Flight Test Risk Reduction and Lessons Learned from the “Scorpion” Aircraft Development Program

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Overview

- What is the Scorpion Program?

- Aircraft Description

- Risk Reduction/Lessons Learned from 3 Scenarios:
  - Preparation for First Flight
    - Spin Chute Taxi Test
  - Initial Landing Gear Operations

- Conclusion
  - Condense our experiences into one unified safety approach or theme
The Scorpion Program

- **$20M**  
  - Vast Majority of ISR/Strike

- **$$$$$ 5th Gen**
- **$$ 4th Gen**

Scorpion is designed to fill a gap in the tactical aircraft spectrum
Aircraft Description

**DIMENSIONS**
- Wingspan: 47.3 Feet
- Length: 43.5 Feet

**AIRFRAME**
- Composite Structure and Skin

**PAYLOAD BAY**
- Sensors and Comms

**SENSOR**
- EO/IR Ball, Laser Designator

**RADAR**
- Weather, Growth Space

**EXTERNAL STORES**
- Scalable, Precision Munitions

**ELECTRONIC SYSTEMS**
- Modular Architecture

**ENGINES**
- 2 x Turbofans

**STANDARD EMPTY WEIGHT**
- 11,800 lbs

**MAX TAKEOFF WEIGHT**
- 21,250 lbs

**MAX INTERNAL FUEL LOAD**
- 6,000 lbs

**MAX INTERNAL PAYLOAD**
- 3,000 lbs

**MAX EXTERNAL STORES**
- 6,100 lbs

**THRUST**
- >8,000 lbs

**MAXIMUM SPEED**
- 450 KTAS

**SERVICE CEILING**
- 45,000 ft

**FERRY RANGE**
- 2,400 NM

* Design Targets
## Aircraft Description

### Communications
- SAT, Network, UHF, VHF, HF
- Hotspot, Air-Ground, Air-Air, Air-First Responders

### Sensors
- EO/IR Ball
- Passive

### Fuel
- 3,000 lbs
- Auxiliary
Aircraft Description

- **Aircraft Design**
  - Maximum Use of Existing Systems
    - Engines
    - Avionics
    - Ejection Seats
    - Sub-Systems: Hydraulics, Electrical, Fuel, OBOGS, ECS, Flight Controls
  - New Composite Airframe
    - New Main Landing Gear Struts
    - Engine Inlet

Airframe structure, and the main landing gear struts, are the only completely original parts
Aircraft Description

- MLG Axle
- Piston
- MLG Trunnion
- Metering Pin
- Stand Pipe
- Upper Drag Brace
- Lower Drag Brace
- Torque Links
Risk Reduction/Lessons Learned

- Preparation for First Flight – At a “Macro” Level
  - “Where Do You Even Start?”
  - Cessna Engineering Flight Test Processes and Procedures
    - Quality/Configuration Control
    - Test Planning
    - Independent Safety Reviews
    - Flight Readiness Reviews
    - Special Inspection (Pre-First Flight)
  - SETP Pilots Handbook

Resources, processes, and procedures existed to guide macro-level planning
Risk Reduction/Lessons Learned

- Preparation for First Flight – At a “Micro” Level
  - Aircrew involved in design process for over 1½ years before first flight
  - Where are the “booby traps” due to unique configurations/interactions?
  - The 4 Forces of Flight (what’s really important?):

Flight Test had the time to identify and mitigate potential aircraft-unique “booby traps”
Event 1 - Preparation for First Flight

- First Engine Run – September 2013
Event 1 - Preparation for First Flight

- Inlet: Aerodynamics and Airframe Location (behind Gear Doors)
Event 1 - Preparation for First Flight

- Engine Inlet
  - Natural Flow Visualization of Vortices
Event 1 - Preparation for First Flight

- **Inlet Risk Reduction**
  - “What Can You Do to Reduce Risk?”
  - Pre-Flight Taxi: Test “Worst-Case” Gear Door Configuration
Event 1 - Preparation for First Flight

- Landing Gear Availability
  - “What Can You Do to Reduce Risk?”

“The first flight plan should never be more ambitious than the ground test program that supported it…”

SETP Handbook
Event 1 - Preparation for First Flight

“The primary purpose of a First Flight is to make a successful landing...”

SETP Handbook
Event 1 - Preparation for First Flight

- December 12, 2013

“One flight test condition is worth a thousand expert opinions...”

Wernher von Braun
Event 1 - Preparation for First Flight

- Acknowledging the Team’s Efforts

“Share the pilot’s exhilaration of a First Flight with the ground team. It is probably the only good thing that has happened to them in the last 6 months…” — SETP Handbook
Event 2 - Spin Chute Taxi Test

- Pre-Flight Taxi Testing
  - Brakes/Steering
  - Low/Moderate Speed Taxi Testing
  - Elevator Control Power Evaluation (Aerodynamics: Rotation and Flare)
  - Spin Chute Operational Test (Deploy/Jettison)
  - Last-Minute Aircraft Squawk
  - “Were We Ready?”
Event 2 - Spin Chute Taxi Test

- Spin Chute Controls
  - Two Chutes, Fwd and Aft Panels
  - Fwd: “Drive”, Aft: “Execute Test”
Event 2 - Spin Chute Taxi Test

- Crew Resource Management in Action
Event 2 - Spin Chute Taxi Test

- Was my “experience” working against me?
Event 2 - Spin Chute Taxi Test

What I expected:

- “Deploy Confirmed” –or-
  “No Chute, No Chute”

- Mortar Fire Noise

- Kinesthetic (Seat of Pants)

- Visual

- Control Panel
Event 2 - Spin Chute Taxi Test

What I expected:

- “Deploy Confirmed” –or–
  “No Chute, No Chute”

- Mortar Fire Noise

- Kinesthetic (Seat of Pants)

- Visual

- Control Panel

What happened:

- Nothing (Com blocked)

- Nothing (Com blocked)

- Nothing

- Nothing

- No Change

My Conclusion: Failed Chute Deployment
## Event 2 - Spin Chute Taxi Test

<table>
<thead>
<tr>
<th>What I expected:</th>
<th>What happened (Pilot):</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Deploy Confirmed” –or- “No Chute, No Chute”</td>
<td>Nothing (Com blocked)</td>
</tr>
<tr>
<td>Mortar Fire Noise</td>
<td>Heard Mortar Fire</td>
</tr>
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**Pilot Conclusion: Jettison Chute**
Event 2 - Spin Chute Taxi Test

- Inadequate/misleading feedback led to delayed chute jettison
  - Aircrew CRM saved the day
  - Fortunately, the only consequence was a few extra thousand feet of FOD walk for ground crew...
Event 3 - Initial Landing Gear Operations

- Initial Gear Ops – Gear Up Attempt
Event 3 - Initial Landing Gear Operations

- Under airloads, NLG doors overlapped
  - MLG retract sequence did not complete
    - Notice where MLG doors are...
Event 3 - Initial Landing Gear Operations

- Initial Gear Ops – Gear Down Attempt (the one that counts...)

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6/16/2015 9:47 AM  Company Confidential and Competition Sensitive
Event 3 - Initial Landing Gear Operations

- Gear Down
  - “What Would You Report?”
Event 3 - Initial Landing Gear Operations

- Gear Down – Cockpit Indications
Event 3 - Initial Landing Gear Operations

- Chase reported “apparent down and locked”
  - No MLG “greens” due to incomplete sequence?
- We did NOT declare an in-flight emergency
  - We were doing gear testing, after all
  - Experimental License dictates initial takeoffs/landings from home field
- Emergency Gear Extension?
  - Booby Trap: Continuous 3000 psi hydraulics vs. one-shot pneumatics

- Airloads on MLG Drag Brace higher than anticipated
  - Did not quite reach over-center
  - Gear locked over-center during landing rollout
Event 3 - Initial Landing Gear Operations

- Gear Down – After Landing
Event 3 - Initial Landing Gear Operations

- $\sum$ MLG Forces
Event 3 - Initial Landing Gear Operations

- Troubleshooting and Changes
  - For Gear Up: Adjust NLG Doors
  - For Gear Down: Alleviate MLG Drag Loads
    - Positive G and engine RPM (to assist “mechanical advantage”)
    - Adjust airspeed (to reduce airload on MLG drag brace)
    - Sideslip (to change airload direction from aft gear doors; “air dam” effect)
    - Pulse braking on rollout to ensure load assists over-center locking
  - Additional Instrumentation

- Next Attempt
  - NLG closed but mains still didn’t completely lock over-center
  - This time we DID declare an emergency with McConnell Tower...
Event 3 - Initial Landing Gear Operations

- Declaring an Emergency...
  - We were “called to the principal’s office...”
Event 3 - Initial Landing Gear Operations

- Declaring an Emergency...
  - We were “called to the principal’s office…”

“When you come to a fork in the road, take it…” Yogi Berra

We did, but were “wrong” boy!
Event 3 - Initial Landing Gear Operations

- More Troubleshooting and Changes
  - Engineering “Tiger Team”
  - More NLG Door adjustments, and new actuator
  - Aerodynamic Fairing to reduce MLG Drag Loads
  - New MLG actuator

- Final Success
  - Aircraft-unique changes worked
  - Procedural Lessons Learned
  - Follow-on improvements made
Event 3 - Initial Landing Gear Operations

- Drag Brace Aerodynamic Fairing
Event 3 - Initial Landing Gear Operations

- Final Gear Ops – Gear Up (watch for “special” signal...)
Event 3 - Initial Landing Gear Operations

- Final Gear Ops – Gear Down
Event 3 - Initial Landing Gear Operations

- Final Drag Brace Downlock Spring
Conclusion

- “The (Flight Test Safety) Theory of Everything”

  There isn’t one (yet...)

- MACRO: Proven Processes and Procedures
  - Use of Cessna’s Established Methods
  - SETP Guidance
  - Practice Good CRM
  - Ground Test before Flight Test

- MICRO: Integration with Design; aircraft-unique “Booby Traps”
  - Inlet Risk Reduction
  - Elevator Control Power Evaluation
  - Initial Landing Gear Operations
Questions?

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