



Best Practices for Training the Structures Flight Test Engineer

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Some Street Cred...



- **Wendy**

- F-22 Combined Test Force (CTF) Flutter Lead; F-35A Integrated Test Force (ITF) Loads Lead; F-35A ITF Structures Lead (Loads, Flutter, Environments); Structures Technical Expert, 412 Test Wing
- ~600 flights / ~1310 hrs Control room support of mostly high risk envelope expansion flight test

- **Randy**

- F-22 CTF Loads Lead; F-22 CTF Structures Lead (Loads, Flutter, Environments); F-35A ITF Flutter Lead; 412 TW Test System Safety Engineer (Taught USAF TPS Test Safety Course); F-35A ITF Air Vehicle Manager; Chief, Aerostructures Branch, NASA Armstrong Flight Research Center
- ~580 flights / ~1280 hrs Control room support of mostly high risk envelope expansion flight-test

- **Not including ground testing (wet runway, arresting gear system, ground vibration test, loads calibrations, high sink rate landings, braking tests, etc.)**
- **Just demonstrating that we have some experience as structures flight-test engineers and in training structures flight-test engineers**
- **Trained >100 structures flight-test engineers**



Introduction



- **Flight-test equation** (adapted from a well-known quote by David L. Baker)
 - Safe/Effective Flight-test = X% Preparation + Y% Skillful Execution + Z% Luck
 - Preparation & Skillful Execution >> Luck (Luck → Zero)
 - Preparation ≠ Skillful Execution; Preparation > Skillful Execution
- **Comprehensive general training & discipline-specific training plans impact preparation and execution; Foundational for successful (safe/effective) flight-test**
- **“Aviation in itself is not inherently dangerous. But..., it is terribly unforgiving of any carelessness, incapacity or neglect.” (Captain A. G. Lamplugh of the British Aviation Insurance Group, London, circa the early 1930s)**
 - Entering flight-test with inadequately trained engineering staff can be just as “unforgiving” as an inadequately trained pilot; both result in incapacity to perform the task and are careless and neglectful
- **Training need recognized worldwide --> Various military and private Test Pilot Schools**
- **No discipline specific depth --> Specific training needed**
- **Today – Specific to Structures, but any high risk discipline**



Best Practice 1



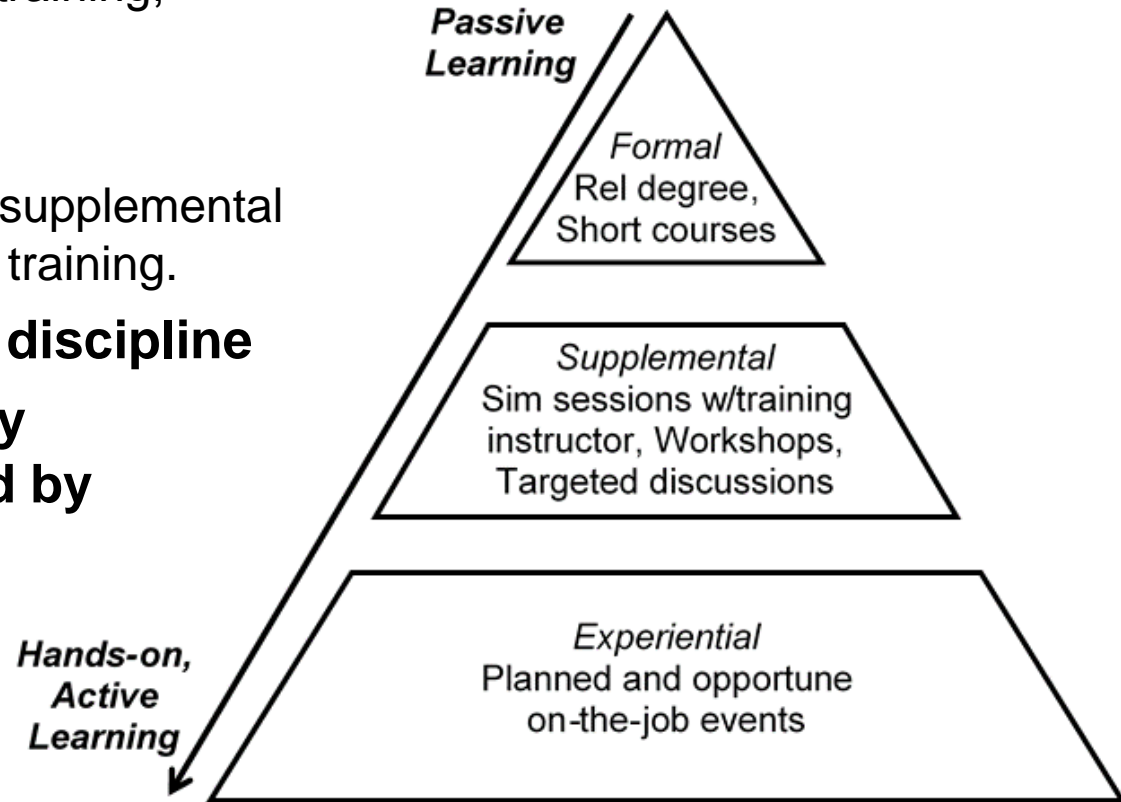
- **Formal training plan**

- Provides organizations and individuals with training framework
- Emphasize demonstrated knowledge and experience, not completed checklist
- Danger in “Check the box” training;
 - Educated ≠ Trained
 - Box checked ≠ Trained
- Basics = formal education, supplemental education, and experiential training.

- **Recognize flight-test as a discipline**

- **Understanding/proficiency demonstrated and verified by senior engineer acting as mentor/trainer**

- **Training tracked in “letter of Xs” or project unique tool**

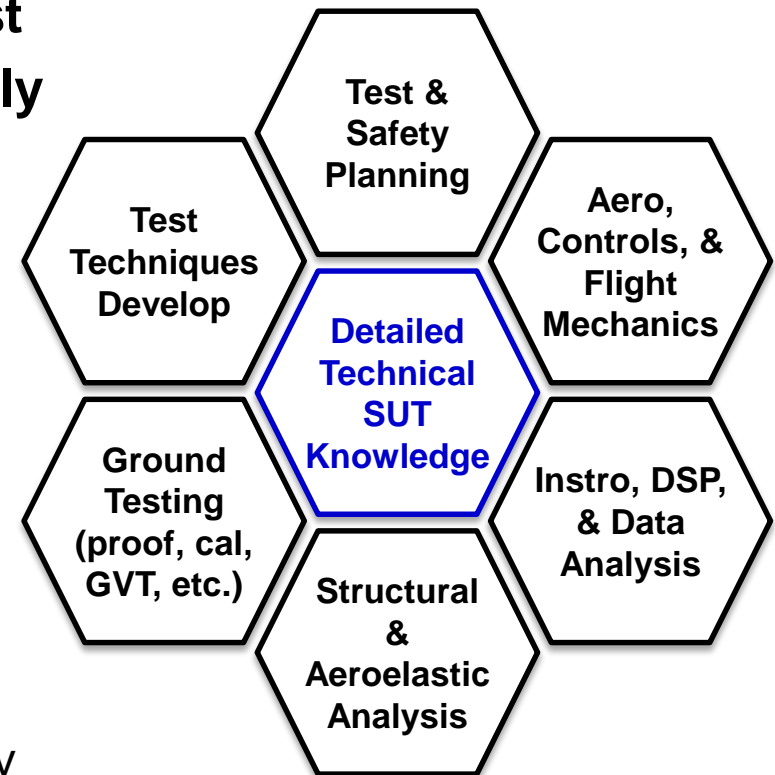


Develop discipline-specific training plan that emphasizes understanding and proficiency. Avoid box-checking training.



Best Practice 2

- **Errant perception... Any engineer can support any discipline-specific flight-test with minimal amount of “differences” training**
 - Views the flight-test engineer as simply a “display watcher” (e.g., making sure the squiggly line stays in the box, the display does not turn red, etc.)
- **Misunderstands level of technical expertise required to safely and effectively conduct high-risk flight-test**
- **Level of knowledge/expertise not easily gained over only 2-3 years**
- **Also enables researching and developing new tools and test techniques AND trains and grows next generation of engineers**
- **Management issue**
 - Character + Competence = Trust
 - Flight-test managers must themselves be technically competent
 - Trust impacts morale which impacts safety



Value technical expertise. Flight-testing as a discipline requires multi-disciplinary, rigorous technical dedication in order to be safe and effective.



Best Practice 3



- **Documenting lessons learned is one of a test organization's most important tasks**
 - Train next generation; Provides next team with good to emulate & bad to avoid
 - An idea that generally has widespread support, but very little practical support
 - As flight-testing progresses – Little time devoted to documenting lessons learned; Majority of the effort spent executing tests, performing analyses, addressing anomalies, writing technical reports, etc.
 - End of flight-testing – Significant personnel turnover; Few resources left for documenting lessons learned; Often after-the-fact and rarely rigorous
- **Plan to succeed**
 - Plan for a lessons-learned database in project formulation
 - Be intentional
 - Mindset – Project personnel continually thinking of documenting the good, the bad, and the ugly for posterity
 - Periodic group discussions; Known project milestones; Expected (and unexpected events); Event-based questionnaire
 - Assign moderator to avoid finger pointing

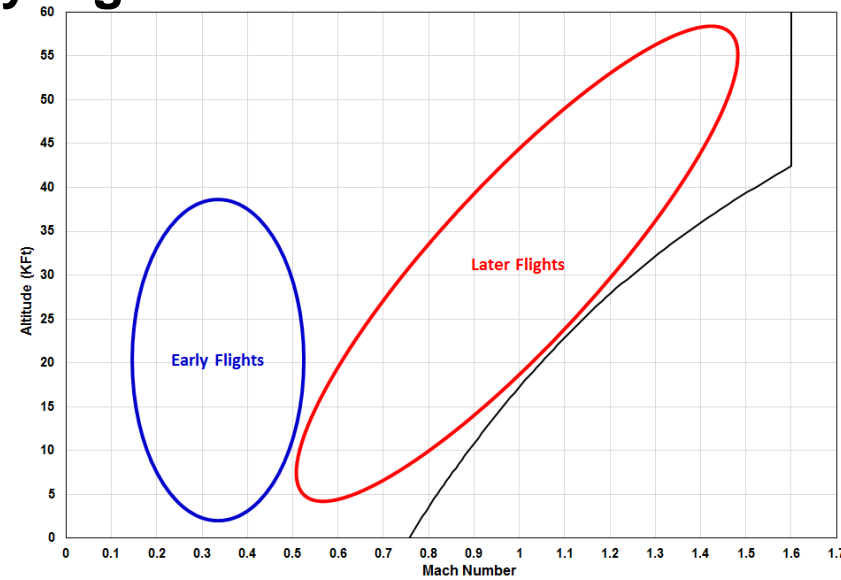
Prioritize documenting lessons learned throughout the project (from formulation to completion).



Best Practice 4



- **Be as prepared for later flights as early flights**
- **Early flight generalizations**
 - Most risky from a system standpoint
 - Most experienced engineers
 - Most rigorous training w/significant emphasis
 - Least risky for structures; Cleared by analysis with sufficient margins; Structural monitoring often not required
- **Later flight generalizations**
 - Most risky for structures – Edge of envelope (M, Alt, Nz, Pb); Less structural margin; More difficult maneuvers
 - Often, less experienced team by this time in the project
 - Generally, most rigorous training w/significant emphasis
- **Training discrepancies (early vs. later)**
 - Quality and quantity
 - Early – Detailed A/C fam; Many full CR sims; First flight readiness reviews
 - Later – PowerPoint A/C fam; 1-3 Mentored flights; Pre-flight mission briefing



Train for later project flights with similar emphasis as early flights since high risk emphasis simply changes from systems to structure later in the project.



Best Practice 5



- **Be open to training opportunities outside your organization**
 - Deficit in knowledge/experience may be fulfilled by partnering with sister orgs
 - Develops close working relationships among related organizations allowing for sharing of personnel, information, and expertise
 - Cross-org training excellent way to gain experience (flight-testing, ground testing, or analysis) through engineer exchange, test observation, Technical Interchange Meetings (TIMs), etc.
- **Examples (412 TW and AFRC)**
 - 412 TW regularly performs high-pace/high-risk envelope expansion testing; AFRC much less frequently; AFRC detailed two engineers to F-35 ITF Structures to aid 412TW, but also to gain experience
 - AFRC regularly performs loads and flutter analysis, loads ground tests, and Ground Vibration Tests (GVTs); 412TW has observed ground testing
 - Hold regular TIMs
- **Challenge – Shortsighted management**
 - Often, most vigorous opposition; Unwilling to release staff for training
 - Deprives organization of invaluable training opportunities that will pay enormous dividends

Look within the broader flight test community for training opportunities that fill a deficit of knowledge or experience within your organization.



Best Practice 6



- **One-size-fits-all training may not provide sufficient depth to address specific issues and needs that arise in any given project**
- **Historically, short courses have been used to fulfill specific gaps in formal education or to provide refresher training**
 - Direct application/practice needed to become part of engineer's tool set
 - If not readily applied, training can be quickly forgotten
- **Tailor training based on project and engineer individual needs**
 - Training designed to fill a specific need and available on demand can provide engineers with specific training opportunities as the need arises
 - Allows engineers to directly apply what they have learned for better retention
- **Utilize intra and inter-organizational training opportunities**
 - Intra – Dedicated training days; Internal SME training, brown bags, train-the-trainer, share-the-learning (if you learn, we all learn), mentoring, etc.
 - Inter – Sister org TIMs, site visits, opportune test/analysis events, etc.
 - On-demand – NASA's NESC Academy, coursera, YouTube, etc.

Look to utilize unique discipline training modalities to meet busy project demands at the appropriate timing for maximum retention.



Best Practice 7



- **Control room monitoring during flight-testing mitigates test hazards**
- **Not all flight-test missions are equal in difficulty, complexity, risk, etc.**
 - E.g., loads, flutter, high AoA, or departure resistance vs. avionics
 - Perhaps control room monitoring experience not relevant
- **Projects should establish special qualification for high risk testing**
 - Designed to familiarize a test team with a specific type of test – specific test procedures, simulator-based training scenarios, and special mentoring
 - Provide relevant control room monitoring experience
 - For smaller-scope projects, extensive simulator training can replace mentoring
- **A proficiency level should be set and tracked**
 - E.g., after initial qualification, X special mission every Y days or requalification required
 - Safety and proficiency are linked
- **Similarly, special mission qualifications and proficiency requirements should be put in place for test pilots**



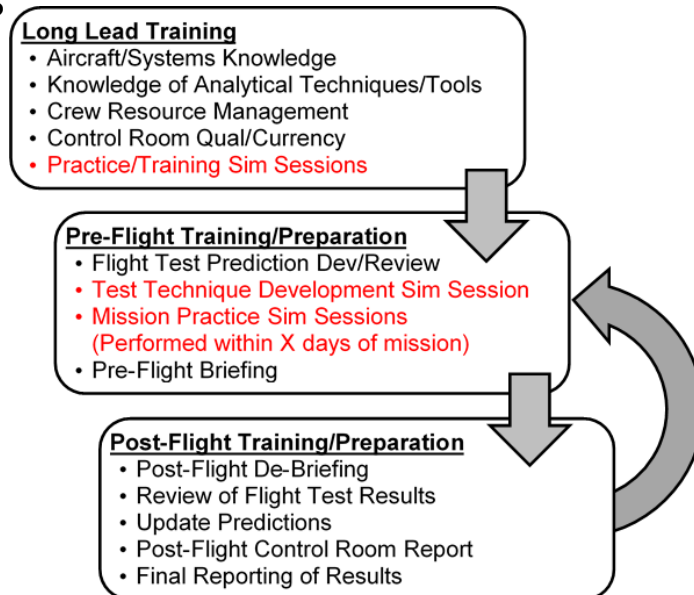
Establish special mission qualifications for high risk testing. Track proficiency of engineers and pilots since safety and proficiency are linked.



Best Practice 8



- **Consistent best practice project-to-project --> flight test support simulator co-located with the flight test team**
- **Structures test maneuvers often difficult to perform and conditions difficult to achieve**
- **Simulators used to...**
 - Develop new flight-test techniques
 - Practice maneuvers, set-ups, and recoveries (safety linked to proficiency)
 - Train new engineers/pilots or re-hack currencies (discipline specific or entire control room team)
- **Effective training/planning device**
 - High-fidelity, pilot-in-the-loop with up-to-date controls, aerodynamics, and propulsion models
 - Realistic aircraft inceptors and displays
 - Identical engineer monitoring displays
 - Incorporating realistic structural responses would represent a significant advancement in providing realistic training scenarios



Utilize high fidelity pilot-in-the-loop simulation to aid in maneuver development, initial training, and proficiency of engineers and pilots.



Summary



- **Goal**
 - Preparation & Skillful Execution >> Luck (Luck → Zero); Preparation > Skillful Execution
- **Presented best practices for training structures flight test engineers**
 1. Develop discipline-specific training plan that emphasizes understanding and proficiency. Avoid box-checking training.
 2. Value technical expertise. Flight-testing as a discipline requires multi-disciplinary, rigorous technical dedication in order to be safe and effective
 3. Prioritize documenting lessons learned throughout the project (from formulation to completion).
 4. Train for later project flights with similar emphasis as early flights since high risk emphasis simply changes from systems to structure later in the project.
 5. Look within the broader flight test community for training opportunities that fill a deficit of knowledge or experience within your organization.
 6. Look to utilize unique discipline training modalities to meet busy project demands at the appropriate timing for maximum retention.
 7. Establish special mission qualifications for high risk testing. Track proficiency of engineers and pilots since safety and proficiency are linked.
 8. Utilize high fidelity pilot-in-the-loop simulation to aid in maneuver development, initial training, and proficiency of engineers and pilots.

“Always take the job seriously, but never take yourself seriously.”
~Bill Dana, the consummate thorough preparer

