the PF to directly control pitch, bank, yaw, or thrust (or any combination thereof) so as to correct the trajectory or energy of the aircraft. This will generally involve disconnecting the autopilot, or autothrust, or both, and establishing an attitude and power setting that places the aircraft on the desired flight path.”
    b. “Pilot competence and confidence in manual handling across all flight regimes is needed, and therefore this scenario-based recovery training module must be built on a foundation of basic hand-flying competency training.”
    c. Suggested Training scenarios incorporate various energy states from “descend via” clearance scenarios to significant post-escape situations.

6. Recommendation 18-1: Reasonableness Checks of Information Automation Systems
    a. Examples of the Application of Reasonableness Checks includes “Issues with Top of Descent Calculation” where the crew evaluates FMS depicted TOD with what the aircraft is capable of achieving in the conditions.

Attachment B: FAA and industry documents discussing, in part, Energy Management

The Flight Path Management Workgroup (FPM WG) conducted a review of FAA and industry documents related to energy management with specific focus on air carrier operations. The list below is not intended to be comprehensive but is designed to provide the FAA with a list of relevant information/guidance related to energy management.

Industry documents reviewed:

1. IATA Guidance Material and Best Practices for the Implementation of Upset Prevention and Recovery Training (2nd Edition)
    a. Section 5 – Academic Training
    b. Section 8 – Instructors
        i. 8.3.1 Understanding AOA (Topic is partially addressed in FAA AC 120-111, Appendix 1)
        ii. 8.4.5 Energy Management (Topic is addressed in FAA AC 120-111, Appendix 1)

2. ICAO Doc 10011 Manual on Aeroplane Upset Prevention and Recovery Training
    a. Subjects and training elements – Energy Management
    b. Section 3 – Energy Management

3. Airplane Upset Recovery Training Aid (Rev 2)
    a. Section 2.5.2 – Energy States
    b. Section 2.5.5.11.9 – Automation during High Altitude Flight
        i. High altitude stall warning setup (Topic is partially addressed in FAA AC 61-138, 12(a))

4. Flight Safety Foundation Approach and Landing Accident Reduction Kit (FSF ALAR)
    a. Briefing Note 4.1 (Descent and approach Profile Management)
        i. Descent Profile Monitoring and recommendations. Discussion includes items such as planning to be at certain altitude/distances from the airport to allow for proper deceleration and descent
        ii. Descent Profile Adjustment/Recovery and recommendations of how to correct the profile
        iii. Adverse Factors and Typical Errors listed to help mitigate/avoid.
    b. Briefing Note 4.2 (Energy Management)
        i. Aircraft energy conditions
        ii. Aircraft deceleration characteristics
        iii. Description and informational points of flying the power curve
    c. Briefing Note 6.2 (Manual Go-around)
        i. Understanding the flight dynamics of the go-around including methods to mitigate the compounding pitch effects during the procedure
        ii. Flying a go-around and recommendation for an “ultimate value” of pitch attitude that should not be exceeded, as applicable to the aircraft
    d. Briefing Note 7.4 (Visual Approaches)

        i. Visual approach factors listed to help mitigate/avoid. List includes topics such as downwind leg too short, incorrect anticipation of aircraft deceleration characteristics, and belief that the aircraft will be stabilized at the minimum stabilization height.
    e. Briefing Note 8.3 (Landing Distances) (Topic addressed in FAA AC 91-79A)
        i. Landing distance factor table, easy way to depict how several factors influence the stopping distance
    f. Briefing Note 8.4 (Braking Devices) (Topic addressed in FAA AC 91-79A)
        i. Visual and graphical descriptions of the deceleration potential of the braking devices at landing
        ii. List of factors effecting braking
    g. Briefing Note 8.5 (Wet or Contaminated Runways) (Topic addressed in FAA AC 91-79A)
        i. Operational guidelines for landing with wet or contaminated runways

5. Flight Safety Foundation Go-Around Decision-Making and Execution Project
    a. Section 6.2 – Analysis: Go-Around Execution
    b. Section 6.5 – Recommendations: Go-Around Execution (Rec #5, 7, 11)

FAA documents reviewed:

1. AC 61-138 Change 1 Airline Transport Pilot Certification Training Program
    a. Academic Training
        i. 12 (a)(1) High Altitude Operations
        ii. 12 (a)(3)(c) Upset Prevention and Recovery Training
    b. FSTD Training
        iii. 15 (b)(2) Automation
        iv. 15 (c)(1) Runway Safety and Adverse Weather
        v. 15 (c)(2) High altitude operations, Stall and Upset prevention and recovery
2. AC 91-79A Change 1 Mitigating the Risks of a Runway Overrun Upon Landing
    a. Discussion of stabilized approach and it's conditions/effects
        a. Flaps, speed, rate of descents, etc.
    b. Reference to and use of FSF ALAR study (e.g. excess airspeed, reverse thrust use, braking use, factors affecting landing distance, etc.)
    c. Appendix 4 – Unstabilized Approach Case Study
3. AC 120-71B Standard Operating Procedures and Pilot Monitoring Duties for Flight Deck Crewmembers
    a. 6.7 Training for PM
        a. Discussion of vectors off, then back on a STAR and what to do with the automation.
4. AC 120-109A Change 1 Stall Prevention and Recovery Training
    a. 3-2(c) Discussion of AOA understanding
    b. 3-2(d) Discussion of high altitude considerations
5. AC 120-111 Change 1 Upset Prevention and Recovery Training

- a. 2.5 Instructor Training
  - a. e. Energy Management
- b. Appendix 1
  - a. Aerodynamics
    - i. (b) Advanced aerodynamics
  - b. Energy Management
    - i. Academic and Flight
  - c. Flightpath Management
    - i. Academic and Flight

6. Airline Transport Pilot and Type Rating for Airplane Airman Certification Standards (FAA-S-ACS-11) Change 1
   - [1] Preflight prep - High altitude aerodynamics
     - (a) Knowledge – Energy Management
     - (b) Skill – If a cruise altitude is reached, manage the airplane's systems and energy state
   - [2] Normal approach and landing
     - (a) Knowledge – A stabilized approach, to include energy management concepts
   - [3] Go-around/Rejected Landing
     - (a) Knowledge – A stabilized approach, to include energy management concepts
   - [4] Powerplant failure
     - (a) Knowledge – A stabilized approach, to include energy management concepts

Attachment C: Energy management training objectives and training scenarios

In addition to the energy management tasks detailed in current FAA and industry documents, the following potential training scenarios have been identified to help pilots plan and control management of airspeed (or groundspeed), altitude, thrust, and aerodynamic drag (speed brakes, slats/flaps, gear), to control the trajectory and meet established constraints and criteria to achieve desired outcomes/targets.[5] As noted in Recommendation 16-9, Manual Flight Operations, a pilot requires foundational knowledge and skill proficiency in areas including pitch and power basics; high vs. low altitude aircraft performance; aircraft type-specific factors with an impact on handling; and timing, coordination, and anticipation. Those remain appropriate prerequisites before training the scenarios noted in this Attachment. For the purpose of this discussion, it is assumed the pilot knows the desired targets.

At a very basic level, managing energy can be described as being able, for each moment of the flight, to answer these three questions for the current situation:

- Am I high or low, and am I fast or slow in comparison to where I need to be right now?
- Will the aircraft be on the vertical profile[6] and at the speed target I want at various points in the future?
- What do I need to do to adjust the vertical trajectory[7] or speed if it's not on, or on track to reach the desired target?

The ability to answer these three questions requires the following knowledge and skills:

> <u>Assessment</u> - the ability to determine where the aircraft is in time and space, in terms of both physical position and energy state (*i.e.*, if it is too high/low/fast/slow in comparison to the vertical profile and speed target),
>
> <u>Projection</u> - the ability to predict where the aircraft will be in time and space (minutes or miles) in both position and energy state, in comparison to where it will need to be, and
>
> <u>Intervention</u> - the ability to make the proper flight control inputs (whether through manual control or automation) required to adjust the flight path (trajectory and energy) to achieve the desired targets.

Pilots should continuously monitor and evaluate the energy state of the aircraft (High/Low/Fast/Slow) so that they are able to assess when changes to the energy state are needed, occur, or are projected to occur. Pilots should be able to maintain the flight path in both manual and automated flight.

Examples:

1. In a speed on pitch mode (*e.g.*, Flight Level Change [FLCH], Open Descent [OPDES]),

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[5] Established constraints and criteria are often referred to as targets. These may include items such as Estimated Time of Arrival (ETA) or Required Time of Arrival (RTA).
[6] Vertical Profile is the desired vertical flight path the aircraft is expected to fly, as defined by waypoints, altitudes, and vertical angles. The vertical profile is based upon operational requirements, airspace design, and aircraft capability.
[7] Vertical Trajectory is the actual vertical flight path flown by the aircraft to achieve the desired vertical profile. The vertical trajectory is affected by the aircraft energy state due to flight conditions, aircraft configuration, pilotage, aircraft systems performance, and flyability of the vertical profile.

correcting the rate of descent while maintaining the current mode requires a change of thrust or drag.

2. In a Flight Management System (FMS) path mode (*e.g.*, Vertical Navigation [VNAV] path, Descent [DES]), correcting airspeed while maintaining the current mode requires a change of thrust or drag.

The list of training scenarios should include the following, but should be based on the operator's specific circumstances (*e.g.*, pilot demographics and operational environment) or "gotchas," as identified through operator/industry safety programs:

- A) Lightweight takeoff with low altitude level-off;
- B) Climb restriction, which may include procedures determined to be complex and challenging;
- C) High altitude, performance-limited situations;
- D) Temperature changes at high altitude;
- E) Descent restriction, which may include procedures determined to be complex or challenging;
- F) Visual approaches—
    - a. From initially high and fast situations
        - i. To include identifying general conditions where recovery to a stable approach may not be possible and a go-around is necessary;
        - ii. To include identifying what combination of drag, thrust, and pitch is appropriate to your aircraft type;
    - b. From initially low and slow situations
        - i. To include identifying general conditions where recovery to a stable approach may not be possible and a go-around is necessary;
        - ii. To include identifying what combination of drag, thrust, and pitch is appropriate to your aircraft type;
    - c. From scenarios where air traffic control (ATC) does not vector the aircraft to final;
    - d. From scenarios when groundspeed is significantly different from indicated airspeed, but when environmental conditions permit landing;
- G) Approaches where ATC does not assign speed;
- H) Runway changes;
- I) Landing heavy weight on a short/contaminated or performance-limited runway;
- J) Planning for turnoff after landing;
- K) Lightweight go-around with low altitude level-off;
- L) Deceleration and descent capabilities
    - a. What is the aircraft able to accomplish? Include type-specific "gotchas," if applicable (For example, descent range at idle at best glide speed and in contrast with other configurations, and speeds with varying wind/groundspeed);
    - b. Appropriate use of speedbrakes/flaps/gear;
- M) Max performance escape maneuvers;
- N) Late ATC instructions.