VALIDATION OF ADVANCED FLIGHT SIMULATORS FOR OPERATIONAL EVALUATION AND TRAINING PROGRAMS

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VALIDATION OF ADVANCED FLIGHT SIMULATORS

• Definitions:
  - Simulator - A flight training device with full six-degree of freedom motion system, a visual system that meets FAA Level D requirements and meets performance standards of AC 120-40.
  - Operational Evaluation Program - Test programs to support operational or equipment approval conducted in a realistic operational environment using advanced flight simulators.
  - Aircraft Data Base - Aircraft performance data base representing flight test data from the aircraft manufacturer.
  - Simulator Approval - Granting approval or certification for a simulator device meeting the requirements of FAA AC 120-40 or ICAO equivalent.
• Types of Simulation
  - Full Flight Simulators - Levels A thru D
  - Training Devices - Levels 1 thru 7
  - Part Task Simulators
  - Laboratory Simulators
  - Unmanned Integrated Modeling
  - Mathematical Modeling
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• History of Flight Simulators
  - World War II
  - Application to Civilian Pilot Training
  - Development of Computers
  - Development of Motion Bases
  - Development Of Visual Systems
  - Advanced Simulator Program in 1970s
  - Application of Actual Aircraft Performance Data Bases
VALIDATION OF ADVANCED FLIGHT SIMULATORS

• Uses of Full Flight Simulators
  – Advanced Training Program
    • Level A thru D
    • Level D requires no Aircraft flight time for transition training with approved training program
    • Aircraft and systems modeling to highest level of fidelity possible – no effort to model pilot
  • Attributes – Discussion
  • Operation Evaluation Programs
  • Networking
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• Simulator Costs
  - Approximately $14M for Level D Device
  • Includes:
    - Spares
    - Training
    - Tolls and Test Equipment
    - Instructors/Operators Facilities
    - HLA/DIS Compatible
    - Delivery/Installation/Certification
    - Warranty
• Issues for Using Simulators for Operational Evaluation Programs
  - Flight performance fidelity throughout flight envelope under test
  - Systems Fidelity
  - Realistic environmental conditions
  - Realistic faults/failures
  - Realistic operating environment
  - Realistic pilot workload
• Primary drivers for operational evaluation programs
  - New equipment certification and operational approval
  - New procedures - closely spaced runways, land and hold short, increased system through-put
  - New Air traffic procedures and rules
  - New airport design and infrastructure
  - Testing for operating environment phenomena
• Pilots as test subjects
  - System is set up to define minimum pilot performance requirements
  - Highly trained and retrained
  - Select group – changing in civil world
  - Cadre of pilot test subjects must be representative of pilot population at large
    - age distribution, current in aircraft type, line pilot.
  - Active to age 60 - then forced to retire under current law
VALIDATION OF ADVANCED FLIGHT SIMULATORS

• Validation of aircraft flight performance
  - Advanced simulator program ensures performance against known aircraft data
  - Confirmed by objective comparison of plotted performance variables plus expert subjective testing
  - Advanced simulators checked twice annually against selected maneuvers
  - Includes visual, motion and throughput/latency testing
### Qualification Test Guide

**Initial Conditions**

**Mass Properties/Configuration**

- Gross Weight: 49,846 Lb
- Empty Weight: 20,950 Lb
- Lavatique Co. G.: 0.51 ft³
- FM Height of Center of Gravity: 122.69 ft
- FM Height of Center of Gravity: 37.68 ft
- Distance from CG to FM: 42.68 ft
- Wing Load: 57.25 Lb/ft²
- Flap Position: 14.52°
- Landing Gear Position: Down

**Position:** Thrust/Control PNL

**Rules & Aero Angles/Modes/Accelerations**

- Pitch Angle: 0.00°
- Roll Angle: 0.00°
- Heading Angle: 0.00°
- Angle of Sideslip: 0.00°
- Body Axis Roll Rate: 0.00 deg/sec
- Body Axis Pitch Rate: 0.00 deg/sec
- Body Axis Yaw Rate: 0.00 deg/sec

**Engines**

- Engine #1 Controller FA: 78.90 Lb
- Engine #2 Controller FA: 78.90 Lb
- Engine #3 Controller FA: 78.90 Lb
- Engine #4 Controller FA: 78.90 Lb
- Engine #1 Torque: 90.00 %
- Engine #2 Torque: 90.00 %
- Engine #3 Torque: 90.00 %
- Engine #4 Torque: 90.00 %
- Engine #1 Propeller Speed: 1199.90 RPM
- Engine #2 Propeller Speed: 1199.90 RPM
- Engine #3 Propeller Speed: 1199.90 RPM
- Engine #4 Propeller Speed: 1199.90 RPM
- Engine #1 Statfed Flag: On
- Engine #2 Statfed Flag: On

**Closed-Loop Controllers**

- Pitch Axis: Inactive
- Roll Axis: Inactive
- Yaw Axis: Inactive

**Speed/Altitude/Aerodynamics**

- Calibrated Airspeed: 58.28 Kts
- Mach Number: 0.00
- Ground Speed: 86.23 Kts
- True Airspeed: 1.00 Deg
- Pressure Altitude: 30000 ft
- Static Pressure: 29.92
- Dynamic Pressure: 60000 ft
- Inertial Elevator: 0.00
- Inertial Acceleration: 0.00
- Wind Direction: 290.00 Deg

**Flight Controls and Surfaces**

- Colored Surface: (VAB)
- Left Elevator Deflection (VAB): 0.00 Deg
- Right Elevator Deflection (VAB): 0.00 Deg
- Left Aileron Deflection (VAB): 0.00 Deg
- Right Aileron Deflection (VAB): 0.00 Deg
- Left Flap Deflection (VAB): 0.00 Deg
- Right Flap Deflection (VAB): 0.00 Deg
- Pedal Position (VAB): 0.00 Deg
- Brake Pedal Position: 0.00
- Throttle Pedal Position: 0.00

**Aircraft Control Status**

- Colored Controller: (VAB)
- Brake Pedal: Inactive
- Throttle Pedal: Inactive
- Pedal Pedal: Inactive

**4.1.2.3 - Minimum Unstick Speed**

**Flap 15, Gear DOWN**

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**Graphs and Data**

- **Calibrated Airspeed (kts)**
- **Pressure Altitude (ft)**
- **Pitch Attitude (deg)**

**Legend**

- Reference Data
- CAS Simulator Data

**4.2.C.1 - Power Change Dynamics**

Flaps 15, Gear UP

Date & Time: 2002-Jul-25 16:09:49
Result Type: Auto Driven
Airline/Operator: CAT - Maastricht
Simulator: ATR 72-500 STF
Reference: SO0214500, pages 2c(1)-1 to 3
(Airbus ATR 72-500 Aerospatiale Flight Test Data)
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Calibrated Airspeed (kts)
Tolerance: +/-3 kts

Pitch Attitude (deg)
Tolerance: +/-1.5 deg

Reference Data
--- CAE Simulator Data

4.1.B.3 - Minimum Unstick Speed
Flap 15, Gear DOWN

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Reference: S00214500, pages 1b(3)1-1 to 3 (ATR 72-500 Aerospatiale Flight Test Data)
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Angle of Attack (deg)

Left Elevator Deflection (deg)

Reference Data

4.1.B.3 - Minimum Unstick Speed
Flap 15, Gear DOWN

Date & Time: 2002-Sep-09 16:15:55
Result Type: Auto Driven
Airline/Operator: CAT - Maastricht
Simulator: ATR 72-500 STF
Reference: S00214500, pages 1b(3)1-1 to 3
(ATE 72-500 Aerospatiale Flight Test Data)
• Systems Validation
  - Navigation performance tested as part of approval process against terminal area geographical data base (Runway positioning and visual scene)
  - On commercial simulators you must confirm en-route geo positioning
  - Must validate specific system fidelity if critical to current evaluation
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• System Modeling
  - Uses actual equipment manufacturers design data
  - Emulation (uses actual aircraft display software with non-airworthy hardware) of flight deck displays preferred to simulated instruments if actual aircraft hardware not used.
  - May need to develop test plan to test specific critical systems
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- Distributed Interactive Simulation
  - Commercial simulators generally not HLA compliant
  - Much less data typically transferred than with military DIS
  - Simulators manufactured to different hardware specs
  - Extremely price competitive - Hence, few bells and whistles
  - Little interest for normal training requirements
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• Typical Operational evaluation programs
  - Low visibility operations
  - New technology
  - New procedures
  - Airport Infrastructure
  - New airport designs
  - Navigation
  - Communications
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• Analysis of results
  – Collect data on critical performance variables
    • Attitude
    • Airspeed
    • Altitude
    • Three dimensional track data (X, Y, Z or Lat/Long)
    • Monitor for pilot actions
    • Video
    • Audio
Advantages of using advanced flight simulators
- Collaborative research environment
- High fidelity operational environment
- Low risk to equipment and personnel
- Much cheaper than actual aircraft
- Better control of test environment
- Scenario repeatability
- Equipment availability
- Ability to modify and manipulate system performance through software
- Ability to network
- Data collection capabilities
• Disadvantages of using approved advanced simulators
  - Cheaper than aircraft but still costly ($300 to $1200 flight hour
  - Limited availability
  - Requires expert technical support
  - Can require special system validation
  - Changes to hardware and software on approved simulators cannot affect approved performance or equipment configuration
  - Must compete with training programs for time
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• Examples of a recent program
  - Laser Visual Interference
    • Worked with Brooks AFB Labs, FDA, Others
    • Worked with Laser industry
    • Supported by SAE G-10 HBET Committee to provide technical oversight and expert guidance
    • Used live laser coupled via fiber optic cable to cockpit
    • Illuminated pilot at critical junctures in typical flight operations in the terminal airspace
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• Laser - Continued
  - Approximately 40 pilots tested
  - Three levels of exposure

• Results
  - New standards for use of lasers in commercial airspace
  - New Advisory Circular for education of FAA and pilot community
  - Used to develop new international (ICAO) standards
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• New Technology on the Flight Deck
  - Head-Up Display
  - Cockpit display of traffic information
  - Multi-function displays
  - ADS-B
  - Data link communications
  - Hazard avoidance/detection
  - Navigation - GPS, LAAS, WAAS
  - Communications
  - Fly-by-wire technology
• Airport Design and Infrastructure
  - New Denver Airport
  - Approach lighting
  - High-speed exits
  - Markings and signage
  - Land and Hold Short operations
  - Runway incursions
  - Contaminated runways
  - Over-run protection
VALIDATION OF ADVANCED FLIGHT SIMULATORS

• Environmental Phenomena
  - Wake Vortex
  - Icing
  - Unusual attitudes
  - Low visibility operations
  - Wind shear detection and recovery
• Summary –
  – Open, collaborative test environment
  – Enhanced data collection capabilities
  – Serve as a bridge between the laboratory and the aircraft
  – Widely distributed geographically
  – Lower risk than using actual aircraft
  – Repeatability
Summary - Continued

- Advanced simulators available for virtually all commercial aircraft
- More cost effective than using actual aircraft
- Lower operating cost - $300 to $1200/hr, than actual aircraft (Typically 1/10 th the cost)
- Offer a high fidelity, realistic operating environment
- Able to modify software and hardware within defined constraints