LEARN TO TURN

Reducing Loss of Control through an Improved Training Methodology

by Rich Stowell and Billy Winburn

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ABSTRACT

Loss of Control Inflight (LOC-I) is the primary cause of fatalities in aviation. It dominates among homebuilts, in general aviation as a whole, and in the commercial jet fleet worldwide. National Transportation Safety Board Member Earl Weener has called LOC-I a "stubbornly recurrent safety challenge."

Stubborn indeed. Wolfgang Langewiesche wrote in Stick and Rudder in 1944, "Almost all fatal flying accidents are caused by loss of control during a turn." He concluded, "pilots, as a group, simply don't know how to turn right or left." More recently, nearly 900 pilots were asked, "What is the primary control surface you use when turning an airplane?" The answers:

- Elevator, 14 percent
- Rudder, 23 percent
- Ailerons, 63 percent

Eighty-six percent did not recognize "elevator" as the correct answer. Nearly 1-in-4 believed the rudder turned the airplane despite multiple warnings to the contrary in the Federal Aviation Administration's (FAA's) Airplane Flying Handbook. Pilots historically have been shown how to mimic only the most basic turns. Many never reach the application or correlation levels of learning vis-à-vis the maneuvering flight envelope. It is easy to see why LOC-I while maneuvering has persevered as the top phase of flight where fatal loss of control occurs.

The general aviation fleet will continue to be diverse. Improved standards, technology, and products will continue to be pushed into the aviation pipeline. But not every airplane will end up with a supplemental angle of attack system, and not everyone will be able to afford the latest technologies or products. Absent a concerted effort to improve pilot performance during turns, these enhancements alone are unlikely to yield the desired safety dividends. The reason: whether the airplane is commercially manufactured or homebuilt, powered by reciprocating or jet engines, or equipped with or without the latest technology, human behavior ultimately determines the fate of each flight.

Pilots are the common thread. Consequently, the Learn to Turn (LTT) initiative takes a decidedly stick-and-rudder approach to LOC-I mitigation. Three performance diagrams inform LTT content, while three factors that motivate pilots to fly inform LTT marketing.

LTT offers a skills-based solution for any pilot to reduce the threat of LOC-I. It is a joint effort between Master Instructor Rich Stowell and Billy Winburn, President of Mindstar's Community Aviation. The LTT approach is consistent with best practices outlined in the International Civil Aviation Organization's Manual on Aeroplane Upset Prevention and Recovery Training (UPRT), recommendations in FAA publications, and output from the Society of Aviation and Flight Educators' Pilot Training Reform Symposium. These include:

- Incorporating UPRT language and concepts;
- Combining scenario- and maneuvers-based training;
- Expanding angle of attack and G-load awareness;
- Addressing human factors and accident causes;
- Improving manual handling and LOC-I recognition, prevention, and recovery skills;
- Teaching energy and flight path management;
- Training in spiral dives, steep turns, high angle of bank recoveries, accelerated stalls, and slow flight; and,
- Integrating academic and practical training using Community Aviation's "Learn-Do-Fly" framework.

LTT addresses two special emphasis areas in the FAA WINGS program as well: basic flying skills and stall/spin awareness. It is consistent with the FAA's belief that improving knowledge and skills for manual flight operations are necessary for safe flight.

LTT targets the primary driver of LOC-I; therefore, it should be highly effective in reducing its occurrence. A preliminary study will be undertaken to validate LTT as a deterrent against loss of control and identify areas for improvement.

LTT is independent of airplane type. Any pilot can benefit from this training initiative; hence, it has the widest possible applicability.

Every pilot interacts with an educator, flight school, flight instructor (CFI), or designated pilot examiner (DPE) at some point. These interactions provide opportunities to educate pilots about LOC-I mitigation using LTT concepts. Accordingly, implementation of this initiative will be widespread and will include:

- Internet-based content
- WINGS programs for FAA Safety Team Representatives
- Exercises that can be incorporated into flight reviews as well as simulation, transition, and recurrent training sessions
- Outreach to:
  - EAA Chapters
  - type clubs
  - aviation organizations
  - flight schools
  - university aviation programs
  - CFIs and DPEs
  - flight instructor refresher clinics
  - pilot proficiency programs
- Recognition for those who satisfactorily complete LTT programs

LTT-101 in particular will rely on industry collaboration and sponsorship to ensure access to online content and exercises that can be incorporated into training and evaluation flights. Consequently, the incremental cost to pilots (especially instructors) would be low.

Hundreds of individuals representing several countries have registered their support for the "Learn to Turn" concept already. Hundreds more were exposed to LTT with an FAA Wings-approved forum and simulator training exercises at the EAA Pilot Proficiency Center during AirVenture 2016. Recognition and funding of LTT-101 by key stakeholders will facilitate increased support for, and positive action toward, reducing LOC-I.

GLOSSARY

Academic training. Training that places an emphasis on studying and reasoning designed to enhance knowledge levels of a particular subject.[1] This is “Learn” in Community Aviation’s training framework.

AOA (α). Angle of Attack. Most commonly the angle formed between the relative wind and the chord line of the main wing of an airplane.

AOB (ø). Angle of Bank. The position of the wings relative to the horizon.

AOS. Angle of Sideslip. Typically described as either skidded, slipped, or coordinated flight.

AOPA. Aircraft Owners and Pilots Association.

Bridge training. Additional training designed to address shortfalls in knowledge and skill levels so that all trainees possess the prerequisite levels upon which a given training program was designed.[2] “Learn to Use the Primary Controls” is bridge training for “Learn to Turn 101.”

CFI. Certificated Flight Instructor.

DPE. Designated Pilot Examiner.

EAA. Experimental Aircraft Association.

FAA. Federal Aviation Administration.

FSTD. Flight Simulation Training Device.[3]

GAJSC. General Aviation Joint Steering Committee.

$G_{Cockpit}$ (G_C). The load factor that would be registered on a typical G-meter installed in the cockpit; the G felt by the pilot as a result of elevator inputs (i.e., $G_C = L/W$). Also denoted as *n*, G_Z, or just G.

$G_{gravity}$ (G_g). Represented as the ratio W/W acting toward the center of the earth. By definition, $G_g = +1.0$.

G_{Radial} (G_R). The portion of G_C acting in the plane of turn; the centripetal or radial G acting toward the center of a curving flightpath. The “result of a change in direction such as when a pilot performs a sharp turn, pushes over into a dive, or pulls out of a dive.”[4]

HOV. Horizontal, Oblique, and/or Vertical.

IAC. International Aerobatic Club.

ICAO. International Civil Aviation Authority.

ICAS. International Council of Air Shows

L. The total lift produced by the main wing of an airplane.

LOC-I. Loss of Control-Inflight.

LTT. Learn to Turn.

Negative G (−G). Results when pushing on the elevator control causes the Lift vector to emanate from the bottom surface of the wing, regardless of airplane attitude relative to the horizon.

Negative training. Training which unintentionally introduces incorrect information or invalid concepts, which could actually decrease rather than increase safety.[5]

NTSB. National Transportation Safety Board.

Positive G (+G). Results when pulling on the elevator control causes the Lift vector to emanate from the top surface of the wing, regardless of airplane attitude relative to the horizon.

Practical training. Describes training that places an emphasis on the development of specific technical or practical skills, which is normally preceded by academic training.[6] This encompasses "Do" and "Fly" in Community Aviation's training framework.

Spin. The helical descending flight path resulting from simultaneously (or near-simultaneously) stalling and yawing an airplane.

Stall. Most commonly, the turbulent separation of otherwise smooth airflow from the main wing of an airplane.

UPRT. Upset Prevention and Recovery Training.

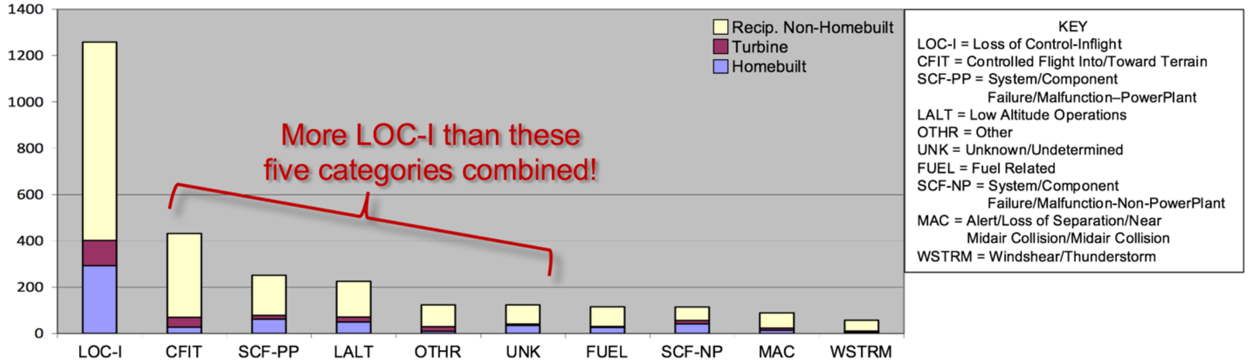
V. Airspeed. On most performance diagrams, either calibrated or true airspeed.

VFR in VMC. Visual Flight Rules in Visual Meteorological Conditions.

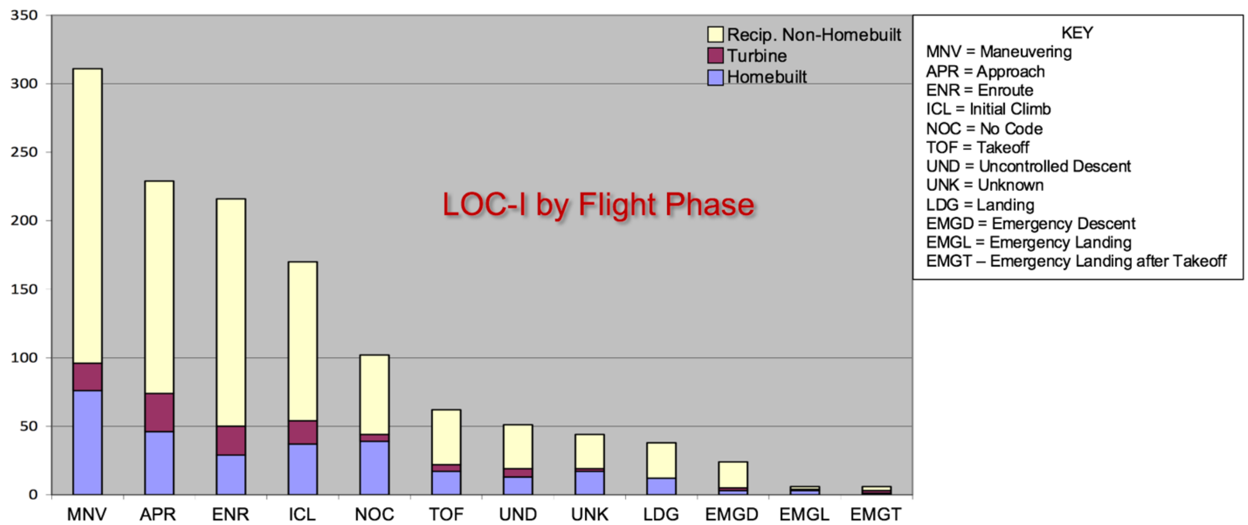
W. The weight of the airplane.

THE PROBLEM

Inflight loss of control is the leading cause of fatalities in aviation. It dominates among homebuilts, in general aviation as a whole, and in the commercial jet fleet worldwide. For the period 2001–2010, the GAJSC found that more fatal general aviation accidents resulted from LOC-I than from the next five occurrence categories combined.[7]



One-in-four fatal LOC-I accidents occurred during the maneuvering phase of flight—more than during any other phase. (If separated into its own broad occurrence category, LOC-I while maneuvering would rank third overall, behind CFIT.)



Accordingly, LOC-I has been a focus not only of FAA Safety Stand Downs since 2012, but also of NTSB's Most Wanted Lists for the last two years.[8,9] In 2015, NTSB hosted the forum "Humans and Hardware: Preventing General Aviation Inflight Loss of Control."[10]

Stubbornly Recurrent

NTSB Member Earl Weener has called LOC-I a "stubbornly recurrent safety challenge."[11] Stubborn indeed. In addition to the findings for 2001–2010, consider this:

1993–2001: Twenty-seven percent of all fatal accidents and 41 percent of fatal stall/spins occurred while maneuvering.[12,13]
1965–1973: Fifty-four percent of fatal stall/spins occurred while maneuvering/inflight.[14]
1944: "Almost all fatal flying accidents are caused by loss of control during a turn."[15]

"Every one of these pilots who has spun in was a product of the system, the product of a certificated instructor, and he had been checked by a [DPE] before getting his certificate."[16] Sadly, this observation by Wolfgang Langewiesche has rung true now for 72 years. What is it about turning flight that has entrenched it as the top cause of fatal LOC-I in general aviation?

Flawed Assumptions

While attempts to improve stall/spin awareness and encourage technologies to reduce LOC-I certainly have merit, what if the underlying issue is more basic than that? We have been teaching turns the same way for decades, with the same results. Perhaps it is time to critique the methodology.

We assume pilots are competent at turning. After all, turning is fundamental to flying. Turns are introduced practically on day one of flight training. Pilots do turns all the time. But if pilots thoroughly understood and were competent with turns, why do too many of them intentionally skid into a spin when overshooting the turn to final, or when attempting to turn back to the runway following engine failure on takeoff? These pilots actively drove the loss of control process by applying precisely the inputs necessary for a stall/spin. As the data have been telling us for a long time, "the best of us sometimes make bad turns," especially when under pressure.[17]

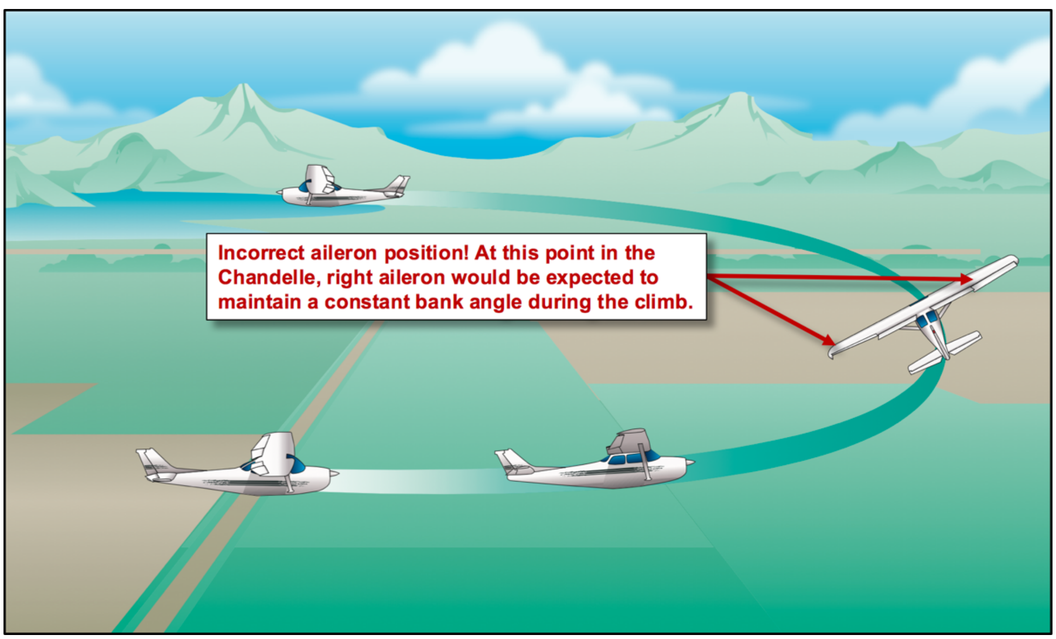
During safety programs over the last couple of years, nearly 900 pilots were asked, "What is the primary control surface you use when turning an airplane?" The answers:

- Elevator, 14 percent
- Rudder, 23 percent
- Ailerons, 63 percent

Eighty-six percent did not recognize "elevator" as the correct answer. Nearly 1-in-4 believed the rudder turned the airplane despite multiple warnings to the contrary in the FAA's Airplane Flying Handbook.[18] Even while in an established turn, trainees often fail to identify the elevator as the control being used at that moment to curve the flight path. Hence Langewiesche's conclusion, "pilots, as a group, simply don't know how to turn."[19]

Evidence suggests the flight training industry long ago succumbed to Tony Kern's twin demons of complacency and perceived competence.[20] We have been complacent about the way we teach turns, thereby leaving pilots with a false sense of competency.

Pilots historically have been shown how to mimic only the most basic turns. Many never reach the application or correlation levels of learning vis-à-vis the maneuvering flight envelope. Details matter, yet many pilots—including CFIs—are unable to visualize various maneuvers by positioning the control surfaces accurately on a model airplane. Control positions are not clear even to the FAA as evidenced in the following graphic of a Chandelle to the left.[21]



The result according to Juan Merkt is often "a pilot who possesses basic flying skills but lacks satisfactory understanding of aircraft performance and its underlying principles."[22] Deficiencies in knowledge and experience are magnified during critical flight operations. Absent better turn awareness, the ability to prevent or recover from LOC-I while maneuvering will continue to be compromised.

We also tend to be quick to assume that technology is the best solution to the problem; that what works in military and airline flight environments will be equally effective in general aviation. When used appropriately, technology certainly can reduce accidents. However, as long as a human is an active part of the system, Kern advises, "Error control will never be engineered out of existence with technology."[23] Further, the airline and military flight environments are highly structured; the pilots, selectively chosen, extremely well trained, and engaged in continuous recurrent training and evaluation. Technology applied in that context would be expected to enhance already superior levels of knowledge and skill.

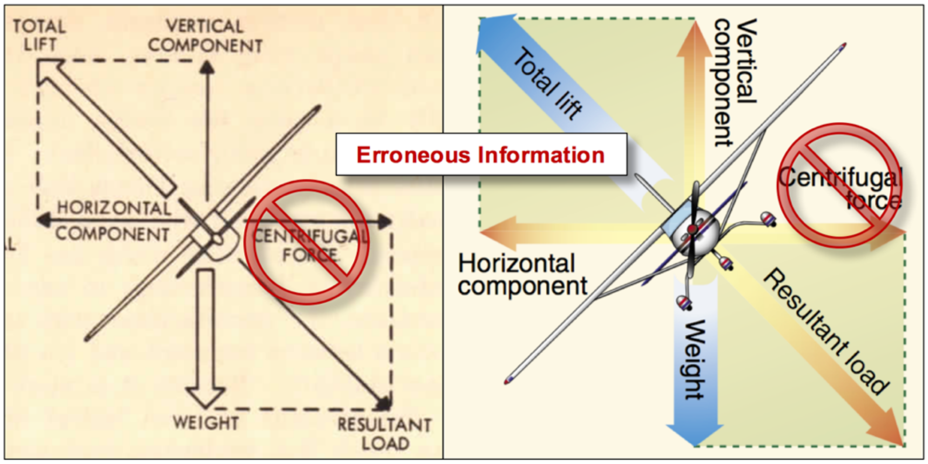
In contrast, general aviation is far less structured. It has a significantly larger pilot population. It is open to anyone who can meet minimum (and varying) standards of skill and precision. Recurrent training is largely optional. Contact flying is the norm (i.e., daytime VFR in VMC using outside visual references). Add in the knowledge and skill deficiencies regarding turns and it is unlikely the full benefits of any technological improvements will be realized. Instead, technology could end up being used as another band aid covering the real problem.

Operational Errors

Pilot error is listed as a cause or factor in more than 80% of aviation accidents.[24] In commercial aviation, pilot-induced accidents are the most frequently-identified cause of LOC-I, with four of the top five reasons sharing common ground with general aviation accidents, specifically:[25]

- application of inappropriate control inputs;
- poor energy management;
- distraction;
- improper training.

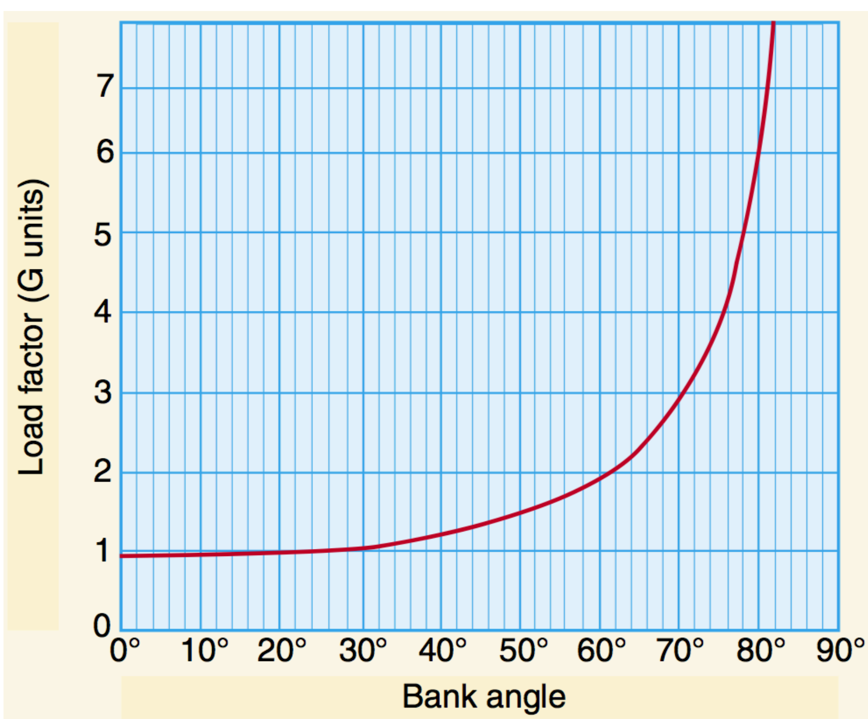
Operational pilot errors in particular can be traced back to errors or omissions committed during the transfer of knowledge between aviation educators and their students. A common example of an error during instruction is the false notion of centrifugal force in turns. Not only is this incorrect, but it also adds nothing of value to the academic discussion. Nonetheless, it has appeared in FAA publications for decades.



1980 Airplane Flying Handbook 2008 Pilot's Handbook of Aeronautical Knowledge

To answer the obligatory question "what turns an airplane," pilots memorize "the horizontal component of lift." That is an acceptable answer provided you are talking only about level turns, but airplanes are capable of climbing and descending turns, too. In the broadest sense, turns can occur in the horizontal, oblique, or vertical planes, and they occur for one simple reason: excess Lift (or alternatively, excess G).[26]

An area where discussion becomes vague involves the familiar graph of bank angle versus G-load (ø-G) for level turns. [27]



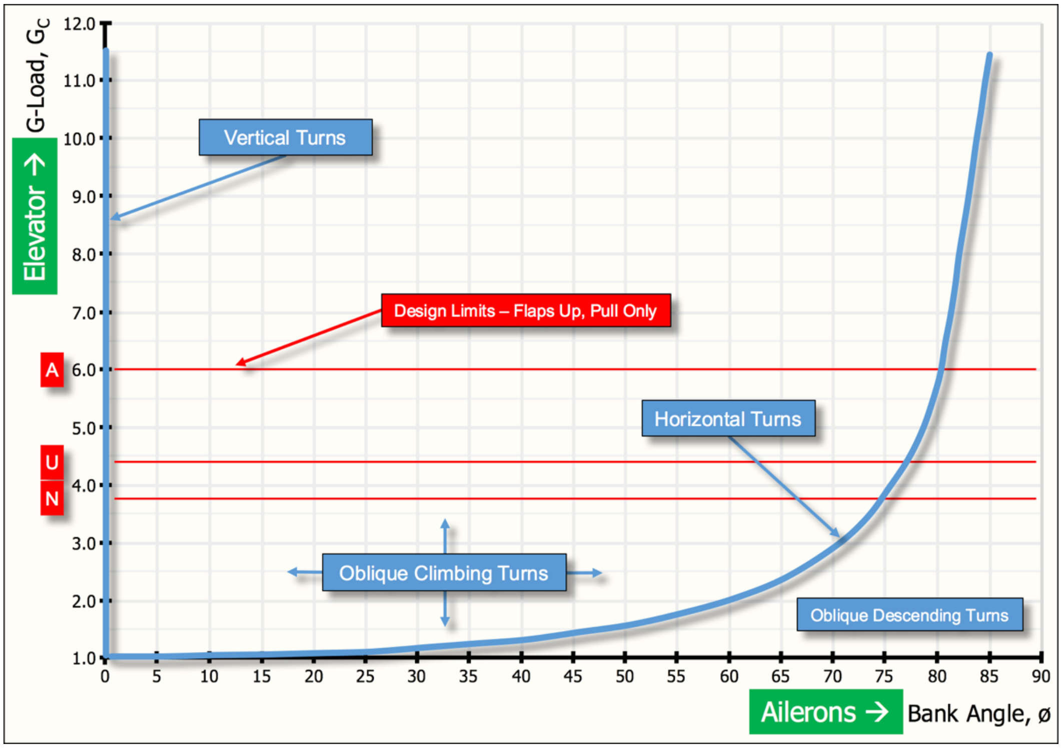
Sixty degrees of bank is a popular reference point to illustrate the relationship between bank angle and G-load. Consider these representative examples found in aviation publications:

1. "A 2g turn is achieved by banking the airplane at an angle of 60 degrees"[28]
2. "in a 60-degree bank, the airplane is experiencing a 2-g acceleration."[29]
3. "increasing the bank angle increases the load factor."[30]

The implication in each case is that the 2G turn happens by virtue of the 60-degree bank; ignored is the role of the pilot as the lead actor in the process. Turns do not happen to the pilot, but because of the pilot. In the first example, a 2G turn (given sufficient energy) is initiated any time the pilot pulls 2G, regardless of bank angle. In the second example, the airplane does not experience a 2G acceleration unless the pilot commands it. In the third example, increasing the bank angle does not increase the load factor—it increases the load factor required of the pilot in order to sustain a level turn.

The pilot must command not only the desired angle of bank, but the commensurate G as well. The pilot must roll to 60 degrees of bank and must pull 2G. Failure to apply the requisite G results in a different kind of turn: a climbing turn with more than the required G; a descending turn with less than the required G.

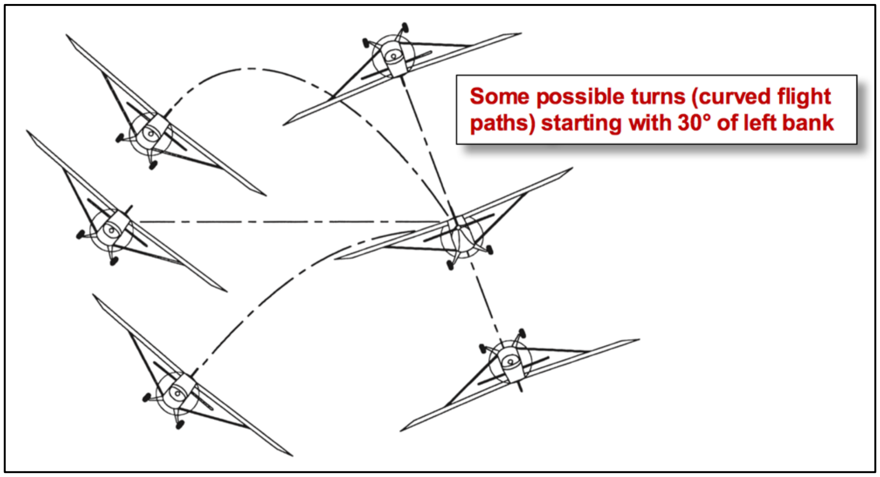
A lot of operationally useful information can be coaxed out of the traditional ø–G diagram to provide the trainee with deeper insight. For instance, an aviation educator should be able to superimpose layer upon layer of information to create a composite graphic similar to the one that follows:



The most egregious error committed by our flight training industry is the unnecessary ambiguity in identifying which control is used to turn the airplane. The information, however, can be found if one is looking for it. For example:

- "The elevator…'pulls' the nose of the airplane around the turn."[31]
- "It is back pressure applied after the bank is established that makes the plane turn."[32]
- "An airplane is turned by laying it over on its side and lifting it around through back pressure on the stick."[33]
- "Use just enough back pressure on the stick to make the nose follow the horizon."[34]
- Regarding accelerated stalls in coordinated turns at 30 degrees of bank: "Reduce speed by steadily and progressively tightening the turn with the elevator"[35]
- Chandelle: "After the appropriate bank is established, a climbing turn should be started by smoothly applying back-elevator pressure"[36]

The reality is surprisingly straightforward. Airplanes are relegated to flight along either straight lines or curves, and those paths are controlled by the elevator. At the correlation level of learning, the myriad flight paths possible at a given angle of bank become readily apparent.



Acknowledging the Hazard

According to Kern, “inadequate knowledge or training to conduct a specific task” creates a hazard; moreover, the hazard “becomes more risky when it is unknown, unaccounted for or underappreciated.” [37,38] The overabundance of low quality, fragmentary information about turns disseminated by the flight training industry has been creating a quantifiable hazard. Poor communications/information transfer, for example, raises the probability of pilot error by a factor of 5.5, while faulty risk perception raises it by a factor of four.[39]

The risk associated with maneuvering flight has been well documented. It is not as if pilots have been superbly trained and are doing the absolute best they can, yet are falling victim to random circumstances beyond their control. Rather, pilots actively (even if accidentally) continue to propel themselves into LOC-I while maneuvering. Even though pilots can cause rudimentary turns to happen usually without getting into trouble, they have not been given the education and experience to master turns. The fact that pilots have been left unaware of the elevator-as-turn-control unquestionably has compounded the risk involved.

“Risk management begins with hazard identification.”[40] With the hazard now identified, a targeted solution to the problem of LOC-I is proposed.

THE SOLUTION

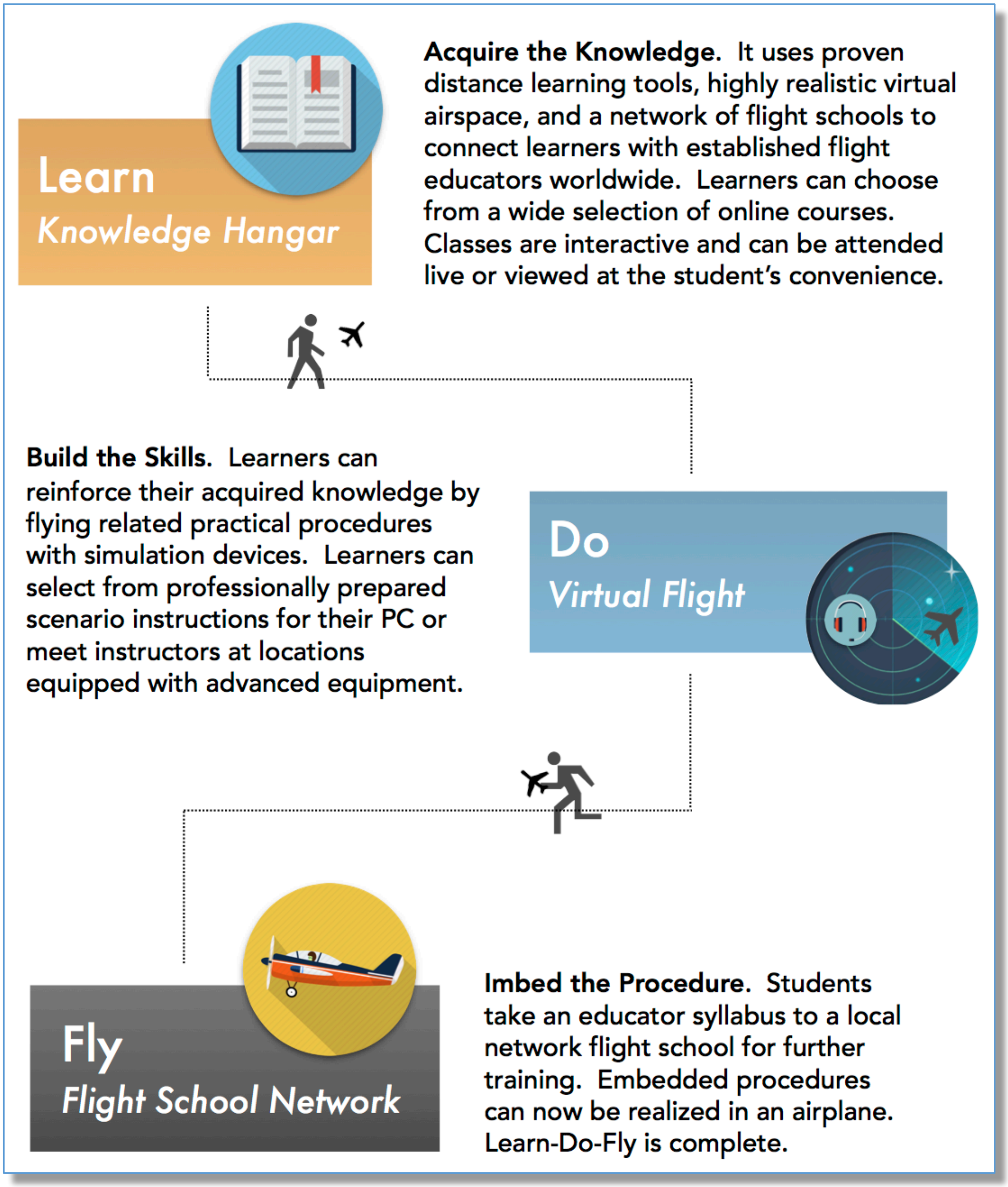
According to NTSB, we can reduce LOC-I accidents through "education, technologies, flight currency, self-assessment, and vigilant situational awareness in the cockpit."[41] Four of these elements point directly at the pilot; hence, "Learn to Turn" takes a decidedly pilot-centric, stick-and-rudder approach to mitigating LOC-I.

The general aviation fleet will continue to be diverse. Improved standards, technology, and products will continue to be pushed into the aviation pipeline. But not every airplane will end up with supplemental angle of attack or similar technologies, and not everyone will be able to afford the latest technologies or products. Absent a concerted effort to improve pilot performance during turns, these enhancements alone are unlikely to yield the desired safety dividends. The reason: whether the airplane is commercially manufactured or homebuilt, powered by reciprocating or jet engines, or equipped with or without the latest technology, human behavior ultimately determines the fate of each flight.

Pilots are the common thread. Consequently, LTT offers a knowledge- and skills-based solution for any pilot to reduce the threat of LOC-I. The LTT approach is consistent with best practices outlined in ICAO's Manual on Aeroplane Upset Prevention and Recovery Training, recommendations in FAA publications, and output from the Society of Aviation and Flight Educators' Pilot Training Reform Symposium. The goals of the LTT initiative include:

- Incorporating UPRT language and concepts;
- Combining scenario- and maneuvers-based training;
- Expanding angle of attack and G-load awareness;
- Addressing human factors and accident causes;
- Improving manual handling and LOC-I recognition, prevention, and recovery skills;
- Teaching energy and flight path management; and
- Training in spiral dives, steep turns, high angle of bank recoveries, accelerated stalls, and slow flight.

Moreover, Community Aviation's "Learn-Do-Fly" framework will be used to integrate academic and practical training into a cohesive methodology for the delivery of LTT content.



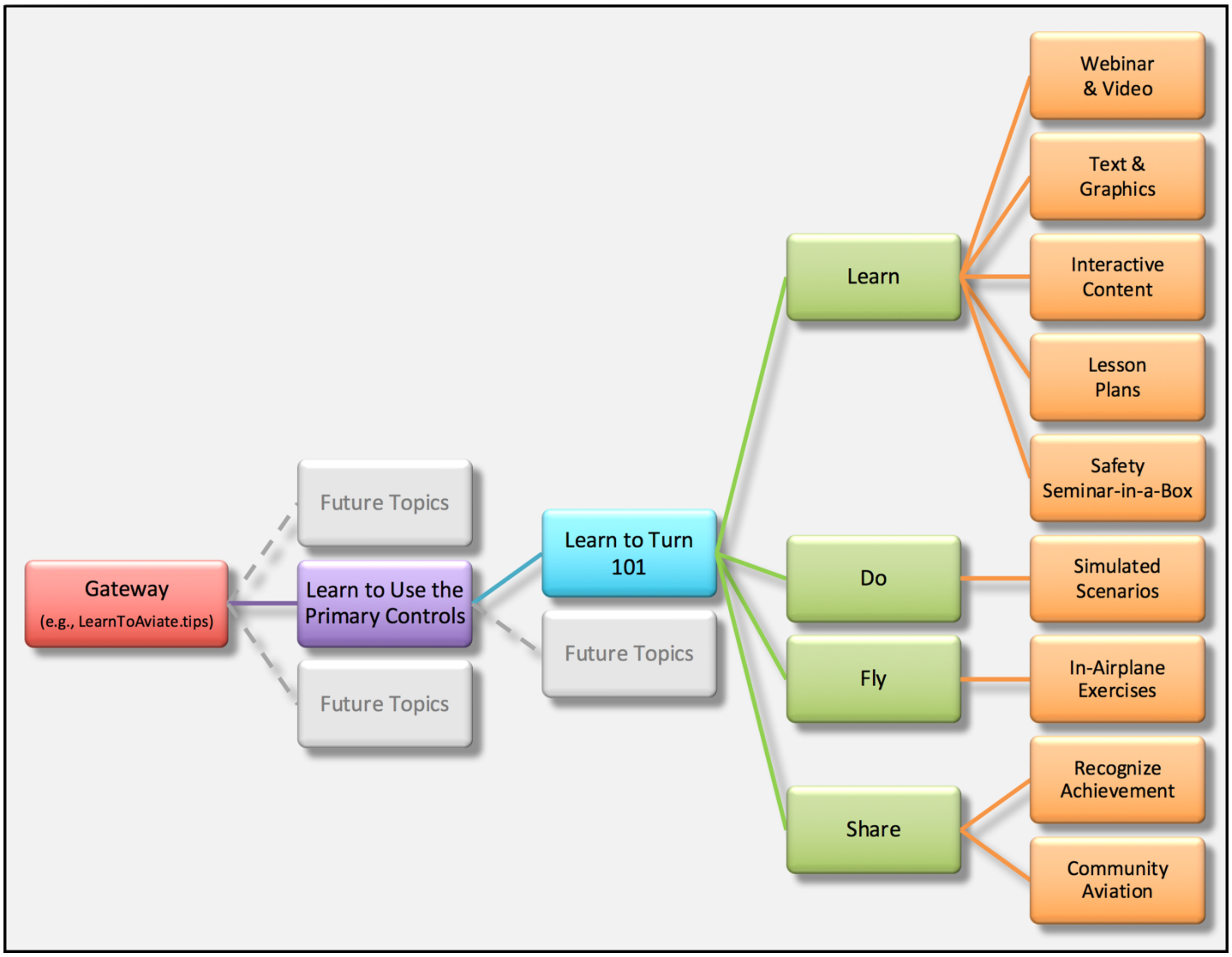
Developing the core competencies suggested by ICAO is an objective as well:[42]

Competency	Competency Description	Behavioral Indicator
Application of Procedures	Identifies and applies procedures in accordance with published operating instructions and applicable regulations, using the appropriate knowledge	Follows SOPs unless a higher degree of safety dictates an appropriate deviation Identifies and follows all operating instructions in a timely manner Correctly operates aircraft systems and associated equipment Complies with applicable regulations Applies relevant procedural knowledge
Manual Flight Path Management	Controls the airplane flight path through manual flight, including appropriate use of flight management systems and flight guidance	Controls the airplane manually with accuracy and smoothness as appropriate to the situation Detects deviations from the desired airplane trajectory and takes appropriate action
Leadership and Teamwork	Demonstrates effective leadership and team working	Admits mistakes and takes responsibility Carries out instructions when directed Communicates relevant concerns and intentions Gives and receives constructive feedback Confidently intervenes when important for safety
Problem Solving and Decision Making	Accurately identifies risk and resolves problems; uses appropriate decision making processes	Seeks accurate and adequate information from appropriate sources Employs proper problem-solving strategies Perseveres in working through problems without reducing safety Uses appropriate and timely decision-making processes Sets priorities appropriately Identifies and considers options effectively Monitors, reviews, and adapts decisions as required Identifies and manages risk effectively Improvises when faced with unforeseeable circumstances to achieve the safest outcome
Situational Awareness	Perceives and comprehends all of the relevant information available and anticipates what could happen that may affect the operation	Identifies and assesses accurately: • the state of the airplane and its systems • the airplane's vertical and lateral position, as well as its anticipated flight path • the general environment and how it might affect the operation Keeps track of time and fuel Maintains awareness of the people involved in or affected by the operation Anticipates accurately what could happen, plans ahead and stays ahead of the situation
Workload Management	Manages available resources efficiently to prioritize and perform tasks in a timely manner under all circumstances	Maintains self-control in all situations Plans, prioritizes, and schedules tasks effectively Manages time efficiently when carrying out tasks Offers and accepts assistance, delegates when necessary, asks for help early Reviews, monitors, and cross-checks actions conscientiously Verifies tasks are completed to the expected outcome Manages and recovers from interruptions, distractions, variations, and failures effectively

LTT also addresses two special emphasis areas in the FAA WINGS program: basic flying skills and stall/spin awareness. It is consistent with the FAA's belief that improving knowledge and skills for manual flight operations are necessary for safe flight.[43]

Outline

The information in this section presents the general scope of LTT-101.



Gateway

- Online Access to LTT Content (LearnToAviate.tips, Community Aviation, etc.)
- How to Use & FAQs

Learn to Use the Primary Controls

- Bridge Training
- Pilot-Oriented Approach
  - Developing Visual References
    - Internal vs. External Cues
  - Thinking in Terms of "Action → Consequence"
    - Aileron, Rudder, Elevator, Throttle

Learn to Turn 101

- Introduction
- Objectives & Course Format

Learn

- Webinar & Video
- Text & Graphics
- Interactive Content
- Lesson Plans for Aviation Educators
- Safety Seminar-in-a-Box for FAA Safety Team Programs

Do

- Simulated Scenarios
  - Flight Simulation Training Devices
  - Thought Experiments
  - Visualization Techniques

Fly

- In-Airplane Exercises
  - Generic & Airplane-specific Exercises
  - Performance Standards
  - Self-Critiquing

Share

- Recognizing Achievement
  - Completion Certificate/Badge
  - FAA Wings Program Credit
  - Insurance Industry Discounts/Incentives
- Building a Community
  - Networking
    - Forums, Meet-ups, Fly-outs
    - Group Training Opportunities
  - Advocating

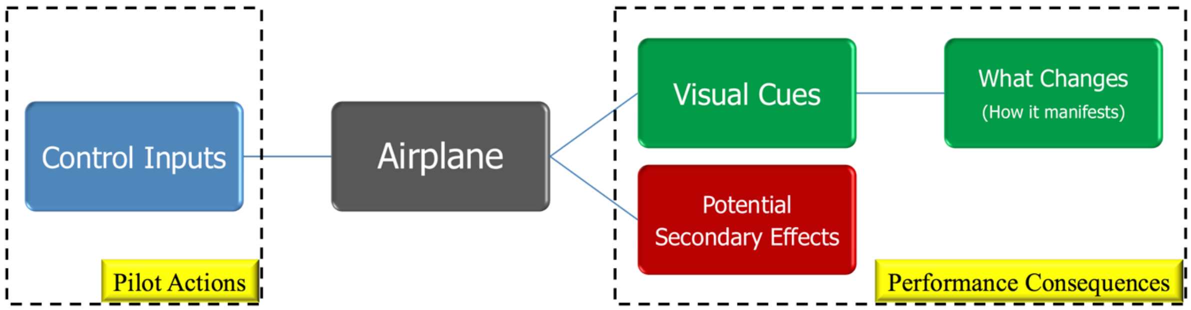
LTT content is informed by three performance diagrams:

1. G-Loads in Turns
2. Bank Angle versus G-Load (ø-G)
3. Speed versus G-load (V-G)

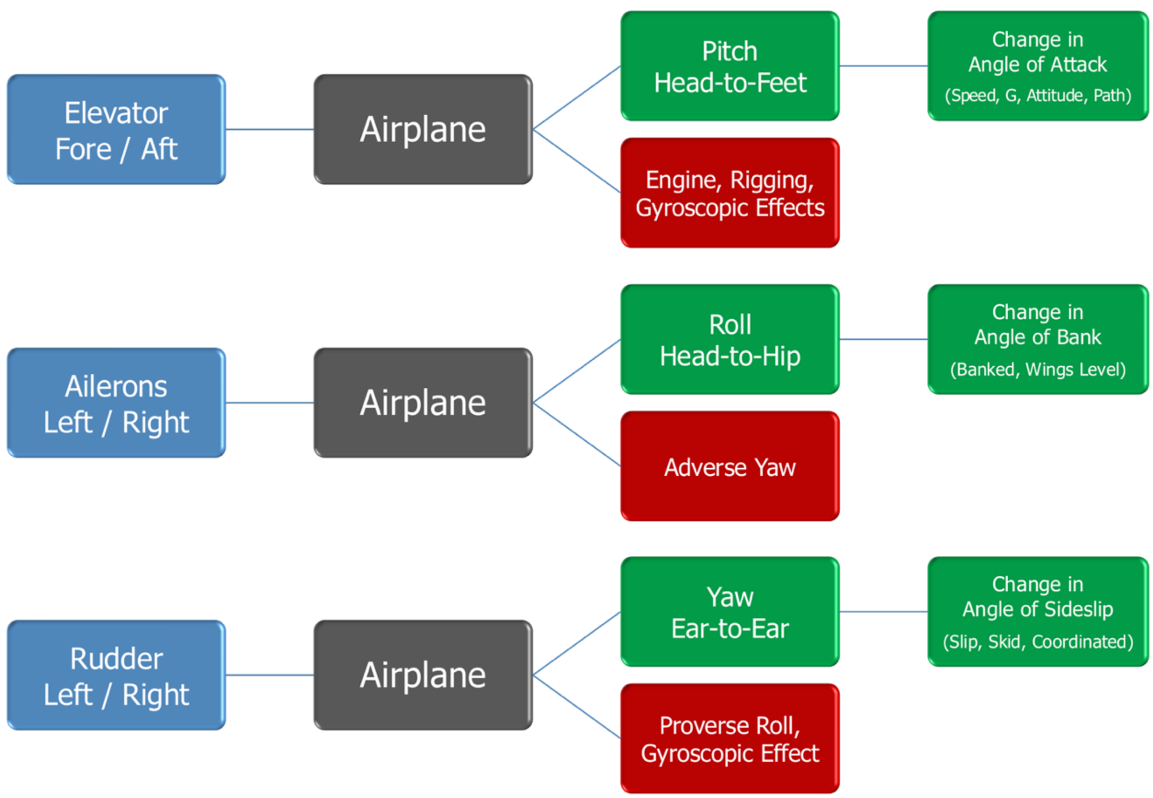
Sampling of LTT Content

The graphics in this section, admittedly crude at this point, provide insight into our vision for LTT content.

Learn: A pilot's "knowledge of aerodynamics, flight dynamics and aeroplane design principles" is essential to the prevention of upsets.[44] LTT begins with the bridge training, "Learn to Use the Primary Controls." Trainees are taught about the primary controls using the following template. Emphasis is placed on how the airplane moves relative to the pilot.



Correlating pilot actions directly with performance consequences "leads not only to better understanding of the subject matter but also to greater motivation to learn."[45] Using such a template ensures a consistent and operationally relevant presentation of pitch, roll, and yaw:



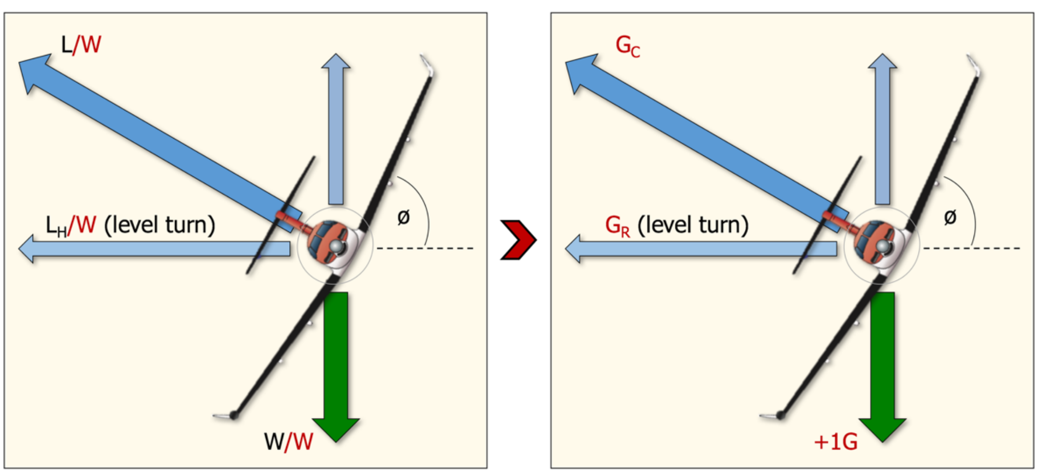
Coupling the use of training aids (e.g., a model airplane with moveable control surfaces) reinforces the concepts and helps the trainee build the proper mental model of cause-and-effect between pilot inputs and airplane responses. Visualizing the mental model during the Do and Fly stages further cements the learning.

In "Learn to Turn 101," the key attributes of turning flight are identified, namely: curving flight path, G-load, turn radius, and rate of turn. Turn performance is generalized to encompass curved flight whether in the horizontal, oblique, or vertical plane. Discussion can shift naturally to specific cases such as level turns, Chandelles, even loops. This is consistent with the Navy's approach to instruction in air combat maneuvering, the International Council of Air Shows' approach to air show performer safety and education, the <u>RV-Type Training Guide's</u> approach to transition training (freely available to the nearly 10,000 RV aircraft currently flying), and the Air Force Test Pilot School's approach to teaching performance flight testing.[46,47,48,49]

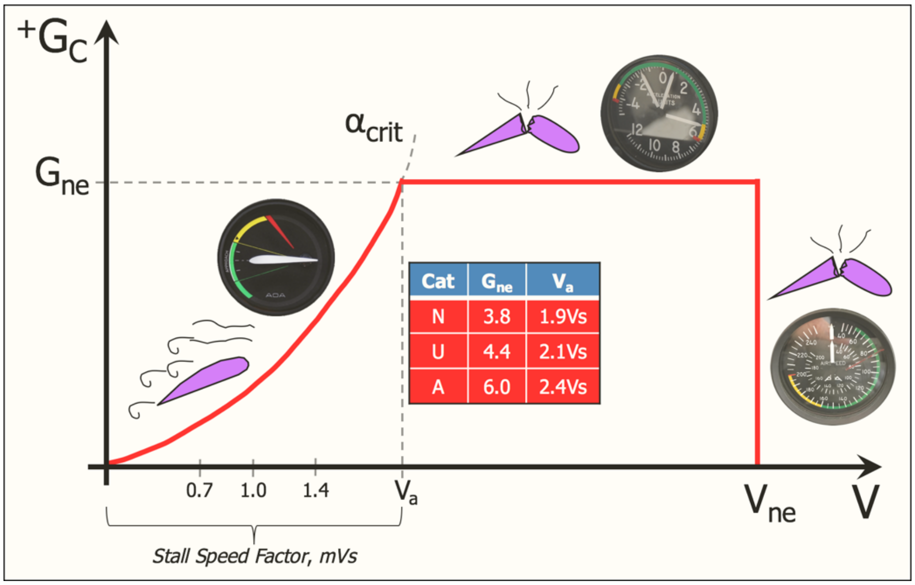
Also consistent with the above-mentioned approaches, turn performance is presented in terms of G-load rather than just the forces of Lift and Weight. This offers several advantages:

1. Our proprioception is attuned to changes in G-load
2. The link between elevator inputs and G-load is intuitive
3. G-load appears on the y-axis on ø-G and V-G diagrams

Modifying the traditional "forces in a level turn" graphic to "G-loads in a level turn" (where radial G points toward the center of the turn) ensures continuity with ø-G and V-G diagrams.

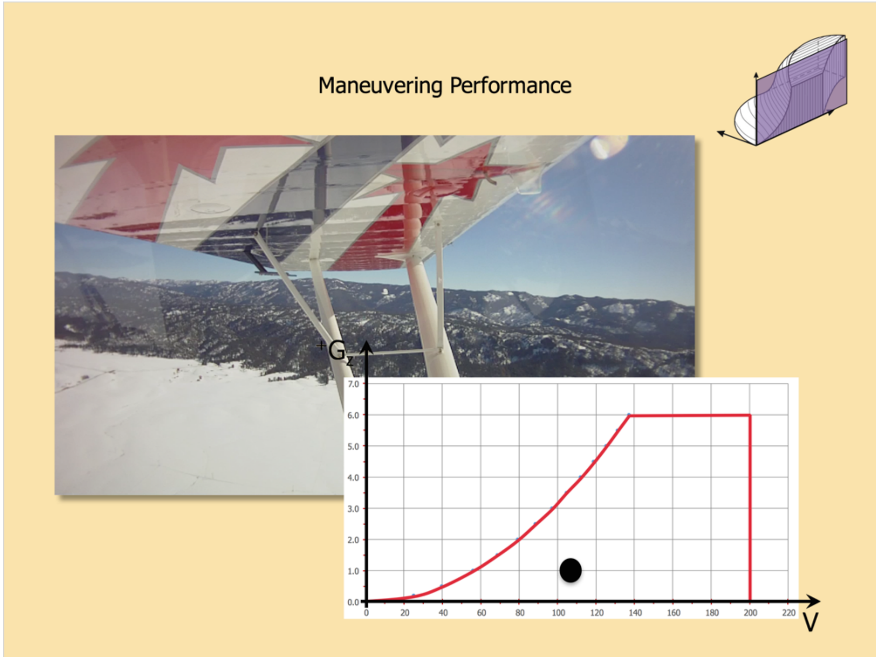


Just as the ø-G diagram has been underutilized in training, the potential of the V-G diagram as a powerful teaching tool has been underappreciated as well. V-G defines the maneuvering envelope of the airplane. It offers a perfect opportunity to tie together stall speeds, design limits, and key V-speeds in a single, convenient graphic. And just like ø-G, the diagram can be built up with operationally relevant information as needed. A generic yet information-rich picture for the case of positive G with flaps-up and no rolling might look this:



A current application of V-G information synchs in-flight video with an animated graphic. The screenshot on the following page is a PowerPoint slide used during safety seminars. The video portion shows the change in pitch attitude looking down the left wing in a Decathlon during a power off, ≈1G deceleration. As pitch attitude increases and speed decays, the black dot on the V-G graphic simultaneously slides to the left along the 1G line. As the dot crosses the red aerodynamic limit line (α_{crit}), the wing is seen pitching forward due to the separation of airflow.

Presented this way, a clear link is made between academics and practical experience. Similar examples are planned for accelerated stalls from various turns to illustrate that “back pressure on the stick, tightness of turn, g load, nearness to the stall, are all really the same thing.”[50]



Do: Merkt states, "an integrated, energy-centered, top-down training approach will lead to a better mental model of how the airplane works…for safe and efficient operation."[51] The Learn-Do-Fly framework promotes consistency from academic through practical training. The Do stage focuses on the use of FSTDs (all levels, including desktop PCs) to deliver challenging training scenarios targeting risk management and decision making, among other skills. Community Aviation has created the virtual airport KLOC to serve as a base of operations for LTT simulator scenarios that will include distractions in the pattern, overshoots, crosswinds, engine failures on takeoff, and more.

Fly: "The practice and application of skills acquired during on-aeroplane UPRT provides experience and confidence that cannot be fully acquired in the simulated environment alone."[52] LTT training is not complete until its concepts and the lessons learned during simulation are applied in an airplane in flight. For nearly 30 years, LTT exercises have been an integral part of the Emergency Maneuver Training program taught to military, government, and civilian pilots from around the world. Outlines for several of those exercises follow.

- Climbing Dutch Rolls.
    a) Demonstrate adverse yaw.
    b) Develop visual references over the nose and at the wing tips.
    c) Develop control feel and interaction of aileron and rudder inputs.
- Level Turns.
    a) Demonstrate the actual turn process.
    b) Identify the primary role of elevator during turns.
    c) Develop visual scan for traffic.
    d) Demonstrate the roles of ailerons and rudder once turning has begun.
    e) Emphasize coordination of aileron and rudder when changing bank angle.
- Aerobatic-style Level Turns.
    a) Separate roll actions used to bank from elevator actions used to turn.
    b) Emphasize control discipline: bank → stop → turn → stop → bank.
    c) Perform medium-banked turns left and right.
- Turning Dutch Rolls.
    a) Combine Dutch Rolls with Aerobatic-style Turns.
    b) Look at nose and wing references.
    c) Note effect of variable bank angles on turn performance.
    d) Perform to the left and to the right.
- Spirals.
    a) Illustrate aerodynamic differences between spirals, stalls, and spins.
    b) Perform descending spirals with Power–Push–Roll recovery actions.
    c) Emphasize how aft elevator aggravates spiral/turn characteristics.
- Skidded Turns.
    a) Demonstrate the classic skid/spin scenario from simulated base-to-final turns.
    b) Emphasize the importance of proper yaw control in the traffic pattern.
    c) Develop visual and kinesthetic cues of the skid/spin process.
    d) Initiate PARE spin recovery at spin entry (spins-approved airplanes only).
- Slipping Turns Left and Right.
    a) Change headings while in a slip.
    b) Vary rudder, elevator, and aileron pressures to start and stop slipping turns.
    c) Perform S-turns while slipping.

Share: Improving safety vis-à-vis a reduction in loss of control accidents is the desired outcome. But according to Ed Wischmeyer, "The key to successfully marketing safety is to appeal to the underlying desires of the pilots."[53] Given that flying has a significant cognitive component, we need to engage pilots by appealing to their primary motivations to fly, namely: autonomy, mastery, and purpose.[54] Further, if we can "provide them with the knowledge and tools to recognize and prevent their personal mistakes," Kern says, "most people who care about their performance will do so of their own accord."[55]

We believe the majority of pilots want better information about flying techniques and aspire to improve their skills. To invest them in LTT and foster a mindset of lifelong learning, Community Aviation is building a network where participants will be able to:

- Pick and choose their entry points, levels of participation, and desired depth of knowledge (autonomy);
- Challenge themselves with skill-building experiences designed to expand their personal operating envelopes, improve awareness, and bolster confidence (mastery);
- Share their experiences with like-minded individuals and be acknowledged for their commitment to recurrent training (purpose).

In addition to an online presence, Community Aviation will facilitate meet-ups, group training opportunities, and other face-to-face interactions. Actively promoting the EAA Pilot Proficiency Center during AirVenture is one high-profile example.

As a result of this and other marketing efforts, more than 200 people attended the FAA Wings-approved "Learn to Turn" forum presented at the EAA Pilot Proficiency Center during AirVenture 2016 (see Appendix 1–Forum PowerPoint Slides). Ten-minute "Learn to Turn" training sessions were offered in a Redbird motion simulator at the Proficiency Center as well (see Appendix 2–Sim Training Pre-Brief Lesson Plan).

As an example of the potential reach of social media, the first generation "Learn to Turn" YouTube video has been viewed more than 5,000 times (see Appendix 3–Online Video). Hundreds of people have submitted an online form registering support for, and offering help with, the LTT concept as well (see Appendix 4–Some Supporters of LTT).

KEY CONSIDERATIONS

Effectiveness in Reducing LOC

LTT targets maneuvering flight, which is the primary driver of LOC-I. Therefore, it should be highly effective in reducing the number of fatal LOC-I accidents. A preliminary study will be undertaken to validate LTT as a deterrent against loss of control and identify areas for improvement.

Applicability

LTT is independent of airplane type. Any pilot can benefit from this training initiative; hence, it has the widest possible applicability.

Ease of Implementation

Every pilot interacts with an educator, flight school, CFI, or DPE at some point. These interactions provide opportunities to educate pilots about LOC-I mitigation using LTT concepts. Accordingly, implementation of LTT-101 in particular will include:

- Internet-based content
- WINGS programs for FAA Safety Team Representatives
- Exercises that can be incorporated into flight reviews as well as simulation, transition, and recurrent training sessions
- Outreach to:
    - EAA Chapters
    - type clubs
    - aviation groups and organizations
    - flight schools
    - college aviation programs
    - CFIs and DPEs
    - flight instructor refresher clinics
    - pilot proficiency programs
- Recognition for those who satisfactorily complete LTT programs, including seeking incentives from the insurance industry for those who participate in LTT programs

For instance, by leveraging the diverse network of EAA chapters—homebuilders, ultralights, light-sports, warbirds, vintage aircraft, aerobatics, IMC clubs—LTT-101 can be distributed directly to EAA members. EAA members then can become ambassadors for the initiative, spreading LTT information to others through outreach efforts at the chapter level.

Effectively reaching aviation educators creates another powerful multiplier effect for the dissemination of LTT concepts; hence, instructor groups and university aviation programs will be targeted. Even so, the use of proven distance learning tools will ensure accessibility to LTT content by anyone anytime and anywhere.

Cost to Participants

LTT-101 will rely on industry collaboration and sponsorship to ensure easy access to online content and exercises that can be incorporated into training and evaluation flights. Consequently, the incremental cost to pilots (especially aviation educators) would be low. Further, LTT-101 will take advantage of existing networks of educators and instructors, FSTDs (all levels, including desktop PCs), and associations and clubs. The use of the internet as the primary knowledge distribution system provides LTT-101 with a decidedly low cost opportunity with a wide reach.

CONCLUSION

Unwittingly, the flight training industry has created a hazard through inadequate training on turn performance. We now need to summon the willpower to attack LOC-I in a meaningful way. We also need to recognize that the pilot is “the strongest part of the safety and performance equation.”[56] Addressing LOC-I must begin with a critical look at what and how we have been teaching general aviation pilots. At a minimum, we need to provide pilots with more complete, more accurate information about turns, while encouraging higher standards of performance. LTT accomplishes this using three insightful diagrams as lynchpins for academic and practical training content: G-loads in turns, ø-G, and V-G. It also appeals directly to the primary motivations pilots have for flying, namely: autonomy, mastery, and purpose.

Hundreds of individuals representing several countries have registered their support for the “Learn to Turn” concept already. At the 2016 EAA Pilot Proficiency Center, more than 200 people attended the FAA Wings-approved “Learn to Turn” forum, and ten-minute “Learn to Turn” training sessions were delivered in a Redbird motion simulator. Recognition and funding of LTT-101 by key stakeholders will allow us to create content and bring the myriad pieces together into a cohesive training initiative capable of reaching multiple thousands of pilots. Further, it will facilitate increased support for, and positive action toward, reducing LOC-I.

***

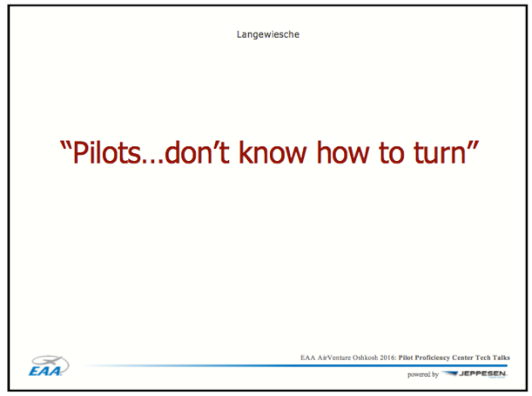
AUTHOR BIOS

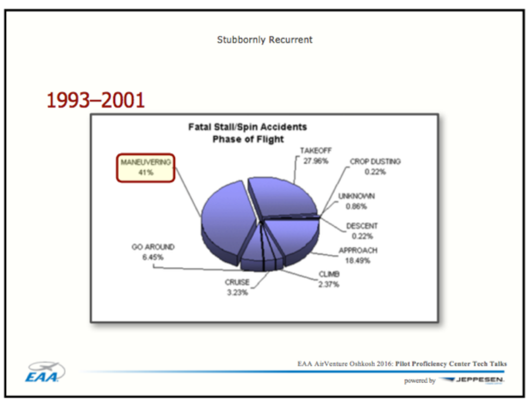
Rich Stowell is a 32-year member of AOPA, EAA, and IAC. He has specialized in spin, emergency maneuver, and aerobatic training for 29 years, and is a nine-time Master Instructor. He is also the 2014 National FAA Safety Team Representative of the Year and the 2006 National Flight Instructor of the Year. Among other honors, Stowell has been designated an "Official Spin Doctor" by the IAC. For his dedication to aviation safety and education, he has received an IAC President's Award and was made an honorary member of the International Association of Natural Resource Pilots. Stowell has authored three aviation books, published more than 80 aviation-related articles, and delivered more than 350 aviation talks. He has logged just shy of 10,000 flight hours with 8,900 hours of dual instruction given, performing 24,800 landings and 34,100 spins along the way. Stowell is a Charter and Life member of the Society of Aviation and Flight Educators, and holds a Bachelor of Science in Mechanical Engineering from Rensselaer Polytechnic Institute.

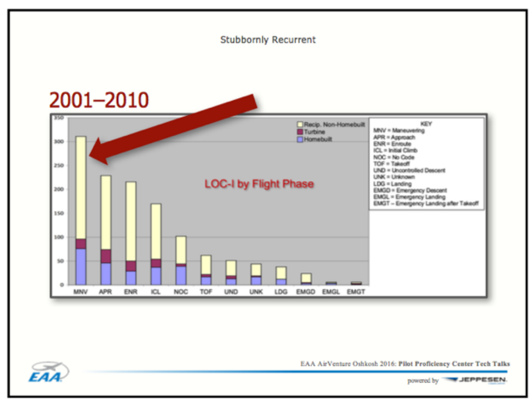
Billy Winburn is an instrument rated pilot and the president of Community Aviation, a virtual learning community for pilots, educators and aviation enthusiasts. Winburn has been an active leader in business and real estate ventures since 1995 with the creation of CityLynx, the first local digital community on AOL. Since then he has founded or participated in more than five start-ups ranging from an online home furnishings company acquired by Hearst New Media, to a local co-working community in the Washington, DC area. Winburn was a member of the original development team for the Kentlands community in Gaithersburg, MD, a new urbanist project designed by the architectural firm Duany Plater-Zyberk. He is also the CEO of Mindstar Solutions. Winburn lives in Alexandria, VA in a very small house.

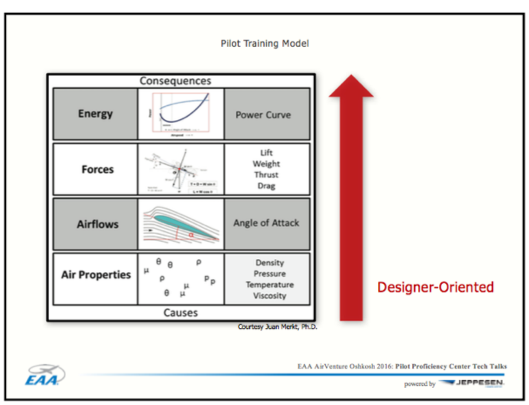
APPENDIX 1

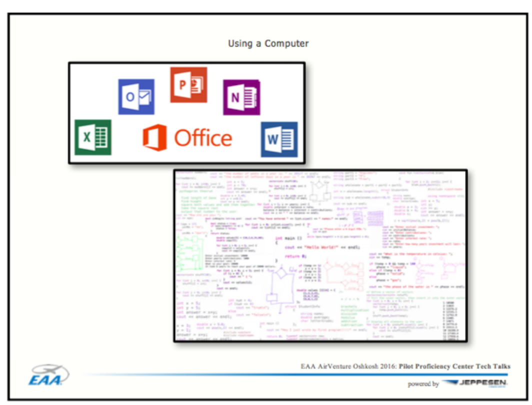
More than 200 people attended the FAA Wings-approved “Learn to Turn” forum at the EAA Pilot Proficiency Center in July 2016. Following are screenshots of the PowerPoint slides used (slide progression: top row, left–right; middle row, left–right; bottom row, left–right):

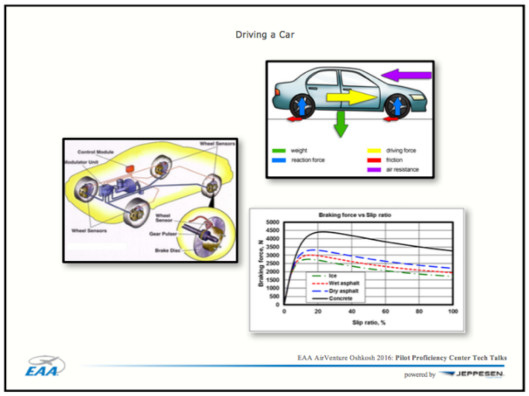


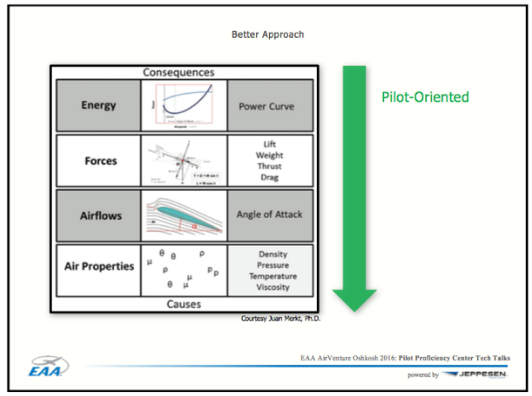


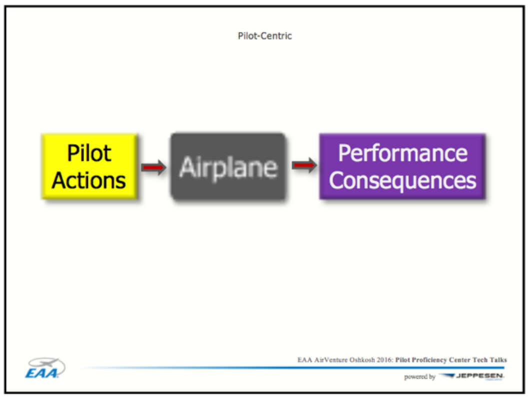


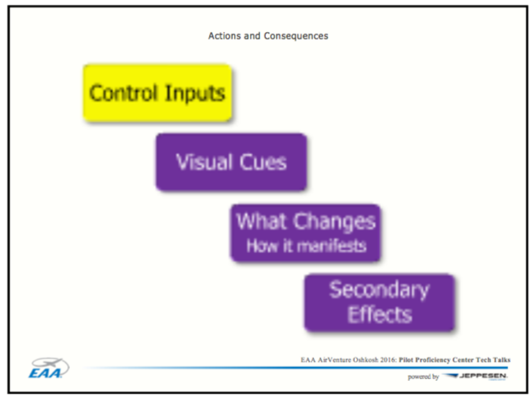


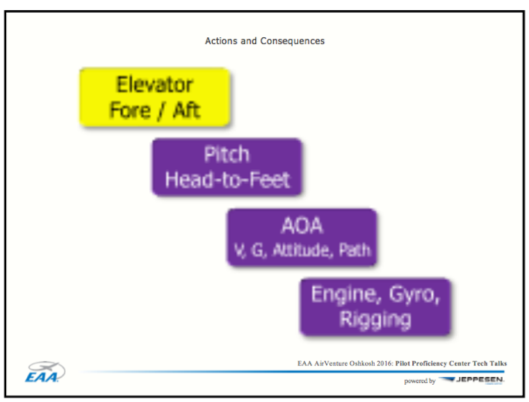


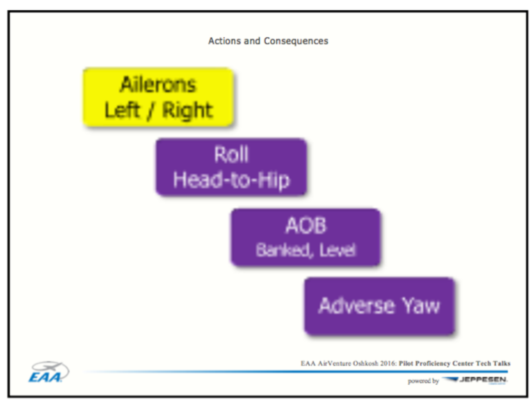

Driving a Car
Control Module
Modulator Unit
Wheel Sensors
Wheel Sensors
Wheel Sensor
Gear Pulser
Brake Disc
weight
reaction force
driving force
friction
air resistance
Braking force vs Slip ratio
Braking force, N
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Ice
Wet asphalt
Dry asphalt
Concrete
0
20
40
60
80
100
Slip ratio, %
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN

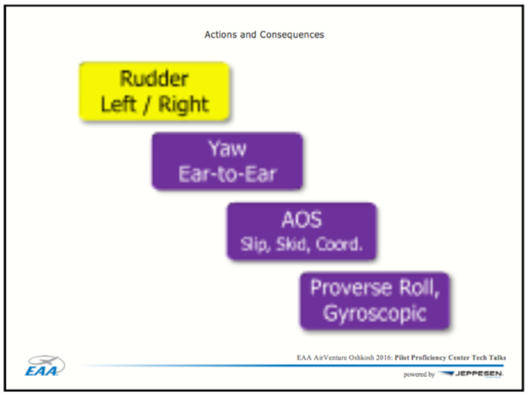

Better Approach
Consequences
Energy
Power Curve
Forces
Lift
Weight
Thrust
Drag
Airflows
Angle of Attack
Air Properties
Density
Pressure
Temperature
Viscosity
Causes
Courtesy Juan Merkt, Ph.D.
Pilot-Oriented
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN

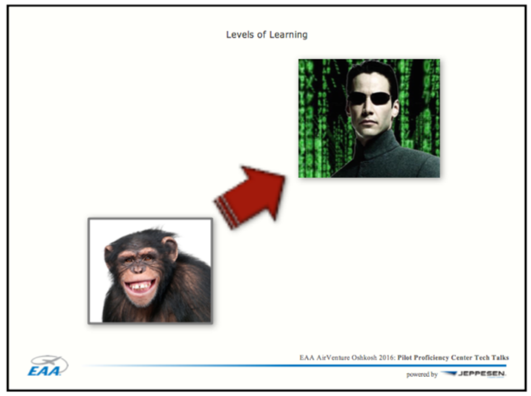

Pilot-Centric
Pilot Actions
Airplane
Performance Consequences
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Actions and Consequences
Control Inputs
Visual Cues
What Changes
How it manifests
Secondary Effects
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Actions and Consequences
Elevator
Fore / Aft
Pitch
Head-to-Feet
AOA
V, G, Attitude, Path
Engine, Gyro, Rigging
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Actions and Consequences
Ailerons
Left / Right
Roll
Head-to-Hip
AOB
Banked, Level
Adverse Yaw
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Actions and Consequences
Rudder
Left / Right
Yaw
Ear-to-Ear
AOS
Slip, Skid, Coord.
Proverse Roll,
Gyroscopic
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Levels of Learning
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
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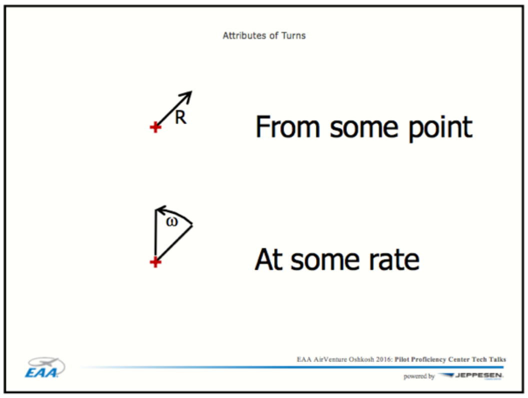
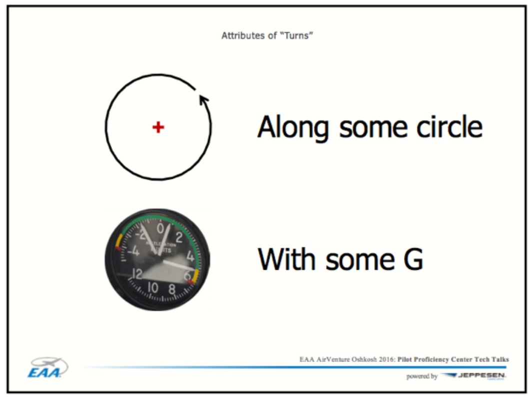
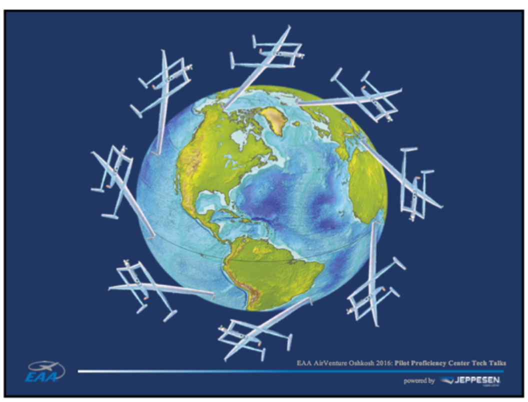

Attributes of Turns
R
From some point
ω
At some rate
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Attributes of "Turns"
Along some circle
With some G
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN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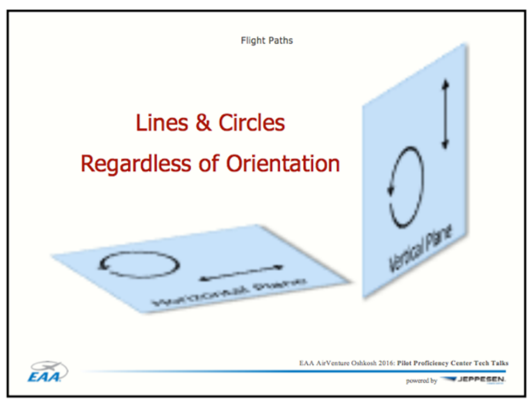
Flight Paths
Lines & Circles
Regardless of Orientation
Horizontal Plane
Vertical Plane
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
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Three Examples

Maneuver	Plane	"Turn Performance"			
		Radius	Rate	Curved	G-Load
Level Turn	Horizontal	✔	✔	✔	✔
Chandelle	Oblique	✔	✔	✔	✔
Loop	Vertical	✔	✔	✔	✔

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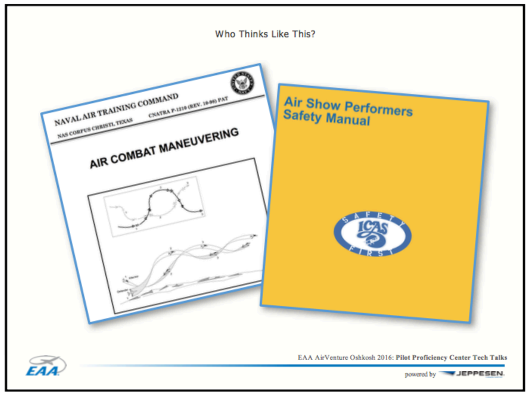
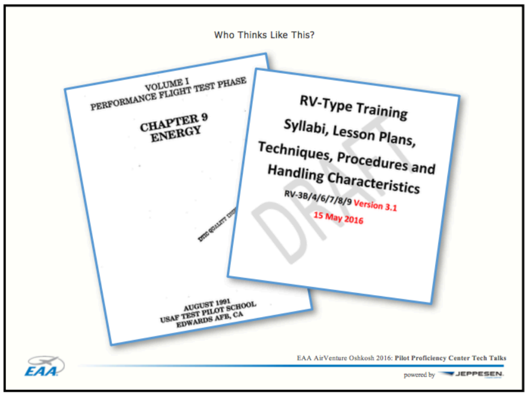
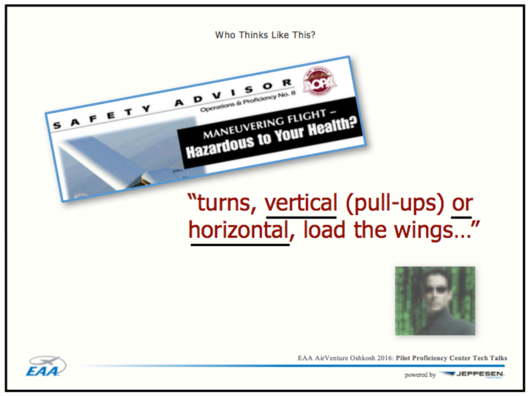
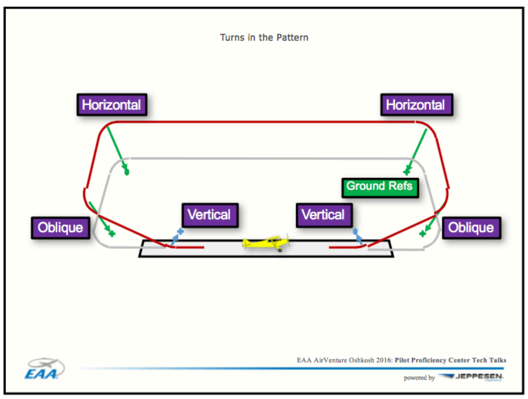
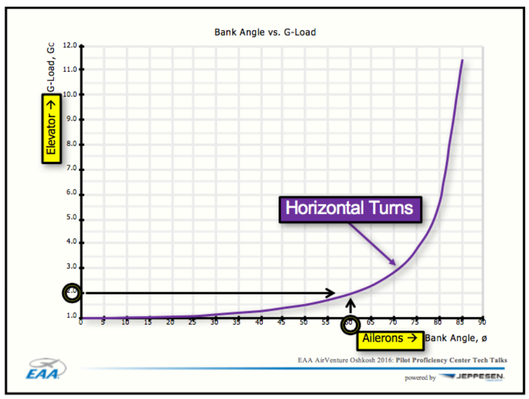
powered by JEPPESEN

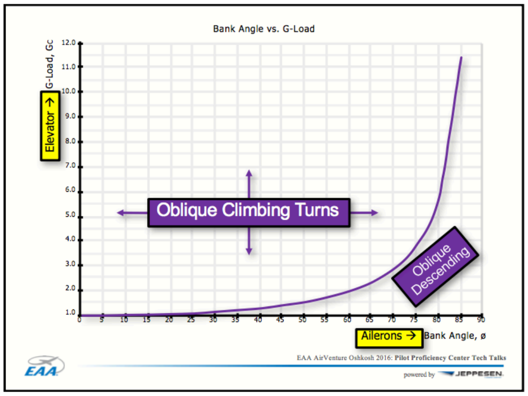


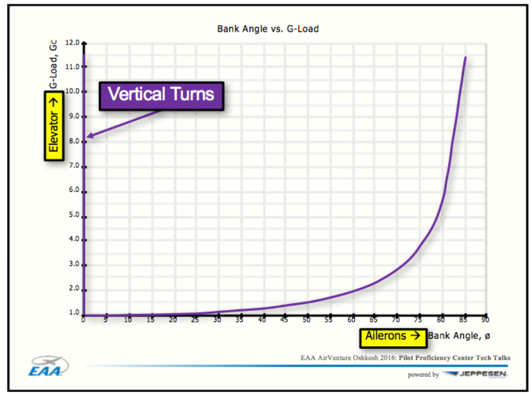


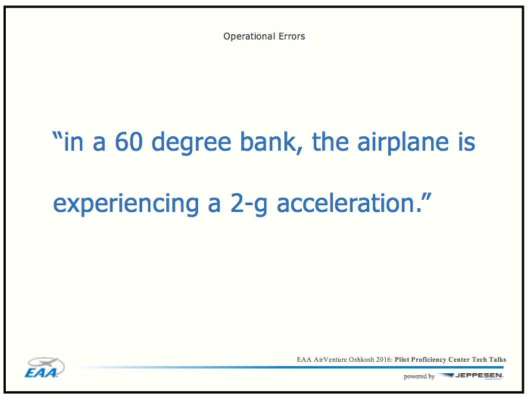


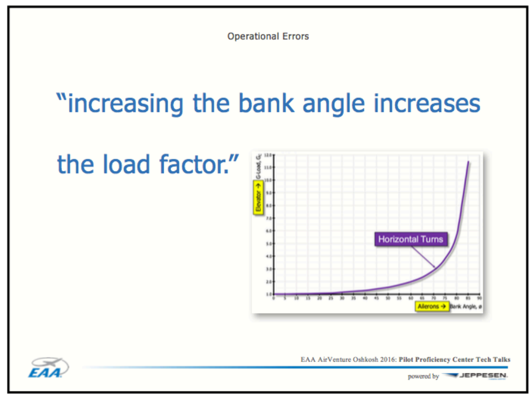


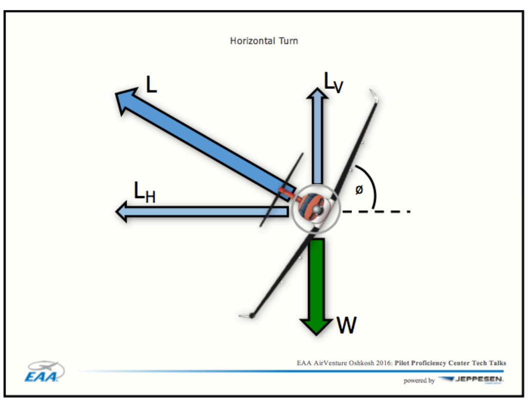


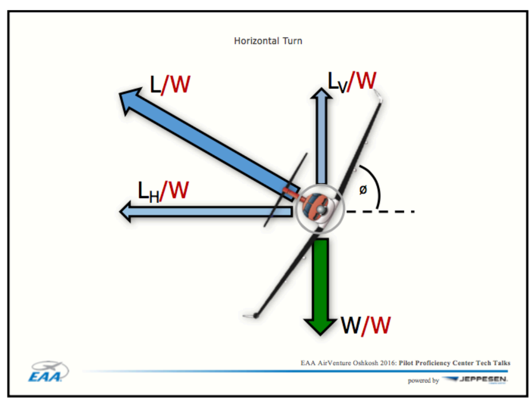

Bank Angle vs. G-Load
G-Load, Gc
Elevator →
Oblique Climbing Turns
Oblique Descending
Ailerons →
Bank Angle, ø
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN

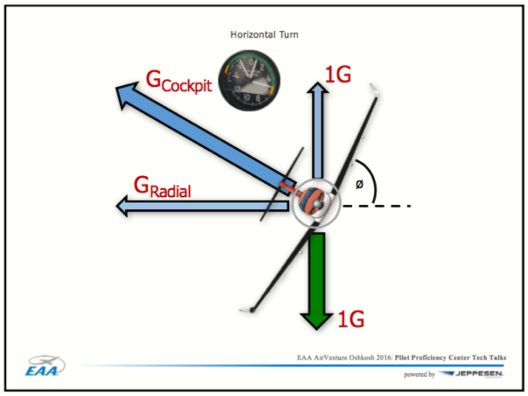

Bank Angle vs. G-Load
G-Load, Gc
Elevator →
Vertical Turns
Ailerons →
Bank Angle, ø
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN

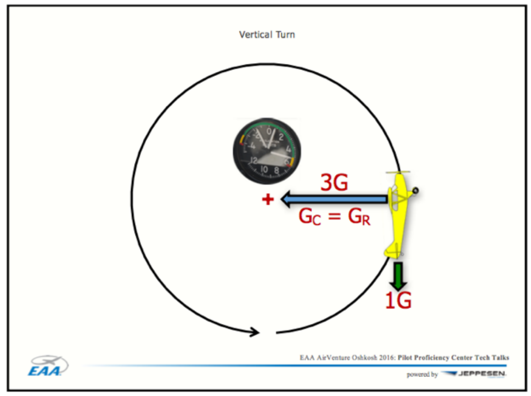

Operational Errors
"in a 60 degree bank, the airplane is experiencing a 2-g acceleration."
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN

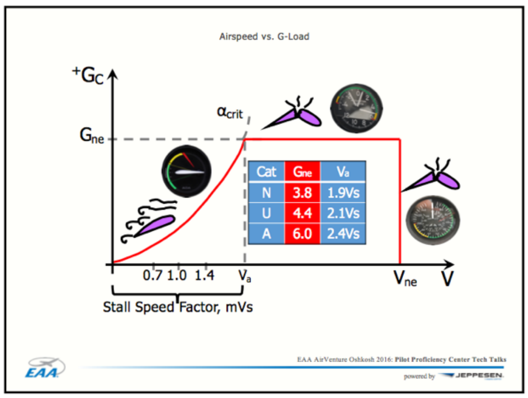

Operational Errors
"increasing the bank angle increases the load factor."
Horizontal Turns
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN

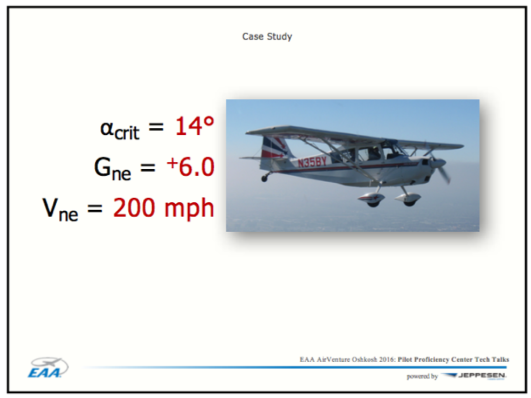

Horizontal Turn
L
LV
LH
ø
W
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN

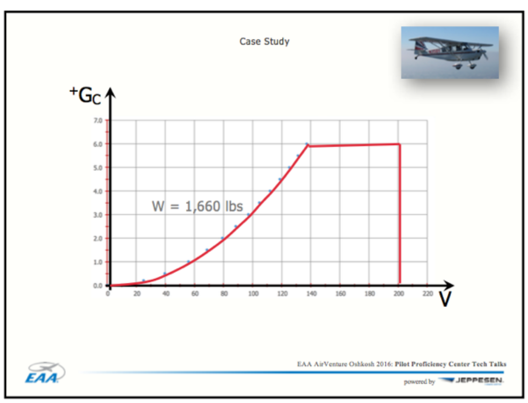

Horizontal Turn
L/W
LV/W
LH/W
ø
W/W
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Horizontal Turn
GCockpit
1G
GRadial
ø
1G
EAA
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Vertical Turn
3G
GC = GR
1G
EAA
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Airspeed vs. G-Load
+GC
Gne
αcrit
Cat | Gne | Va
N | 3.8 | 1.9Vs
U | 4.4 | 2.1Vs
A | 6.0 | 2.4Vs
0.7 1.0 1.4
Va
Vne
V
Stall Speed Factor, mVs
EAA
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Case Study
αcrit = 14°
Gne = +6.0
Vne = 200 mph
N358Y
EAA
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
powered by JEPPESEN


Case Study
+GC
W = 1,660 lbs
V
EAA
EAA AirVenture Oshkosh 2016: Pilot Proficiency Center Tech Talks
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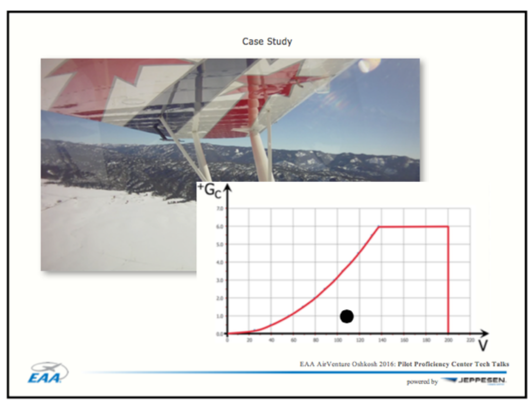
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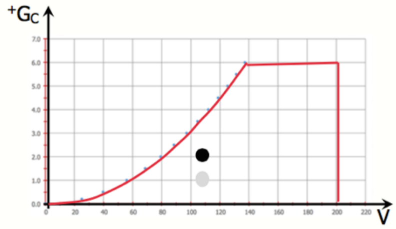
Case Study



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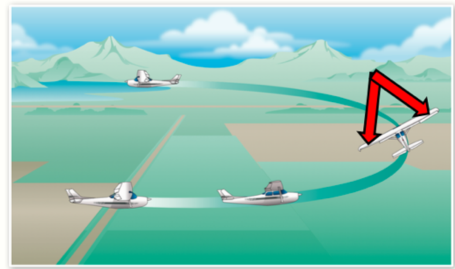

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Training Exercises

1. Coordination Exercise
2. Normal Turn
3. Acro-Style Turn

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Join Us

Learn to Turn Initiative

CommunityAviation.com/RichStowell

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APPENDIX 2

A "Learn to Turn" lesson plan was provided for the Redbird MCX simulator at the 2016 EAA Pilot Proficiency Center. To ensure the motion simulator more accurately modeled the behavior of a real airplane, the authors worked with Redbird CEO Todd Willinger on-site to adjust the simulator software. Consequently, the MCX was able to deliver a worthwhile LTT experience for participants. The instructor lesson plan follows:

EAA PILOT PROFICIENCY CENTER

AIRCRAFT CONTROL #1 – "LEARN TO TURN" LESSON PLAN

OBJECTIVE: Instill in the Pilot-in-Training (P-I-T) that the elevator is the turn control.

INSTRUCTOR NOTES:

- This is part of a safety initiative described in the white paper, "LEARN TO TURN – Reducing Loss of Control through an Improved Training Methodology" submitted as part of the 2015–2016 EAA Founder's Innovation Prize competition.
- If any question exists about the veracity of "elevator as the turn control," please refer to the white paper. **If any doubt about elevator-as-turn-control remains after reading the paper, you are not authorized to instruct in this exercise.**
- Please be consistent and specific about what the primary controls do:
  - Ailerons roll/bank the airplane (and that's all they do).
  - Rudder is used mostly to cancel yaw; otherwise, the result is a skid/spin or a slip.
  - Elevator controls AOA, which manifests as changes in some or all of the following: airspeed, G-load, attitude, flight path.
- Note there are only two flight paths an airplane can follow: either a straight line or a curved path. At the correlation level of learning, it does not matter where or how these lines and curves are oriented in space—they can be in the horizontal, the vertical, or anywhere in between.
  - Regardless of bank angle (within energy and AOA constraints), what the P-I-T does with the elevator largely determines whether the airplane follows a straight line or a curved flight path.

TRAINING ELEMENTS:

- Introduction
  - Demonstrate the controllability/maneuverability of the ATD.
- Coordination Exercise
  - Demonstrate banking without turning
  - Rock the wings smoothly and continuously left and right, remaining on heading
  - Apply coordinated aileron and rudder inputs
    - Same time and same side (left aileron and left rudder, right and right, etc.)
    - More aileron than rudder
    - Visual references (ignore the slip/skid ball)
    - Symmetry, e.g., 30–45 degrees of bank left and right

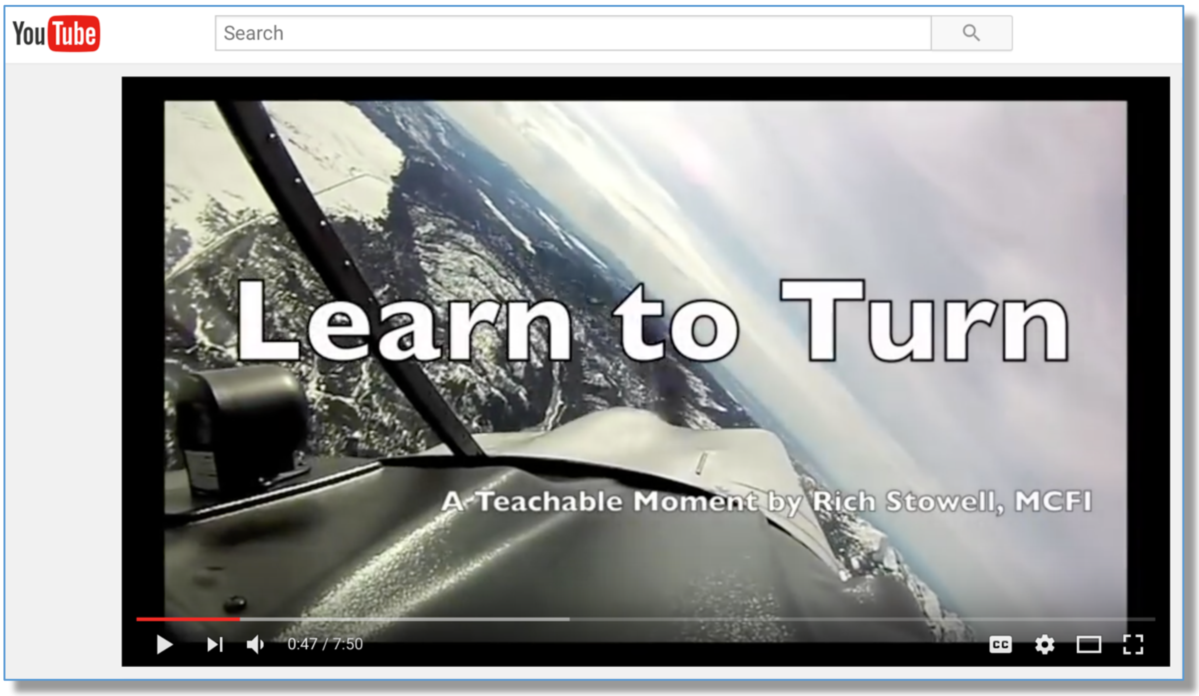
- <u>Normal Coordinated Turn</u>
    - Demonstrate the effect elevator has on flight path
    - Establish a level, coordinated turn (i.e., horizontal turn)
        - Note the amount of aft elevator needed for the nose of the airplane to track parallel to the horizon at the given angle of bank
        - Then apply more aft elevator than necessary
            - Note the initiation of a climbing turn (i.e., oblique turn)
            - Adjust elevator to reacquire the level turn again
        - Then release some aft elevator, allowing the nose to drop
            - Note the initiation of a descending turn (i.e., oblique turn)
            - Reapply enough aft elevator to reacquire the level turn again
- <u>Acro-Style Turn</u>
    - Demonstrate an alternative method for practicing level turns
        - Separate the roll inputs (aileron & rudder) from the turn input (elevator)
        - Develop precision and discipline with the control movements
    - Use visual references only
        - Ignore the slip/skid ball, as well as the DG/compass
    - Sequence of inputs: **Roll → Stop → Turn → Stop → Roll**
        - Roll – coordinate aileron and rudder inputs to establish the bank
        - Stop – neutralize aileron and rudder at the desired angle of bank
        - Turn – pull sufficient aft elevator so the nose tracks along the horizon
        - Stop – release aft elevator to stop the turn on a point on the horizon
        - Roll – coordinate aileron and rudder inputs to level the wings
    - Important Points
        - "Roll" and "Turn" actions are applied IN SEQUENCE, not simultaneously
        - Each "Stop" represents a positive movement of the control(s) to neutral before commencing the next input(s) in the sequence

<u>COMMON ERRORS</u>:

- <u>Coordination Exercise</u>
    - Too little aileron deflection (more is better during this exercise)
    - Too much rudder applied too late (add just enough rudder simultaneously with the aileron input)
    - Failing to reverse rudder with aileron, i.e., lagging with the rudder
- <u>Normal Coordinated Turn</u>
    - Improper coordination
    - Inadvertently returning to wings level while manipulating the elevator
- <u>Acro-Style Turn</u>
    - Blending roll and turn inputs (separate these actions from each other)
    - Failing to neutralize rudder when neutralizing aileron once the bank is established, i.e., dragging the inside rudder/skidding the turn (move the rudder simultaneously with the aileron – same time, same side)
    - At the end of the turn, forgetting to release aft elevator before rolling to wings level

APPENDIX 3

The first generation “Learn to Turn” video was uploaded to YouTube in March 2014 and has been viewed more than 5,000 times. The Community Aviation website has a video trailer on its “Learn to Turn” landing page as well.



Watch the Community Aviation trailer: http://www.communityaviation.com/rich-stowell

Watch the full version YouTube video: https://www.youtube.com/watch?v=nWbk3jn0GK4

APPENDIX 4

Several hundred individuals have submitted an online form in support of the “Learn to Turn” concept. Some of those supporters are listed below:

Mark Dukorsky	Founder	SafeFlight Alliance, Inc.
Colt Feimster	CFI	Liberty University
Rob Bremmer	Owner	Bremmer Learning
Michael Wilson	Aerobatic Instructor	Namao Flying Club in Canada
Amy Hoover	Owner	Canyon Flying
Chris Front	Aerospace Medicine	FAA
David St. George	Manager	East Hill Flying Club
Gerry Dick	Chief Instructor	Aerobatics Australia PTY Ltd
Clay Phelps	President	CP Aviation, Inc.
Sean VanHatten	Instructor Pilot	Advanced Flight Dynamics
Russ Still	President	Gold Seal Online Ground School
Jim Foster	Instructor	Red Arrow Flight Academy
Dudley Henriques	Flight Safety Consultant	ICAS
Bill Montagne	CEO	Montagne Aircraft LLC
Jerry Marshall	Founder	Pilot Disorientation Prevention Technologies
Andy Davis	CEO	Trig Avionics Limited
Doug Auclair	President	Air Ventures Flying School LLC
Don Cummins	Owner	Air Data Solutions LLC
Lukasz Gancarz	Executive Director	Warter Aviation in Europe
Ken Mercer	President	Gnoss Field Community Association
Garry Wing	CFI	Fly The Wing Flight Training
John Kolmos	Aviation Safety Officer	Farmingdale State College
Chris Ricci	Chief Instructor	Rockcliffe Flying Club in Canada
Minard Thompson	FAASTeam Manager	FAA Spokane FSDO
Jacob Canty	Assistant Site Manager	UND Aerospace
Ben Sclair	Publisher	General Aviation News
Dale Armstrong	Owner	Aviation Incident Investigations, Inc.
Gene Benson	CEO	Bright Spot, Inc.
Alan Davis	Charter Member	Society of Aviation and Flight Educators
Doug Stewart	President	DSFI, Inc.

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