Broken Wing LLC

Innovation IS as Innovation DOES
Innovation is the creation of better or more effective products, processes, services, technologies or ideas that are accepted by markets, governments, and society.

Innovation differs from invention in that innovation refers to the use of a new idea or method, whereas invention refers more directly to the creation of the idea or method itself.

- Innovation requires practical application;
- Innovation is as Innovation does
Introduction/Background

- **Sponsor** -
  - Discovery Channel / UKCh4 / German Pro Seiben

- **Team** -
  - Current / former Point Mugu T&E folks + a few friends

- **Purpose** -
  - Conduct a live crash safety demonstration similar to proven automotive (AHSI) and DoD live-fire models
  - Execute a realistic, relatable, scenario-based demonstration of an excessive rate of descent impact (windshear or power-related)
  - Provide a test bed for onboard scientific experiments
  - Provide proof of concept for a cost-effective and mission-effective method of test
  - Provide a proof of concept demonstration supporting follow-on events
Selected Flight Profile and Method of Test -

- Relevant descent profile leading to controlled impact of large (passenger-size) aircraft
- Crash aircraft to be manned for takeoff/rehearsal/transit
- OPV / UA ops via remote control from chase aircraft in close visual formation
- Flight crew abandon aircraft by parachute only after all safety protocols have been met (“Green Range”)
- Crash aircraft unmanned only during final terminal phase
Leverage Team Experience with OPV and NOLO control of Full Scale Aerial Targets (QF-4 Phantom II)

Leverage Team Experience with F-16/QF-4 chase control override of Tomahawk missile (TLAM) tests

“Aphrodite”: WWII technique using parachute egress to reduce exposure to risk by avoiding transitions and allowing airborne checkout prior to “go” decision

Build-up and rehearsal via OPV operations prove systems, earn confidence of regulatory agencies, and reduce operational risk
QF-4 Full Scale Aerial Target / OPV / NOLO
Principle: design, develop, install and test a new systems only when absolutely necessary
- Utilize existing and proven remote control systems
- Exploit installed and fully-certified B-727 systems

Principle: provide simple, reliable and effective redundancy
- Primary and secondary remote transmitters
- Redundant primary flight control actuators
- Independent “last ditch” transmitter and actuators
- Use of ship’s power and battery backup
Operational Risk Management – Apply the Basics

- Basic organizational principles incorporated into contract / SOW
- Clear and unambiguous lines of Authority / Accountability / Responsibility
- Unified Chain of Command: no solo actors; all hand-picked, proven, known, and experienced operators
- Standard flight test practices enforced on ground & in-flight
  - Formal Test Plan and aggressive application of ORM
  - Development of Operational Procedures
  - Phased Approach and Independent Review
  - Parachute jumps at design points tested as part of buildup
  - Disciplined process of buildup, rehearsal, review, execution
Our Movie Star
Technical Approach/Philosophy (cont)

- **B727-212:**
  - N293AS, “a.k.a” XB-MNP, “a.k.a” “Big Flo”
  - Impressive material condition
  - Until recently in passenger service
  - Interior upgraded with “wide body” mod
  - Mechanical flight control system
  - Rear ramp providing added mission safety for controlled parachute egress
Beechcraft A-23: “Muskateer”
Role: Range Safety, Comm relay

Cessna 337: “Skymaster”
Role: Secondary Chase, Range Safety, Emergency Transport

SIAI Marchetti SF.260
Role: Primary Chase
Technical Approach/Philosophy (cont)
Primary Control Station
- Futaba 8FG, 8-channel digital proportional RC radio
- Commercial off-the-shelf (COTS) system using frequency hopping spread spectrum technology

Secondary Control Station
- Futaba 8U, 8-channel digital proportional RC radio
- COTS system using frequency hopping spread spectrum technology

Flight Termination Station
- Futaba 8U, 8-channel digital proportional RC radio
- COTS system using Pulse Coded Modulation (PCM)
Remote Control Mechanism

1. 12 VDC Electromagnetic clutch
2. 12 VDC Control Actuator
3. Control/feedback mechanism
4. Control relay box
5. 5 VDC RC servo
6. Engage arm
7. Control arm
Technical Approach/Philosophy (cont)
Science -
- European Crash Investigators
- Massachusetts Institute of Technology Crash Sciences: Lead Investigator
- Developmental Digital Flight Data Recorder
- Crash test dummies
  - Mass models
  - Anatomical /Instrumented
- Overhead bin load integrity tests
- High speed cameras
- Accelerometers throughout the cabin and in the cargo compartment
Location
Technical Approach/Philosophy (cont)
Procedural Details – the Plan

- Weather / Range Recce takeoff 1 hour prior, transit, confirm Green Range, winds acceptable for jumpers
- Test Conductor takeoff 30 mins prior, establish comm relay
- Captain (CA), First Officer (FO), Second Officer (SO), Jumpmaster (JM) and Tandem Jumpmasters (TJM), board 727 with parachute harnesses on
- Primary chase takeoff just prior to B727 for airborne pickup
- Takeoff and transit with chase
- Complete dry run to wave-off and re-establish downwind
- FO, SO and Tandem Jumpmasters egress on downwind leg, in level flight at 6000 ft AGL, ~ 130 KIAS
Technical Approach/Philosophy (cont)
Technical Approach/Philosophy (cont)

- **Procedural Details – the Plan (cont)**
  - Autopilot engaged in altitude and heading hold on downwind leg
  - Remote transmitter engaged with #2 thrust lever approximately mid-range, airspeed controlled manually with #1 and #3 thrust levers
  - On final autopilot switched to airspeed hold and auxiliary (GPS) navigation allowing capture of final run-in line
  - CA establishes glideslope with #1 and #3 thrust levers
  - Chase begins modulating #2 thrust lever to maintain glideslope
  - CA and JM egress at approximately 2000 ft AGL
  - Chase maintains glideslope until approximately 600 ft then retards #2 throttle to idle to establish excessive rate of descent at impact
Distance vs. Altitude Quick Reference

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Results

- 16-17 August 2011 -
  - 5.0 hours ground tests

- 25 March 2012 -
  - 1.3 hours initial flight test

- 24-27 April 2012 -
  - 5.8 hours flight test and dress rehearsal concluding in successful crash event
Well, of course it wasn't going to be that easy!

- Helicopter camera ship delayed a day in arriving
- Day prior to first test / dress rehearsal day:
  - Test team notified of the presence of 4 remotely controlled surveillance helicopter drones in impact area. Required an airborne EMC SOFT and a day delay.
  - Throttle servo burned out. Replacement required disassembly of throttle actuator.
- Winds out of limits for jumpers on following day
- Backup day built into ORM plan and contract / SOW
Still not that easy – on the actual filming day:

- Primary chase aircraft (Marchetti) declares no start.
- Test Conductor in C337 hears transmission, turns back towards Mexicali
- Primary chase declares itself hard down for fuel pump
- Test Conductor passes TC responsibilities to BW3, airborne
- Test Conductor lands Mexicali, swaps aircraft with primary remote control crew.
- Primary remote control crew experienced and comfortable with C337 having conducted airborne tests in that aircraft earlier

Mission continues in backup mode; 30 minute delay
Results (cont)
Goods

- Safe execution, no injuries, no collateral damage
  - Best outcome possible only with a well chosen, fully empowered team
- Technical Approach/Philosophy validated
  - Utilization of existing technology to the maximum extent possible
  - Incorporation of simple but effective redundancy
  - Minimize required NOLO phase, simplify design requirements
- Location, location, location
  - Government of Mexico DGAC professional, cooperative and engaged
  - Natural mountain “backstop” provided enhanced safety
Sure, “innovation is as innovation does, but…

- If you don’t get to do it, you can’t prove it can be done.
- Stick to your guns. What you’ve been taught actually works.
- Persistence is the first cousin of innovation.
- In a clash of cultures, the folks with more money normally call the shots…
- …but a good SOW is worth it’s weight in gold; especially when someone comes in at the last moment with a bright idea
Follow-on Projects

- Some near-term, doable ideas using the proven set up
  - “Lessons Applied” - from first event; landing gear, seats, etc.
  - “Project Intercept” - demonstrate non-cooperative, non-lethal intercept and control capability
  - “Fire Suppression” - conduct comparative fire suppression system effectiveness testing (wing foam, de-misting, inerting, and others) for large aircraft similar to 1984 NASA test.
You know its true...
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