



Development of the Mod II X-57 Piloted Simulator and Flying Qualities Predictions

Ryan D. Wallace, James Reynolds, Mike Frederick
NASA Armstrong Flight Research Center

Dana McMinn, David E. Cox, Nicholas K. Borer
NASA Langley Research Center

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X-57 Maxwell



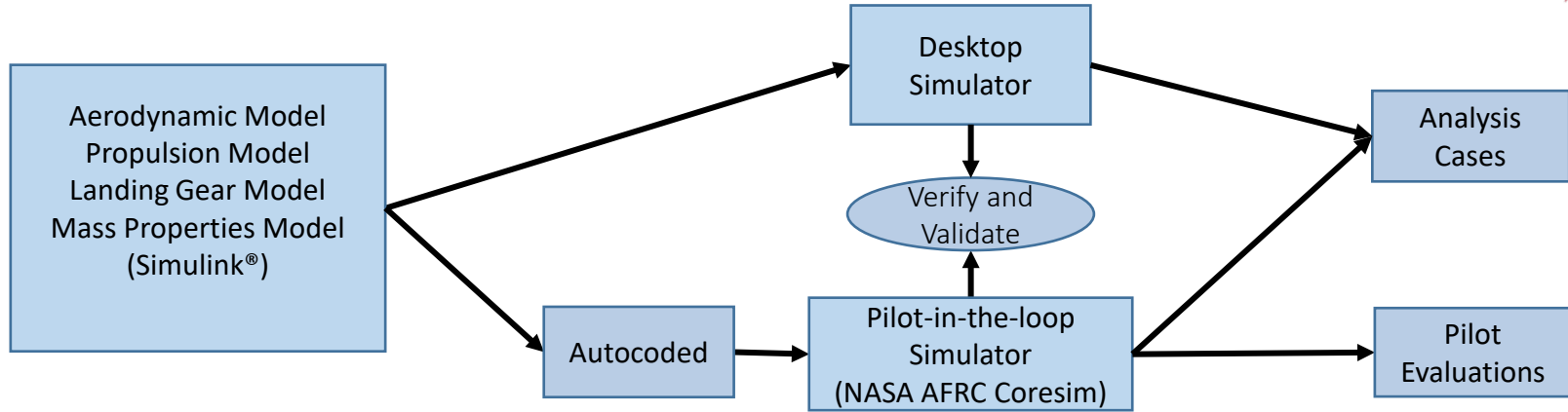
- Multi-phase development

- Mod I
 - Instrumented Tecnam P2006T tested by NASA AFRC
- Mod II
 - Electrified Tecnam P2006T, minor outer mold line changes
- Mod III
 - Cruise-optimized wing with wingtip propulsors
- Mod IV
 - Disturbed propulsors along the cruise-optimized wing





Mod II Sim Architecture



- Simulator developed to predict flying qualities and stability as well as help develop flight maneuvers and emergency procedures
 - Desktop simulator for batch analysis
 - Pilot-in-the-loop simulator for both batch analysis and pilot evaluations
- Simulator cross checks and pilot evaluations
- Comparison with ground and flight data

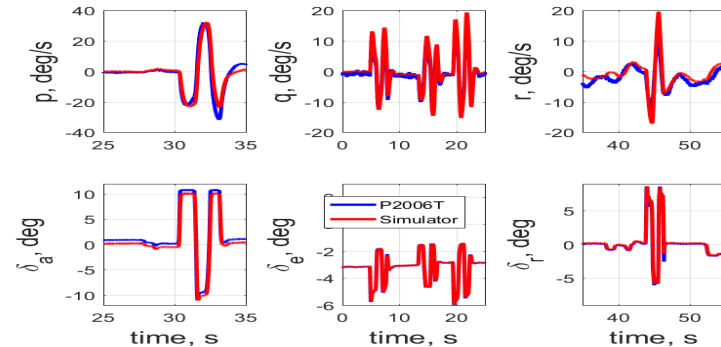


Mod II Aero and Propulsion Model



- Aero Model

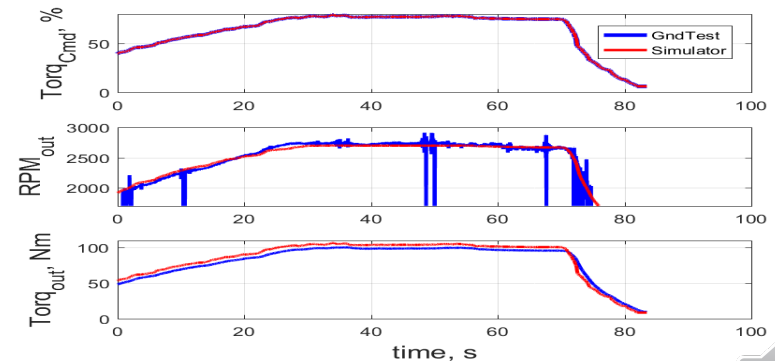
- Parameter identification analysis
 - Mod I data
 - Assume OML changes have minor affects
- Drag calculated using P2006 pilot's handbook
- Hinge moments based on vehicle geometry and CFD tail analysis
- Stall and ground effects not modeled



Mod I flight data versus Mod II sim data

- Propulsion model

- Motor modeled as proportional torque command
 - Efficiencies and motor speed protections
- Propellor model based on Blade element theory analysis (XROTOR®)
 - Advance ratio and torque
- Battery model is a Thevenin equivalent circuit model
 - State of charge and temperatures



Mod II ground testing data versus Mod II sim data

Mod II Models



- Landing Gear Model
 - Based on legacy NASA Langley Research Center landing gear model
 - Modified with X-57 landing gear and tire parameters
- Mass Properties Model
 - Weight and CG locations measured from airplane
 - Inertias from CAD model



Piloted Simulator Cockpit



- Dashboard
 - Gauges and Switches
- Control surface inceptors
 - Yoke, rudder pedals, toe brakes
 - Active force feedback system
 - Trim: yaw and pitch
- Motor control inceptors
 - Torque levers (1 per motor)
 - Propeller pitch levers (1 per motor)
- Seat (from actual aircraft)
- Aural Alerts
 - Stall warning, battery health, etc.
- Out-the-window view
 - 120° horizontal degree field-of-view
 - 34° vertical degree field-of-view



Mod II Dashboard Compared



Photo Credit: NASA
Genaro Vavuris

Airplane Cockpit

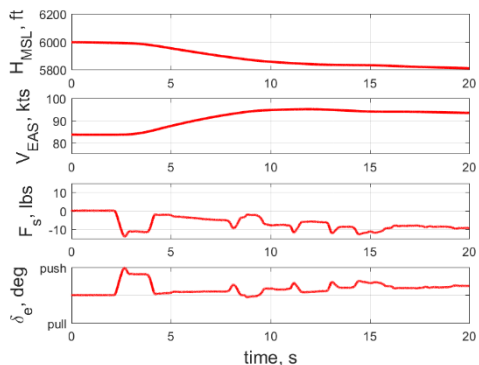


Piloted Simulator Cockpit



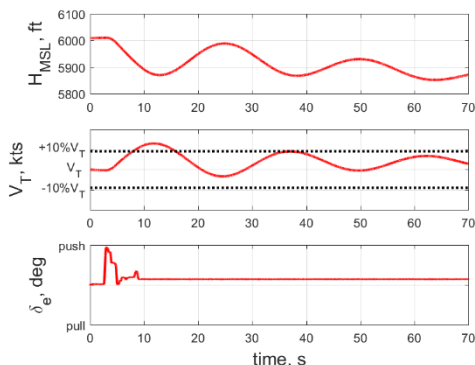


Static Stability



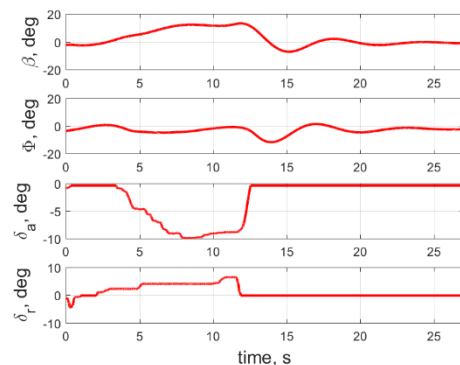
FAR §23.173

- Pilot-in-the-loop study to determine if yoke forces are not excessive and in the correct direction



FAR §23.175

- Pilot-in-the-loop study to determine if the airplane with return within $\pm 10\%$ trim speed yoke free for a longitudinal yoke displacement



FAR §23.177

- Pilot-in-the-loop study to determine if the airplane with return from a sideslip to a steady lateral position yoke free

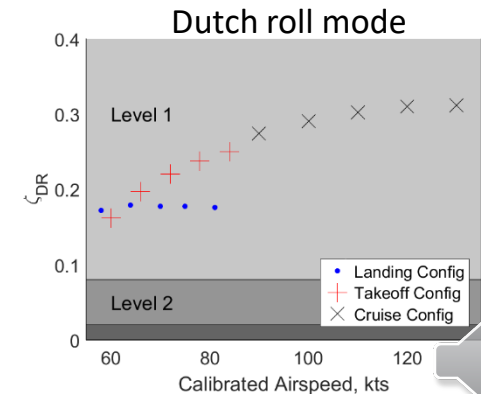
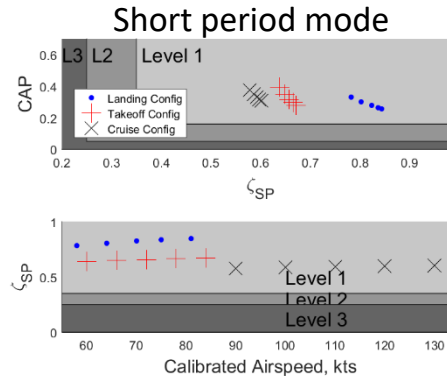
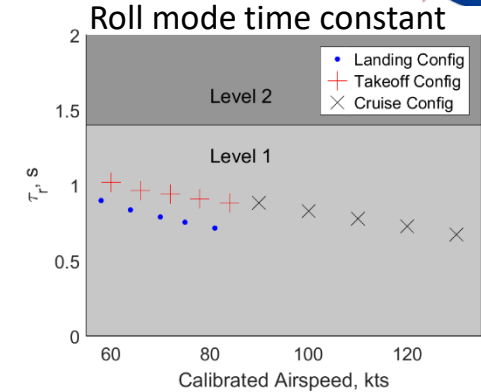
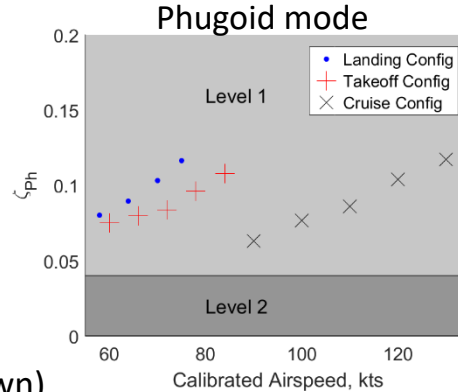


Flying Qualities Predictions



Flying qualities predictions

- Piloted sim linear analysis
- Military standards handbook
- Multiple points in the flight envelop
 - Landing configuration (flap full, gear down)
 - Takeoff configuration (flap 15°, gear down)
 - Cruise configuration (flap up, gear down)





Conclusions

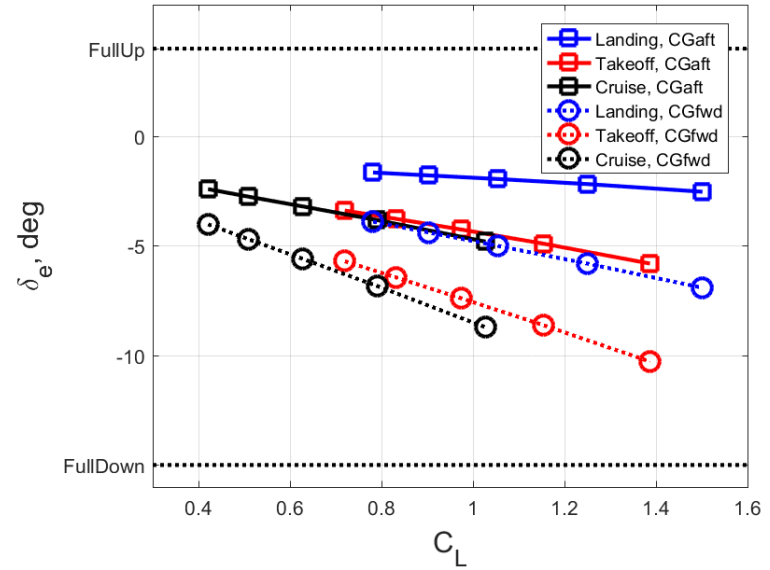
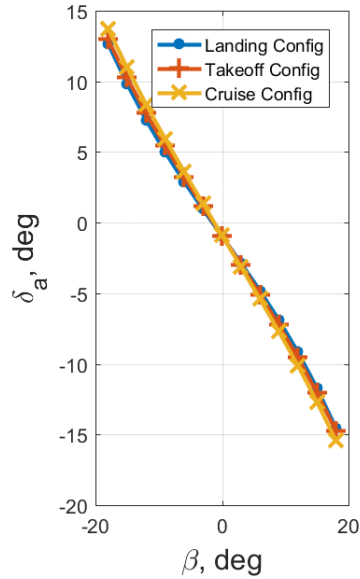
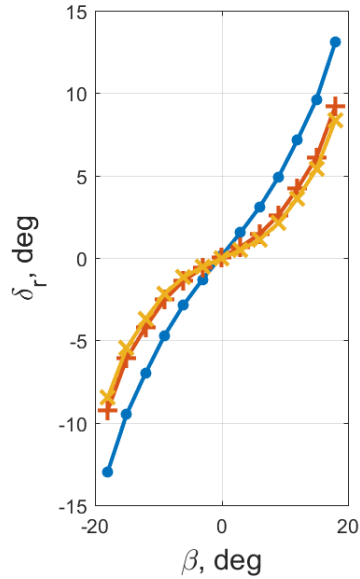
- The piloted-in-the-loop, fixed base nonlinear simulator has been built up as flight maneuver development tool, emergency procedure trainer, and flight analysis instrument
- Simulation studies predict that the airplane will be both longitudinally and laterally stable
- Simulation studies to predict the flying qualities to be Level 1





Backup

Stability





Stability

