FY2010 Task 1, Report 4:

RUNWAY THREAT AND ERROR MANAGEMENT SYLLABUS FITS TRAINING

A FAA/Industry Training Standards (FITS) Runway Incursion and Wrong Runway Threat and Error Management Training Syllabus for Pilots

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Development of a FITS Threat and Error Management syllabus for Runway Incursions

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INTRODUCTION

As part of the National Runway Safety Plan, the Office of Runway Safety presents a single national strategy for reducing runway incursions and surface incidents. The plan is coordinated across Federal Aviation Administration organizations, and involves airport operators and airspace system users. The plan identifies and prioritizes activities and objectives the Federal Aviation Administration will undertake to improve runway safety. The purpose of the national plan is to provide an overall strategy and ensure that all organizations are working together in a coordinated fashion towards common goals and objectives. The objective of this research is to develop a FAA/Industry Training Standards (FITS) Threat and Error Management (TEM) syllabus for runway incursions and wrong runway incidents. This training syllabus is based on threat and error management and the FITS tenets. The syllabus is divided into three sections covering FITS, TEM, and the runway incursion and wrong runway incidents training scenarios.

In early 2009 the Office of Runway Safety published the National Runway Safety Plan for Fiscal Year (FY) 2009 – FY 2011. The National Runway Safety Plan outlines the FAA's goals to improve runway safety including near and mid-term actions designed to reduce the severity and occurrence of runway incursions. The plan addresses recommendations from the Department of Transportation Inspector General, National Transportation Safety Board, and the General Accounting Office for:

1) Human factors that lead to runway incursions
2) Improvements to airport layout and movement areas to increase safety
3) Improvements to airport signage, lighting and markings, training, education and awareness programs
4) The need for increased industry participation, international cooperation, and the development of various technologies (FAA, 2009a).

This FITS syllabus is intended as a guide for aircraft manufacturers, training providers, and flight schools to use in developing a specific FITS curriculum for their aircraft, geographic region, and customer base. This syllabus is unique in several ways. First, it is a syllabus that uses real-world scenarios as the foundation of the training as the use of real-world scenarios is used to enhance the pilot's decision making skills. The syllabus presents situations and circumstances that pilots face everyday as learning experiences and lessons.

FITS TRAINING PHILOSOPHY

FITS Training is a scenario-based approach to training pilots. It emphasizes the development of critical thinking and flight management skills, rather than solely on traditional maneuver-based skills. The goal of this training philosophy is the accelerated acquisition of higher-level decision-making skills. Such skills are necessary to prevent pilot-induced accidents. The primary tenet of FITS training is that the pilot in training (PT) prepares for the real world of flying by acting as a pilot while in training. Therefore, throughout the syllabus, thePT will take on different tasks or jobs. The second important unique feature of this syllabus and of FITS training is that it is all competency based. When the PT masters a particular skill area in the syllabus, he/she moves on regardless of how much time it takes to reach that point of mastery. This means that each lesson

does not necessarily equal one flight. It may take several flights before the PT masters the elements of the lesson and is ready to move on to the next lesson. Please note that FITS training is conducted under the current Federal Aviation Regulations. Although philosophically FITS is competency based, many training organizations must still require their pilots in training to meet the FAA minimum training hours. Courses under 14 CFR Part 142 and section 141.55(d) may be approved to train to competency and not require an hours minimum.

FITS Training Goals

- Higher Order Thinking Skills
- Aeronautical Decision Making
- Situational Awareness
- Pattern Recognition (Emergency Procedures) and Judgment Skills
- Automation Competence
- Planning and Execution
- Procedural Knowledge
- Psychomotor (Hand-Eye Coordination) Skills
- Risk Management
- Task Management
- Automation Management
- Controlled Flight Into Terrain (CFIT) Awareness

Previous training philosophies assumed that newly certified pilots generally remain in the local area until their aviation skills are refined. This is no longer true with the advent of Technically Advanced Aircraft (TAA). Offering superior avionics and performance capabilities, these aircraft travel faster and further than their predecessors. As a result, a growing number of entry-level pilots are suddenly capable of long distance/high speed travel—and its inherent challenges. Flights of this nature routinely span diverse weather systems and topography requiring advanced flight planning and operational skills. Advanced cockpits and avionics, while generally considered enhancements, require increased technical knowledge and finely tuned automation competence. Without these skills, the potential for an increased number of pilot-induced accidents is daunting. A different method of training is required to accelerate the acquisition of these skills during the training process.

Research has proven that learning is enhanced when training is realistic. In addition, the underlying skills needed to make good judgments and decisions are teachable. Both the military and commercial airlines have embraced these principles through the integration of Line Oriented Flight Training (LOFT) and Crew Resource Management (CRM) training into their qualification programs. Both LOFT and CRM lessons mimic real-life scenarios as a means to expose pilots to realistic operations and critical decision-making opportunities. The most significant shift in these programs has been the movement from traditional maneuver-based training to incorporate training that is scenario-based.

Maneuver-based training emphasizes the mastery of individual tasks or elements. Regulations, as well as Practical Test Standards (PTS), drive completion standards. Flight hours and the ability to fly within specified tolerances determine competence. The emphasis is on development of motor skills to satisfactorily accomplish individual maneuvers. Only limited emphasis is placed

on decision-making. As a result, when the newly trained pilot flies in the real-world environment, he or she is inadequately prepared to make crucial decisions. Scenario Based Training (SBT) and Single Pilot Resource Management (SRM) are similar to LOFT and CRM training. However, each is tailored to the pilot's training needs. These techniques use the same individual tasks that are found in Maneuver Based Training, but script them into scenarios that mimic real-life cross-country travel. By emphasizing the goal of flying safely, the pilot in training correlates the importance of individual training maneuvers to safe mission accomplishment. In addition, the instructor continuously interjects "What If?" discussions as a means to provide the trainee with increased exposure to proper decision-making. Because the "What If?" discussions are in reference to the scenario, there is a clear connection between decisions made and the final outcome. The "What If?" discussions are designed to accelerate the development of decision-making skills by posing situations for the pilot in training to consider. Once again, research has shown these types of discussions help build judgment and offset limited experience.

Questions or situations posed by the instructor must be open-ended (rather than requiring only rote or one-line responses). In addition, the instructor guides the pilot in training through the decision process by: 1) Posing a question or situation that engages the pilot in training in some form of decision-making activity. 2) Examining the decisions made. 3) Exploring other ways to solve the problem. 4) Evaluating which way is best. For example, when the pilot in training is given a simulated engine failure, the instructor might ask questions such as: "What should we do now?" Or, "Why did you pick that place to land?" Or, "Is there a better choice?" Or, "Which place is the safest?" Or, "Why?" These questions force the pilot in training to focus on the decision process. This accelerates the acquisition of improved judgment, which is simply the decision-making process resulting from experience. It is not innate. All of our life experiences mold the judgment tendencies we bring to our flight situations. By introducing decision-making opportunities into routine training lessons, we speed-up acquisition of experience, thus enhancing judgment.

FITS TEACHING METHODS

Scenario Based Training

For Scenario Based Training (SBT) to be effective there must be a purpose for the flight and consequences if it is not completed as planned. It is vital that the pilot in training and the Instructor communicate the following information well in advance of every training flight:

- Purpose of flight
- Scenario destination(s)
- Desired pilot in training learning outcomes
- Desired level of pilot in training performance
- Desired level of automation assistance
- Possible in-flight scenario changes (during later stages of the program)

With the guidance of the Instructor, the pilot in training should make the flight scenario as realistic as possible. This means the pilot in training will know where they are going and what will transpire during the flight. While the actual flight may deviate from the original plan, it allows the pilot in training to be placed in a realistic scenario.

Scenario Planning

Prior to the flight, the Instructor will brief the scenario to be planned. The Instructor will review the plan and offer guidance on how to make the lesson more effective. Discussion, in part, will reflect ways in which the Instructor can most effectively draw out a pilot in training's knowledge and decision processes. This enables the Instructor to analyze and evaluate the pilot in training's level of understanding. After discussion with the Instructor, the pilot in training will plan the flight to include:

- Reason to go flying
- Route
- Destination(s)
- Weather
- NOTAMs
- Desired pilot in training learning outcomes
- Possible alternate scenarios and emergency procedures

Example of Scenario Based Training

Consider the following example: During traditional MBT, the Instructor provides a detailed explanation on how to control for wind drift. The explanation includes a thorough coverage of heading, speed, angle of bank, altitude, terrain, and wind direction plus velocity. The explanation is followed by a demonstration and repeated practice of a specific flight maneuver, such as turns around a point or S turns across the road until the maneuver can be consistently accomplished in a safe and effective manner within a specified limit of heading, altitude, and airspeed***. At the end of this lesson, the pilot in training is only capable of performing the maneuver.***

Now, consider a different example: The pilot in training is asked to plan for the arrival at a specific uncontrolled airport. The planning should take into consideration the possible wind conditions, arrival paths, airport information and communication procedures, available runways, recommended traffic patterns, courses of action, and preparation for unexpected situations. Upon arrival at the airport the pilot in training makes decisions (with guidance and feedback as necessary) to safely enter and fly the traffic pattern using proper wind drift correction techniques. This is followed by a discussion of what was done, why it was done, the consequences, and other possible courses of action and how it applies to other airports. ***At the end of this lesson the pilot in training is capable of explaining the safe arrival at any uncontrolled airport in any wind condition.***

The first example is one of traditional learning, where the focus is on the maneuver. The second is an example of scenario-based training, where the focus is on real world performance. Many course developers in flight training have built on the former option. Traditional training methods in many instances are giving way to more realistic and fluid forms of learning. The aviation

industry is moving from traditional knowledge-related learning outcomes to an emphasis on increased internalized learning in which learners are able to assess situations and appropriately react. Knowledge components are becoming an important side effect of a dynamic learning experience.

Reality is the ultimate learning situation and scenario-based training attempts to get as close as possible to this ideal. In simple terms, scenario-based training addresses learning that occurs in a context or situation. It is based on the concept of situated cognition, which is the idea that knowledge cannot be known and fully understood independent of its context. ***In other words, we learn better, the more realistic the situation is and the more we are counted on to perform.*** Michael Hebron, a well-known golf instructor, suggests that there is little the expert can do in the way of teaching the learner particular motions of the golf swing. Instead, learning has to be experiential and feedback based; only a handful of basic principles are involved. The same goes, he says, for any and all kinds of learning. ***"It's about learning, not about golf."***

Scenario-based training (SBT) is similar to the experiential model of learning. The adherents of experiential learning are fairly adamant about how people learn. ***They would tell us that learning seldom takes place by rote.*** Learning occurs because we immerse ourselves in a situation in which we are forced to perform. We get feedback from our environment and adjust our behavior. We do this automatically and with such frequency in a compressed timeframe that we hardly notice we are going through a learning process. Indeed, we may not even be able to recite particular principles or describe how and why we engaged in a specific behavior. Yet, we are still able to replicate the behavior with increasing skill as we practice. If we could ask Mark MacGuire to map out the actions that describe how he hits a home run, he would probable look at us dumbfounded and say, "I just do it." On the other hand, Mark McGwire could probably describe in detail the size and characteristics of every one of the baseball diamonds he was playing in as well as the strengths, weaknesses and common practices of every one of the pitchers he faced.

Developing Scenario-Based Training

Scenario-based training best fits an open philosophy of blended and multiple learning solutions in which change and experience are valued and the lines between training and performance improvement are blurred. For scenario-based training to be effective it must generally follow a performance improvement imperative. The focus is on improved outcomes rather than the acquisition of knowledge and skills. Success requires a blended, performance-based, and reinforced solution.

An athletic exercise such as basketball might prove to be a very good example. Clearly, the team's objective is to win, which means scoring more points than the other team. That's the performance objective. Each member of the team also has personal performance goals. The coach can stand at a blackboard and explain defensive and offensive diagrams with players, the rules of the game, and so forth. By doing that, he has identified a set of learning subjects (rules and play patterns) that are best delivered in a traditional fashion.

On the other hand, the application of these subjects and the level of proficiency required in their use can only be learned on the court. The scenario in this example is a scrimmage. During a typical scrimmage, experienced players are mixed with non-experienced players and matched against a similarly constituted practice team. The two teams play a game, and the coaches stop the action at appropriate intervals to offer feedback. Learning takes place in a highly iterative fashion often without the player realizing that specific bits of learning are taking place. The scrimmage provides a player with the opportunity to make several decisions, engage in complex and fast-paced behaviors, and immediately see impact. The coach may have some general ideas of basketball in mind and perhaps some specific learning objectives for the day, but in most cases does not know precisely which of them will be addressed during the scrimmage – that depends on the flow of practice.

Similarly, most flight training consists of both kinds of subjects: those amenable to traditional instructional design techniques and those better approached through scenario-based training. Neither is all that useful without the other. Before a learner can engage in a scenario, he or she needs some basic subject knowledge and skill. However, the strongest adherents of the scenario-based approach suggest very little subject knowledge is needed in order to take advantage of SBT. ***The main point is that knowledge without application is worth very little.***

The first step in the scenario design process is to engage a number of subject matter experts in a series of discovery sessions and interactive meetings for the purpose of identifying issues and learning objectives including higher-level and performance objectives. With clearly identified learning objectives, appropriate techniques and where to use them can be specified. In the basketball example, players need some rudimentary knowledge of the game and basic skill in order to make the practice session efficient and effective. Consequently, the required knowledge and skill objects need to be integrated into the actual sessions of practice. So, like a train pulling a number of boxcars, a traditional piece of learning precedes or is integrated into a scenario, with the scenario dictating what information is covered in the traditional piece. If, as described in the scrimmage session above, you don't precisely know what will come up in the practice, you shouldn't waste time in the traditional preparation. It's more efficient to share very basic principles and devote your resources to preparing to teach any situation that may arise. What is important, however, is to establish the boundaries of the scenarios. These are done using performance-based learning objectives (Internalized Responses) as opposed to knowledge-based learning objectives, and are worded as performance objectives rather than skill-based behavior objectives.

For example, in the traditional, more repetitive, intensive flight training sessions, objectives are knowledge-based and tend to be specific and limited. On the other hand, in scenario-based training we are simply trying to determine whether the learner has the minimum necessary knowledge/skill to qualify for the scenario. With scenario-based objectives, we are looking for performance behaviors and indicators of internalized responses, which are usually situational recognition indicators.

Scenario design sessions should resemble focus groups in which participants work through a series of issues, from broad scenario outlines to very specific scenario details. Direct participants to address two general areas: content and style.

Sessions to determine content usually ask participants to:

- Share experiences about the subject event
- Describe desirable outcomes
- Share best practices or known instances of consistent achievement of the desired outcomes
- Create indicators of successful outcomes
- Create strategies expected to lead to successful outcomes
- Establish descriptions of successful and unsuccessful performance behaviors related to these strategies (note that outcome measures and performance behaviors will constitute the evaluative criteria for assessing performance in the scenario).

After the content discussion, ask participants to review the look, feel, and flow of the scenario. This is much like the process used for instructional design. Develop a storyboard with a general beginning and end, using the boundaries established earlier. Talk through the scenario in the session and, through iteration, create a flow script from the results.

With these two elements in place, you can begin the actual construction of the scenario. A subcommittee of Flight Instructors and subject matter experts (SME's) should review and revise the scenario to fit into the whole course of instruction.

Scenarios are meant to be real situations. In an ideal world, an assessment team would evaluate behavior and agree on several critical performance dimensions. The key indicators should come from the initial SME's, in which they also create strategies expected to lead to successful outcomes and establish descriptions of successful and unsuccessful performance behaviors. Outcome measures and performance behaviors will constitute the evaluative criteria for assessing performance in the scenario.

Examples of indicators of successful outcomes are whether an airplane arrived and was secured at the destination airport and how safe were all aspects of the flight or were there any regulatory violations. Strategies are clusters of internally consistent behaviors directed toward the achievement of a goal. Performance behaviors are the key behaviors in those strategies. Establishing these dimensions should be a group process and is usually completed in the subject matter expert design session.

Review, obtain learner feedback, and revise. All learning, even the most traditional, is iterative. The key to creating a useful scenario is to see it as a learning experience for the designers as well as the learners. This means that results and comments about the learning experience are shared with the SME's and the designer so that they can review and modify the scenarios as necessary. Obtain open –ended qualitative data from the learner and the Flight Instructor about the experience and review the data with the SME's and the designer.

Based on this kind of feedback, scenarios can be revised to better target the learner population. That process mirrors the original design steps. There are some cautions, however, in the revision process. First, there is an old saying: “It doesn’t take a cannon to blow away a tin can.” Basically, revisions should not needlessly complicate the scenario or the technology needed to employ it. It is crucial to weigh the risks of complication against the genuine learning needs.

Before any revision, affirm the original purpose statement and the categorization of learning elements.

Also, do not let principles and main points become diluted by revisions. It is tempting to add more items and nuances in a scenario, but doing so further complicates the learning process. Save complexity for a full-scale "capstone" experience. Remember, adding an item in traditional learning complicates the learning process in a linear fashion. In scenarios, complication grows non-linearly with the addition of learning items. So, beware. A rule of thumb is to reduce rather than increase principles and main points in a revision.

Always review success and failure paths for realism. Remember that any change in a scenario item complicates all items on the path following it. Any time a decision node is altered, chances are that the decision nodes and information items following it must change. With every revision, follow and ensure the consistency of associated paths.

Finally, remember that traditional learning elements should service the scenario-based learning elements, which are situated in a real context and based on the idea that knowledge cannot be known and fully understood independent of its context. It is essential to place boundaries around scenarios to make the transitions between scenarios and traditional learning as efficient as possible.

Table 1

Scenario-Based Training Main Points

• Scenario-based training (SBT) is situated in a real context and is based on the idea that knowledge cannot be known and fully understood independent of its context.
• SBT accords with a performance improvement and behavior change philosophy of the learning function.
• SBT is different from traditional instructional design and one must be aware of the differences to successfully employ SBT.
• All learning solutions should employ both traditional and scenario-based training.
• Traditional learning elements should service the scenario-based training elements.
• It is essential to place boundaries around scenarios to make the transitions between scenarios and traditional learning as efficient as possible.
• Use interactive discovery techniques with subject matter experts (SME's) and designers to establish the purpose and outcomes of scenarios create the scenarios and appropriate strategies and performance behaviors, and develop learner evaluation criteria.
• SBT occurs by following success and failure paths through a realistic situation. Typically, these paths must be limited to stress the main learning objective. Otherwise the scenario can become too complex and unwieldy.
• Open-ended qualitative learner feedback is key to successful scenario revision, but revisions should not further complicate the scenario unless highly justified.

Adapted from Kindley, R. (2002). Scenario-Based E-Learning: A Step Beyond Traditional E-Learning.

Single Pilot Resource Management

Single Pilot Resource Management (SRM) is defined as the art and science of managing all the resources (both on-board the aircraft and from outside sources) available to a single-pilot (prior and during flight) to ensure that the successful outcome of the flight is never in doubt. Most of us remember a favorite Instructor from our past that showed us the best way to solve in-flight problems and unforeseen circumstances. The FITS team has combined much of this collective CFI body of knowledge with some innovative teaching methods to give pilots practical tools to teach aeronautical decision-making and judgment. SRM includes the concepts of Aeronautical Decision Making (ADM), Risk Management (RM), Task Management (TM), Automation Management (AM), Controlled Flight Into Terrain (CFIT) Awareness, and Situational Awareness (SA). SRM training helps the pilot maintain situational awareness by managing the automation and associated aircraft control and navigation tasks. This enables the pilot to accurately assess and manage risk and make accurate and timely decisions. This is what SRM is all about, helping pilots learn how to gather information, analyze it, and make decisions.

Teaching pilots to identify problems, analyze the information, and make informed and timely decisions is one of the most difficult tasks for Instructors. By way of comparison, the training of specific maneuvers is fairly straightforward and reasonably easy to understand. We explain, demonstrate, and practice a maneuver until proficiency is achieved. We are teaching the pilot in training "what to think" about each maneuver, and sign them off when they demonstrate proficiency. Teaching judgment is harder. Now we are faced with teaching the pilot in training "how to think" in the endless variety of situations they may encounter while flying out in the "real world." Often, they learn this by watching Instructors. They observe reactions, and more importantly, actions, during flight situations and they often adapt the styles of the Instructor to their own personalities.

Pilots in training may range from 100-hour Visual Flight Rules only pilots, all the way to multi-thousand hours Airline Transport Pilots. The strength of this format is that the participants learn not only from their Certified Flight Instructor (CFI), but from each other as well. The collective knowledge of many pilots, when guided by an experienced CFI, is much greater than the knowledge of each participant, including the Flight Instructor. In these scenarios, there are no right answers, rather each pilot is expected to analyze each situation in light of their experience level, personal minimums, and current physical and mental readiness level, and make their own decision.

The SRM scenarios incorporate several maneuvers and flight situations into realistic flight scenarios. The scenarios are much like the Line Oriented Flight Training (LOFT) employed by the major corporate and airline training organizations for years. Table 2 gives an example of the performance, standards and conditions using SRM.

Table 2

Single Pilot Resource Management (SRM)

Performance The training task is:	**Standards** The pilot in training will:	**Conditions** The training is conducted during:
1. Task Management (TM)	Prioritize and select the most appropriate tasks (or series of tasks) to ensure successful completion of the training scenario.	Note: All tasks under SRM will be embedded into the curriculum and the training will occur selectively during all phases of training. SRM will be graded as it occurs during the training scenario syllabus.
2. Automation Management (AM)	Program and utilize the most appropriate and useful modes of cockpit automation to ensure successful completion of the training scenario.	Note: All tasks under SRM will be embedded into the curriculum and the training will occur selectively during all phases of training. SRM will be graded as it occurs during the training scenario syllabus.
3. Risk Management (RM) and Aeronautical Decision-Making (ADM)	Consistently make informed decisions in a timely manner based on the task at hand and a thorough knowledge and use of all available resources.	Note: All tasks under SRM will be embedded into the curriculum and the training will occur selectively during all phases of training. SRM will be graded as it occurs during the training scenario syllabus.
4. Situational Awareness (SA)	Be aware of all factors such as traffic, weather, fuel state, aircraft mechanical condition, and pilot fatigue level that may have an impact on the successful completion of the training scenario.	Note: All tasks under SRM will be embedded into the curriculum and the training will occur selectively during all phases of training. SRM will be graded as it occurs during the training scenario syllabus.
5. Controlled Flight Into Terrain (CFIT) Awareness	Understand, describe, and apply techniques to avoid CFIT encounters: a. During inadvertent encounters with IMC during VFR flight. b. During system and navigation failures and physiological incidents during IFR flight.	Note: All tasks under SRM will be embedded into the curriculum and the training will occur selectively during all phases of training. SRM will be graded as it occurs during the training scenario syllabus.

Adapted from Federal Aviation Administration (FAA). (2007). FITS Generic Private Pilot ASEL Syllabus.

The "5P" Check

SRM sounds good on paper, however, it requires a way for pilots to understand and deploy it in their daily flights. This practical application is called the "Five P's (5P's)" The 5P's consist of "the Plan, the Plane, the Pilot, the Passengers, and the Programming". Each of these areas consists of a set of challenges and opportunities that face a single pilot. And each can substantially increase or decrease the risk of successfully completing the flight based on the pilot's ability to make informed and timely decisions. The 5P's are used to evaluate the pilot's current situation at key decision points during the flight, or when an emergency arises. These decision points include, pre-flight, pre-takeoff, hourly or at the midpoint of the flight, pre-descent, and just prior to the final approach fix or for VFR operations, just prior to entering the traffic pattern.

The 5P's are based on the idea that the pilots have essentially five variables that impact his or her environment and that can cause the pilot to make a single critical decision, or several less critical decisions, that when added together can create a critical outcome. These variables are the Plan, the Plane, the Pilot, the Passengers, and the Programming. The authors of the FITS concept felt that current decision-making models tended to be reactionary in nature. A change has to occur and be detected to drive a risk management decision by the pilot. For instance, many pilots ascribe to the use of risk management sheets that are filled out by the pilot prior to takeoff. These catalog risks that may be encountered that day and turn them into numerical values. If the total exceeds a certain level, the flight is altered or cancelled. Informal research shows that while these are useful documents for teaching risk factors, they are almost never used outside of formal training programs. The number of pilots who use them before each and every flight approaches zero. The 5P concept is an attempt to take the information contained in those sheets and in the other available models and operationalize it.

The 5P concept relies on the pilot to adopt a "scheduled" review of the critical variables at points in the flight where decisions are most likely to be effective. For instance, the easiest point to cancel a flight due to bad weather is before the pilot and passengers walk out the door and load the aircraft. So the first decision point is Pre-Flight in the flight planning room, where all the information is readily available to make a sound decision, and where communication and FBO services are readily available to make alternate travel plans.

The second easiest point in the flight to make a critical safety decision is just prior to takeoff. Few pilots have ever had to make an "emergency take-off". While the point of the 5P check is to help you fly, the correct application of the 5P before takeoff is to assist in making a reasoned go-no-go decision based on all the information available. That decision will usually be to "go", with certain restrictions and changes, but may also be a "no-go". The key point is that these two points in the process of flying are critical go-no go points on each and every flight.

The third place to review the 5Ps is at the mid point of the flight. Often, pilots may wait until the ATIS is in range to check weather, yet at this point in the flight many good options have already passed behind the aircraft and pilot. Additionally, fatigue and low altitude hypoxia serve to rob the pilot of much of their energy by the end of a long and tiring flight day. This leads to a

transition from a decision-making mode to an acceptance mode on the part of the pilot. If the flight is longer than 2 hours, the 5P check should be conducted hourly.

The last two decision points are just prior to decent into the terminal area and just prior to the final approach fix, or if VFR just prior to entering the traffic pattern, as preparations for landing commence. Most pilots execute approaches with the expectation that they will land out of the approach every time. A healthier approach requires the pilot to assume that changing conditions (the 5Ps again) will cause the pilot to divert or execute the missed approach on every approach. This keeps the pilot alert to all manner of conditions that may increase risk and threaten the safe conduct of the flight. Diverting from cruise altitude saves fuel, allows unhurried use of the autopilot, and is less reactive in nature. Diverting from the final approach fix, while more difficult, still allows the pilot to plan and coordinate better, rather than executing a futile missed approach. Now lets look in detail at each of the "Five P's".

The Plan

The "Plan" can also be called the mission or the task. It contains the basic elements of cross country planning, weather, route, fuel, publications currency, etc. Unlike risk management sheets that pilot fill out before a flight, the "Plan" should be reviewed and updated several times during the course of the flight. A delayed takeoff due to maintenance, fast moving weather, and a short notice Temporary Flight Restriction (TFR) may all radically alter the plan. Several excellent flight planning software packages are available that automate this process, allowing the pilot additional time to evaluate and make decisions. Some include real time and graphical TFR depictions. The "plan" is not just about the flight plan, but the entire days events surrounding the flight and allowing the pilot to accomplish the mission. The plan is always being updated and modified and is especially responsive to changes in the other four remaining P's. If for no other reason, the 5P check reminds the pilot that the day's flight plan is real life and subject to change at any time.

Obviously the weather is a huge part of any "plan." The addition of real time data link weather information give the TAA pilot a real advantage in inclement weather, but only if the pilot is trained to retrieve, and evaluate the weather in real time without sacrificing situational awareness. And of course, weather information should drive a decision, even if that decision is to continue on the current "plan." Pilots of aircraft without datalink weather should get updated weather in-flight through a Flight Service Station and/or Flight Watch.

The Plane

Both the "plan" and the "plane" are fairly familiar to most pilots. The "plane" consists of the usual array of mechanical and cosmetic issues that every aircraft pilot, owner, or operator can identify. For example, Is everything working properly? Is the fuel situation where you expected it to be at that point? Are you using anti-ice equipment? However, with the advent of the Technically Advanced Aircraft (TAA), the "plane" has expanded to include database currency, automation status, and emergency backup systems that were unknown a few years ago. Much has been written about single pilot IFR flight both with, and without, an autopilot. While this is a personal decision, it is just that, a decision. Low IFR in a non-autopilot equipped aircraft may

depend on several of the other "P's" we will discuss. Pilot proficiency, currency, and fatigue are among them. The TAA offers many new capabilities and simplifies the basic flying tasks, but only if the pilot is properly trained and all the equipment is working as advertised.

The Pilot

This is an area all pilots are learning more and more about each day. Flying, especially when used for business transportation, can expose the pilot to high altitude flying, long distance and endurance, and more challenging weather. Technically Advance Aircraft (TAA), simply due to their advanced capabilities can expose a pilot to even more of these stresses. The traditional "IMSAFE" checklist is a good start. However, each of these factors must be taken in consideration of the cumulative effect of all of them together and the insidious effects of low altitude hypoxia. The authors informal survey of TAA pilots show that almost half fly with pulse oxymeters to display the effects of low altitude hypoxia in a graphic manner.

The combination of late night, pilot fatigue, and the effects of sustained flight above 5,000 feet may cause pilots to become less discerning, less critical of information, less decisive and more compliant and accepting. Just as the most critical portion of the flight approaches (for instance a night instrument approach, in the weather, after a four hour flight) the pilot's guard is down the most. The "5P" process emphasizes that pilot recognize the physiological situation they are placing themselves in at the end of the flight, before they even takeoff, and continue to update their condition as the flight progresses. Once identified, the pilot is in an infinitely better place to make alternate plans that lessen the effect of these factors and provide a safer solution.

The Passengers

One of the key differences between CRM and SRM is the way passengers interact with the pilot. In the airline industry the passengers have entered into a contractual agreement with the pilots company with a clearly defined set of possible outcomes. In corporate aviation, the relationship between crew and passengers is much closer, yet is still governed by a set of operating guidelines and the more formal lines of corporate authority. However, the pilot of a highly capable single engine or light twin engine aircraft has entered into a very personal relationship with the passengers, in fact, they sit within an arms reach all of the time.

It may be easy, especially in business travel, for the desire of the passengers to make airline connections or important business meetings to enter into the pilot's decision-making loop. If this is done in a healthy and open way, it is a very positive thing. However, this is not always the case. For instance, imagine a flight to Dulles Airport and the passengers, both close friends and business partners, need to get to Washington D.C. for an important meeting. The weather is VFR all the way to southern Virginia then turns to low IFR as the pilot approaches Dulles. A pilot employing the 5P approach might consider reserving a rental car at an airport in northern North Carolina or southern Virginia to coincide with a refueling stop. Thus, the passengers have a way to get to Washington, and the pilot has an out to avoid being pressured into continuing the flight if the conditions do not improve.

Passengers can also be pilots. The old joke says that when four Certified Flight Instructors (CFI) board a light general aviation, a NOTAM should be posted. There is some truth to this. If no one is designated as pilot in command and unplanned circumstances arise, the decision-making styles of four self confident CFI's may come into conflict. Another situation arises when an owner pilot flies with a former CFI in the right seat on a business trip. Unless a clear relationship is defined and briefed prior to the flight, the owner pilot may feel some pressure to perform for the CFI (possibly beyond his or her capability), and the CFI may feel inhibited from intervening in small decisions until it is clearly evident that the pilot is making poor decisions. This is actually a CRM situation and requires clear pre-flight understanding of roles, responsibilities, and communication. Non-Pilots can also cause the pilot to review the SRM process.

Pilots need to understand that non-pilots may not understand the level of risk involved in the flight. There is an element of risk in every flight. That's why SRM calls it risk management not risk elimination. While a pilot may feel comfortable with the risk present in a night IFR flight, the passengers may not and may manifest this during the flight. The human reaction to fear and uncertainty is as varied as the shapes of our ears. Some become quiet, some talk incessantly, and in extreme cases anger and fear are strongly manifested. This may be the last thing the pilot needs to deal with while shooting the ILS to 400 feet and a mile visibility at midnight.

A pilot employing SRM should ensure that the passengers are involved in the decision-making and given tasks and duties to keep them busy and involved. If, upon a factual description of the risks present, the passengers decide to buy an airline ticket or rent a car, then a good decision has generally been made. This discussion also allows the pilot to move past what he or she "thinks" the passengers want to do and find out what they "actually" want to do. This removes a load of self-induced pressure from the pilot.

The Programming

The TAA adds an entirely new dimension to the way General Aviation aircraft are flown. The Glass Cockpit, GPS, and Autopilot are tremendous boons to reduce pilot workload and increase pilot situational awareness. And frankly, the programming and operation of these devises is fairly simple and straightforward. However, unlike the analog instruments they replace, they tend to capture the pilot's attention and hold it for long periods of time (like a desktop computer). To avoid this phenomenon, the pilot should plan in advance when and where the programming for approaches, route changes, and airport information gathering should be accomplished…as well as times it should not. Pilot familiarity with the equipment, the route, the local air traffic control environment, and their own capabilities vis-à-vis the automation should drive when, where, and how the automation is programmed and used.

The pilot should also consider what his or her capabilities are in response to last minute changes of the approach (and the reprogramming required) and ability to make large-scale changes (a re-route for instance) while hand flying the aircraft. Since formats are not standardized, simply moving from one manufacturer's equipment to another should give the pilot pause and require more conservative planning and decisions.

The SRM Decision Process

The SRM process is simple. At least five times, during the pre-flight and during the flight, the pilot should review and consider the “Plan, the Plane, the Pilot, the Passengers, and the Programming” and make the appropriate decision required by the current situation. It is often said that failure to make a decision is a decision. Under SRM and the 5P’s, even the decision to make no changes to the current plan, is made through a careful consideration of all the risk factors present.

Example of Single Pilot Resource Management

The teaching of SRM is best accomplished in a seminar environment. The authors conducted a set of classroom seminars that presented real time flight scenarios to a room full of qualified pilots of varied experiences. The first scenario presented was a night MVFR/IFR flight from St Augustine Florida to Washington Dulles Airport. The original “Plan” called for a non-stop flight with a 45-minute fuel reserve. The “Plane” was a well-equipped TAA with a minor navigation light problem that delayed departure by an hour. The “Passengers” were one pilot and one non-pilot. The non-pilot seemed nervous about the trip and a little ill. Both passengers needed to get to Washington DC for an important meeting the next day. The “Pilot” had spent a full day at a flight refresher clinic, including a two-hour flight and a three-hour class, and felt reasonably refreshed at the 5 PM departure time. And finally, the GPS/MFD, the "Programming,” combination looked like it would make the flight a snap. However, there were questions about the currency of the database that required the pilot’s attention.

The discussion that followed revolved around the reliability of the weather data, the fatigue of the pilot landing at Dulles at 9 PM, alternate ways to get the passengers to their meeting, minimum requirements for aircraft night flight, and a more complete understanding of the benefits and challenges posed by GPS programming and database currency. The 5p’s ensured that each pilot looked at the entire picture prior to making the critical decisions that would lay the groundwork for success or failure over four hours later in Washington.

Predictably, the destination weather deteriorated slowly as the flight proceeded northbound. The pilot’s fatigue level, low altitude/long duration hypoxia, a succession of minor annoyances caused by the airplane and the passengers, began to become a factor. Again, the pilots applied the 5p’s, and many decided to land short of Washington Dulles, check the weather, and secure a rental car as a backup for the Monday morning meeting (in fact many decided this prior to takeoff).

For the purposes of the discussion, this aircraft was equipped with a ballistic parachute system. For those that proceeded to Dulles, the scenario ended with a spatial disorientation incident at 1500 feet, 10 miles short of the airport caused by pilot fatigue, latent hypoxia, and failure to use the autopilot. For many, it was the first time they had considered all the options available, and the criticality of quick and accurate decisions. In the background, another instructor began calling out altitudes and speeds as the aircraft descended to the ground, providing an added dose of realism and pressure. Should the class initiate an unusual attitude recovery, and if it did not

work should they attempt another? How much will the passengers help or hinder the pilots thought processes? When, and how, should the ballistic parachute system be deployed, and what are its limitations. This scenario sparked questions about the capabilities and limitations of the autopilot, cockpit automation, and the parachute system. More importantly, it caused the pilots in the room to examine how they should gather critical information, assess the risks inherent in the flight, and take timely action. All agreed that a few accurate decisions before and during the early part of the flight reduced the risk to pilot and passengers.

All these questions were discussed in a lively thirty-minute session following the scenario. In this type of Scenario Based Training, the group discussion is just as important as the actual situation, for it is during the discussion that the pilots are most ready to learn, and begin to develop a mental model of how they might react to situations. Instead of encountering a once in a lifetime, life or death, situation alone on the proverbial dark and stormy night, the participants could examine how the situation had developed, understand the options available to them, and begin to develop a general plan of action well ahead of time.

Learner Centered Grading

The third component of the FITS training method, following each flight scenario, is to use the concept of "learner-centered grading." Learner centered grading includes two parts: learner self assessment and a detailed debrief by the instructor. The purpose of the self assessment is to stimulate growth in the learner's thought processes and, in turn, behaviors. The self-assessment is followed by an in-depth discussion between the instructor and the pilot in training which compares the instructor ratings to the pilot in training's self-assessment.

To improve learning, it is recommended that learners prepare to learn from their experiences both before and after key events. This preparation should increase learning and enhance future performance. Pre-briefs are essential for setting goals. During key events, especially those that require high levels of attention, there may be little time for learning; most individuals allocate the bulk of their cognitive resources to performing the actual task; however, they may also dedicate some cognitive resources to self-monitoring, learning, and correction.

How facilitation and feedback occur is important to the learning process. In order for feedback to be useful for both informational and motivational purposes, it should be designed systematically. For example, the facilitator (Flight Instructor) should avoid lecturing the learner, and should withhold their observations and opinions of the exercise until the learner has given their opinion. The use of closed-ended questions may stymie the usefulness of the feedback process as well, as they encourage one-word/yes/no types of answers that do not elicit opinions of performance or suggestions for improvement. It is more effective to use open-ended questions that probe the learner to assess their own performance. Allotting enough time for the feedback is also important. Debriefs that are rushed often turn into one-way "lectures" due to time constraints. Referring to prior pre-briefs when conducting subsequent debriefs provides a sense of continuity, reliability, and consistency, all of which are desirable attributes of a feedback source. Reminding learners of goals and lessons learned from prior exercises helps them plan for future events. Learners may also be more receptive to feedback during a debrief if they were appraised of the goal criteria in a pre-brief.

The FITS approach utilizes scenarios to teach Single Pilot Resource Management (SRM) while simultaneously teaching individual tasks such as landings and takeoffs. SRM requires a new approach to the pilot in training's performance measurement. Traditional grading approaches are generally teacher centered and measure performance against an empirical standard. The following example of a traditional flight syllabus demonstrates a grading scale.

Table 3

A Traditional Grading Scale

Excellent - the pilot in training has performed in an excellent manner
Good – the pilot in training has exceeded basic requirements
Satisfactory – the pilot in training has met basic standards
Marginal – the pilot in training has failed to perform the task standards
Unsatisfactory – the pilot in training has demonstrated significant performance difficulties

Adapted from Federal Aviation Administration (FAA). (2007). FITS Generic Private Pilot ASEL Syllabus.

Table 4

A Traditional Lesson

Lesson Tasks	Lesson Sub Tasks	Lesson Grading
Flight Planning	Flight Planning Weight and Balance and Aircraft Performance Calculations	U, M, S, G, E U, M, S, G, E
Normal Preflight and Cockpit Procedures	Normal Pre-Takeoff Checklist Procedures GPS/Avionics Programming MFD / PFD Setup	U, M, S, G, E U, M, S, G, E U, M, S, G, E

Adapted from Federal Aviation Administration (FAA). (2007). FITS Generic Private Pilot ASEL Syllabus.

This type of grading scale (See Table 4), or something similar, is in wide use throughout the aviation training industry. While it appears to be based on published standards, in reality it is often used as a tool to determine pilot in training progress and provide motivation. Thus, on the first lesson a pilot in training may receive an “Excellent” grade for attempting to plan the flight and accomplishing the weight and balance with a few minor errors. However, by the third flight, that same performance may only earn a “Satisfactory” grade due to lack of pilot in training progress (note that while performance remained the same, the grade changed). Additionally, the Flight Instructor awards the grade based on his or her observation of the pilot in training's performance. This observation, while accurate, may not be based on an understanding of the pilot in training’s level of knowledge and understanding of the task. Lastly, the pilot in training

has been conditioned since grade school to look at grades as a reward for performance and may feel that there is a link between grades earned and their self-esteem. In reality, none of this aids pilot in training performance in any meaningful way.

The learner centered grading approach addresses these the above concerns. First, the grade is now a "Desired Scenario Outcome." These outcomes describe pilot in training-learning behavior in readily identifiable and measurable terms. They reflect the pilot in training's ability to see, understand, and apply the skills and tasks that are learned to the scenario.

For instance, a pilot in training who can "explain" a successful landing has achieved the basic level of competence to begin the learning process. Once the pilot in training can "explain" the effect of crosswind and speed reduction on rudder effectiveness, they have achieved a level of learning that will allow for meaningful "Practice." The "Perform" level denotes unsupervised practice and self-correction of errors. These grades are equally applicable to the first scenario to the last since they are not lesson dependent.

The grade of "Manage/ Decide" is used solely for SRM grading and the grade of "Perform" is used solely for task grading. A pilot in training who is becoming proficient at aeronautical decision-making and risk management would be graded first at the "Explain" level, then at the "Practice", and finally at the "Manage/Decide" level. A Manage/Decide or Perform grade does not describe perfection. Rather, these grades simply show a proficient pilot who corrects their own errors so that the outcome of the flight is never in doubt. Realistically, this is the performance level we desire. All pilots make mistakes, it is in learning to identify and correct mistakes that they become proficient pilots.

Desired Outcomes

The objective of scenario-based training is a change in the thought processes, habits, and behaviors of the pilot in training during the planning and execution of the scenario. Since the training is learner centered, the success of the training is measured in the following desired pilot in training outcomes.

<u>Maneuver Grades (Tasks)</u>

- Describe – at the completion of the scenario, the PT will be able to describe the physical characteristics and cognitive elements of the scenario activities. *Instructor assistance is required to successfully execute the maneuver.*
- Explain –at the completion of the scenario the PT will be able to describe the scenario activity and understand the underlying concepts, principles, and procedures that comprise the activity. *Significant instructor effort will be required to successfully execute the maneuver.*
- Practice – at the completion of the scenario the pilot in training will be able to plan and execute the scenario. *Coaching, instruction, and/or assistance from the CFI will correct deviations and errors identified by the CFI.*
- Perform – at the completion of the scenario, the PT will be able to perform the activity without assistance from the CFI. Errors and deviations will be identified and corrected by the PT in an expeditious manner. *At no time will the successful completion of the activity be in doubt.*

("Perform" will be used to signify that the PT is satisfactorily demonstrating proficiency in traditional piloting and systems operation skills)

- Not Observed – Any event not accomplished or required

Single Pilot Resource Management (SRM) Grades

- Explain – the pilot in training can verbally identify, describe, and understand the risks inherent in the flight scenario. *The pilot in training will need to be prompted to identify risks and make decisions.*
- Practice –the pilot in training is able to identify, understand, and apply SRM principles to the actual flight situation. *Coaching, instruction, and/or assistance from the CFI will quickly correct minor deviations and errors identified by the CFI. The pilot in training will be an active decision maker.*
- Manage/Decide - the pilot in training can correctly gather the most important data available both within and outside the cockpit, identify possible courses of action, evaluate the risk inherent in each course of action, and make the appropriate decision. *Instructor intervention is not required for the safe completion of the flight.*
- Not Observed – Any event not accomplished or required

Grading will be conducted independently by the pilot in training and the instructor, and then compared during the post flight critique. Learner centered grading (outcomes assessment) is a vital part of the FITS concept. Previous syllabi and curriculum have depended on a grading scale designed to maximize pilot in training management and ease of instructor use. Thus the traditional: "excellent, good, fair, poor" or "exceeds standards, meets standards, needs more training" often meet the instructor's needs but not the needs of the pilot in training. The learner centered grading described above is a way for the instructor and pilot in training to determine the pilot in training's level of knowledge and understanding. "Perform" is used to describe proficiency in a skill item such as an approach or landing. "Manage-Decide" is used to describe proficiency in the SRM area such as ADM. Describe, explain, and practice are used to describe pilot in training learning levels below proficiency in both.
Grading should be progressive. During each flight, the pilot in training should achieve a new level of learning (e.g. flight one, the automation management area, might be a "describe" item by flight three a "practice" item, and by flight five a "manage-decide" item.

Example of Learner Centered Grading

Immediately after landing, and before beginning the critique, Flight Instructor Linda asks her pilot in training Brian to grade his performance for the day. Being asked to grade himself is a new experience but he goes along with it. The flight scenario had been a two-leg IFR scenario to a busy class B airport about 60 miles to the east. Brian had felt he had done well in keeping up with programming the GPS and the MFD until he reached the approach phase. He had attempted to program the ILS for runway 7L and had actually flown part of the approach until ATC asked him to execute a missed approach.

When he went to place a grade in that block he noticed that the grades were different. Instead of satisfactory or unsatisfactory he found, “Describe, Explain, Practice, and Perform”. He decided he was at the Perform level since he had not made any mistakes.

When Linda returned Brian discovered that she had graded his flight as well, with a similar grade sheet. Most of their grades appeared to match until the item labeled “programming the approach”. Here, where he had placed a “Perform” Linda had placed a “Explain”. This immediately sparked a discussion. As it turned out, Brian had selected the correct approach, but he had not activated it. Before Linda could intervene, traffic dictated a go around. Her explain grade told Brian that he did not really understand how the GPS worked and he agreed. Now, learning could occur.

In Table 5, the desired outcome table denotes a pilot in training near the middle of training and the grades reflect proficiency of the pilot in training to an expected level of performance in each of these areas. These grades are not self-esteem related since they do not describe a recognized level of prestige (such as A+ or “Outstanding”), rather a level of performance. You can’t flunk a lesson. However, you can fail to demonstrate the required flight and SRM skills. By reflecting on the lesson and grading their own performance, the pilot in training becomes actively involved in the critique process. Pilot in training participation in the process also reduces the self-esteem issue. But most importantly, this establishes the habit of healthy reflection and self-criticism that marks most competent pilots.

Table 5

Learner Centered Scenario Grading-Desired Outcome Table

Scenario Activities	**Scenario Sub Activities**	**Desired Scenario Outcome**
Flight Planning	1. Scenario Planning 2. Weight and Balance and Aircraft Performance Calculations 3. Preflight SRM Briefing 4. Decision making and risk management	1. Perform 2. Perform 3. Perform 4. Explain/Practice
Normal Preflight and Cockpit procedures	1. Normal Pre-Takeoff Checklist Procedures 2. GPS Programming 3. MFD Setup 4. PFD Setup	1. Perform 2. Explain/Practice 3. Practice 4. Explain/Practice
Engine Start and Taxi Procedures	1. Engine Start 2. Taxi 3. SRM/Situational Awareness	1. Perform 2. Perform 3. Explain/Practice

Before Takeoff Checks	1. Normal and Abnormal Indications 2. Aircraft Automation Management 3. Aeronautical Decision Making and Risk Management	1. Perform 2. Explain/Practice 3. Manage/Decide

Adapted from Federal Aviation Administration (FAA). (2007). FITS Generic Private Pilot ASEL Syllabus.

Threat and Error Management

Threat and Error Management (TEM) is based on a model developed by the Human Factors Research Project of the University of Texas in Austin (Helmreich, Klinect, & Wilhelm, 2001). TEM is an overarching safety concept regarding aviation operations and human performance. TEM is not a revolutionary concept, but one that has evolved gradually, as a consequence of the constant drive to improve the margins of safety in aviation operations through the practical integration of Human Factors knowledge (International Civil Aviation Organization, 2008).

The easiest way to understand TEM is to liken it to defensive driving for a motorist (Merritt & Klinect, 2006). The purpose of defensive driving is not to teach people how to drive a vehicle (e.g., how to shift a manual transmission) but to emphasize driving techniques that people can use to minimize safety risks (e.g., techniques to control rear-wheel skids). Similarly, TEM does not teach pilots how to technically fly an airplane; instead, it promotes a proactive philosophy and provides techniques for maximizing safety margins despite the complexity of one's flying environment. In this sense, TEM training can be framed as defensive flying for pilots (Merritt & Klinect, 2006).

TEM proposes that threats (such as adverse weather), errors (such as a pilot selecting a wrong automation mode), and undesired aircraft states (such as an altitude deviation) are everyday events that flight crews must manage to maintain safety (Grote, Helmreich, Strater, Hausler, Zala, & Sexton, 2004). Therefore, flight crews that successfully manage these events regardless of occurrence are assumed to increase their potential for maintaining adequate safety margins. It is this notion that provides the objective of TEM; to provide the best possible support for flight crews in managing threats, errors, and undesired aircraft states (Merritt & Klinect, 2006).

The Framework of Threat and Error Management

TEM was developed as a product of collective aviation industry experience (Maurino, 2005). Such experience fostered the recognition that past studies and, most importantly, operational consideration of human performance in aviation had largely overlooked the most important factor influencing human performance in dynamic work environments: the interaction between people and the operational context (i.e., organizational, regulatory and environmental factors) within which people discharged their operational duties (Federal Aviation Administration, 2006). The TEM framework is a conceptual model that assists in understanding, from an operational perspective, the inter-relationship between safety and human performance in dynamic and challenging operational contexts (Grote, Helmreich, Strater, Hausler, Zala, & Sexton, 2004). The TEM framework focuses simultaneously on the operational context and the people discharging

operational duties in such a context. The framework is descriptive and diagnostic of both human and system performance. It is descriptive because it captures human and system performance in the normal operational context, resulting in realistic descriptions. It is diagnostic because it allows quantifying the complexities of the operational context in relation to the description of human performance in that context, and vice-versa (International Civil Aviation Organization, 2008).

The TEM framework focuses simultaneously on the operating environment and the humans working in that environment. Because the framework captures performance in its "natural" or normal operating context, the resulting description is realistic, dynamic, and holistic. Because the TEM taxonomy can also quantify the specifics of the environment and the effectiveness of performance in that environment, the results are also highly diagnostic (Merritt & Klinect, 2006). Originally developed for flight deck operations, the TEM framework can nonetheless be used at different levels and sectors within an organization, and across different organizations within the aviation industry (Helmreich, Klinect, & Wilhelm, 2001). It is therefore important, when applying TEM, to keep the user's perspective in the forefront. Depending on "who" is using TEM (i.e. front-line personnel, middle management, senior management, flight operations, maintenance, air traffic control), slight adjustments to related definitions may be required.

The TEM framework can be used in several ways. As a safety analysis tool, the framework can focus on a single event, as is the case with accident/incident analysis; or it can be used to understand systemic patterns within a large set of events, as is the case with operational audits. The TEM framework can be used to inform about licensing requirements, helping clarify human performance needs, strengths and vulnerabilities, thus allowing the definition of competencies from a broader safety management perspective (Grote, Helmreich, Strater, Hausler, Zala, & Sexton, 2004). Subsequently the TEM framework can be a useful tool in On-the-Job Training. The TEM framework can be used as guidance to inform about training requirements, helping an organization improve the effectiveness of its training interventions, and consequently of its organizational safeguards. The TEM framework can be used to provide training to quality assurance specialists who are responsible for evaluating facility operations as part of certification (International Civil Aviation Organization, 2008).

An understanding of flight safety can only be gained from valid, empirical data about normal operations. There are several sources of such data, each incomplete. However, in combination they can provide a good understanding of the strengths and weaknesses of operations. Aside from proficiency checks of technical competence, usually conducted in the simulator, sources of data include:

1. *Accident investigation*. Exhaustive analyses of factors surrounding accidents have been a primary source of safety information in aviation. However, accidents are infrequent events that usually reflect the concatenation of rare factors as eloquently described by James Reason in his classic 'Swiss cheese' model. As a result, such investigations probably do not uncover normative, unsafe operational practices.
2. *Incident reports*. These are useful because they provide insights into a far larger database of saves and near misses. They suffer, however, because of their voluntary nature and the resultant fact that the actual baseline of occurrence of various categories of events is unknown. Despite efforts to assure pilots and other aviation personnel of the non-jeopardy nature of reports under initiatives such as the Aviation Safety Action, these programs do not elicit complete reporting. This is both because of embarrassment at acknowledging error and

because of suspicion about being sanctioned. Nevertheless, programs such as ASAP do provide invaluable information and allow organizations to take needed safety action prior to serious accidents and incidents.

3. *Line Checks*. Although required by civil aviation regulators in most countries, line checks generally lack in diagnosticity, especially in the United States, where grading is generally on a pass-fail basis and in many organizations fewer than 1% are deemed unsatisfactory. As a result, there is minimal diagnosticity obtained at significant cost (one major airline cites a cost of $1,000 per line check with no utility in obtained information). Pilots are certainly displaying their best, not necessarily their normative behavior during a line check.
4. *Flight Data Recorder monitoring*. Especially in new generation aircraft, it has become almost routine to utilize flight recorder data to monitor exceedences in performance of the aircraft and to use these data for safety analysis, without jeopardy to flight crews. While FOQA data provide essential information about what happens in terms of deviations from organizational expectations, the data do not provide any insights into why the deviations occurred.
5. *Normal Flight Monitoring – LOSA*. The Line Operations Safety Audit (LOSA) was developed by the University of Texas Human Factors Research Project in conjunction with major airlines in the United States as a means of collecting normative data on crew performance during line flights. LOSA and the application of LOSA data for research, organizational safety initiatives, and training have changed significantly since its introduction into the airline training industry (Helmreich, Klinect, & Wilhelm, 2001).

History of TEM

The origin of TEM is inextricably tied to the origin of Line Operations Safety Audits (LOSA) (Grote, Helmreich, Strater, Hausler, Zala, & Sexton, 2004). It began with a simple question: “Do the concepts taught in training transfer to normal, everyday flight operations?” The question prompted a partnership between The University of Texas (UT) Human Factors Research Project and Delta Airlines in 1994 to develop a line audit methodology utilizing jump-seat observations on regularly scheduled flights. All parties realized that in order for the audit to work, i.e., to really see what happened on the line, there had to be a guarantee of confidentiality with no regulatory or organizational jeopardy for the crews that were observed. Crews had to believe there would be no individual repercussions; otherwise, they would revert to their best “angel performance” when being observed and the audit would uncover nothing more than what was learned from line check or training data.

The first observation form was designed by the UT researchers to evaluate Crew Resource Management (CRM) behaviors (Helmreich, 2002). The form was then expanded to address error and its management. As well as type of error committed, the form prompted observers to note who caused the error, the response to the error (i.e., whether the error was detected and by whom), and the outcome of the error. Knowing an error occurred without really knowing the conditions under which it occurred seemed to tell only part of the story. Hence, the researchers developed and included the concepts of threat and threat management in the observation form to capture the full operational complexity of a flight (Helmreich, 2002).

The first full TEM-based LOSA was conducted at Continental Airlines in 1996 (Helmreich, 2002). Data from the observation forms were aggregated to develop an airline profile. As well as

the original CRM indicators such as leadership, communication, and monitoring/cross-checking, the TEM organizational profile highlighted the most frequent threats, threats that were well managed versus more problematic threats (i.e., those that were mismanaged at higher rates than other threats), the most common errors, the least versus more problematic errors, and the rate of Undesired Aircraft States, including unstable approaches. Among other things, the airline learned that it had issues with its checklists. It also realized there were no clear guidelines on when to execute a missed approach, which could explain the rate of unstable approaches. With a data-driven report that highlighted operational strengths and weaknesses, the airline set up cross-departmental committees from Flight Operations, Ground Operations, Training, and the Safety Department to work on solutions (Helmreich, 2002).

The company also instigated a one-day TEM training course for all its pilots. Trainers introduced the concepts of Threat and Error and then debriefed the LOSA findings. As a result, pilots were able to see a different perspective of safety performance at their airline as reflected in organizational threat and error prevalence and management rates. The pilots responded positively, analyzing the data for reasons, and using what they learned to proactively enhance their own performance. Using the 1996 LOSA results as a baseline, Continental conducted a follow-up LOSA in 2000. Captain Don Gunther, Senior Director of Safety & Regulatory Compliance at Continental Airlines stated that the 2000 LOSA data, when compared to the results of 1996, showed the pilots had not only accepted the principles of error management but incorporated them into everyday operations. The 2000 LOSA data showed a sizeable improvement in the areas of checklist usage, a 70 percent reduction in non-conforming approaches (i.e., those not meeting stabilized approach criteria), and an increase in overall crew performance. It could be said that Continental had taken a turn in the right direction (Helmreich, Klinect, & Wilhelm, 2001).

Based on the success at Continental as well as other LOSA carriers, the International Civil Aviation Organization (ICAO) made LOSA a central focus of its Flight Safety and Human Factors Program and endorsed it as an industry best practice for normal operations monitoring (Intentional Civil Aviation Organization (ICAO, 2002). The FAA also endorses LOSA as one of its voluntary safety programs (Federal Aviation Administration, 2006). As a result, TEM and LOSA are now recognized world-wide (Merritt Klinect, 2006).

Line Operations Safety Audits (LOSA)

Line Operations Safety Audits (LOSA) consists of a family of methodologies applied to normal flight operations to assess their strengths and weaknesses. At the heart of LOSA is the non-jeopardy, systematic assessment from the aircraft jump-seat of operational threats and cockpit crew errors and their management. Tabulation of threats and errors is augmented by assessment of CRM-related behaviors associated with effective and ineffective flight-deck management (Helmreich, Klinect, & Wilhelm, 2001).

LOSA practice combines the observational data with structured interviews of crewmembers regarding safety issues and/or a survey of attitudes regarding safety practices, safety and organizational culture, and cockpit management using a specialized version of the University of Texas Flight Deck Management Attitudes Questionnaire (Helmreich, Klinect, & Wilhelm, 2001).

The key to obtaining useful data is the credible assurance to pilots that the observations are without jeopardy to them. A picture of flight operations with LOSA data is quite different from data that is obtained by a check airman conducting a line check or an FAA inspector riding on the jump-seat. The fact that numerous instances of procedural and regulatory violations are observed attests to the achievement of trust with those observed (Merritt & Klinect, 2006).

At a more macro level, the interview, survey, and observations provide both objective and subjective data on strengths and weaknesses associated with professional and organizational culture, the National Airspace System, aircraft design (especially issues related to automation), and the level of support provided to crews by ground operations, maintenance, and dispatch (Helmreich, Klinect, & Wilhelm, 2001).

LOSA History

The significant shift to include recording of threats and errors and their avoidance and management was initiated in collaboration with Captain Bruce Tesmer of Continental Airlines. At the same time, the addition of the survey and/or interview as an integral part of the data collection was finalized (Helmreich, 2002). Many LOSAs with the threat and error orientation have been completed in U.S. major and regional carriers and major international airlines. Daniel Maurino of the International Civil Aviation Organization (ICAO) has been a strong supporter of normal process monitoring as represented by LOSA. LOSA has been presented at meetings of ICAO, the International Air Transport Association, the Air Transport Association, and the ICARUS Committee of the Flight Safety Foundation. LOSA concepts were presented at a regional human factors conference in Mexico City in February, 2001. An Asian LOSA Summit involving the major carriers in the region was held in March, 2001, hosted by Cathay Pacific in Hong Kong (Helmreich, Klinect, & Wilhelm, 2001).

TEM and LOSA

For safe operations, in addition to the technical task of flying, crews must accomplish four safety tasks: (1) use proactive strategies to avoid committing errors. (2) manage operational complexity, which translates into threat management. (3) manage crew errors. Error is an inevitable result of human limitations such as fatigue and other physiological factors, limited memory and processing capacity, external stressors, poor group dynamics, and cultural influences. (4) manage aircraft deviations, which are defined in the model as undesired aircraft states (for example, wrong configurations, speed, heading, etc.) (Maurino, 2005).

The distinction among safety tasks is important because different CRM practices (which can be defined as threat and error countermeasures) are differentially associated with effective accomplishment of each of the four tasks. When the cockpit crew has put an aircraft is in an undesired state (for example, at the wrong speed or altitude), the primary task is recovery from the undesired state. LOSA data has validated the importance of observable CRM skills in accomplishing these tasks. The necessary skills fall into four groups: (1) Team Climate; (2) Planning; (3) Task Execution; and (4) Review and Modify. Not surprisingly, team climate behaviors such as active leadership and establishing a team environment are critical for all four safety tasks. Planning, in contrast, is most related to error avoidance and threat management.

Task Execution behaviors such as monitoring and workload management are central to error management. Review and modify countermeasures, which include evaluation of plans, inquiry and assertiveness, are most relevant for threat management and undesired aircraft state management (Maurino, 2005).

Using LOSA Data

LOSA data have three major uses – for research, for organizational safety initiatives, and for the development of training curricula. In research, LOSA data are invaluable as they capture the behavior of professionals performing challenging work in the real world. Several findings have already emerged that are of both theoretical and practical interest, including findings that showed under conditions of operational complexity crew performance was significantly better with the captain serving as pilot not flying while under more benign conditions it made no difference (Helmreich, Merritt, Wilhelm, 1997). Other studies show that crews with more positive (and congruent) safety attitudes commit errors that are more likely to be inconsequential, trap more errors, are less likely to commit sequences of errors, and less likely to make unstable approaches (Sexton, Wilhelm, Helmreich, Merritt, & Klinect, 2001). This linkage between attitudes and behavior is important both practically and in addressing an old controversy in psychology about the linkage between attitudes and behavior. This also represents a start towards understanding the reasons why crews fail to comply with procedures.

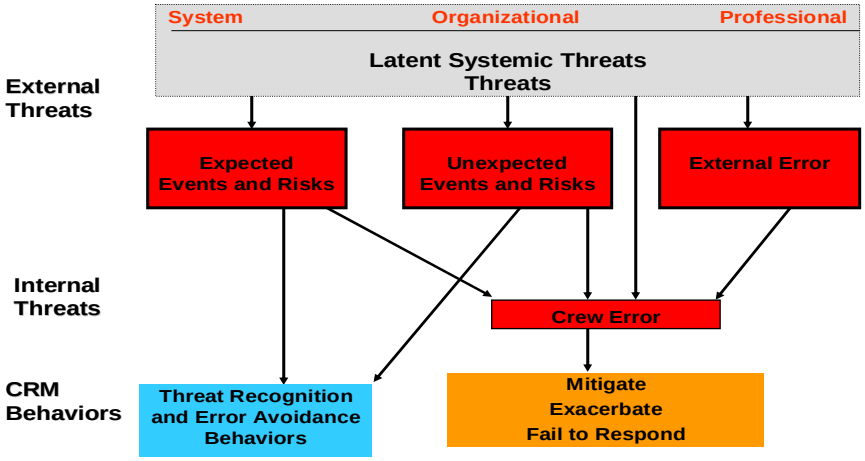
As enhanced safety initiatives, LOSA data provide organizations with concrete data on line operations. Continental Airlines, for example, has used the data to address procedures and to provide guidance for crews regarding high threat operations. The data can also be integrated with information from quick access recorders to provide greater insight into areas of risk (Federal Aviation Administration, 2006). To be effective in establishing a safety culture in an organization, it must be established based on data regarding the organizations practices the operational context. Multiple sources are used, one of which is the LOSA in which expert observers collect data in the cockpit during normal operations. In LOSA, trained observers record and code potential threats to safety and how the threats are addressed during the flight. They also record and code the errors such threats generate, and how flight crews manage these errors. The TEM model has been successfully incorporated into airline training programs and, in some cases, has replaced CRM training (Flight Safety, 2004).

With reference to training and curriculum development, LOSA data provide insights into areas in need of special training. For example, one airline initiated new training on captain leadership because this was an area identified as weak (Helmreich, Klinect, & Wilhelm, 2001). Another important characteristic of LOSA data is the identification of superior performance. Examples of outstanding behavior (instead of failures) can provide powerful learning. Continental Airlines under the direction of Captain Donald Gunther developed a CRM Threat and Error Management course that is being given to all pilots (Gunther & Tesmer, n.d.). The course is built directly on data from LOSA and, as a result, has high credibility with pilots (Helmreich, Klinect, & Wilhelm, 2001).

The complex data developed through LOSA are best understood in a model of threat and error in the aviation system that reflects not only external threats and errors (for example, operational errors by air traffic controllers), but also enables probing for latent threats residing in the organization or system such as organizational and professional cultures, rostering practices, design factors, etc. Figure 1 illustrates the threat and error management model.

Figure 1.

Threat and Error Management Model I



Adapted from Helmreich, Klinect, & Wilhelm. (2001). System Safety and Threat and Error Management: The Line Operations Safety Audit (LOSA).

The Components of the TEM Model

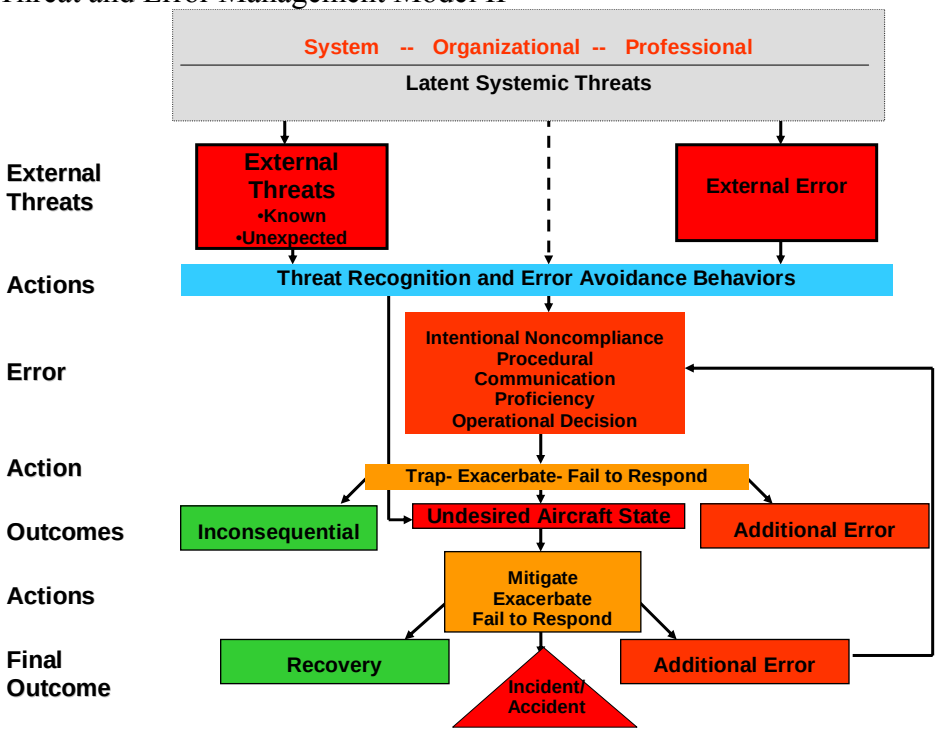
There are three basic components in the TEM model, from the perspective of flight crews: threats, errors and undesired aircraft states (Merritt & Klinect, 2006). The model proposes that threats and errors are part of everyday aviation operations that must be managed by flight crews, since both threats and errors carry the potential to generate undesired aircraft states. Flight crews must also manage undesired aircraft states, since they carry the potential for unsafe outcomes. Undesired state management is an essential component of the TEM model, as important as threat and error management. Undesired aircraft state management largely represents the last opportunity to avoid an unsafe outcome and thus maintain safety margins in flight operations (Maurino, 2005).

It is inevitable that error will occur within a system no matter how strenuously it was engineered out. TEM is a framework for understanding operational performance in complex environments. It focuses simultaneously on the operating environment and the humans working in it. The TEM model proposes that threats and errors are an integral part of daily flight operations and that they must be managed by the flight crews to ensure the safe outcome of flights (Merritt & Klinect,

2006). Threats are events that are external to the flight deck and must be managed by flight crew during normal everyday flights. In the model of threat and error management, external threats are defined as situations, events or errors that originate outside of the cockpit, i.e. high terrain, poor weather, aircraft system malfunction, errors made by the crew or maintenance, and Air Traffic Controllers. Such events increase operational complexity and pose a potential safety risk to the mission (Merritt & Klinect, 2006). Figure 2 shows a TEM model that shows errors as they relate to threats and outcomes.

Figure 2.

Threat and Error Management Model II



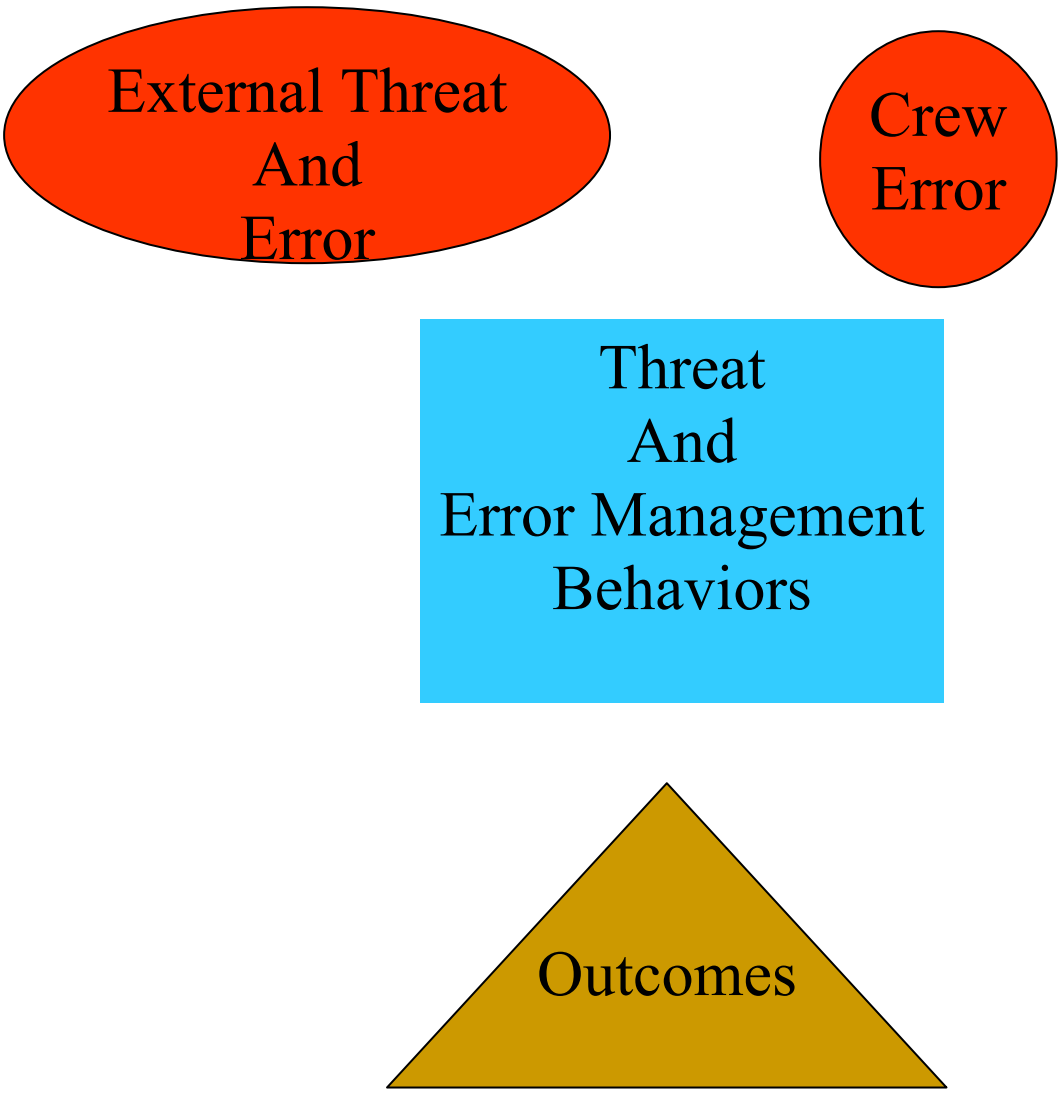
Adapted from Helmreich, Klinect, & Wilhelm. (2001). System Safety and Threat and Error Management: The Line Operations Safety Audit (LOSA).

Threats are to be expected by the crew and briefed in advance. They may also be unexpected, appearing without warning or possibility of briefing. Some threats are minor (a slight discrepancy in dispatch papers) or major (an incorrect altitude assignment). Threat management is the act of minimizing the potential for the threat to occur. Errors are actions or inactions by the crew that lead to deviations from organizational or flight crew intentions or expectations. Errors in the operational context tend to reduce the margin of safety and pose a potential risk to the flight (Flight Safety, 2004).

Figure 3 shows the basic components of Threat and Error Management. The discussion that follows describes in detail each of these components.

Figure 3.

Components of Threat and Error Management



Adapted from Helmreich, Klinect, & Wilhelm. (2001). System Safety and Threat and Error Management: The Line Operations Safety Audit (LOSA).

Threats

Threats are defined as "events or errors that occur beyond the influence of the flight crew, increase operational complexity, and which must be managed to maintain the margins of safety." During typical flight operations, flight crews have to manage various contextual complexities. Such complexities would include, for example, dealing with adverse meteorological conditions, airports surrounded by high mountains, congested airspace, aircraft malfunctions, errors committed by other people outside of the cockpit, such as air traffic controllers, flight attendants or maintenance workers, and so forth. The TEM model considers these complexities as threats

because they all have the potential to negatively affect flight operations by reducing margins of safety. Some threats can be anticipated, since they are expected or known to the flight crew. For example, flight crews can anticipate the consequences of a thunderstorm by briefing their response in advance, or prepare for a congested airport by making sure they keep a watchful eye for other aircraft as they execute the approach (Maurino, 2005).

Some threats can occur unexpectedly, such as an in-flight aircraft malfunction that happens suddenly and without warning. In this case, flight crews must apply skills and knowledge acquired through training and operational experience. Lastly, some threats may not be directly obvious to, or observable by, flight crews immersed in the operational context, and may need to be uncovered by safety analyses. These are considered latent threats. Examples of latent threats include equipment design issues, optical illusions, or shortened turn-around schedules (Maurino, 2005).

Table 6 presents examples of threats, grouped under two basic categories derived from the TEM model. Environmental threats occur due to the environment in which flight operations take place. Some environmental threats can be planned for and some will arise spontaneously, but they all have to be managed by flight crews in real time. Organizational threats, on the other hand, can be controlled (i.e., removed or, at least, minimized) at the source by aviation organizations. Organizational threats are usually latent in nature. Flight crews still remain the last line of defense, but there are earlier opportunities for these threats to be mitigated by aviation organizations themselves. The list below is not inclusive of all examples of threats.

Table 6

Threat Types with Examples

Environmental	**Threats Examples**
Adverse Weather	Thunderstorms, turbulence, poor visibility, wind shear, icing conditions, IMC
Airport	Poor signage, faint markings, runway/taxiway closures, INOP navigational aids, poor braking action, contaminated runways/taxiways
ATC	Tough-to-meet clearances/restrictions, reroutes, language difficulties, controller errors
Environmental	Operational
Pressure	Terrain, traffic, TCAS TA / RA, radio congestion
Organizational (Airline)	**Threats Examples**
Aircraft	Systems, engines, flight controls, or automation anomalies or malfunctions; MEL items with operational implications; other aircraft threats requiring flight crew attention
Airline	Operational pressure on-time performance pressure, delays, late arriving aircraft or flight crew
Cabin	Cabin events, flight attendant errors, distractions, interruptions

Dispatch/Paperwork	Load sheet errors, crew scheduling events, late paperwork, changes or errors
Ground/Ramp	Aircraft loading events, fuelling errors, agent interruptions, improper ground support, de-icing
Ground Maintenance	Aircraft repairs on ground, maintenance log problems, maintenance errors
Manuals/Charts	Missing information or documentation errors

Adapted from Merritt & Klinect. (2006). Defensive Flying for Pilots: An Introduction to Threat and Error Management.

Threat management is a building block to error management and undesired aircraft state management. Although the threat-error linkage is not necessarily straightforward, although it may not be always possible to establish a linear relationship, or one-to-one mapping between threats, errors and undesired states, archival data demonstrates that mismanaged threats are normally linked to flight crew errors, which in turn are oftentimes linked to undesired aircraft states. Threat management provides the most proactive option to maintain margins of safety in flight operations, by voiding safety-compromising situations at their roots. As threat managers, flight crews are the last line of defense to keep threats from impacting flight operations (Merritt & Klinect, 2006).

Errors

Errors are defined "actions or inactions by the flight crew that lead to deviations from organizational or flight crew intentions or expectations". Unmanaged and/or mismanaged errors frequently lead to undesired aircraft states. Errors in the operational context thus tend to reduce the margins of safety and increase the probability of adverse events.

Errors can be spontaneous (i.e., without direct linkage to specific, obvious threats), linked to threats, or part of an error chain. Examples of errors would include the inability to maintain stabilized approach parameters, executing a wrong automation mode, failing to give a required callout, or misinterpreting an ATC clearance (Maurino, 2005).

From the TEM perspective, error is a crew action or inaction that leads to a deviation from crew or organizational intentions or expectations. Put simply, threats come "at" the crew, while errors come "from" the crew. Flight crew errors can be the result of a momentary slip or lapse, or induced by an expected or unexpected threat. For example, a late runway change might induce a procedural shortcut that results in further error, just as a gate agent interruption could distract the flight crew from completing a checklist, causing them to miss an incorrect flaps setting for takeoff. Other errors are more deliberate. Known as intentional noncompliance errors in the TEM taxonomy, these errors are often proven shortcuts used by flight crews to increase operational efficiency even thought they are in violation of Standard Operating Procedures. High rates of noncompliance at an airline can often indicate systemic over-procedualization (Merritt & Klinect, 2006).

Errors may be minor (selecting the wrong altitude into the mode control panel, but catching it quickly) or major (forgetting to do an essential checklist). The TEM model provides a

quantifiable framework to collect and categorize safety data (Flight Safety, 2004). Regardless of the type of error, an error's effect on safety depends on whether the flight crew detects and responds to the error before it leads to an undesired aircraft state and to a potential unsafe outcome. This is why one of the objectives of TEM is to understand error management (i.e., detection and response), rather than solely focusing on error causality (i.e., causation and commission). From the safety perspective, operational errors that are timely detected and promptly responded to (i.e., properly managed), errors that do not lead to undesired aircraft states, do not reduce margins of safety in flight operations, and thus become operationally inconsequential. In addition to its safety value, proper error management represents an example of successful human performance, presenting both learning and training value (Klinect, 2002). Capturing how errors are managed is then as important, if not more, than capturing the prevalence of different types of error. It is of interest to capture if and when errors are detected and by whom, the response(s) upon detecting errors, and the outcome of errors. Some errors are quickly detected and resolved, thus becoming operationally inconsequential, while others go undetected or are mismanaged. A mismanaged error is defined as an error that is linked to or induces an additional error or undesired aircraft state (Klinect, 2002).

Although not inclusive, Table 7 presents examples of errors, grouped under three basic categories derived from the TEM model. In the TEM concept, errors have to be "observable" and therefore, the TEM model uses the "primary interaction" as the point of reference for defining the error categories (Adapted from Merritt & Klinect, 2006).

Table 7

Error Types with Examples

Aircraft Handling Errors	**Examples**
Automation	Incorrect altitude, speed, heading, auto-throttle settings, mode executed, or entries
Flight Control	Incorrect flaps, speed brake, auto-brake, thrust reverser or power settings
Ground Navigation	Attempting to turn down wrong taxiway/runway/Missed taxiway/runway/gate
Manual Flying	Hand flying vertical, lateral, or speed deviations
	Missed runway/taxiway failure to hold short, or taxi above speed limit
Systems/Radio/Instruments	Incorrect pack, altimeter, fuel switch or radio frequency settings
Procedural Errors	**Examples**
Briefings	Missed items in the brief, omitted departure, takeoff, approach, or handover briefing
Callouts	Omitted takeoff, descent, or approach callouts
Checklist	Performed checklist from memory or omitted checklist

	Missed items, wrong challenge and response, performed late or at wrong time
Documentation	Wrong weight and balance, fuel information, ATIS, or clearance recorded. Misinterpreted items on paperwork
Pilot Flying (PF)/Pilot Not Flying (PNF) Duty	PF makes own automation changes, PNF doing PF duties, PF doing PNF duties
SOP Cross-verification	Intentional and unintentional failure to cross-verify automation inputs
Other Procedural	Other deviations from government regulations, flight manual requirements or standard operating procedures
Communication Errors	**Examples**
Crew to External	Missed calls, misinterpretation of instructions, or incorrect read-backs to ATC wrong clearance, taxiway, gate or runway communicated
Pilot to Pilot	Within-crew miscommunication or misinterpretation

Adapted from Merritt & Klinect. (2006). Defensive Flying for Pilots: An Introduction to Threat and Error Management.

The TEM model classifies errors based upon the primary interaction of the pilot or flight crew at the moment the error is committed. Thus, in order to be classified as aircraft handling error, the pilot or flight crew must be interacting with the aircraft (e.g. through its controls, automation or systems). In order to be classified as procedural error, the pilot or flight crew must be interacting with a procedure (e.g. checklists; SOPs; etc). In order to be classified as communication error, the pilot or flight crew must be interacting with people (ATC; ground crew; other crewmembers, etc.) (Maurino, 2005).

Aircraft handling errors, procedural errors and communication errors may be unintentional or involve intentional non-compliance. Similarly, proficiency considerations (i.e., skill or knowledge deficiencies, training system deficiencies) may underlie all three categories of error. In order to keep the approach simple and avoid confusion, the TEM model does not consider intentional non-compliance and proficiency as separate categories of error, but rather as sub-sets of the three major categories of error (Merritt & Klinect, 2006).

Error management is now recognized as an inevitable part of learning, adaptation, and skill maintenance; hence, a primary driving force behind TEM is to understand what types of errors are made under what circumstances (i.e., the presence or absence of which threats) and how crews respond in those situations (Merritt & Klinect, 2006). For example, do crews detect and recover the error quickly, do they acknowledge the error but do nothing, perhaps because they believe it is inconsequential or will be trapped later, or do they only “see” the error when it escalates to a more serious undesired aircraft state? This is the heart of error management: detecting and correcting errors. However, approximately 45% of the observed errors in the LOSA Archive were errors that went undetected or were not responded to by the flight crew, which gives credence to an important point for effective error management: An error that is not detected cannot be managed (Maurino, 2005). An error that is detected and effectively managed

has no adverse impact on the flight. On the other hand, a mismanaged error reduces safety margins by linking to or inducing additional error or an undesired aircraft state.

Undesired Aircraft States

Undesired aircraft states are defined as 'flight crew-induced aircraft position or speed deviations, misapplication of flight controls, or incorrect systems configuration, associated with a reduction in margins of safety". Undesired aircraft states that result from ineffective threat and/or error management may lead to compromising situations and reduce margins of safety in flight operations. Often considered at the cusp of becoming an incident or accident, undesired aircraft states must be managed by flight crews (Maurino, 2005).

Examples of undesired aircraft states would include lining up for the incorrect runway during approach to landing, exceeding ATC speed restrictions during an approach, or landing long on a short runway requiring maximum braking. Events such as equipment malfunctions or ATC controller errors can also reduce margins of safety in flight operations, but these would be considered threats. Undesired states can be managed effectively, restoring margins of safety, or flight crew response(s) can induce an additional error, incident, or accident. Table 8 (list not inclusive) presents examples of undesired aircraft states, grouped under three basic categories derived from the TEM model.

Table 8

Examples of Undesired Aircraft States

Undesired Aircraft States Types with Examples

UAS Types	**Examples**
Aircraft Handling	Vertical, lateral or speed deviations/Unnecessary weather penetration/Unstable approach/Long, floated, firm or off-center-line landings
Ground Navigation	Runway/taxiway incursions/ Wrong taxiway, ramp, gate, or hold spot/Taxi above speed limit
Incorrect Aircraft Configuration	Automation, engine, flight control, systems, or weight/balance events

Adapted from Merritt & Klinect. (2006). Defensive Flying for Pilots: An Introduction to Threat and Error Management.

An important learning and training point for flight crews is the timely switching from error management to undesired aircraft state management. An example would be as follows: a flight crew selects a wrong approach in the Flight Management Computer. The flight crew subsequently identifies the error during a crosscheck prior to the Final Approach Fix (FAF). However, instead of using a basic mode (e.g. heading) or manually flying the desired track, both flight crew become involved in attempting to reprogram the correct approach prior to reaching the FAF. As a result, the aircraft "stitches" through the localizer, descends late, and goes into an

unstable approach. This would be an example of the flight crew getting "locked in" to error management, rather than switching to undesired aircraft state management. The use of the TEM model assists in educating flight crews that, when the aircraft is in an undesired state, the basic task of the flight crew is undesired aircraft state management instead of error management. It also illustrates how easy it is to get locked in to the error management phase (Merritt & Klinect, 2006).

Also from a learning and training perspective, it is important to establish a clear differentiation between undesired aircraft states and outcomes (Maurino, 2005). Undesired aircraft states are transitional states between a normal operational state (i.e., a stabilized approach) and an outcome. Outcomes, on the other hand, are end states, most notably, reportable occurrences (i.e., incidents and accidents). An example would be as follows: a stabilized approach (normal operational state) turns into an un-stabilized approach (undesired aircraft state) that results in a runway excursion (outcome). The training and remedial implications of this differentiation are of significance. While at the undesired aircraft state stage, the flight crew has the possibility, through appropriate TEM, of recovering the situation, returning to a normal operational state, thus restoring margins of safety. Once the undesired aircraft state becomes an outcome, recovery of the situation, return to a normal operational state, and restoration of margins of safety is not possible (Sexton, Wilhelm, Helmreich, Merritt, & Klinect, 2001). Regardless of whether threats are expected, unexpected, or latent, one measure of the effectiveness of a flight crew's ability to manage threats is whether threats are detected with the necessary anticipation to enable the flight crew to respond to them through deployment of appropriate countermeasures (Maurino, 2005).

Applications of TEM

Threat management can be broadly defined as how crews anticipate and/or respond to threats. A mismanaged threat is defined as a threat that is linked to or induces flight crew error. Some of the common tools and techniques used in commercial aviation to manage threats and prevent crew errors include reading weather advisories, turning weather radar on early, thorough walk-arounds during pre-departure, correct use of procedures to diagnose unexpected aircraft malfunctions, briefing an alternate runway in case of a late runway change, briefing cabin crew as to acceptable times and reasons for interruptions, and loading extra fuel when the destination airport is in question due to poor weather or restricted access (Merritt & Klinect, 2006).

The principles of TEM are not new to aviation. In fact, Orville and Wilbur Wright no doubt practiced threat and error management when they took their first controlled flight with the Wright Flyer in 1903 (Maurino, 2005). Since then, various tools and techniques have been developed over the past century to help flight crews manage threats, errors, and undesired aircraft states. Some tools—the "hard" safeguards—are associated with aircraft design, and include automated systems, instrument displays, and aircraft warnings. The Traffic Collision Avoidance System, which provides flight crews with visual and audio warnings of nearby airplanes to prevent midair collisions, is a good example of a "hard" TEM safeguard. Even with the best designed equipment however, these "hard" safeguards are not enough to ensure effective TEM performance (Merritt & Klinect, 2006).

Other tools—the "soft" safeguards—are very common in aviation (and other high-risk industries). They include regulations, standard operating procedures, and checklists to direct pilots and maintain equipment; and licensing standards, checks, and training to maintain proficiency. With the hard and soft safeguards in place, the last line of defense against threat, error, and undesired aircraft states, is still, ultimately, the flight crew. Checklists only work if flight crews use them; the autopilot only works when engaged in the correct mode. Therefore, TEM tools work best when pilots adopt TEM techniques (Flight Safety, 2004).

The TEM philosophy stresses three basic concepts: *anticipation*, *recognition*, and *recovery*. The key to anticipation is accepting that while something is likely to go wrong, you can't know exactly what it will be or when it will happen. Hence, a chronic unease reinforces the vigilance that is necessary in all safety-critical professions. Anticipation builds vigilance, and vigilance is the key to recognizing adverse events and error. Logically, recognition leads to recovery. In some cases, particularly when an error escalates to an undesired aircraft state, recovering adequate safety margins is the first line of action: Recover first, analyze the causes later. For example, a crew enters a Flight Management System approach to runway 26L; however, they mistakenly enter data for 26R. Furthermore, the error is not detected by the flight crew on a required cross-verification. Once the flight crew executes the incorrect entry and the airplane starts flying on a profile to the wrong runway, the flight is considered to be in an undesired aircraft state. At this point, the crew can either analyze what's wrong with the automation and fix the problem or save valuable time by simply disconnecting the autopilot and hand-flying the approach to the correct runway. The latter option is more effective from the TEM perspective because it focuses effort on recovering from the undesired aircraft state rather than analyzing its causes (Merritt & Klinect, 2006).

While "hard" and "soft" safeguards help support pilots to best anticipate, recognize and recover from threats, errors, and undesired aircraft states, there is arguably no better way to manage these events in multi-pilot cockpits than through effective crew coordination. Many of the best practices advocated by CRM can be considered TEM countermeasures (International Civil Aviation Organization, 2008). Initial research in the LOSA Archive has supported links between TEM and CRM (Maurino, 2005). For example, crews that develop contingency management plans, such as proactively discussing strategies for anticipated threats, tend to have fewer mismanaged threats; crews that exhibit good monitoring and cross-checking usually commit fewer errors and have fewer mismanaged errors; and finally, crews that exhibit strong leadership, inquiry, workload management are typically observed to have fewer mismanaged errors and undesired aircraft states than other crews (Merritt & Klinect, 2006).

TEM and the Aviation Industry

The International Civil Aviation Organization (ICAO) has introduced a standard making TEM training mandatory for airline flight crews engaged in international operations (International Civil Aviation Organization, 2008). TEM training must now be delivered during initial as well as during recurrent training. ICAO has also introduced standards making TEM training mandatory for licensing and training requirements of private and commercial pilots and air traffic controllers. In order to support these standards, ICAO is continually developing guidance material on TEM. In addition, the Australian Transport Safety Bureau and Australian Civil

Aviation Safety Authority are facilitating TEM training courses for pilots (Merritt & Klinect, 2006).

LOSA is considered a best practice for normal operations monitoring and aviation safety by both ICAO and the FAA. TEM-based LOSAs continue to provide valuable diagnostic information about an airline's safety strengths and vulnerabilities (Federal Aviation Administration, 2006). Several US airlines now use TEM as the conceptual structure for their incident reporting systems. Reporting forms prompt pilots to report the threats that were present, the errors they may have made, how the event was managed, and how the event may have been avoided or handled better. Even pilots who have not had training in TEM are able to complete the reporting form, a fact that speaks to the intuitive nature of the TEM framework (Merritt & Klinect, 2006).

The International Air Transport Association (IATA) Safety Committee adopted the TEM model as an analysis framework for its Incident Review Meetings, based on its ease of use and utility of the extracted data. IATA has also created the Integrated Threat Analysis Task Force. This group analyses data from accidents, incidents, and normal operations using TEM as the common framework. By selecting specific scenarios, for example, runway excursions from the incident and accident databases, and precursors to runway excursions from the LOSA Archive, it is possible to provide a more complete picture of safety issues within the aviation system (Merritt & Klinect, 2006).

TEM is both a philosophy of safety and a practical set of techniques. Originally designed to simultaneously capture performance and the context in which it occurs, TEM has demonstrated its usefulness in many settings. TEM has proved its utility in many safety management applications. As organizations and individuals continue to adopt TEM as a way to understand and enhance their performance, the utility of the TEM framework continues to enhance safety (Merritt & Klinect, 2006).

Runway Incursions

On October 1, 2007, as part of its Flight Plan Goal for international leadership, the FAA adopted the International Civil Aviation Organization's (ICAO) standard definitions for runway incursions and runway incursion severity. Beginning Fiscal Year 2008, the FAA defined a runway incursion as "any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and takeoff of aircraft" (FAA, 2009a, pg.6).

The FAA previously tracked any incident that did not involve potential aircraft conflicts as a "surface incident." Because the FAA did not consider these incidents to be runway incursions, they were tracked and monitored separately. As a result of the FAA's adoption of the ICAO definition, the FAA has a wider range of incursion data to analyze providing for a greater understanding of contributing factors in the occurrence of runway incursions.

The FAA also adopted the ICAO definitions for runway incursion severity. These definitions categorize those events previously tracked as non-runway incursions in Category D, which are low-risk incidents with either no conflict potential, or ample time or distance to avoid a collision. The majority of runway incursions (See Table 9) in the U.S. were Category C and Category D (see Table 9 and Figure 4) events during the 2005-2008 year period (FAA, 2009a).

Table 9

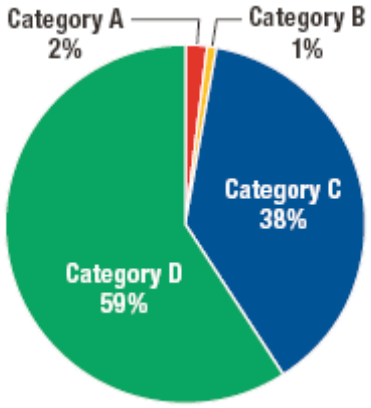
Runway Incursion Severity Classification

Category	Description
Accident	Refer to ICAO Annex 13 definition of an accident.
A	A serious incident in which a collision was narrowly avoided.
B	An incident in which separation decreases and there is a significant potential for collision, which may result in a time critical corrective/ evasive response to avoid a collision.
C	An incident characterized by ample time and/or distance to avoid a collision.
D	Incident that meets the definition of runway incursion such as incorrect presence of a single vehicle/person/aircraft on the protected area of a surface designated for the landing and take-off of aircraft but with no immediate safety consequences.

Adapted from FAA, 2009a, Annual Runway Safety Report.

Figure 4

Runway Incursion Severity Distribution Fiscal Year 2005 through Fiscal Year 2008



Adapted from FAA, 2009a, Annual Runway Safety Report.

Classification of Runway Incursions

Runway incursions are divided into three classification types. These types include pilot deviations, operational/error deviations, and vehicle/pedestrian deviations (See Table 10) (FAA, 2009a). By definition, a pilot deviation is an action taken by a pilot that results in a failure to comply with an air traffic control clearance and/or instruction (Jenkins, 2008). Operational Error/Deviation is defined as an occurrence, attributable to an element of the air traffic control system, that results in less than the applicable separation minimum between two or more aircraft and obstacles (obstacles include vehicles, equipment, and personnel on runways), or an aircraft landing or departing on a runway closed to aircraft after receiving authorization from air traffic control (ALPA, 2007). Vehicle/Pedestrian Deviations is any unauthorized entry to an airport movement area by a vehicle or pedestrian or failure to follow procedures and/or air traffic instruction (Jenkins, 2008).

Table 10

Classifications of Runway Incursions

Pilot Deviations	Operational Errors/Deviations	Vehicle/Pedestrian Deviations
A pilot deviation (PD) is an action of a pilot that violates any Federal Aviation Regulation. For example, a pilot fails to obey air traffic control instructions to not cross an active runway when following the authorized route to an airport gate.	An operational error (OE) is an action of an air traffic controller (ATC) that results in: 1. Less than the required minimum separation between two or more aircraft, or between an aircraft and obstacles (e.g., vehicles, equipment, personnel on runways). 2. An aircraft landing or departing on a runway closed to aircraft. An operational deviation (OD) is an occurrence attributable to an element of the air traffic system in which applicable separation minima were maintained, but an aircraft, vehicle, equipment, or personnel encroached upon a landing area that was delegated to another position of operation without prior coordination and approval.	A vehicle or pedestrian deviation (V/PD) includes pedestrians, vehicles, or other objects interfering with aircraft operations by entering or moving on the movement area without authorization from air traffic control. NOTE: This runway incursion type includes mechanics taxiing aircraft for maintenance or gate re-positioning.

Adapted from FAA, 2009a, Annual Runway Safety Report.

Pilot deviations are the leading classification of runway incursions (See Table 11). The majority of runway incursions caused by pilot deviations occur during the taxiing out for aircraft departure phase (Jenkins, 2008). An analysis of runway incursion data indicates runway incursions that cause accidents generally occur at complex, high volume/density airports. The data also show there is a high incidence of runway incursions involving general aviation pilots that often result from misunderstood controller instructions, confusion, disorientation, and/or inattention (Rankin and Cokley, 2007). Because runway incursions can involve and affect such a wide cross section of pilot skill levels and airport operations, runway incursion prevention measures must be as broad in scope as possible.

Table 11

Number of Incursions for Each Runway Incursion Type

	FY 2005	FY 2006	FY 2007	FY 2008	Total
Pilot Deviations	447	507	575	637	2,166
Operational Errors/Deviations	126	111	124	164	525
Vehicle/Pedestrian Deviations	206	198	193	208	805
Total	**779**	**816**	**892**	**1,009**	**3,496**

Adapted from FAA, 2009a, Annual Runway Safety Report.

Runway Safety Strategy

As part of the Runway Safety Strategy on August 15, 2007 the FAA announced the "Call to Action for Runway Safety". The FAA's Call to Action focused on cockpit procedures, air traffic procedures, airport signage and safety markings, technology, and training. Led by the FAA, more than 40 aviation leaders from airlines, airports, air traffic control, pilot unions, and aerospace manufacturers worked together to identify other places where the National Airspace System may be vulnerable to human error and therefore create potential for runway incursions (FAA, 2009a). Table 12 describes two runway incursions that furthered action towards the FAA's updated runway safety strategy.

Table 12

Runway Incursion Events That Prompted Action

Event Date	Airport Code	Airport	Brief Summary
3/21/2006	ORD	Chicago O'Hare	An Airbus A319 was instructed to hold short of Runway 4L, as an another aircraft was exiting the same runway. Simultaneously, an Embraer E145, was instructed to hold short of an intersecting runway. When the aircraft cleared runway 4L, the A319 was cleared for takeoff from Runway 4L. After approximately half-a-minute the Embraer was also cleared for take-off on the intersecting runway. Shortly thereafter the Local Monitor noticed both aircraft were rolling at the same time and told the Local Control, who canceled takeoff instructions to both aircraft. Closest proximity reported was 100 feet horizontal when the Embraer aborted its take-off after having applied maximum breaking. The Embraer had entered the intersection and the A319 had stopped just prior to edge of the intersection.
07/11/2007	FLL	Fort Lauderdale/ Hollywood	An Airbus A320 was instructed to taxi to Runway 9L. The A320 missed a left turn and ended up Runway 9L without a clearance. A go around was issued to a Boeing B757 who was about to touch down on Runway 9L. The B757 executed a go around immediately and over flew the A320 by approximately 50 feet.

Adapted from FAA, 2009a, Annual Runway Safety Report.

Cockpit procedures address the vital communications, such as the completion of safety checklists, which occur between members of a flight crew during all phases of flight, from

pushback to arrival. Flight communications must be crisp and precise to ensure that the crew works as an effective team and that a sterile cockpit operating environment is maintained. It is also critical for a flight crew to seamlessly communicate with air traffic control. The FAA asked air carriers to review cockpit procedures to identify and develop a plan to address elements that contribute to pilot distraction during taxi. Of the 112 active air carriers, all have reported that they are in compliance (FAA, 2009a).

Runway Incursion Aviation Industry Training

As previously mentioned, pilot deviations are the leading cause of runway incursions (See Table 11), with the majority of runway incursions caused by pilot deviations occurring during the taxiing out for aircraft departure phase (Jenkins, 2008). Since almost two thirds of runway incursions in 2009 resulted from pilot deviations, the FAA required air carriers to retrain their crews (FAA, 2009a). The FAA moved to have the carriers review cockpit procedures to identify and develop plans to minimize pilot distractions during taxi. All 112 carriers have complied with these efforts. Air carriers also are emphasizing their recurrent training programs for non-pilots who operate aircraft or other vehicles on the airfield (FAA, 2009a). Table 13 exhibits an example of air carrier threat and error management response factors.

Table 13

Air Carrier Threat and Error Management Response Factors

AIR CARRIER THREAT AND ERROR MANAGEMENT RESPONSE FACTORS

Situational Awareness	Properly comprehend taxi clearance and trap inherent errors, and know their position on the airport surface.
See and Be Seen	Adopt techniques to enhance the likelihood of being seen by traffic on final when moving on the airport surface.
Expectation Bias	Resist temptation to expect a certain clearance based on past experience with commonly used movement patterns.
Distraction	Avoid unnecessary distractions that could divert attention from safe taxi.
Haste	Avoid errors and undesired aircraft state resulting from time compression.
Fatigue	Address vulnerability to this ever-present human physiological factor.

Adapted from the Commercial Aviation Safety Team (CAST) Supplemental Implementation Plan for CAST Safety Enhancement 60.

CFR Part 91 and 135 Carriers

Advisory Circular 91-73A addresses the single pilot operations and taxi procedures. This Advisory Circular (AC) provides guidelines for the development and implementation of standard operating procedures (SOP) for conducting safe aircraft operations during taxiing. It is intended for use by persons operating aircraft single pilot under parts 91 and 135 of Title 14 of the Code of Federal Regulations (14 CFR). The FAA recommended that these guidelines become an integral part of all SOPs, flight operations manuals, and formal flight training programs (FAA, 2003b).

Runway Incursion and Wrong Runway Training Scenarios

The potential for runway incidents and accidents can be reduced through adequate planning, coordination, and communication. The FITS TEM runway incursion and wrong runway incident training scenarios present situations and circumstances that pilots face every day as learning experiences and lessons. The times shown in each lesson are target times and should not be considered the minimum or maximum ground/flight time for the lesson. This means that each lesson does not necessarily equal one training session. It may take several training sessions before the pilot in training (PT) masters the elements of the lesson and is ready to move on to the next lesson. The PT will be placed in a scenario where he/she will be expected to manage the situation and "fly" the airplane. The following FITS TEM training scenarios are intended to help pilots cope more effectively with current airport conditions during taxi operations.

Lesson 1 - Taxiing and Airport Markings

Scenario: Once you're on the ground, you're safe, right? Oh, no! What if you pull out on to a runway when you aren't supposed to, and a 747 bounces on top of you? That would be really bad. Fortunately, this is very easy to avoid, providing that you follow ATC clearances and you know what the runway markings mean as well all airport signage. This scenario is about taxiing procedures and interpreting airport signage.

Lesson Objective: To learn proper taxiing techniques and how to interpret airport runway markings and lighting, and ground clearances. Runway incursion avoidance practices will be explained as well as a review of aircraft ground operations.

Pre-Briefing: This portion of the lesson will serve as the ground lesson for this training scenario. The instructor will lead a guided discussion on aircraft taxiing procedures, runway incursion avoidance, and how to interpret airport runway markings and lighting.

Materials: airworthy aircraft for taxing only, 14 CFR/AIM and any other supporting materials, such as visual aids of types of runway/taxiway signs and airport markings, lighting, and hand signals.

Development: This ground lesson is divided into two sections. The first section will address airport signage while the second part addresses taxi procedures. The instructor will give an overview and explanation of all airport signs and taxiway/runway markings. Using pictures, explain the following:

Wind sock, tetrahedron, wind-T
Segmented circle
Six kinds of runway signs (MIDDLR)
Hold-short line
ILS hold-short line

Chevrons vs. displaced thresholds
Fixed-distance (aiming point) markings and touchdown zone indicators
Threshold markings and runway heading
Threshold (green/red) lights
Beacons: types and meaning, day and night
Blue taxiway edge lights
White runway edge lights
REIL
ALS
VASI, PLASI, PAPI, Tri-color VASI
Pilot-controlled lighting

For an overview and explanation of taxiing procedures, the instructor can use the aircraft before engine start, after engine start, before taxi checklist, and taxi checklist to explain the following:

1. How to receive a clearance to taxi, and read it back to ATC. How to prepare the aircraft before you move, such as having radios tuned, airport diagram available, etc.
2. How to do a brake check before beginning to taxi.
3. How to position the aircraft controls for wind: such as dive away from or turn into wind.
4. How to use rudders for steering: small control movements.
5. How to use the throttle to control speed, not brakes. Use brakes very sparingly.
6. How to follow the appropriate airport markings and signs, and to follow the ATC clearance.

The instructor will explain common errors while taxiing, such as:

Trying to steer with the yoke
Yoke not positioned correctly for wind

Distractions such as tuning radio
Not on the centerline
Poor speed control: brakes instead of throttle
Hand not on throttle
Disorientation, loss of SA on airport

Suggested oral evaluation/quiz and discussion questions:

Q: If ATC ground tells you to taxi to runway 23, what type of clearance should you expect?
What is the proper clearance used to cross runways?
Q: If you're told to taxi and hold short of runway 29, where do you have to stop, exactly?
Q: What is an ILS hold area?
Q: How do you control the speed of the aircraft when taxiing?
Q: How do you position the yoke for various wind directions?
Q: How would you know where the wind is coming from?
Q: If the airport beacon is running during daylight hours, what does that mean?
Q: When taxiing, identify the various kinds of runway signs.

Completion Standards:

This lesson is complete when the pilot in training (PT) demonstrates a working knowledge of proper taxiing techniques, how to interpret airport runway markings and lighting, ground and other ATC clearances, runway incursion avoidance practices, and all aircraft ground operations. With reference to airport signage, the PT can identify the various airport signs and runway/taxiway markings, understands meaning of rotating beacons at night and in daylight hours, shows understanding of lighting systems through use and explanation. While taxiing, the PT positions aircraft controls for wind, maintains control of aircraft with accuracy and safety, obtains and follows ATC ground clearances as appropriate.

Desired Outcome Grade Sheet: Although this scenario is a no-flight scenario, the PT should know how to perform a normal takeoff and approach to landing depending on the PT's knowledge and skill level. Although the PT is not actually flying, the PT should be able to explain the before takeoff checks, takeoff and approach procedures, as well as proper landing techniques.

Scenario Tasks	**Scenario Sub Tasks**	**Desired Performance**
Flight Planning	1. Scenario Planning 2. Certificates and Documents 3. Airport Diagrams 4. Preflight SRM briefing 5. Decision making and risk management	Describe Explain Describe Explain Explain
Normal preflight and cockpit procedures	1. Use of Checklists 2. Preflight Inspection 3. Minimum equipment list 4. Cockpit management 5. Airplane Servicing 6. Operation of systems 7. Positive exchange of flight controls 8. Aircraft preflight inspection 9. Checklist usage and flow patterns 10. SRM/TEM/CRM	Explain Describe Describe Explain Describe Describe Practice Explain Explain Explain
Engine Start and Taxi Procedures	1. Engine start 2. Airport and runway markings and lighting 3. Radio Communications 4. Normal and crosswind taxi operations 5. SRM/Situational awareness	Explain Describe Describe Describe Explain

Before Takeoff Checks	1. Normal and abnormal indications 2. Wind shear avoidance 3. Aircraft automation management 4. Aeronautical Decision Making and Risk management	Explain Explain Explain Explain
Takeoff	1. Normal takeoff 2. Situational awareness 3. SRM and risk management	Describe Explain Explain
Approach Procedures	1. Traffic pattern entry procedures 2. Collision avoidance precautions 3. Situational awareness, task management and SRM 4. Wind shear avoidance 5. Communications 6. Normal approach 7. SRM/TEM/CRM	Explain Explain Explain Explain Explain Explain Explain
Landing	1. Before landing procedures 2. Normal landing 3. After landing procedures 4. SRM/TEM/CRM	Explain Explain Explain Explain
Taxi and aircraft shutdown and securing procedure	1. Use of Checklist 2. Aircraft ground operations and parking 3. Post Flight 4. Securing 5. SRM/TEM/CRM	Explain Explain Describe Explain Explain

Post-Briefing: The flight instructor should solicit a self-critique from the Pilot in Training (PT) about their personal performance by having the PT grade their performance based on the desired outcomes for the flight. Compare the PT's self evaluation to the instructor's grades and discuss any differences in the assessment. The flight instructor should then use this information to direct an analysis of the flight. Additionally, the instructor should discuss the role SRM played in the training activity and why it is critical to always consider how a flight or a situation could have been better managed to achieve the optimal outcome. The instructor will provide guidance on what the tasks and objectives will be for the next training activity and how the PT should prepare for it.

Notes to the Instructor: On the ground while taxiing, the flight instructor should demonstrate proper taxiing technique and explain airport signs as they taxi. Practice proper control position for wind and rudder technique, answer questions regarding airport signs, clearances, and runway incursion avoidance. Because of side by side seating, the PT might need help for putting the nose wheel on the taxiway center line. Move the aircraft so as to be centered on a line. See the AIM for taxiing signals.

The most likely aircraft ground accident occurs while taxiing. Casual taxiing and parking attitudes are preludes to accidents, so always taxi with the correct yoke movement. In windy conditions, one could only have seconds to correctly position the controls before an incident occurs. Taxiing is flying with the wheels on the ground. You can control the speed with the throttle and the direction with the combination of rudder and brake. Reduce power once the aircraft begins to taxi. Staying on the yellow lines should give obstacle clearance but watch out for traffic.

During each departure, flight checkpoints along the flight line should be pointed out as to identification, distance, and runway orientation. These points will be incorporated into the radio work for subsequent arrivals. This radio planning for arrivals is best done on the ground prior to departure to be followed by a known arrival.

Taxiing starts once you leave the parking spot after doing the brake check. Taxiing also begins when you cross the hold bar lines on clearing the runway and completing the post-landing checklist. Difficulty controlling taxi direction is indicative of a brake or wind problem. If you are having taxiing difficulty, slow down. Make sharp turns with careful use of a brake-power combination. Do all taxiing that does not involve sharp turns by use of the rudder pedals and not the brakes, assuming a steerable nose wheel. Airplanes with free caterings nose wheels should be turned by gently using differential breaking in necessary. Do not ride the brakes. Hot brakes lose their ability to stop the plane.

Arrive at the run up area so as to allow the engine to face the wind for additional cooling and to allow maximum room for other aircraft. Circumstances such as blowing dust or noise may require that aircraft be facing a specific direction while in the run up area. Remain as far back from the taxiway as possible to allow safe passage of long winged aircraft.

Although this scenario is a no-flight scenario, the PT should know how to perform a normal takeoff and approach to landing depending on the PT's knowledge and skill level. Although the PT is not actually flying, the PT should be able to explain the before takeoff checks, takeoff and approach procedures, as well as proper landing techniques. Before takeoff practice, clearing the final and base leg should be a part of every takeoff. Monitoring the radio alone is not sufficient insurance to be sure that another aircraft is not in conflict with your aircraft.

Encourage the PT to look for the information he/she needs and teach the PT how to find the information. Discuss the actions taken by the PT during the training scenario, why these actions were taken, what other actions could have been taken, and which of the actions would have been best. These discussions develop judgment and allow a single training scenario to be used to teach the PT appropriate responses in various situations.

Lesson 2 – HOT Spots

Scenario: Next week the PT is planning a flight to San Francisco to visit friends and family for the weekend. The PT has never been to San Francisco, so the airport and airspace will be unfamiliar. The San Francisco International airport (KSFO) is typically a busy airport traffic area. In reviewing the KSFO airport diagram, the PT saw HOT spots on the diagram and did not know what they meant. The PT hasn't flown in a couple of months either so perhaps a flight to KSFO with an instructor is the safest plan of action.

Lesson Objective: To become familiar with HOT spots and how to avoid runway incursions.

Pre-Briefing: This portion of the lesson will serve as the ground lesson for this training scenario. The instructor will lead a guided discussion on HOT spots and how to avoid runway incursions.

Materials: KSFO airport charts, airworthy aircraft, 14 CFR/AIM and any other supporting materials.

Development: The instructor will give an overview and explanation of HOT spots and how to avoid runway incursions. Using pictures and supporting materials, the instructor will explain how the National Aeronautical Charting Office (NACO) diagrams bring attention to movement areas that have previously contributed to the occurrence of runway incursions. ICAO defines a HOT spot as "a location on an aerodrome movement area with a history or potential risk of collision or runway incursion, and where heightened attention by pilots and drivers is necessary". The use of labels for HOT spots on all NACO diagrams will make it easier for users of an airport to plan the safest possible path of movement in and around that airport. Planning is a crucial safety activity for airport users, both the pilots and the air traffic controllers. By making sure that aircraft surface movements are planned and properly coordinated with air traffic control, pilots add another layer of safety to their flight preparations. Proper planning helps avoid confusion by eliminating last-minute questions and building familiarity with known problem areas.

Suggested oral evaluation/quiz and discussion questions:

Q: If ATC ground tells you to taxi to runway 23, what type of clearance should you expect? What is the proper clearance used to cross runways?

Q: If you're told to taxi and hold short of runway 29, where do you have to stop?
Q: What is a HOT spot?
Q: Where is the legend for interpretation of the HOT spots? (NACO or Jeppesen charts)
Q: What methods can you think of that avoid runway incursions?
Q: What practices contribute to runway incursions?
Q: How do you familiarize yourself with an unfamiliar airport and airspace?

Completion Standards:

This lesson is complete when the pilot in training (PT) demonstrates a working knowledge of HOT spots and how to safely avoid runway incursions at any given airport.

Desired Outcome Grade Sheet:

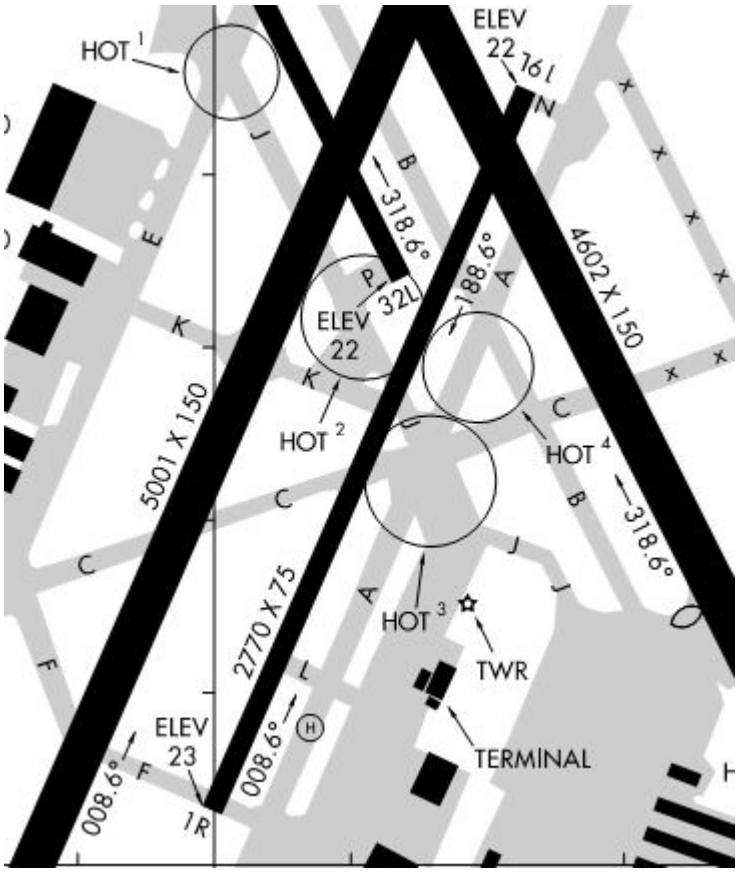
Scenario Tasks	**Scenario Sub Tasks**	**Desired Performance**
Flight Planning	1. Scenario Planning 2. Certificates and Documents 3. Airport Diagrams and HOT spots 4. Preflight SRM briefing 5. Decision making and risk management	Describe Explain Explain Practice Practice
Normal preflight and cockpit procedures	1. Use of Checklists 2. Preflight Inspection 3. Minimum equipment list 4. Cockpit management 5. Aircraft preflight inspection 6. Checklist usage and flow patterns 7. SRM/TEM/CRM	Explain Explain Explain Practice Practice Practice Practice
Engine Start and Taxi Procedures	1. Engine start 2. Airport and runway markings and lighting 3. Radio Communications 4. Normal and crosswind taxi operations 5. Runway incursion avoidance 6. SRM/Situational awareness	Explain Explain Practice Practice Practice Practice
Before Takeoff Checks	1. Normal and abnormal indications 2. Wind shear avoidance 3. Aircraft automation management 4. Aeronautical Decision Making and Risk management	Explain Explain Explain Explain
Takeoff	1. Normal takeoff 2. Situational awareness and wrong runway avoidance 3. SRM and risk management	Practice Practice Practice

Approach Procedures	1. Traffic pattern entry procedures 2. Collision avoidance precautions 3. Situational awareness, task management and SRM 4. Wind shear avoidance 5. Communications 6. Normal approach 7. SRM/TEM/CRM	Explain Explain Explain Explain Explain Explain Explain
Landing	1. Before landing procedures 2. Normal landing 3. After landing procedures 4. SRM/TEM/CRM	Explain Explain Explain Explain
Taxi and aircraft shutdown and securing procedure	1. Use of Checklist 2. Aircraft ground operations and parking 3. Post Flight 4. Securing 5. SRM/TEM/CRM	Explain Explain Practice Explain Explain

Post-Briefing: The flight instructor should solicit a self-critique from the Pilot in Training (PT) about their personal performance by having the PT grade their performance based on the desired outcomes for the lesson. Compare the PT's self evaluation to the instructor's grades and discuss any differences in the assessment. The flight instructor should then use this information to direct an analysis of the lesson. Additionally, the instructor should discuss the role SRM played in the training activity and why it is critical to always consider how a flight or a situation could have been better managed to achieve the optimal outcome. The instructor will provide guidance on what the tasks and objectives will be for the next training activity and how the PT should prepare for it.

Notes to the Instructor: On the KSFO airport diagram, there are four areas marked "HOT." The legend for the airport diagram only identifies them as HOT spots. However, after the legend there's an index of all the HOT Spots, similar to how alternate minimums or departure procedures are listed in the TERPs. The preface describes the HOT spots as movement areas with a history or risk of collision or runway incursion. Makes sense as all of these HOT spots are at complex intersections or intersections with high intersection angles. The HOT spot number refers to an index of explanations for each spot. In the KSFO example, two of the spots identify areas where pilots often make wrong turns, another is for the complex intersection of Rwy 01R-19L, Twy J, Twy A, Twy C, and Twy K, and the last is a hold-short area for 32L.

KSFO Airport Diagram with HOT Spots



Prior to entering the plane, after the preflight is completed, a complete discussion and analysis of both planned departure and arrival are made. The instructor should always encourage the PT to look for the information he/she needs and teach the PT how to find the information. Discuss the actions taken by the PT during the training scenario, why these actions were taken, what other actions could have been taken, and which of the actions would have been best. These discussions develop judgment and allow a single training scenario to be used to teach the PT appropriate responses in various situations.

Lesson 3 – Uncontrolled Airport Procedures

Scenario: You are flying to an uncontrolled airport. You are familiar with this airport as you have landed there many times for fuel. However, this time ATC is unavailable due to after-hours so the airport is now operating as an uncontrolled airport.

Lesson Objective: To learn proper airport surface operations at non-towered airports and at airports when the ATC tower is closed. The PT will practice runway incursion avoidance procedures.

Pre-Briefing: This portion of the lesson will serve as the ground lesson for this training scenario. The instructor will lead a guided discussion on the absence of an operating ATC tower and how it creates a need for increased vigilance on the part of pilots operating at those airports. There are also specific communications procedures that differ from those used at towered airports. As is the case at towered airports, planning, clear communications, and enhanced situational awareness during airport surface operations will reduce the potential for surface incidents at airports without an operating control tower.

Materials: Any airport charts, airworthy aircraft, 14 CFR/AIM manual, and any other supporting materials such as visual aids of types of runway/taxiway signs and airport markings, lighting, and hand signals.

Development: During this ground lesson, the instructor should discuss with the PT what items should be considered when operating at an airport without an operating control tower. Pilots should familiarize themselves with the local traffic pattern. Pilots should remember that not all airports use a standard traffic pattern and that the pattern altitude should be checked. During calm or nearly calm wind conditions, be aware that flight operations may occur at more than one runway at the airport. Also, aircraft may be using an instrument approach procedure to runways other than the runway in use for visual flight rules (VFR) operations. The instrument approach runway may intersect the VFR runway. It is also possible that an instrument arrival may be made to the opposite end of the runway from which a takeoff is being made. Be sure that the taxi plan is understood.

While maintaining situational awareness is important in all circumstances, it is particularly important when operating at an airport without an operating control tower. To achieve situational awareness, pilots should be fully aware of their intended taxi route and be able to follow the planned route correctly. Without ATC to verbally tell pilots where they should taxi and where and when to stop, they must rely on visual cues to maintain situational awareness and maintain their planned taxi route. These visual cues include airport signs, markings, and lighting, together with the airport diagram. Other things to consider that can help pilots maintain situational awareness while operating at an airport without an operating control tower include the following:

(1) Monitor the appropriate frequency. Pilots should listen to what the pilots of other aircraft on the frequency are saying.
(2) If possible, pilots should monitor the approach control frequency to alert them to instrument flight rules (IFR) traffic inbound to the airport.

(3) Prior to crossing the hold short line or entering or crossing any runway, pilots should scan the full length of the runway, including approach areas. Do not engage in any other flightdeck or cockpit duties while crossing a runway. Full attention must be given to crossing and clearing the runway.
(4) Pilots should use exterior lighting to make their aircraft more conspicuous to other pilots.

Communication rules and guidelines and aeronautical data for operations at airports without an operating control tower differ from those applicable at towered airports. Various regulations, the AIM, approved pilot training programs, and operational procedure manuals provide information to the pilot on standard phraseology, communication, and data requirements.

The instructor should explain how to:

1. Begin monitoring the CTAF radio well away from the airport.
2. Over-fly above pattern altitude if you are uncertain of pattern or procedures.
3. Adhere to AIM recommended procedures.
4. Report all legs of pattern entry and the pattern itself. Be sure to include your altitude and direction where practical.
5. Acknowledge whether you have any reported or unreported traffic in sight, or not in sight. Advise when you have cleared the runway after landing.
6. Make a full 360 prior to taking the active on departure.
7. Adhere to airport noise abatement procedures and advise traffic of your departure intentions.

Uncontrolled airports may be either UNICOM, in which case the frequency is on the sectional, or not, where the frequency is automatically 122.9. There is no 14 CFR requirement to use the radio at uncontrolled airports but common sense, safety and good operating practices dictates that the radio be used. These are pilot controlled airports which should be addressed from at least 10 miles out. For example, "Rio Vista UNICOM Cessna 1234X Antioch bridge at 2000 request landing advisory Rio Vista". All subsequent calls are addressed to traffic giving airport name as first and last items. Be accurate in giving all pattern positions and altitudes.

Uncontrolled airports put the burden of traffic control and communications on the pilots. The see and be seen concept is the primary collision avoidance system. The more frequently and accurately you give your location, position, and altitude the safer your operation. At pilot controlled airports it is important to give traffic, and procedure advisories to other pilots. This is especially true if non-standard procedures prevail. Initial contact either with UNICOM or traffic should be at least 10 miles out. If unable to determine recommended 45 degree to downwind entry overfly at twice pattern altitude to determine favored runway. Report on 45, downwind, base final, and clear of runway. If the uncontrolled airport has no assigned altitude use 1000' AGL. Be aware that non-radio aircraft such as cropdusters or ultralights may be using the field.

Besides the problems of orientation and communication at an airport there exists aircraft positioning. Common faults during arrivals at airports consist of not arriving on downwind at pattern altitude, failing to be properly trimmed, failing to initiate downwind turn far enough away from airport, failing to make downwind turn parallel to runway, and failing to correct for

wind on downwind. Not infrequently, all of the above will occur with one arrival for the wrong runway or even the wrong airport.

Completion Standards:

This lesson is complete when the pilot in training (PT) demonstrates a working knowledge of proper airport surface operations at non-towered airports and at airports when the ATC tower is closed. The PT will demonstrate runway incursion avoidance procedures and not be disoriented with a loss of SA on the airport.

Desired Outcome Grade Sheet:

Scenario Tasks	**Scenario Sub Tasks**	**Desired Performance**
Flight Planning	1. Scenario Planning 2. Certificates and Documents 3. Airport Diagrams and HOT spots 4. Preflight SRM briefing 5. Decision making and risk management	Explain Explain Explain Practice Practice
Normal preflight and cockpit procedures	1. Use of Checklists 2. Preflight Inspection 3. Minimum equipment list 4. Cockpit management 5. Aircraft preflight inspection 6. Checklist usage and flow patterns 7. SRM/TEM/CRM	Explain Explain Explain Practice Practice Practice Practice
Engine Start and Taxi Procedures	1. Engine start 2. Airport and runway markings and lighting 3. Radio Communications 4. Normal and crosswind taxi operations 5. Runway incursion avoidance 6. SRM/Situational awareness	Explain Explain Practice Practice Practice Practice
Before Takeoff Checks	1. Normal and abnormal indications 2. Wind shear avoidance 3. Aircraft automation management 4. Aeronautical Decision Making and Risk management	Explain Explain Explain Explain

Takeoff	1. Normal takeoff 2. Situational awareness and wrong runway avoidance 3. SRM and risk management	Practice Practice Practice
Approach Procedures	1. Traffic pattern entry procedures 2. Collision avoidance precautions 3. Situational awareness, task management and SRM 4. Wind shear avoidance 5. Communications 6. Normal approach 7. SRM/TEM/CRM	Explain Explain Explain Explain Explain Explain Explain
Landing	1. Before landing procedures 2. Normal landing 3. After landing procedures 4. SRM/TEM/CRM	Explain Explain Explain Explain
Taxi and aircraft shutdown and securing procedure	1. Use of Checklist 2. Aircraft ground operations and parking 3. Post Flight 4. Securing 5. SRM/TEM/CRM	Explain Explain Practice Explain Explain

Post-Briefing: The flight instructor should solicit a self-critique from the Pilot in Training (PT) about their personal performance by having the PT grade their performance based on the desired outcomes for the lesson. Compare the PT's self evaluation to the instructor's grades and discuss any differences in the assessment. The flight instructor should then use this information to direct an analysis of the lesson. Additionally, the instructor should discuss the role SRM played in the training activity and why it is critical to always consider how a flight or a situation could have been better managed to achieve the optimal outcome. The instructor will provide guidance on what the tasks and objectives will be for the next training activity and how the PT should prepare for it.

Notes to the Instructor: Aircraft taxi operations require constant vigilance on the part of pilots. Pilots need to be continually aware of the movement and location of other aircraft and ground vehicles. Taxi operations require the same planning, coordination, and proper execution as other phases of flight operations. Sterile cockpit discipline is always appropriate while taxiing, even under normal weather conditions. During low-visibility taxi operations, additional vigilance is absolutely essential. Safe aircraft operations can be accomplished and incidents eliminated if pilots are properly trained and correctly accomplish standard taxi operating procedures and practices.

Before taxiing pilots should verify that current aeronautical data for the airport is obtained, including the operating hours and status of the control tower and airport communication facilities

or aids are monitored, i.e., CTAF, flight service station (FSS), or Unicom frequency. When taxing for departure, pilots should monitor the CTAF, FSS, or Unicom frequency. Pilots of departing aircraft should monitor/communicate on the appropriate frequency from engine start, during taxi, and until 10 miles from the airport unless appropriate regulations, local procedures, or operations specifications require otherwise.

Pilots should announce all ground movement operations on the CTAF, FSS, or Unicom frequency. When taking the runway pilots should announce their intention to take the runway prior to taking the runway. Pilots should also announce their intention to takeoff on the CTAF, FSS, or Unicom frequency. Pilots should not line up on the departure runway and hold any longer than absolutely necessary. Pilots should always state the name of the airport at the beginning and end of the radio transmission. Some aircraft operating at airports without operating control towers may not be equipped with a radio, so all pilots must remain alert for these aircraft.

Suggested topics on the following procedures should be discussed:

1. Review and understand airfield signage and markings.
2. Review the appropriate airport diagrams.
3. Review any Hot Spots identified on the diagram.
4. Print a copy of the airport diagram for use in the cockpit.
5. Review airfield NOTAMS and current ATIS for any taxiway closures, runway closures, construction activity, or other airfield specific risks.
6. Brief any passengers on the importance to minimize discussions, questions, and conversation during taxi (maintain a “sterile cockpit”).

Lesson 4 – Snow and Poor Visibility (Simulated scenario)

Scenario: You are flying into an airport with heavy snowfall and reduced visibility. All of the aircraft's anti-ice systems are operating and there is no ice accumulating on the aircraft. You land without incident on the runway that has just been cleared of snow. You notice while taxiing to the airport ramp area where you will park your aircraft that there is an estimated 8 inches of loose snow on the ground.

Lesson Objective: To learn how to properly taxi an aircraft in poor visibility conditions and to understand how snow or other contaminants effect taxi procedures.

Pre-Briefing: This portion of the lesson will serve as the ground lesson for this training scenario. The instructor will lead a guided discussion on proper taxi procedures in low visibility conditions which can be complicated by snow, ice, or other surface contaminants.

Materials: Advisory Circular (AC) 120-57A, AC 00-6A, Aviation Weather for Pilots and Flight Operations Personnel, any airport charts, 14 CFR/AIM, and any other supporting materials.

Development: Accumulations of snow and ice can obscure airport surfaces and make it difficult to distinguish usable surfaces from those that are unusable. Pilots should verify the identification of airport surfaces by all available means in conditions where the surface is obscured. Such means include marshalers, follow-me vehicles, and progressive taxi or ramp instructions. Airborne aircraft should use all available tools to support identification of landing surfaces, such as an instrument landing system (ILS) localizer, lighting and signage.

The flight instructor should discuss the use of appropriate speeds during taxi operations so as to minimize the risk of sliding on slippery surfaces covered by ice and/or snow should be practiced. Also, how to include the conspicuity of surfaces, references to distinguish usable from unusable surfaces, and discuss when to consider suspending aircraft operations when airport surfaces are unacceptable for taxi operations due to surface snow and ice contamination. To the extent practical avoid taxiing through slush or loose snow. Under no circumstances should the aircraft be taxied through packed snow drifts that are deeper than the distance from the bottom of the wheel hub to ground. For dealing with slush or loose snow during taxi the following practices are recommended:

1. Speed must be managed to minimize slush or snow impinging on flaps, landing gear doors, propellers, intakes, and brakes.
2. Too high a taxi speed may result in contaminants spraying on the flaps.
3. Too slow a taxi speed may cause snow to be pulled into the propeller.
4. Speed must be sufficient to prevent the aircraft from bogging down in snow.
5. Avoid use of reverse thrust as it may cause contaminants to become airborne and impinge on the aircraft. To reduce speed use zero thrust and judicious braking.
6. When the aircraft is stopped set the engines and propellers to minimize blowing of snow and slush on to the aircraft.

Several factors that occur during winter months require attention to reduce runway incursions further. Keep the following factors in mind:

1. Snow removal and vehicle operations on the runways and other movement areas.
2. Aircraft taxi slower because of surface conditions.
3. Aircraft require more time to exit or cross runways because of surface conditions.
4. Various forms of precipitation reduce controller and pilot visibility.
5. Plowed snow and snowdrifts cause blind spots and potential uncertainty, regarding location, for taxiing aircraft.
6. Bright sunlight reflects off surface snow and ice, causing glare and reducing pilot visibility.

In order to enhance taxiing capabilities in low visibility conditions and reduce the potential for runway incursions, improvements have been made in signage, lighting, and markings. In addition to these improvements, Advisory Circular (AC) 120-57, Surface Movement Guidance and Control System, more commonly known as SMGCS (acronym pronounced 'SMIGS'), requires a low visibility taxi plan for any airport which has takeoff or landing operations with less than 1,200 feet runway visual range (RVR) visibility conditions. This plan affects both air crew and vehicle operators. Taxi routes to and from the SMGCS runway must be designated and displayed on a SMGCS Low Visibility Taxi Route chart.

For low visibility conditions, the instructor may use the following information about lighting systems as a guide to help explain low visibility requirements. A brief detail of SMGCS features is listed below but SMGCS airports may not have all of these features. For additional SMGCS information refer to the Aeronautical Information Manual or the particular airport's SMGCS Low Visibility Taxi Route chart.

Stop bars are required at intersections of an illuminated (centerline lighted) taxiway and an active runway for operations less than 600 feet RVR. These lights consist of a row of red unidirectional, in-pavement lights installed along the holding position marking. When extinguished by the controller, they confirm clearance for the pilot or vehicle operator to enter the runway. Controlled stop bars operate in conjunction with green centerline lead-on lights, which extend from the stop bar location onto the runway.

Normal operation of stop bars include:

When ATC issues a clearance to the pilot to enter the runway they activate a timer. This action causes the red stop bar to be extinguished and the green lead-on lights to illuminate.

After traveling approximately 150 feet beyond the stop bar, the aircraft or vehicle activates a sensor. This sensor relights the red stop bar and extinguishes the first segment of the lead-on lights between the stop bar and the sensor. This protects the runway against inadvertent entry by a trailing aircraft or vehicle.

The aircraft then activates another sensor at approximately 300 feet which extinguishes the remaining lead-on lights.

If either sensor is not activated within a specified time limit, the stop bar will automatically reset to "on" and both sets of lead-on lights will be turned "off."

Should the pilot or vehicle operator have a discrepancy between the condition of the stop bar or lead-on lights and the verbal clearance from the controller, the aircraft or vehicle shall stop immediately.

Pilots Shall Never Cross an Illuminated Red Stop Bar

Runway guard lights, either elevated or in-pavement, will be installed at all taxiways which provide access to an active runway. They consist of alternately flashing yellow lights. These lights are used to denote both the presence of an active runway and identify the location of a runway holding position marking.

Taxiway Centerline lights guide ground traffic under low visibility conditions and during darkness. These lights consist of green in-pavement lights.

Three yellow in-pavement clearance bar lights will be used to denote holding positions for aircraft and vehicles. When used for hold points, they are co-located with geographic position markings.

Runway/Taxiway Arrangement Of SMGCS Features

	Feature	Description
	Stop Bar Lights	Row of red, in-pavement lights that when illuminated designate a runway hold position. ***NEVER CROSS AN ILLUMINATED RED STOP BAR***.
	Runway Guard Lights	Elevated or in-pavement yellow flashing lights installed at runway holding positions.
	Taxiway Centerline Lights	Green in-pavement lights to assist taxiing aircraft in darkness and in low visibility conditions.
	Clearance Bar Lights	In-pavement yellow lights. When installed with geographic position markings they indicate designated aircraft or vehicle hold points.
	Geographic Position Marking (pink spot)	Indicates a specific location on the airport surface.
	Taxiway Centerline Marking	Provides a visual cue to permit taxiing along a designated path. Marking may be enhanced on light-colored pavement by outlining with a black border.

The instructor could also use a low visibility airport diagram chart to explain taxi procedures. The following is an example using three generic airport diagrams.

LOW VISIBILITY TAXI ROUTE CHART

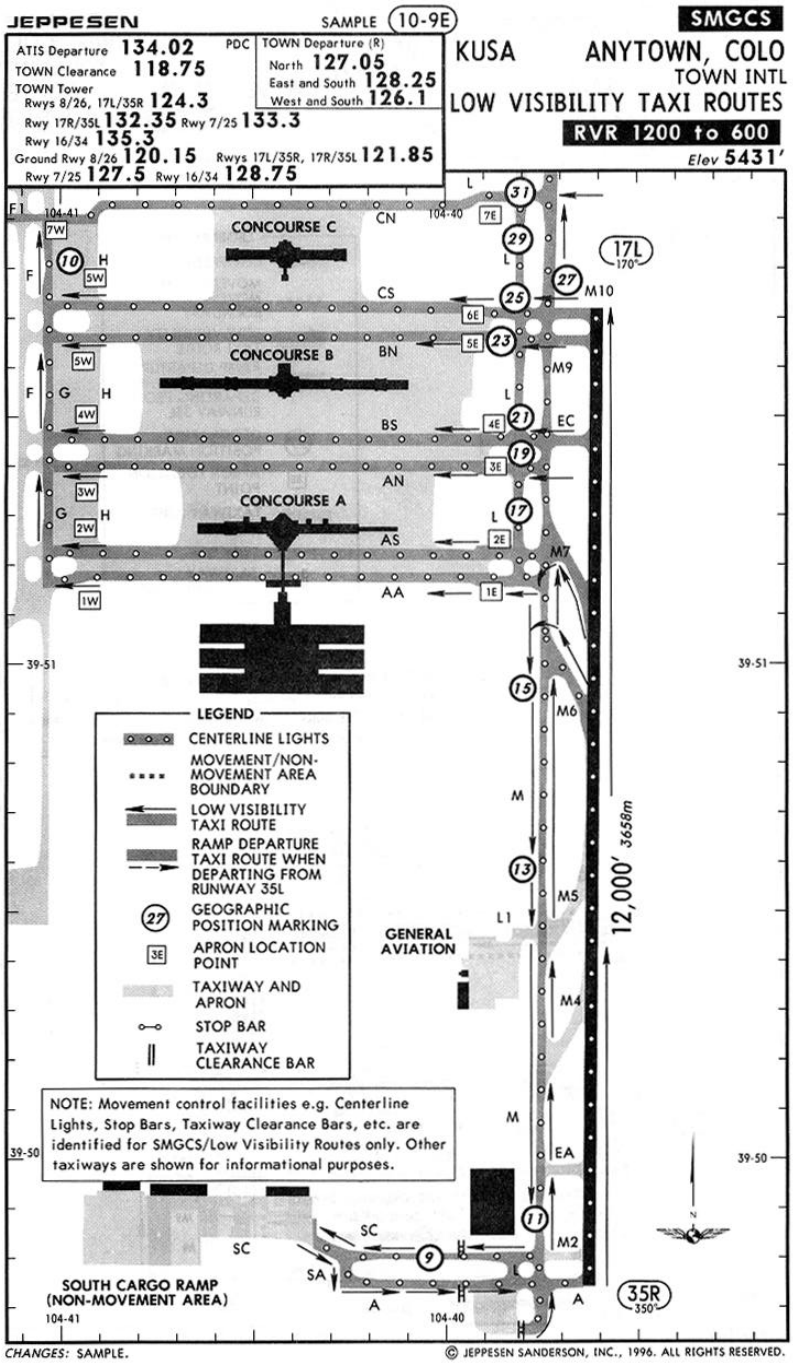


Figure 1 (East Side)

AC 120-57A
Appendix 2

DO NOT USE FOR NAVIGATION

12/19/96

LOW VISIBILITY TAXI ROUTE CHART

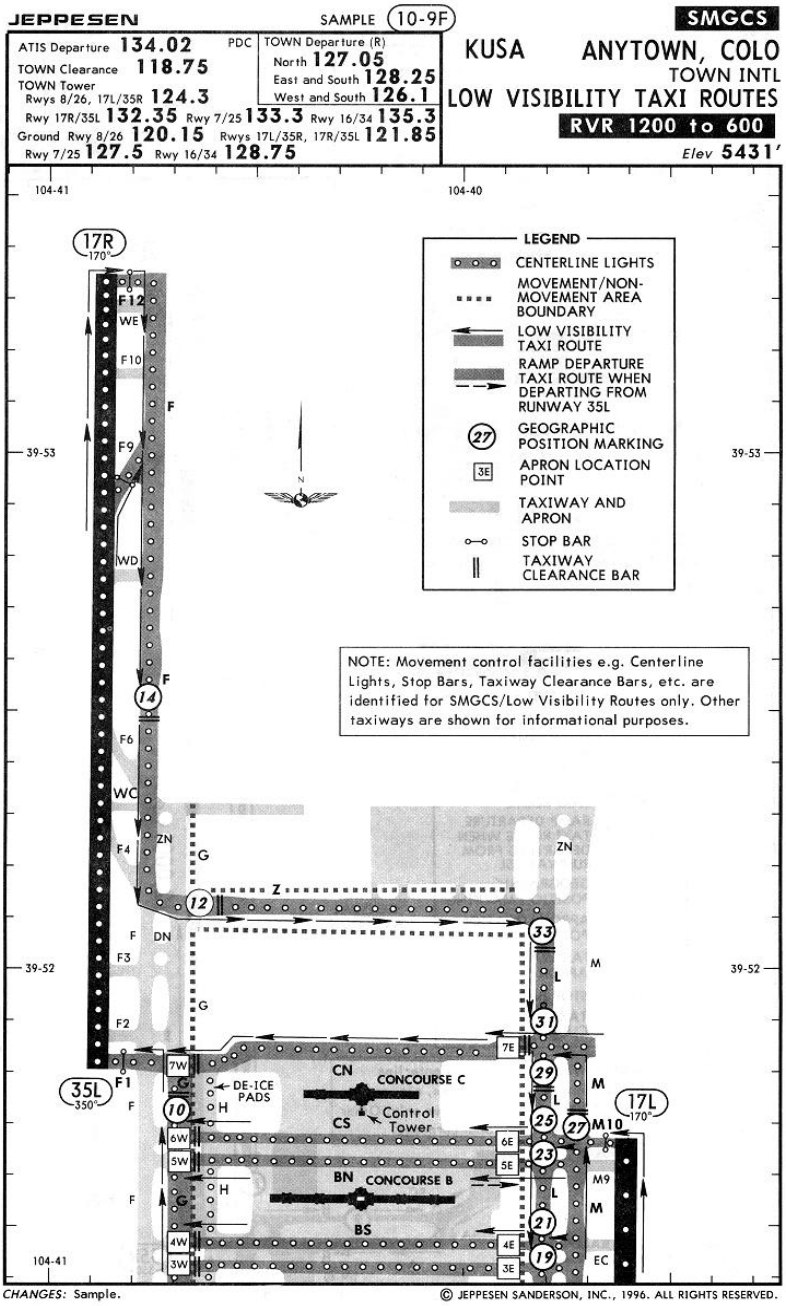


Figure 2 (West Side)

DO NOT USE FOR NAVIGATION

LOW VISIBILITY TAXI ROUTE CHART

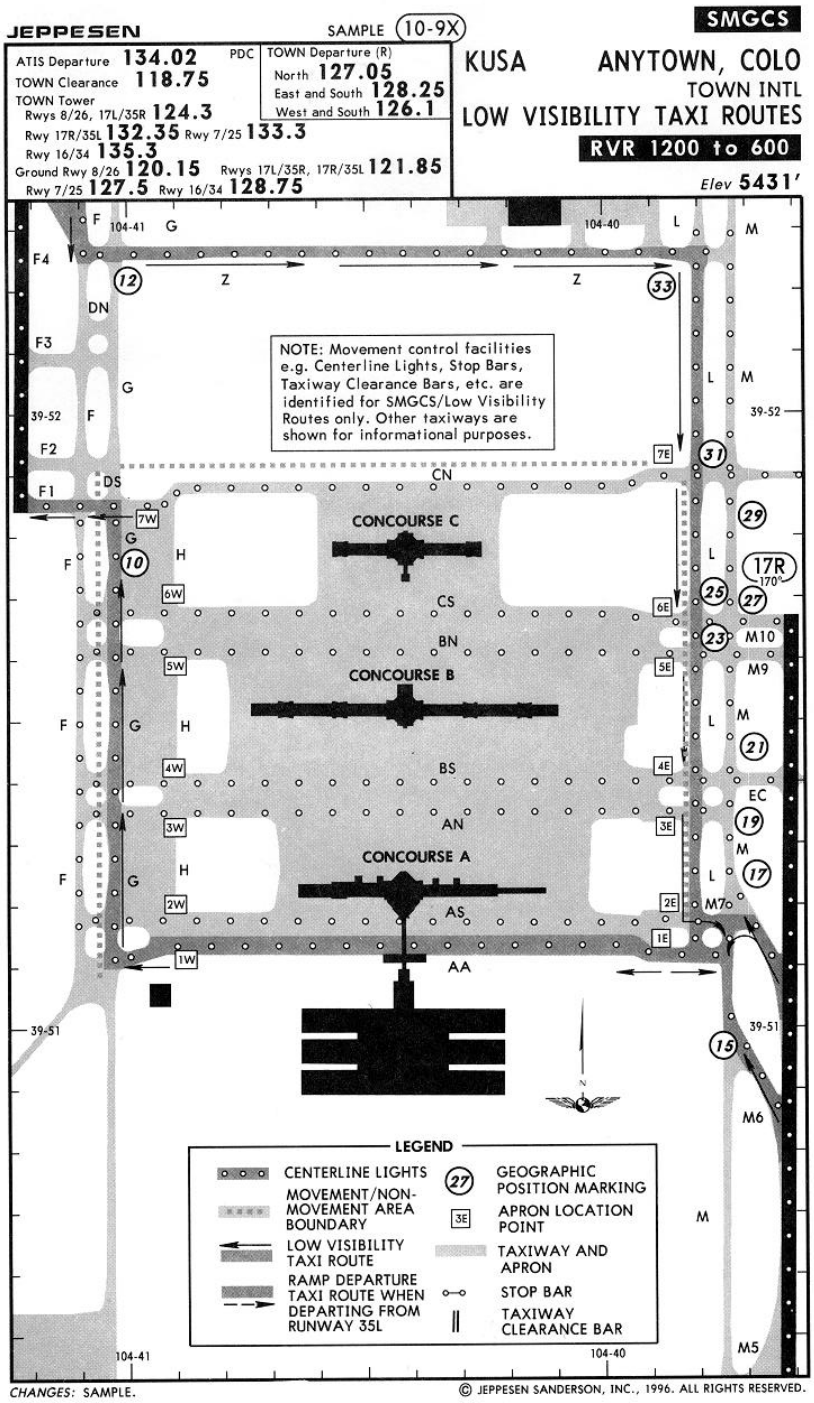


Figure 3 (Apron Area)

Completion Standards:

This lesson is complete when the pilot in training (PT) demonstrates a working knowledge of how to properly taxi an aircraft in poor visibility conditions and can explain how snow or other contaminants effects taxi procedures.

Desired Outcome Grade Sheet:

Scenario Tasks	**Scenario Sub Tasks**	**Desired Performance**
Flight Planning	1. Scenario Planning 2. Certificates and Documents 3. Airport Diagrams and HOT spots 4. Preflight SRM briefing 5. Decision making and risk management	Practice Explain Explain Practice Practice
Normal preflight and cockpit procedures	1. Use of Checklists 2. Preflight Inspection 3. Minimum equipment list 4. Cockpit management 5. Aircraft preflight inspection 6. Checklist usage and flow patterns 7. SRM/TEM/CRM	Explain Explain Explain Practice Practice Practice Practice
Engine Start and Taxi Procedures	1. Engine start 2. Airport and runway markings and lighting 3. Radio Communications 4. Normal and crosswind taxi operations 5. Runway incursion avoidance 6. Low visibility procedures 7. SRM/Situational awareness	Explain Explain Practice Practice Practice Explain Practice
Before Takeoff Checks	1. Normal and abnormal indications 2. Wind shear avoidance 3. Aircraft automation management 4. Aeronautical Decision Making and Risk management	Explain Explain Explain Explain
Takeoff	1. Normal takeoff 2. Situational awareness and wrong runway avoidance 3. SRM and risk management	Practice Practice Practice

Approach Procedures	1. Traffic pattern entry procedures 2. Collision avoidance precautions 3. Situational awareness, task management and SRM 4. Wind shear avoidance 5. Communications 6. Normal approach 7. SRM/TEM/CRM	Explain Explain Explain Explain Explain Explain Explain
Landing	1. Before landing procedures 2. Normal landing 3. After landing procedures 4. Low visibility procedures 5. SRM/TEM/CRM	Explain Explain Explain Explain Explain Explain
Taxi and aircraft shutdown and securing procedure	1. Use of Checklist 2 Aircraft ground operations and parking 3. Taxi with surface contamination 4. Post Flight 5. SRM/TEM/CRM	Explain Explain Practice Practice Practice

Post-Briefing: The flight instructor should solicit a self-critique from the Pilot in Training (PT) about their personal performance by having the PT grade their performance based on the desired outcomes for the lesson. Compare the PT's self evaluation to the instructor's grades and discuss any differences in the assessment. The flight instructor should then use this information to direct an analysis of the lesson. Additionally, the instructor should discuss the role SRM played in the training activity and why it is critical to always consider how a flight or a situation could have been better managed to achieve the optimal outcome. The instructor will provide guidance on what the tasks and objectives will be for the next training activity and how the PT should prepare for it.

Notes to the Instructor: Runway incursions are a real problem often made worse by poor visibility and confused pilots. The instructor should be sure the PT practices the following:

1. Have the airport diagram out and available for immediate reference during taxi. Use the FAA runway safety website to find airport diagrams for all airports.
2. Review current ATIS for any taxiway closures, runway closures, construction activity, or other airfield specific risks.
3. During radio transmissions, use correct terminology and proper voice cadence.
4. Eliminate distractions in the operational area.
5. Maintain a sterile cockpit when taxiing.
6. Maintain appropriate taxi speed.
7. Encourage pilots to have their "eyes out" and a "heads up" policy when taxiing.
8. Encourage use of correct terminology and proper voice cadence.
9. Readback all runway hold short instructions.

Lesson 5 – Task Management while Taxiing

Scenario: You are taxiing out from the ramp to the runway. You are rushed to complete all of the checklists before you depart because the departure runway is very close to the ramp. Also, ATC gave you a full re-route for the clearance and you are re-programming the navigation system as appropriate.

Lesson Objective: To determine the PT can prioritize the various tasks associated with the planning and execution of the flight with the emphasis on taxiing in order to avoid runway incursions or wrong runway incidents.

Pre-Briefing: This portion of the lesson will serve as the ground lesson for this task management training scenario. The instructor will lead a guided discussion on aircraft taxiing procedures, runway incursion avoidance, wrong runway incidents, and how to manage all of the necessary tasks while taxing.

Materials: airworthy aircraft for taxiing only, 14 CFR/AIM and any other supporting materials.

Development: During this ground lesson, the instructor should discuss with the PT what items are considered while taxing an aircraft in order to avoid runway incursions and wrong runway incidents. The emphasis of this ground lesson is task management while taxiing an aircraft.

Runway incursions are aircraft incidents that most of us don't think about much because avoiding them seems obvious. The FAA defines an incursion is any occurrence at an airport involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and takeoff of aircraft. Human error is the primary cause. These are errors by pilots, airport personnel, and ATC. At a towered airport, for example, who in the world would get onto an active runway without clearance? How could he/she do it? Why would he/she do it?

Part of the cause of runway incursions is inherent in airport design and may be local or airport-specific. We all know the regulations, and the ground controller will watch out for us even if we do make a mistake, right? Some problem areas are not visible to ATC which requires the pilot to be even more diligent about safety. Runway incursion avoidance procedures should include the importance of clearing prior to taking any runway. A 360 degree turn is preferred before takeoff at uncontrolled airports. Failure of a pilot to clear a runway without an adequate scan of the approach flight path to both sides of the airport is an easy way to have a runway incursion or worse. Pilots should be familiar with airport markings as presented in the AIM. Impatience or stress is usually the driving force behind a runway incursion.

Review points to discuss with the PT:
1. Check NOTAMS and airport diagrams.
2. Proper phraseology
3. Check and monitor radios
4. Use lights

5. Get ATIS/AWOS and monitor CTAF if at uncontrolled airport. Note that IFR departures from uncontrolled airports may not be monitoring the CTAF.
6. Avoid using land and hold short clearances.
7. If at all uncertain of location or taxi route, ask ATC for a progressive taxi.
8. Clear and report clear of runway when across the hold bars. No part of an aircraft should intrude on the wrong side of the hold bars. Hold bars are made up of four yellow lines two dashed - - - - lines and two _____solid lines. You hold when the solid lines are on your side or you cross when the dashed lines are on your side.

Task Management Notes:
Just as the flight instructor has to prioritize and select the most appropriate tasks (or series of tasks) to ensure successful completion of the training scenario, so too does the PT while taxiing out for departure. The PT should be able to:

1. Explain how to prioritize tasks in such a way to minimize distractions from flying the aircraft.
2. Complete all tasks in a timely manner considering the phase of flight without causing a distraction from flying.
3. Execute all checklists and procedures in a manner that does not increase workload at critical times, such as while taxiing, intercepting the final approach course, etc.

A runway incursion, like any other incident, has several events that lead up to it, and the incursion itself can be a link in an accident chain. There are four parts to preventing an incursion: (1) clearances; (2) communications; (3) ground navigation; and (4) situational awareness, including scanning. If any one of these parts fails, the probability of an incursion increases; if more than one failure occurs, then they're inevitable. Why is each of these components critical?

Let’s look at each of these parts briefly. First, clearances: pilots must understand what they have been instructed to do. If they don't understand, or can't comply, then getting a clarification or an amended clearance is in order.

Second, communications: use the proper procedures, standard words and phrases, and read back your clearance, particularly if it is complex or if you are not familiar with the airport. Request progressive taxi instructions if it is appropriate.

Third, ground navigation: understand the airport layout before starting your engine; use that airport map on the back of your instrument approach chart or in your airport directory. Know and understand the meanings of the airport signage, especially now that the signage has been standardized. The Aeronautical Information Manual now has color pictures showing these signs, so they are easy to learn.

Fourth, situational awareness, including scanning: brief, then use, a passenger (if applicable) to help you monitor your progress across the airport. Monitor your own progress; if you, or your passenger has a question about what's happening, resolve it before proceeding. Use all of your resources, including ATC, to help. Scan for other traffic, including aircraft (helicopters, too) landing or taking off, and watch for pedestrians or vehicles that might not be where they should be. Avoiding runway incursions is a team effort between controllers who are responsible to

coordinate traffic; pilots who are responsible for aircraft safety; and ground personnel in airport operations or ground services.

Completion Standards:
This lesson is complete when the pilot in training (PT) can prioritize the various tasks associated with the planning and execution of the flight with the emphasis on taxiing in order to avoid runway incursions or wrong runway incidents. While taxiing, the PT maintains control of the aircraft with accuracy and safety while he/she obtains and follows ATC clearances as appropriate.

Desired Outcome Grade Sheet: Although this scenario is a no-flight scenario, the PT should know how to perform a normal takeoff and approach to landing depending on the PT's knowledge and skill level. Although the PT is not actually flying, the PT should be able to explain the before takeoff checks, takeoff and approach procedures, as well as proper landing techniques.

Scenario Tasks	**Scenario Sub Tasks**	**Desired Performance**
Flight Planning	1. Scenario Planning 2. Certificates and Documents 3. Airport Diagrams 4. Preflight SRM briefing 5. Decision making and risk management	Perform Perform Perform Perform Manage/Decide
Normal preflight and cockpit procedures	1. Use of Checklists 2. Preflight Inspection 3. Minimum equipment list 4. Cockpit management 5. Airplane Servicing 6. Operation of systems 7. Positive exchange of flight controls 8. Aircraft preflight inspection 9. Checklist usage and flow patterns 10. SRM/TEM/CRM	Perform Perform Perform Perform Perform Perform Perform Perform Perform Manage/Decide
Engine Start and Taxi Procedures	1. Engine start 2. Airport and runway markings and lighting 3. Radio Communications 4. Normal and crosswind taxi operations 5. SRM/Situational awareness 6. Task Management	Perform Perform Perform Perform Manage/Decide Manage/Decide

Before Takeoff Checks	1. Normal and abnormal indications 2. Wind shear avoidance 3. Aircraft automation management 4. Aeronautical Decision Making and Risk management	Perform Perform Manage/Decide Manage/Decide
Takeoff	1. Normal takeoff 2. Situational awareness 3. SRM and risk management	Explain Manage/Decide Manage/Decide
Approach Procedures	1. Traffic pattern entry procedures 2. Collision avoidance precautions 3. Situational awareness and task management 4. Wind shear avoidance 5. Communications 6. Normal approach 7. SRM/TEM/CRM	Explain Explain Manage/Decide Explain Explain Explain Manage/Decide
Landing	1. Before landing procedures 2. Normal landing 3. After landing procedures 4. SRM/TEM/CRM	Explain Explain Explain Manage/Decide
Taxi and aircraft shutdown and securing procedure	1. Use of Checklist 2. Aircraft ground operations and parking 3. Post Flight 4. Securing 5. SRM/TEM/CRM	Perform Perform Perform Perform Manage/Decide

Post-Briefing: The flight instructor should solicit a self-critique from the Pilot in Training (PT) about their personal performance by having the PT grade their performance based on the desired outcomes for the lesson. Compare the PT's self evaluation to the instructor's grades and discuss any differences in the assessment. The flight instructor should then use this information to direct an analysis of the lesson. Additionally, the instructor should discuss the role SRM played in the training activity and why it is critical to always consider how a flight or a situation could have been better managed to achieve the optimal outcome. The instructor will provide guidance on what the tasks and objectives will be for the next training activity and how the PT should prepare for it.

Notes to the Instructor: In task management it is critical for pilots to prioritize tasks and avoid distractions during critical phases of flight. Organizing needed information in the aircraft before engine start will help to reduce pilot workload during busy situations. Pre-programming the GPS and using the electronic aids such as the autopilot, PFD and the MFD will all help the pilot. The pilot in busy airspace is saturated with a multiplicity of tasks. The computers in the cockpit have

reduced the pilot's scan from many instruments to just two or three screens of information. Although this instrumentation helps, it could cause the pilot to have tunnel vision and a reduced sense of situational awareness. However, good task management skills will help keep the pilot focused on the task at hand and will enforce a priority system that keeps tasks in check.

Very few incidents can be explained by a single action. Usually there are a series of very small events that build. But perhaps if we look at aircraft operations as managing different risk events, especially on the ground, we can mitigate them and better enjoy the flight.

Questions for discussion:
1. Where is the airport diagram while the PT is taxiing?
2. What are the risk factors while taxiing?
3. As we taxi, what is happening in the cockpit?
4. As we approach the runway area, is the PT looking for opposite-direction traffic?
5. Did the PT check the brakes to make sure they worked right after we added power and began to move?
6. Under what circumstances would the PT accept an intersection departure?
7. Under what circumstances would the PT ask for progressive taxi instructions?

FAA Recommendations

--Use written taxi instructions in unfamiliar situations.
--Always check the expected with clearance copied.
--When in doubt, stop and communicate your doubts..
--Monitor the taxiing instructions given to other aircraft.
--Use cockpit resources to verify taxi route and clearing.
--Know and use the airport signs, markings, and lighting
--Readback and follow ATC instructions and clearances.
--Preconceptions as to expected clearance is greatest hazard.
--When told to use a runway as a taxiway, taxi near one edge.
--Never stop on a runway after landing. Expedite clearing the runway.
--Scan all runways prior to crossing. When in doubt, communicate with ATC.
--It is important to know where you are and even more important to know where other traffic is.
--When told to taxi into position and hold, retain awareness of your vulnerability from landing aircraft.
--Plan your airport surface movement just as you plan a flight. **(46% of accidents occur while taxiing.)**
--Get clearance to exit on an intersecting runway during the landing rollout, otherwise take next taxiway.
--It is important to know your present location and just as important to know your expected next location.

References

Air Line Pilots Association, International (ALPA). (2007). White paper: Runway incursions: A call for action. Retrieved from http://www.alpa.org/portals/alpa/runwaysafety/ RunwayIncursionwhitepaper.pdf

Commercial Aviation Safety Team (CAST). (2009). Commonly used safe operating practices for taxi safety. Retrieved from http://www.cast-safety.org/pdf/12_01_09_SE_60_SIP_v3.pdf

Federal Aviation Administration (FAA). (2003a). Advisory circular 120-74A. Retrieved from http://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/23220

Federal Aviation Administration (FAA). (2003b). Advisory circular 91-73A. Retrieved from http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/list/AC%2091-73A/$FILE/AC91-73A.pdf

Federal Aviation Administration. (2006). Advisory circular 120-90: Line operations safety audits. Retrieved from http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/list/AC%20120-90/$FILE/AC%20120-90.pdf

Federal Aviation Administration (FAA). (2007). FITS generic private pilot ASEL syllabus. Retrieved from http://www.faa.gov/training_testing/training/fits/training/generic /media/Private_sel.pdf

Federal Aviation Administration (FAA). (2009a). Annual runway safety report. Retrieved from http://www.faa.gov/airports/runway_safety/news/publications/media/Annual_Runway_Safety_Report_2009.pdf

Flight Safety. (2004). Threat error management model. *Flight Safety Information Journal, Fourth Quarter*, 7-8. Retrieved from http://www.fsinfo.org/docs/FSI%204Q04.pdf

Grote, G., Helmreich, R.L., Strater, O., Hausler, R., Zala, G., & Sexton, B. (2004). *The threat and error management model* (Chapter 8). In R. Dietrich & T.M. Childress (Eds.), Group Interaction in High Risk Environments. AldersHOT, UK: Ashgate.

Gunther, D., & Tesmer, B. (n.d.). Threat and error management training. Retrieved from http://www.faa.gov/library/online_libraries/aerospace_medicine/sd/media/Gunther.pdf

Helmreich, R. Merritt, A., & Wilhelm, J. (1997). The evolution of crew resource management training in commercial aviation. Retrieved from http://homepage.psy.utexas.edu homepage/group/HelmreichLAB/Publications/pubfiles/Pub235.pdf

Helmreich, R.L., Klinect, J.R., & Wilhelm, J.A. (2001). *System safety and threat and error management: The line operations safety audit (LOSA)*. Paper presented at the Proceedings of the Eleventh International Symposium on Aviation Psychology,

Columbus, OH. Abstract retrieved from http://homepage.psy.utexas.edu/homepage/group /HelmreichLAB/Publications/Pub%20Project/266.doc

Helmreich, R.L. (2002). Crew performance monitoring program continues to evolve as database grows. *International Civil Aviation Organization (ICAO) Journal*, 57(4), 6-7.

Intentional Civil Aviation Organization (ICAO). (2002). Line Operations Safety Audit (LOSA). DOC 9803-AN/761. Montreal: International Civil Aviation Organization.

International Civil Aviation Organization. (2008). Threat and error management (TEM) in air traffic control (ICAO Cir 314). Quebec, Canada: International Civil Aviation Organization.

Jenkins, D. (2008). Pilot deviations: Risk reduction. Retrieved from http://www.raa.org/Portals/0/CommitteePages/FlightTraining/faa_briefing_oct20_2008.pdf

Kindley, R. (2002). Scenario-Based E-Learning: A step beyond traditional E-Learning. Retrieved from http://www.learningcircuits.org/2002/may2002/kindley.html

Klinect, J.R. (2002). LOSA searches for operational weaknesses while highlighting systemic strengths. *International Civil Aviation Organization (ICAO) Journal, 57*(4), 8-9.

Maurino, D. (2005). Threat and error management (TEM). Retrieved from http://flightsafety.org/files/maurino.doc

Merritt, A., & Klinect, J. (2006). Defensive flying for pilots: An introduction to threat and error management. Retrieved from http://homepage.psy.utexas.edu/homepage/group/ HelmreichLAB/ Publications/pubfiles/TEM.Paper.12.6.06.pdf

Rankin, W., & Cokley, J. (2007). Runway incursions: Airport movement area driver training demographics suggests revisions to airport driver training methods. Journal of Management and Marketing Research. Retrieved from http://www.aabri.com/manuscripts/09213.pdf

Sexton, J, Wilhelm, A., Helmreich, R., Merritt, A., & Klinect, J. (2001). Flight management attitudes & safety survey (FMASS): A short version of the FMAQ. Retrieved from http://homepage.psy.utexas.edu/homepage/group/HelmreichLAB/Publications/59 9.doc

Other Resources

Federal Aviation Administration (FAA). (2009b). Best practices for airfield safety: Pilots. Retrieved from http://www.faa.gov/airports/runway_safety/pilots/

Federal Aviation Administration (FAA). (2010a). Known best practices for airfield safety. Retrieved from http://www.faa.gov/airports/runway_safety/bestpractices.cfm

Halleran, M. (2010b). FY2010 Task 1, Report 1: Literature review on threat and error management. Retrieved from http://www.faa.gov/training_testing/training/fits/

Halleran, M. (2010c). FY2010 Task 1, Report 2: Review of pilot runway safety training. Retrieved from http://www.faa.gov/training_testing/training/fits/

Halleran, M. and Alvarado, J. (2010d). FY2010 Task 1, Report 3: Accident/Incident/Occurrence data evaluation report. Retrieved from http://www.faa.gov/training_testing/training/fits/