Introduction to Subsystems Testing

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"Warriors Committed to Readiness and Quality Support"

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Biography

Mr. Lundberg is a 1986 graduate of San Diego State University and is the Technical Expert for the Subsystems Integration Flight of the Air Force Flight Test Center, 412th Test Wing, 773rd Test Squadron, Edwards AFB, California. He has 27 years experience as a Subsystems Test Engineer at Edwards AFB and 13 years experience as a US Navy depot level Maintenance Engineer at North Island, California, and Atsugi, Japan.

Mr. Lundberg was awarded the Meritorious Civilian Service medal by the US Navy and has provided engineering support for the testing or maintenance of 85 different model/design/series aircraft.

A-4E A-6E A-29A A/V-8B
B-1B B-2A B-21A B-52H/J
C-2A C-5A/B/M C-17A C-32A C-130E/H/J CV-22A
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CH-46E HH-46D CH-53D/E
SH-2F/G SH-3G/H SH-60B/F
UH-1N UH-3H VH-3A

Subsystems Testing Overview

- **Common military and civilian aircraft subsystem disciplines include:**
  - Climatic and All Weather
  - Electrical Power Generation and Distribution
  - Environmental Control
  - Fire Detection
  - Fire Suppression
  - Fuel
  - Hydraulics
  - Landing Gear/Brakes/Anti-skid
  - Oxygen Generation and Distribution

Subsystems Testing Overview

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- **Military unique aircraft subsystem disciplines include:**
  - **Aerial Refueling**
  - **Arresting Gear**
  - **Nitrogen Generation and Distribution**
    - Changing with evolving FAA requirements

Subsystems Testing Overview

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- **Subsystems interface with all aircraft systems**
  - **Need to provide proper information, protection, power, air and fuel to:**
    - Avionics
    - Flight Controls
    - Aircraft Health Management
    - Pilot, Crew and Passengers
    - Propulsion
    - Weapons
- **Subsystems are getting more interdependent**
  - **e.g. a computer controlled ECS that cools avionics, crew and hydraulics while using fuel as a heat dump**
    - What happens when the fuel gets too hot?

Subsystems Testing Overview

- **Subsystems testing is evolving into an avionics based test philosophy**
  - **Subsystems are becoming more automated**
    - The pilot votes; the computers allow, execute and control
      - Integrated Vehicle Subsystem Controller (IVSC)
      - Vehicle Management System (VMS)
      - ECS, Fuel, Hydraulics and Electrical Power System Controllers
  - **The controllers use sensors to detect conditions and issue commands to achieve results**
    - This requires insight into input and output from each component
      - Sensor to data distribution point to controller to effectors to result to feedback

Subsystems Testing Overview

- **Subsystems testing is special**
  - **Every engine start is a test point**
  - **Every taxi out is a readiness for flight check out**
  - **Every flight is in a new aircraft configuration due to part changes and component wear**
  - **We can't prove it will work next flight**
    - Just because it worked today doesn't mean it will work tomorrow
    - Because it worked today may increase the probability it won't work tomorrow
  - **Every weather and flight condition is an opportunity for an unexpected event or deficiency to occur**

Subsystems Testing Overview

- **Subsystems testing is fun**
  - **Not a lot of obscure equations**
  - **Not a lot of coefficients derived from difficult to measure phenomena**
  - **Most measurands are easy to comprehend but may be difficult to measure**
    - Pressure
    - Temperature
    - Flow rate
    - Voltage/Current
  - **Lots of interesting tests with real world application**
    - Does the landing gear retract and extend?
    - Does the aircraft stop safely?
    - Does the aircraft bleed, leak, spark, smoke or smell bad?

Subsystems Testing Overview

- We look at data from before engine start to after engine shutdown
  - Performance on ground electrical, hydraulic and bleed air power
  - System transients and performance as APU and engines are started
  - Taxi out and preparation for takeoff
  - Throughout the flight, whether doing a test point or not
  - Landing and taxi back
  - System transients during shut down
- We expect different performance today than yesterday

Subsystems Testing Overview

- **We usually test to a defined specification**
  - **When the specification is wrong, we try to change it before the test plan is written**
  - **It usually doesn't matter by how much you 'beat' the specification**
    - Actual 115.0 ± 0.1 volts may be just as good as specification required 113.0 to 117.0 volts
- **We Use All Possible Data in Our Evaluation**
  - **Test reports include planned test points and data from all possible ground and flight events**
    - e.g. a dry runway landing gear performance report included data from144 test points and an additional 1,280 braking events

Subsystems Testing Overview

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- Statistical techniques considered for each test effort
  - We love to repeat test points, but…
- Stressor conditions and safety build ups can quickly use up a lot of the planned test points
  - If the number of test points are limited, we usually prefer looking at different stressor conditions rather than repeating test conditions
  - The system may have an unknown stressor, that's why we always watch the data

Subsystems Testing Overview

- **Subsystem engineers protect the aircraft and crew**
  - **Even with no subsystem test points planned, subsystem engineers are usually in the control room or sitting near the phone**
    - Murphy’s Law was developed at Edwards AFB and is rigorously complied with
- **Should see problems developing, quickly separate the truth from the noise, and advise the test team and pilot before an adverse event occurs**

Subsystems Testing Overview

- When the Master Caution Light illuminates all eyes usually turn to the subsystem engineer
  - What happened?
  - What will happen next?
  - What should we do?
- After landing they ask
  - Can we fly tomorrow?

Subsystems Testing Overview

- A perfect test is usually not possible
  - There are too many unknowns, potential weaknesses, and complex inter-relationships between subcomponents to allow for all conditions, or even perhaps the most critical condition, to be known or tested
- We know something bad will happen to someone, someplace; regardless of what we do
  - Service use will differ from that expected
  - System response due to wear and failures can't be fully anticipated

Subsystems Testing Overview

- **We don't want an unsuspecting fleet pilot become an unknowing test pilot**
  - **We want to test every new component**

Subsystems Testing Overview

- The following AFTC Handbooks are on the https://login.dtic.mil/ website
  - Aircraft Arresting Gear Testing
  - Aircraft Brake System Testing Handbook
  - Aircraft Brake System Testing Handbook Addendum
  - All-Weather Testing
  - Electrical Subsystems Flight Test Handbook
  - Engine Inlet/Nose Tire Water Ingestion
  - Environmental Control Subsystem
  - Flight Testing Under Extreme Climatic Conditions
  - Fuel Subsystems Flight Test Handbook
  - Landing Gear Subsystem Testing
  - Hydraulic Subsystem Flight Test Handbook
  - Natural and Artificial Icing/Rain Testing

Subsystems Testing Overview

- AGARD-AG-300 Volume 14, Introduction to Flight Test Engineering
  - Sections 1 and 2 provide insight into the question of why flight test and give a short history of flight test engineering
  - Sections 3 through 10 deal with flight test preparation
  - Sections 11 through 27 describe the various types of flight tests that are usually conducted during the development and certification of a new or modified aircraft
- Accuracy or relevance of the information has not been verified by the AFTC
  - That should keep me out of trouble

Subsystems Test Phases

- Design Phase
  - Must understand and can influence the system design
- Qualification Tests
  - Can it endure the specified environment
- Ground Tests
  - Is it ready for flight
- Flight Tests
  - Test the strengths and weaknesses of the system
- Climatic Lab Tests
  - Is it deployable
- All Weather Tests
  - Can it execute the mission under real world conditions
- Follow On Tests
  - Use flight test corporate knowledge to improve test conduct

Design Phase

- **Modern test teams are integrated into the development process**
  - **Our first chance to see the design and provide comment**
    - We may have experience with previous successful concepts
- **If possible, participate in Preliminary and Critical Design Reviews**
    - Need to protect proprietary information

Design Phase

- Time to start test process by:
  - Influencing final design for usability and operability
  - Learning system requirements, strengths and weaknesses
  - Establishing contacts and building a team mentality
  - Developing the overall test concept

Qualification Tests Caveats

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- **Qualification tests are good build ups, but are not a replacement for flight test**
  - **The flight environment is different from the lab environment**
    - The test spectrum will not match the flight spectrum
  - **The pre-flight lab test components may differ from the production components**
  - **The installation and maintenance of lab and flight line equipment is different**
- **Every smoking hole is filled with equipment that passed every qualification test**

Qualification Tests

- Component level qualification tests
  - Shake and bake, freeze, thaw, heat, salt bath, chemical, and almost everything else you can imagine
- Software Integration
  - Avionics lab and cockpit simulator
- Computer-based system modeling and simulations
  - Be aware of fidelity and configuration control

Qualification Tests

- **The Iron Bird**
  - **Optimally a full-scale replica of all subsystems**
    - With a good representation of line, hose, duct and major component layout
    - May not have a full up fuel system; no skin to define tanks
  - **Can be used to determine and verify flow, pressure, thermal and electrical characteristics**
    - Should correlate with computer models
  - **Generally integrated with avionics and flight control system**
    - Can control flight surfaces and other components
    - May be used to troubleshoot flight test anomalies

Qualification Tests

- **Electrical System Simulator**
  - **Full up reproduction of electrical system**
    - Generators, Power Control Units, buses, electronic breakers, wiring, and most boxes
    - Normal and failure modes should be fully evaluated
  - **A lot of 'real' testing goes on here**
    - Flight test may be a graduation exercise for many functions
    - Difficult to plan and execute failure mode flight tests
      - Not a popular test regime, may disable some redundancy

Ground Tests

Ground Test Overview

- **Demonstrate the aircraft is ready for flight**
  - **Not all system functions can be tested**
  - **Many tests do not use a control room**
    - May use workstations, laptops or eyeballs
- **Participate in as many tests as possible**
  - **Rehearsal for taxi and flight**
  - **Verify instrumentation and data reduction process**
  - **Control room checkout**
    - Learn how to use equipment and modify displays
    - Learn other disciplines screens

Typical Ground Tests

- **Subsystem performance on ground, APU and engine power**
  - **Electrical**
    - Power transfers
    - Avionics operations
    - EMI/EMC
  - **ECS**
    - Heat and cooling under all power modes
  - **Fire Detection and suppression**
    - Detector loop checks
    - Use HFC-125 instead of Halon 1301 for agent release
  - **Fuel**
    - Fuel quantity calculations and transfer
  - **Hydraulics**
    - Flight control and weapon door actuation

Taxi Tests

Taxi Test Overview

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- Last step before flight
  - Rehearsal for first flight
- Typical brake test technique is full brake pedal application with 1 second ramp rate
  - On dry, wet and icy runways
  - Try that on the ride home
- Axle grease and hydraulic fluid fire possible or probable
  - Person at greatest risk is usually ground crew and fire department

Taxi Test Overview

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- Fuse plug release (flat tires) likely
  - Will shutdown the runway
- Dry runway before wet runway
  - Dry is no water on runway
- Wet runway before icy runway
  - Wet runway may follow first flight by months or years
  - Wet should be defined
    - Wet taxi test cannot be done on a grooved surface
      - Friction is too high to be relevant to un-grooved operations
  - Icy runway during all weather testing
    - Deicing trucks with spray nozzles and water make good ice

Taxi Test Overview

- For the AFFTC wet is ≤ RCR 17
  - RCR Runway Condition Report is Mu measured by a Mu-Meter times 32.2
  - Mu measured by other friction measuring systems is not the same
  - Mu measured by a friction measuring system is not the same Mu experienced by the aircraft
- Wet surface must result in an anti-skid response but not so wet that the tire hydroplanes

Taxi Test Overview

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- **May test on more than one surface**
  - **Conventional runway – concrete, asphalt, battle damage repaired**
  - **Semi-prepared, unpaved runways**
    - Lakebed, gravel, dirt, mud, grass, ice, snow, matted runway
- **Good rules of thumb for deceleration performance**
  - **10 to 12 ft/sec^2 on a dry runway**
  - **6 ft/sec^2 on a wet runway**

Flight Test

Flight Test Overview

- **Subsystem test points are often "piggyback" or "ride along" with other disciplines**
  - **For example, performance and flying qualities high alpha test points are great for ECS, fuel and hydraulics testing**
  - **Let some other discipline pay for the test point**
  - **Make sure you keep track of changes in the parent test plan**
- **Make sure you're ready for back up test points**
  - **Back up test cards may be briefed for weeks**
    - Make sure all is ready to test
      - Aircraft stores, configuration, instrumentation and you

Flight Test Overview

- Most flight test points are classical stressor conditions for the system under test
  - New stressors appear with every new design
  - Weak points are fair game
- The AFFTC Handbooks provide a very good overview of standard test concepts and methodology
  - If you had read those, you wouldn't be here
  - There will be a test tomorrow

Flight Test Overview

- **All data on all flights can be used to evaluate performance**
  - **Failures usually have indicators before the event**
  - **The indicators may be difficult to see**
  - **Hindsight is 20/20**
- **Failures and emergencies are fair game for data**
  - **It is unethical and time consuming to cause them, so watch your screen**
  - **Think one to two failures ahead**
  - **Call "data on" when things go wrong**
    - Wait until the situation has stabilized

Follow On Tests

Follow On Tests Overview

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- **Testing of new or improved components**
  - **Avionics, subsystems, materials and technology are always improving**
    - What you have is obsolete
    - Reliability and manufacturing updates are common
    - May be a new pump, controller, control box, sensor, etc.
    - Need to demonstrate no adverse or unexpected system response)
- **Aircraft weight always increase**
  - **New brake tests are common**
  - **New arresting gear tests are less common**
    - Unless loads or dynamics force a redesign, or a new arresting system is fielded

Follow On Tests Overview

- The postproduction maintenance check may not be adequate
  - "Push a button, look for a light" just proves the bulb is not burned out
- Be wary of not testing if there is any impact to safe flight operations
- Hard to justify not taxi testing all brake related changes

Follow On Tests Overview

- Lots of regression testing with new or modified equipment
- Remember that the new component may not go through the same test regimes as the old component
  - High Alpha
  - Stressor Conditions
  - Climatic Lab
  - All Weather

Follow On Tests Overview

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- **Previous test plans and technical reports are an excellent source of data**
  - **May be difficult to repeat a previous test point and provide direct comparison data**
- **Assume the old deficiencies are not fully corrected and new anomalies will occur**
- **Be aware of unintended consequences**
  - **There is just so much power and cooling air available**
    - Changing flow in one branch can change flow in others

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