



# 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.



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **Issues for Using Simulators for Operational Evaluation Programs**
  - **Flight performance fidelity through-out flight envelope under test**
  - **Systems Fidelity**
  - **Realistic environmental conditions**
  - **Realistic faults/failures**
  - **Realistic operating environment**
  - **Realistic pilot workload**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



## Qualification Test Guide

### Initial Conditions

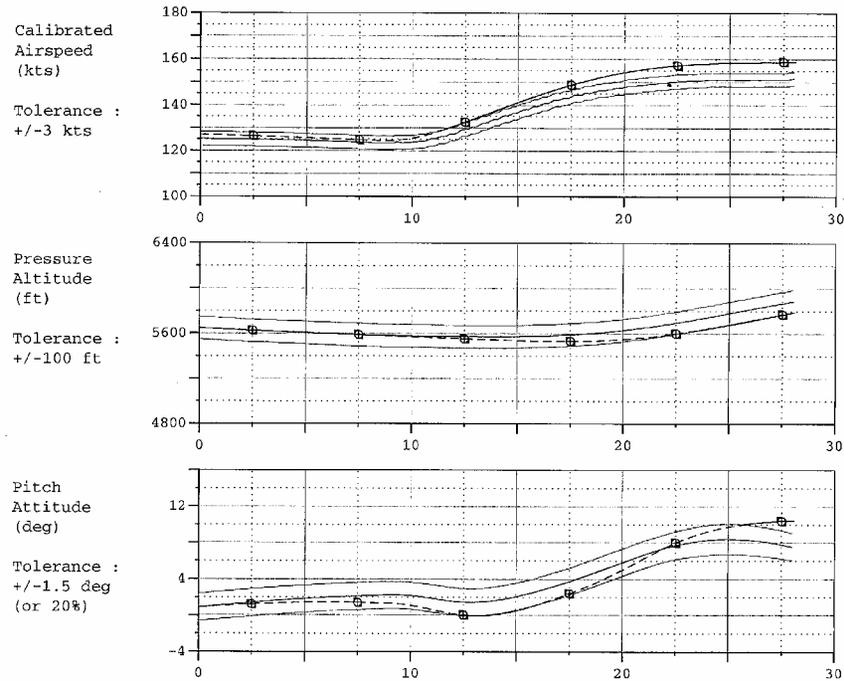
| <u>Mass Properties/Configuration</u>               |                                | <u>Speed/Altitude/Atmosphere</u>    |             |
|--|--------------------------------|-------------------------------------|-------------|
| Gross Weight                                       | 40082.29 lbs                   | Calibrated Airspeed                 | 58.28 kts   |
| Puel Weight  | 2000.00 lbs                    | Mach Number                         | 0.09 -      |
| Longitudinal C.G.                                  | 0.10 Eric mac                  | Ground Speed                        | 44.23 kts   |
| XX Moment of Inertia                               | 192239.97 slug-ft <sup>2</sup> | Rate of Climb                       | 1.64 fpm    |
| YY Moment of Inertia                               | 322326.47 slug-ft <sup>2</sup> | Pressure Altitude                   | 162.21 ft   |
| ZZ Moment of Inertia                               | 543893.12 slug-ft <sup>2</sup> | Height Above Ground                 | 7.99 ft     |
| XX Product of Inertia                              | 15677.16 slug-ft <sup>2</sup>  | Height Above Sea Level              | 507.99 ft   |
| Flap Position                                      | 14.40 detent                   | Ground Elevation                    | 500.00 ft   |
| Landing Gear Position                              | Down                           | Ambient Temperature                 | 21.50 deg C |
| Yaw Damper   | Off                            | Wind Speed                          | 38.18 kts   |
| Powerplant : Pratt&Whitney PW127F Turboprops       |                                | Wind Direction                      | 284.36 deg  |
| <u>Euler &amp; Aero Angles/Rates/Accelerations</u> |                                | <u>Flight Controls and Surfaces</u> |             |
| Pitch Angle  | -1.07 deg                      | Column Position (+ANU)              | -0.25 deg   |
| Roll Angle   | 1.22 deg                       | Left Elevator Deflection (+AND)     | 0.66 deg    |
| Heading Angle                                      | 324.52 deg                     | Right Elevator Deflection (+AND)    | 0.87 deg    |
| Angle of Attack                                    | -0.86 deg                      | Elevator Tab Deflection (+AND)      | 1.67 deg    |
| Angle of Sideslip                                  | -10.58 deg                     | Wheel Position (+RWD)               | -5.00 deg   |
| Body Axis Roll Rate                                | 0.14 deg/sec                   | Left Aileron Deflection (+RMD)      | -1.09 deg   |
| Body Axis Pitch Rate                               | -0.04 deg/sec                  | Right Aileron Deflection (-RMD)     | 0.38 deg    |
| Body Axis Yaw Rate                                 | 0.00 deg/sec                   | Left Spoiler Deflection             | 0.00 deg    |
|  |                                | Right Spoiler Deflection            | 0.00 deg    |
| <u>Engines</u>                                     |                                | Pedal Position (+ANR)               | -1.55 deg   |
| Engine #1 Controller PLA                           | 74.90 deg                      | Rudder Deflection (+ANL)            | -4.85 deg   |
| Engine #2 Controller PLA                           | 74.90 deg                      | Nosewheel Deflection (+ANR)         | 0.00 deg    |
| Engine #1 Controller CIA                           | 99.00 deg                      | Left Brake Pedal Position           | 0.00 -      |
| Engine #2 Controller CIA                           | 99.00 deg                      | Right Brake Pedal Position          | 0.00 -      |
| Engine #1 Torque                                   | 90.01 %                        | <u>Aircraft Control Status</u>      |             |
| Engine #2 Torque                                   | 90.00 %                        | Column Driven                       |             |
| Engine #1 Propeller Speed                          | 1199.99 RPM                    | Wheel Driven                        |             |
| Engine #2 Propeller Speed                          | 1199.99 RPM                    | Rudder Pedal Driven                 |             |
| Engine #1 Status Flag                              | on                             | Spoiler Free                        |             |
| Engine #2 Status Flag                              | on                             | Gear Lever Driven                   |             |
| <u>Closed-Loop Controllers</u>                     |                                | Engine #1 Controller PLA Driven     |             |
| Pitch Axis   | Inactive                       | Engine #2 Controller PLA Driven     |             |
| Roll Axis  | Inactive                       | Engine #1 Controller CIA Driven     |             |
| Yaw Axis   | Inactive                       | Engine #2 Controller CIA Driven     |             |
|  |                                | Nosewheel Driven                    |             |
|  |                                | Brake Pedals Free                   |             |

### 4.1.1.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<br>(ATR 72-500 Aerospaiale Flight Test Data) | Page 1/8                   |



# VALIDATION OF ADVANCED FLIGHT SIMULATORS

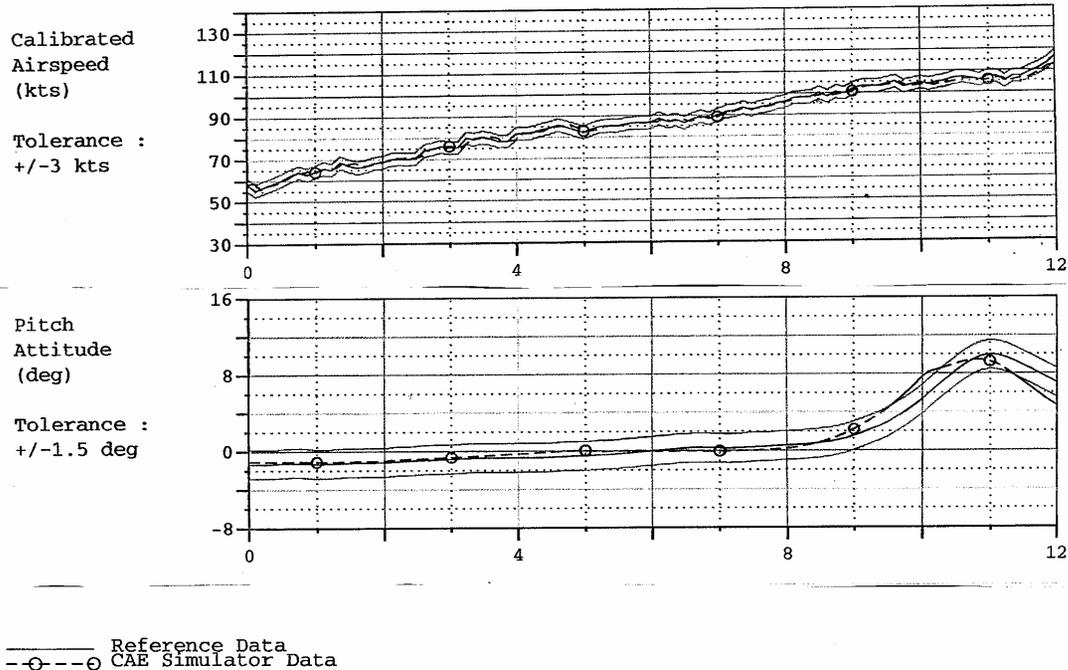


— Reference Data  
 -○- CAE Simulator Data

|   |                            |
|---|----------------------------|
| 4.2.C.1 - Power Change Dynamics<br>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 : S00214500, pages 2c(1)-1 to 3<br>(ATR 72-500 Aerospatiale Flight Test Data) | Page 2/6                   |



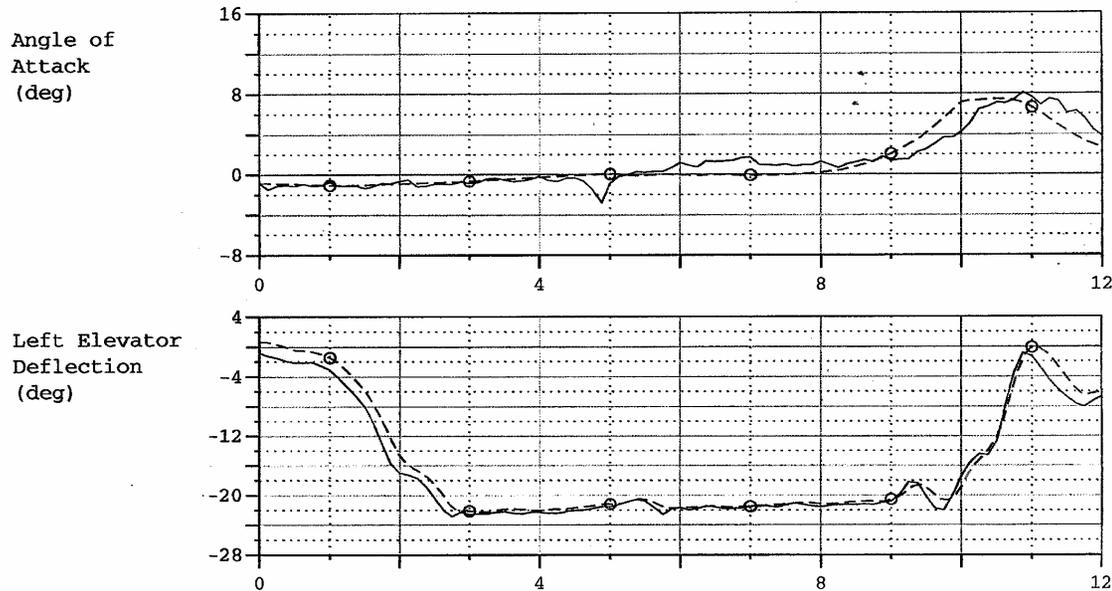
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# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **Typical Operational evaluation programs**
  - **Low visibility operations**
  - **New technology**
  - **New procedures**
  - **Airport Infrastructure**
  - **New airport designs**
  - **Navigation**
  - **Communications**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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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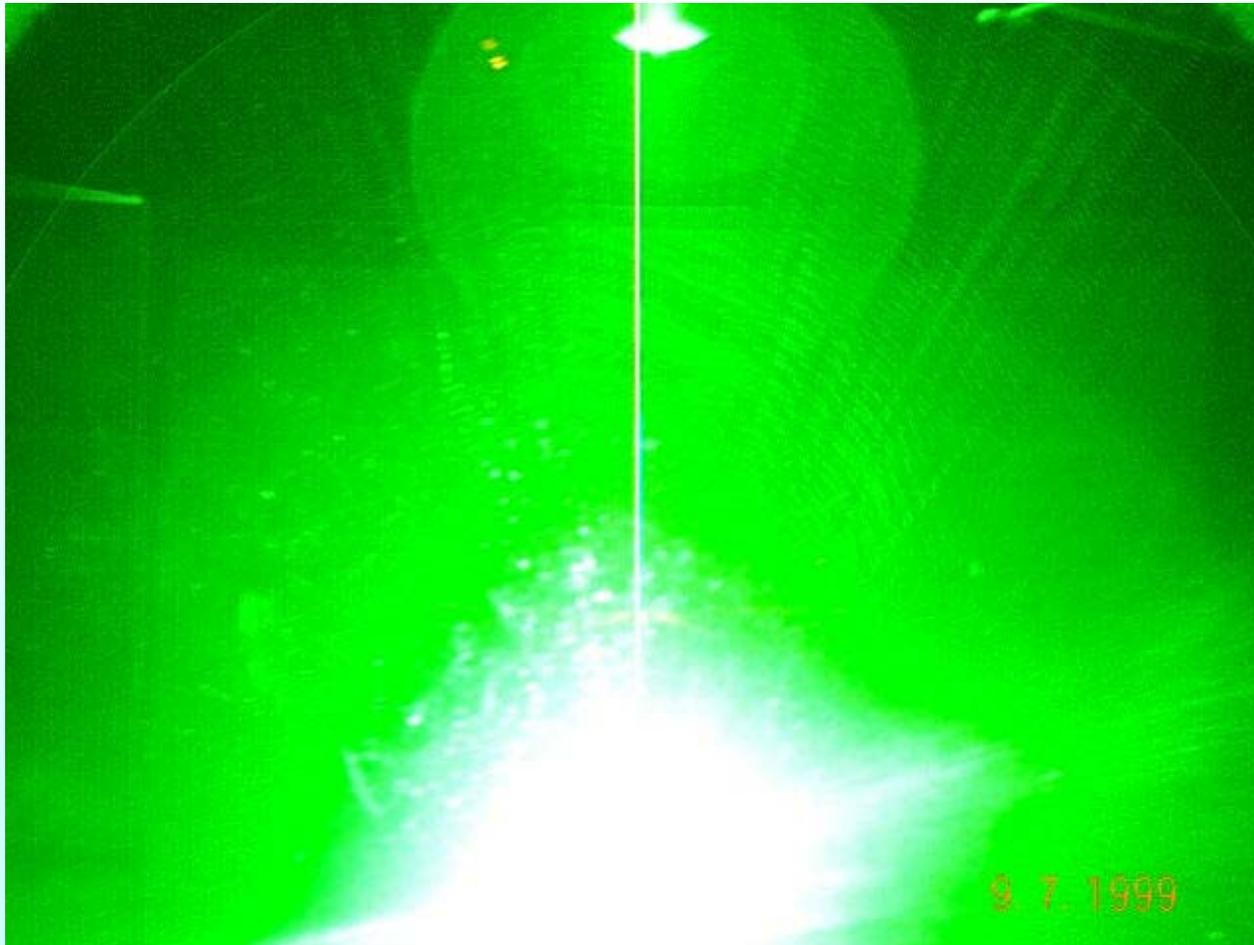


# VALIDATION OF ADVANCED FLIGHT SIMULATORS





# VALIDATION OF ADVANCED FLIGHT SIMULATORS





# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**



# VALIDATION OF ADVANCED FLIGHT SIMULATORS



- **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**