Piloted Evaluation of Fast Engine Response Mode

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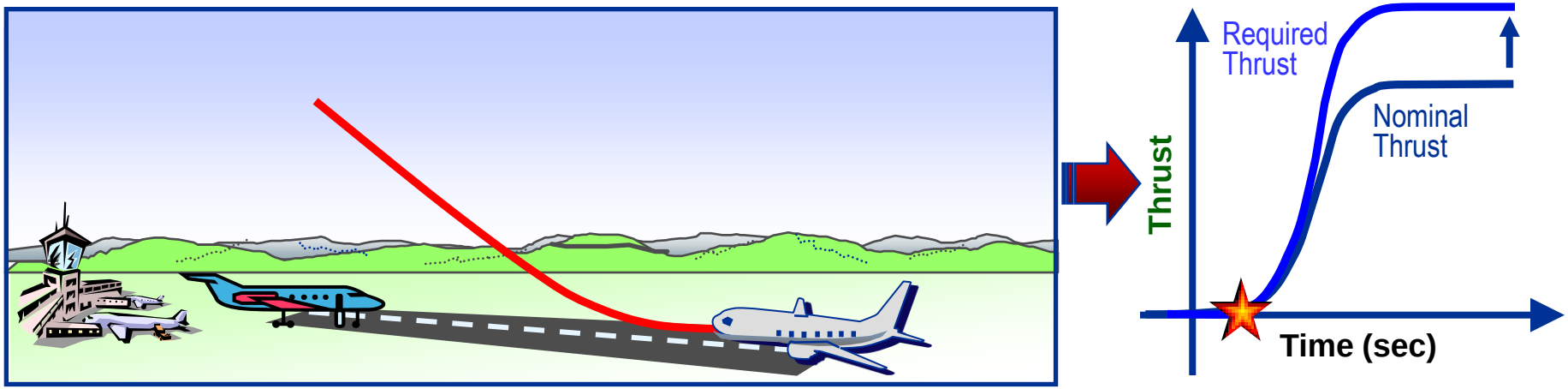
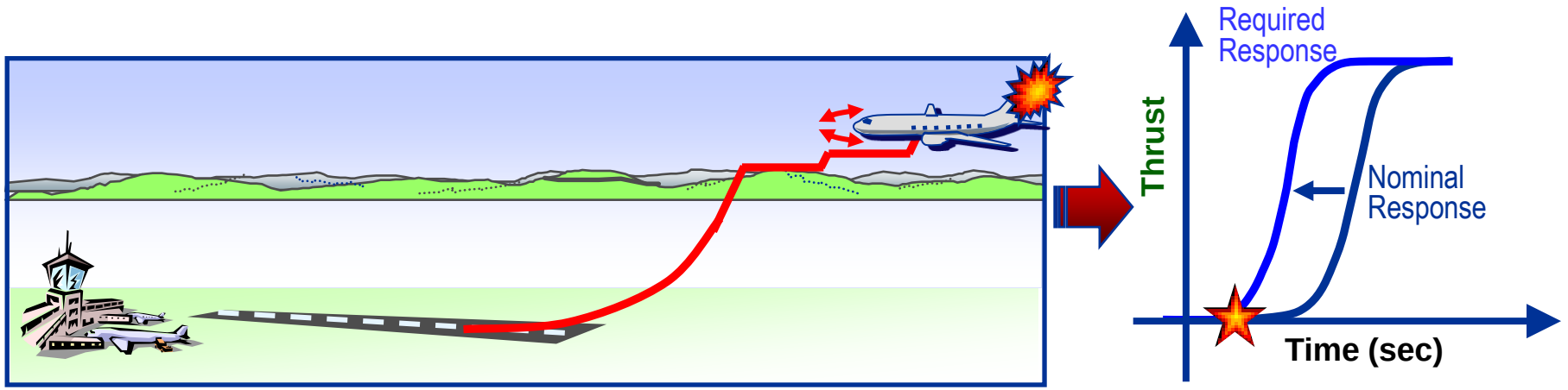
Overthrust for Runway Incursion Scenario



- Need to takeoff in a shortened distance
- More thrust than is typically allowed is needed to safely takeoff
- Develop enhanced propulsion control algorithms for emergency situations

Fast Response for Vertical Tail Damage Scenario

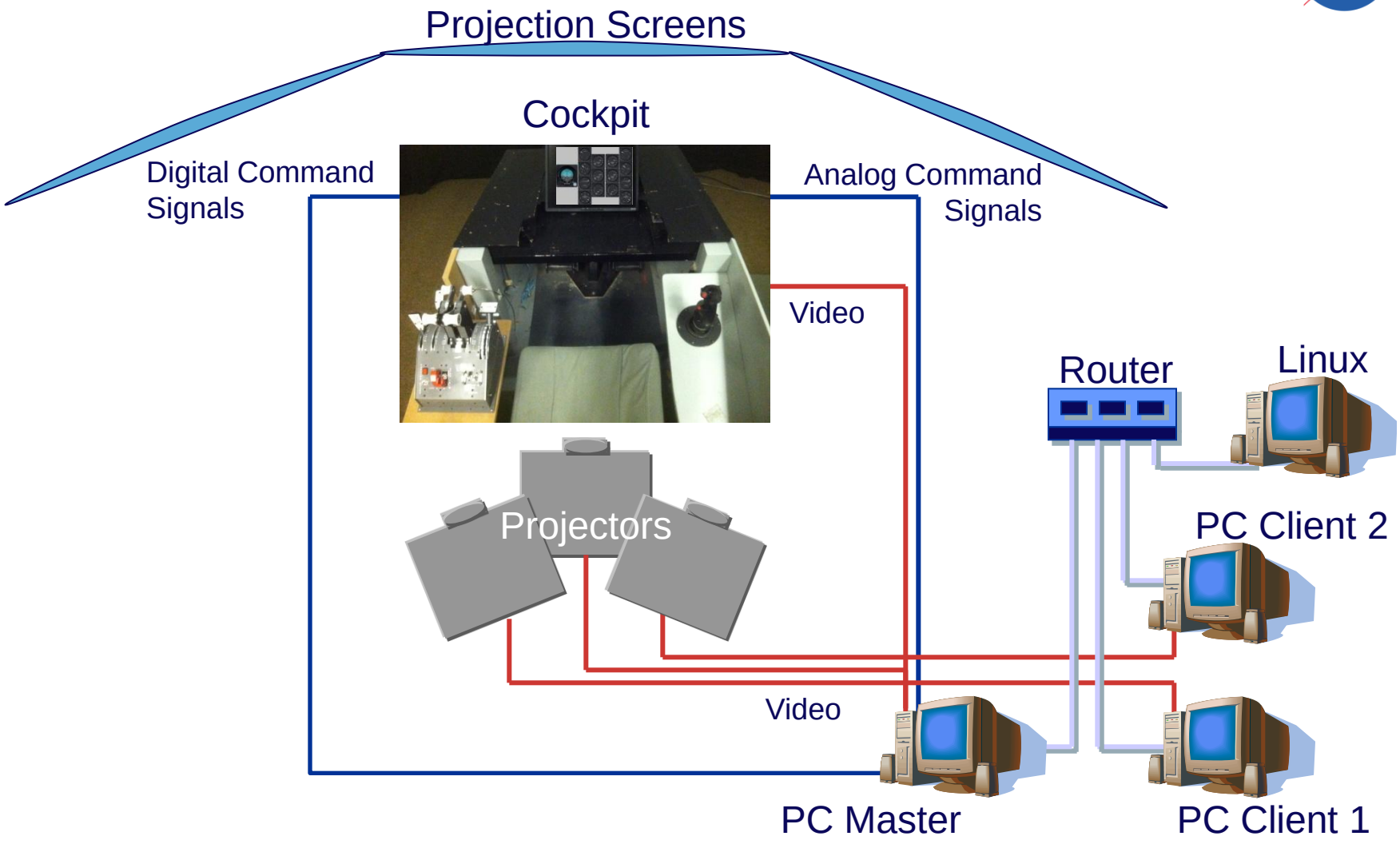


- Vertical tail damage decreases lateral directional stability
- Propulsion system can be used for flight controls
- Engine response is much slower than conventional flight control surfaces
- Develop enhanced propulsion control algorithms for emergency situations

Pilot-in-the-loop testing—Flight Simulator

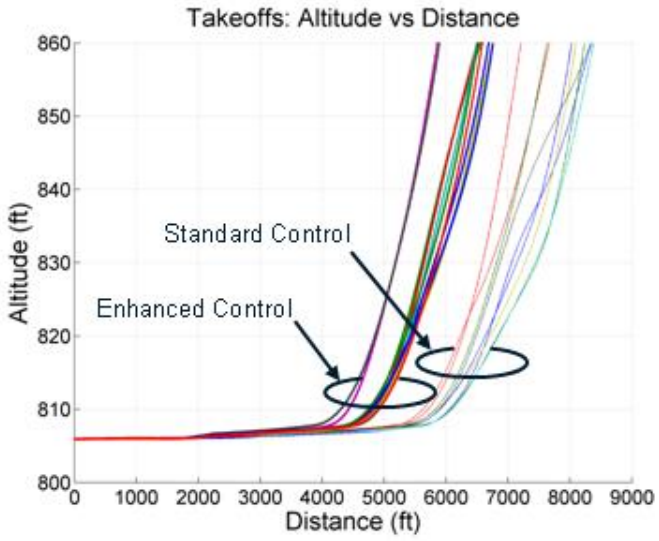
- Dynamic model of a four-engine transport aircraft
- Four copies of C-MAPSS40k are integrated with the airframe and execute in parallel
- The rudder can be locked
- Enhanced control modes can be initiated by the pilot

NASA GRC Piloted Control Evaluation Facility



Pilot-in-the-loop testing—Short runway scenario

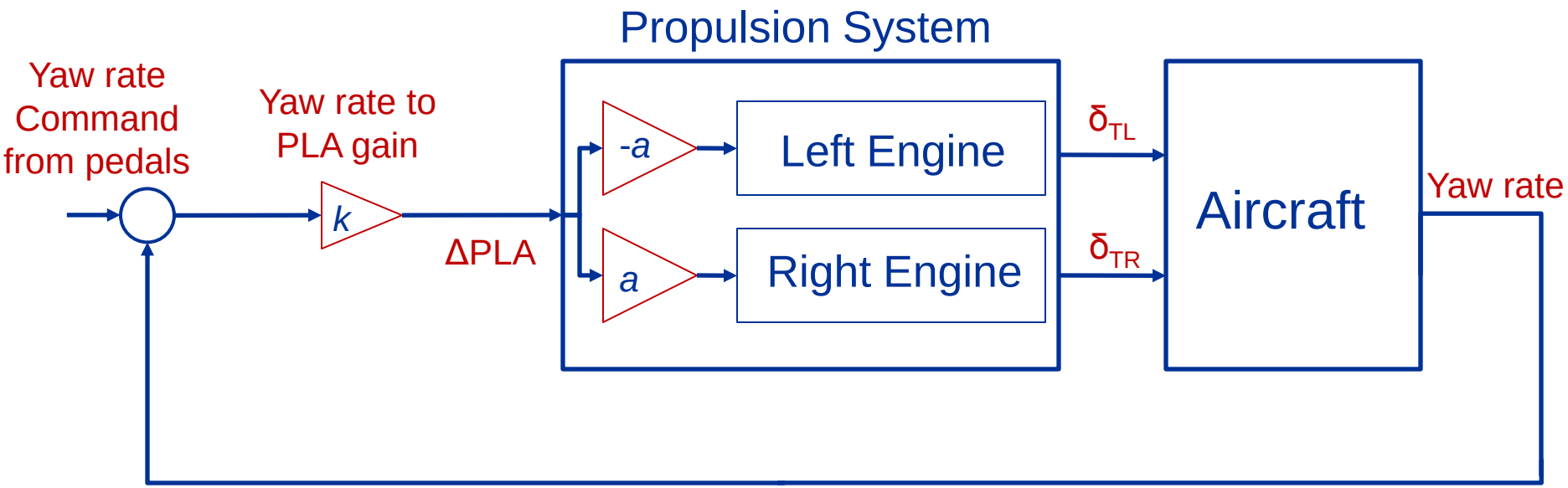
- Goal was to achieve altitude in minimum distance
- Both nominal and enhanced control modes were evaluated
- Proficiency improved with practice
- Takeoff distance was significantly decreased with enhanced control



Pilot-in-the-loop testing—Stuck rudder scenario

- Goal was to maneuver to runway and land
- Pilot manually adjusted throttles to help maneuver, using differential thrust to turn
- Both nominal and enhanced control modes were evaluated
- Proficiency improved in all phases with practice
- Rudderless maneuvering was easier and more consistently successful with enhanced propulsion control
- In addition to Fast Response, pilot found Overthrust very helpful during flare

Yaw Rate Feedback to Throttles

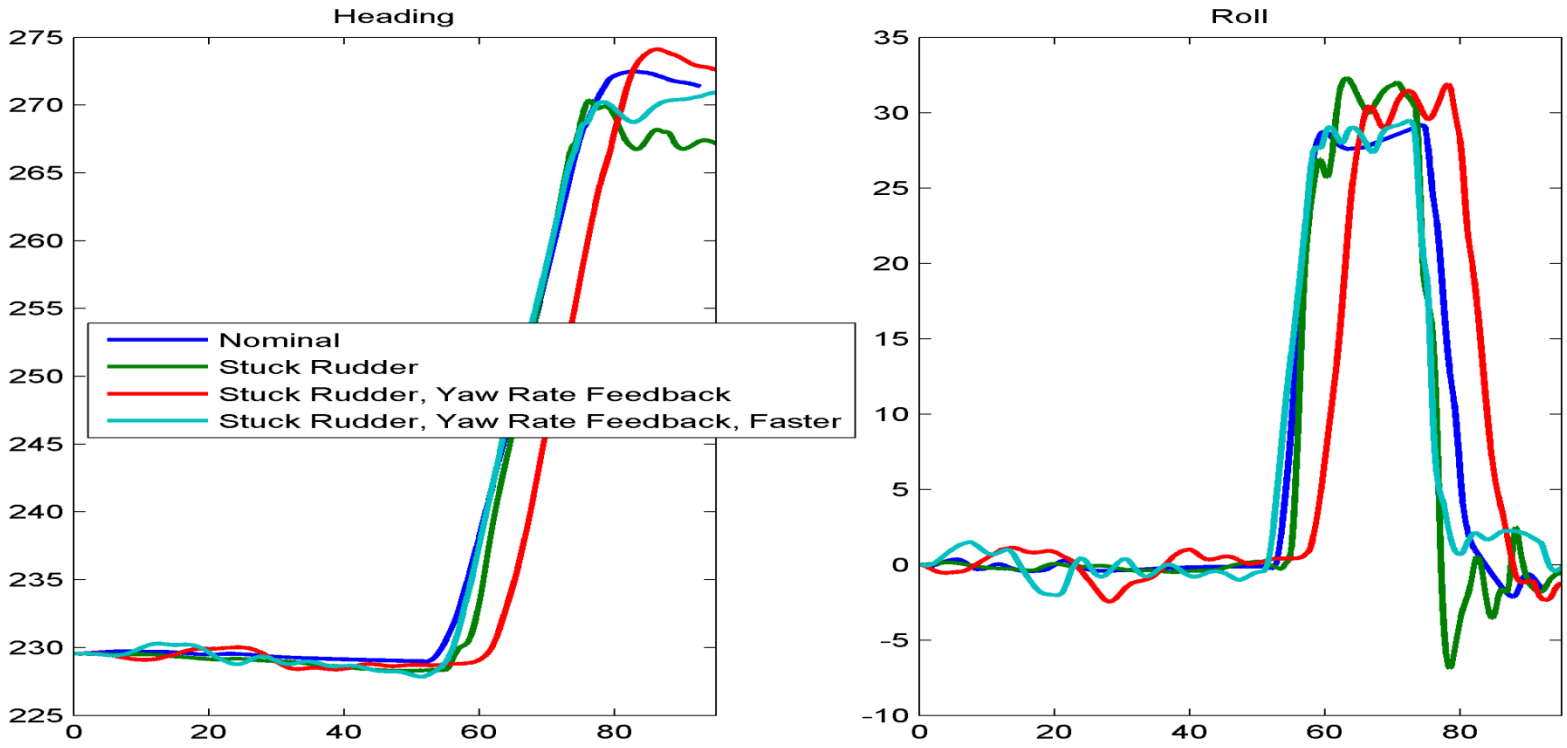


- Implemented yaw rate feedback to throttles to assist in replacing rudder function by introducing differential thrust for enhanced maneuverability and possible Dutch roll damping

Pilot-in-the-loop testing—Stuck rudder scenario Evaluation of yaw rate feedback

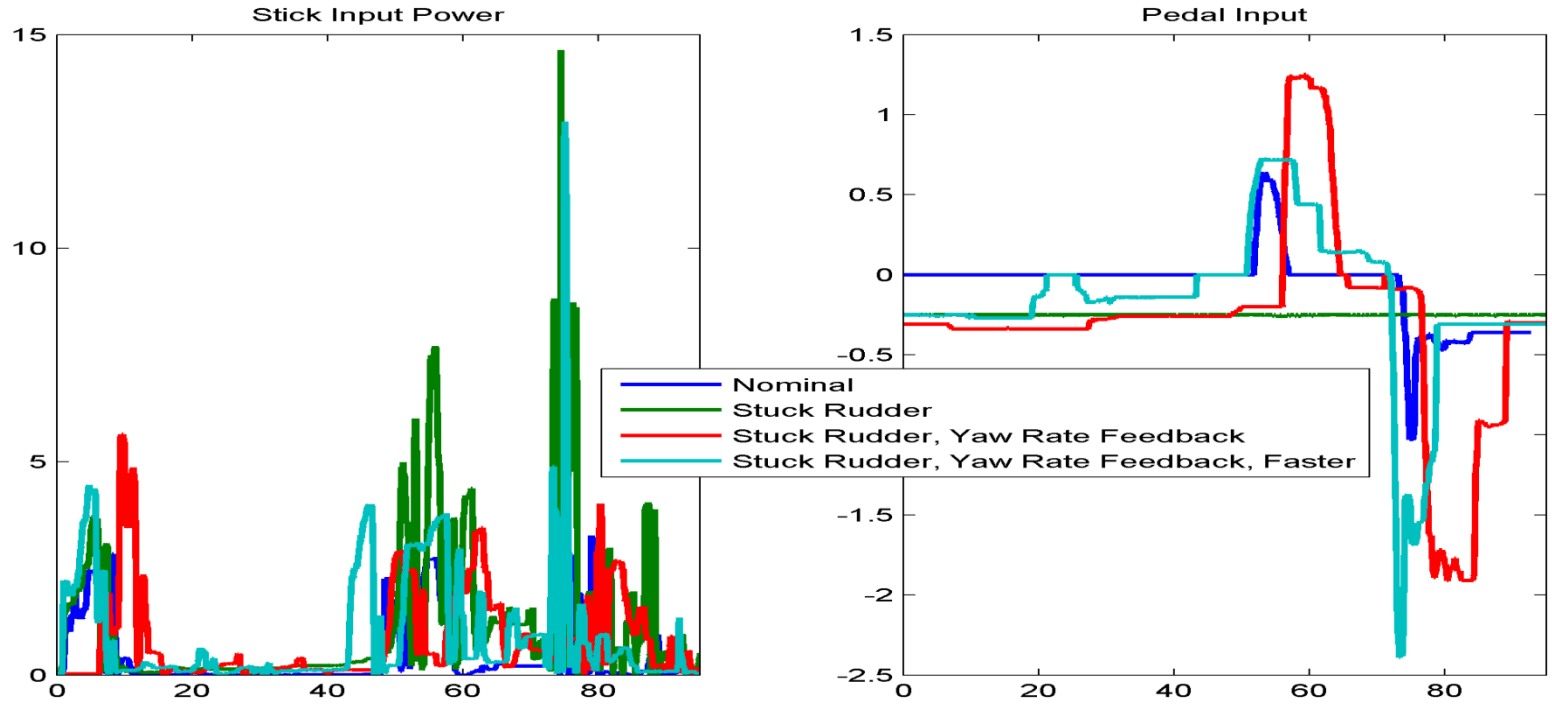
- Task was to roll into a turn, then roll out on a heading
- Cases evaluated:
  - nominal flight control
  - stuck rudder
  - yaw rate feedback with nominal engines
  - yaw rate feedback with Fast Response engines

Pilot-in-the-loop testing—Stuck rudder scenario Evaluation of yaw rate feedback: Attitude



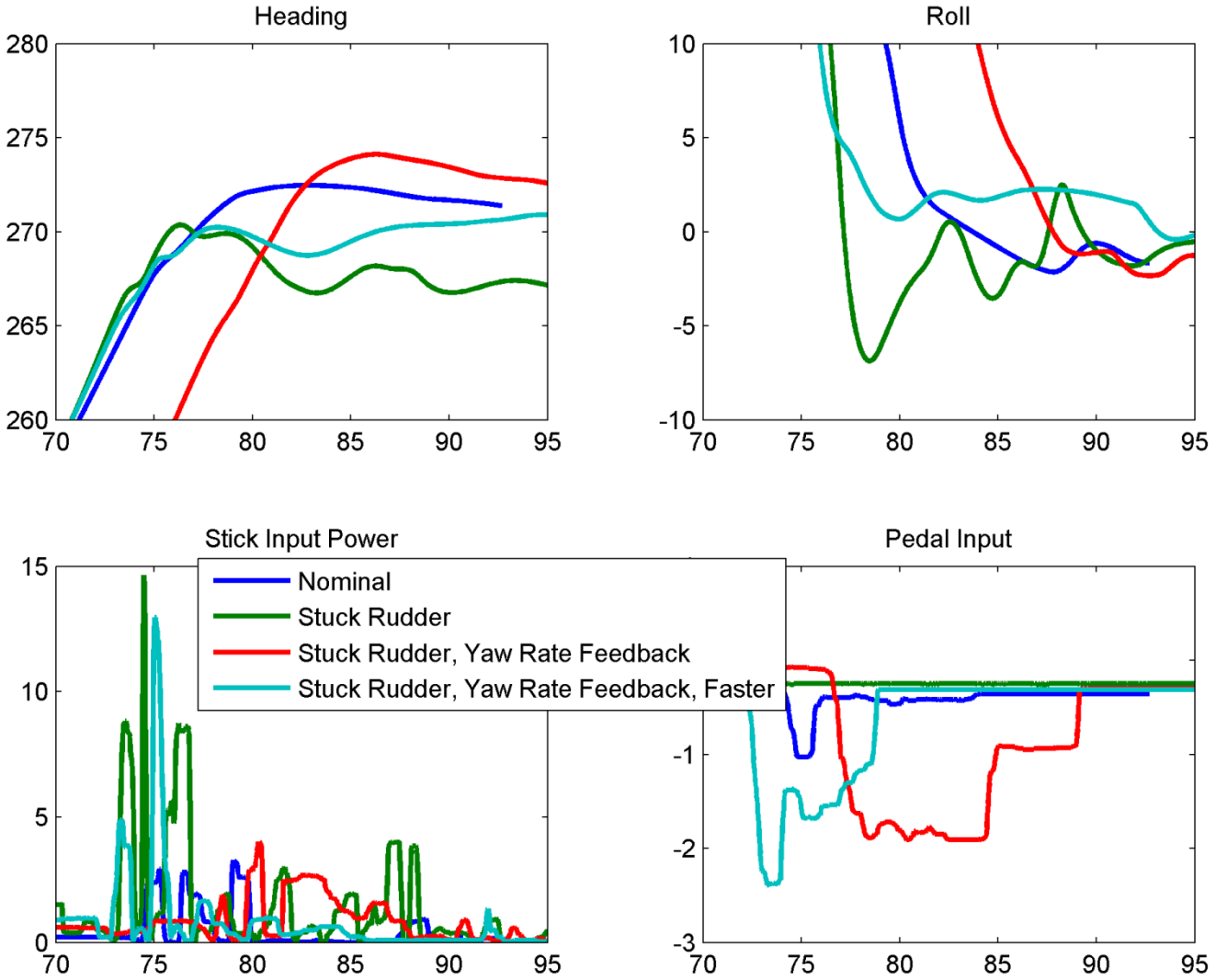
- Smoother control of roll and heading with yaw rate feedback compared to stuck rudder case

Pilot-in-the-loop testing—Stuck rudder scenario
Evaluation of yaw rate feedback: Pilot workload



- Workload, as measured by pilot stick input power (sum of squared amplitude of stick movement), is largest with stuck rudder, less with yaw rate feedback, and with Fast Response, pilot relies more heavily on pedals

Pilot-in-the-loop testing—Stuck rudder scenario
Evaluation of yaw rate feedback: Detail



Conclusions

- Piloted simulations using the enhanced control modes have been performed, demonstrating the benefits of Fast Response and Overthrust modes for emergency operation
- Overthrust significantly shortens takeoff distances
- More maneuverability with enhanced control modes compared to nominal engine response when manually adjusting throttles with stuck rudder
- Preliminary testing shows yaw rate feedback to throttles cannot replace stuck rudder, but can reduce oscillations, and fast response reduces pilot workload

Future Work

- Continue piloted enhanced control mode study