

WHERE ARE WE TODAY WITH UPSET RECOVERY MODELING AND SIMULATION?

John V. Foster
Gautam H. Shah
NASA Langley Research Center
Hampton, VA USA

Presented to
International Committee on Aviation Training in Extended Envelopes
Royal Aeronautical Society, London, UK
16 Nov. 2009

OUTLINE

- Current motivations for upset simulations
- A historical perspective
- Recent advances in flight dynamics modeling of upsets
- Lessons learned
- Challenges and steps forward

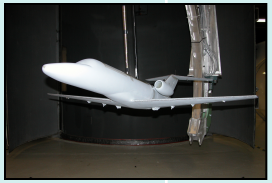
MOTIVATIONS

- Upset training development
  - Industry training guide
  - Questions raised about simulation fidelity for upsets
  - Simulation technology : Ground-based and in-flight training
- Government/Industry look at LOC accidents
  - Commercial Aviation Safety Team (CAST)
  - Simulation recognized as a critical technology
- Advanced controls technology
  - Envelope limiting
  - Adaptive controls





A HISTORICAL PERSPECTIVE OF SIMULATION IN EXTENDED ENVELOPES

Category	60's	70's	80's	90's	2000
Military Fighter	Stall warning / spin training		High alpha airframe/controls technology		
Light GA		Spin resistant wing design		Stall awareness training	Envelope protection
Regional transport				Tail-plane Icing simulation	
Large transport			Envelope protection		Upset training

ADVANCES OVER THE PAST DECADE

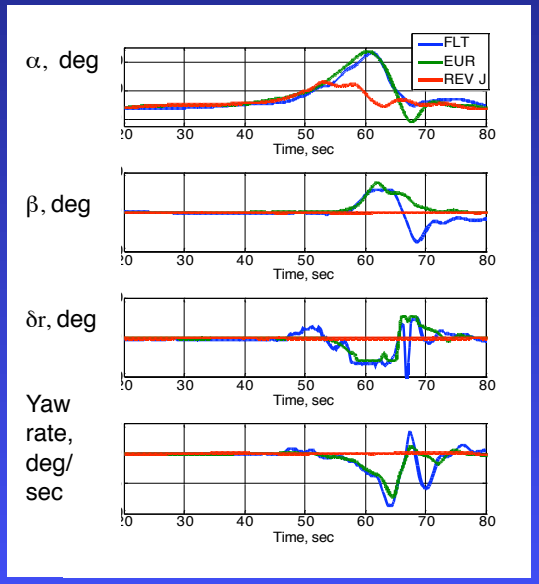
- Aerodynamic database development



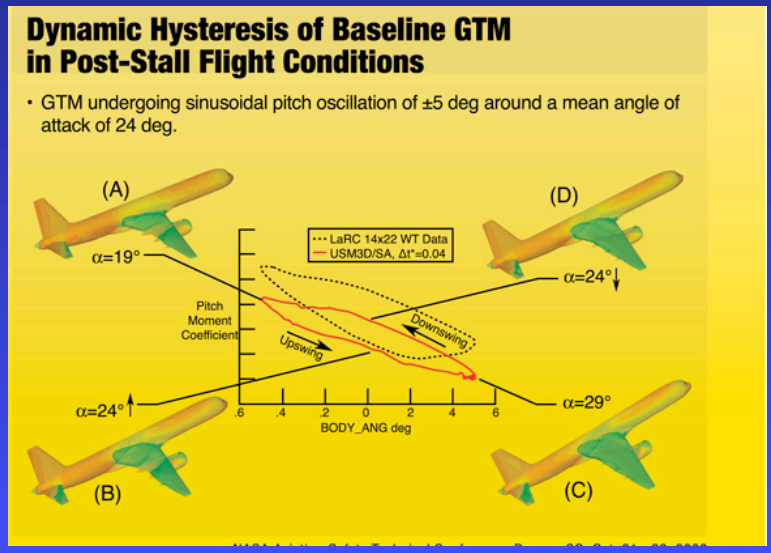
- Tail-plane icing simulation



- Enhanced modeling and prediction



- Computational methods



NASA WIND TUNNEL TESTS



5.5% model on static mount
NASA LaRC 14x22 Ft Tunnel

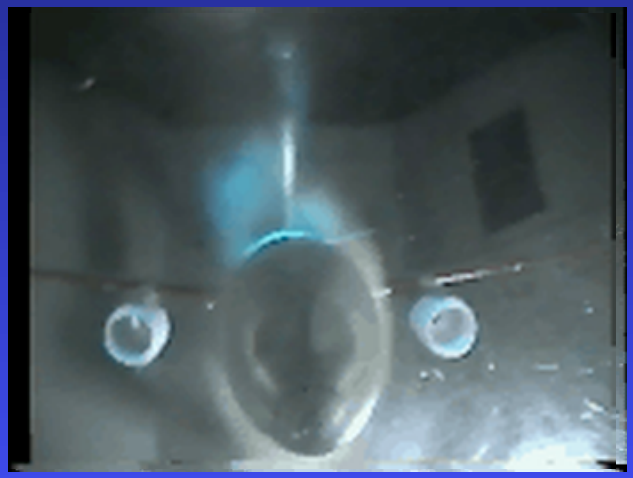
- ***Static***
  - 23,400 data points
  - α: -30 to 90º, β: -45° to +45º
  - Control and flap effects
  - Landing gear effects
  - Component effects
  - Failure conditions
- ***Forced Oscillation***
  - 3600 data points
  - α : -10° to 90º, β : -45° to +45º
  - Frequency and amplitude effects
  - Control and flap effects
  - Landing gear effects
  - Component effects
- ***Rotary Balance***
  - 16,000 data points
  - α : 0° to 90º, β : -45° to +45º
  - Rotational rate effects
  - Control and flap effects
  - Landing gear effects
- ***Free-Spin***
  - 45 test conditions
  - 4 configurations



3.5% model on rotary balance rig
NASA LaRC 20 Ft Vertical Spin Tunnel

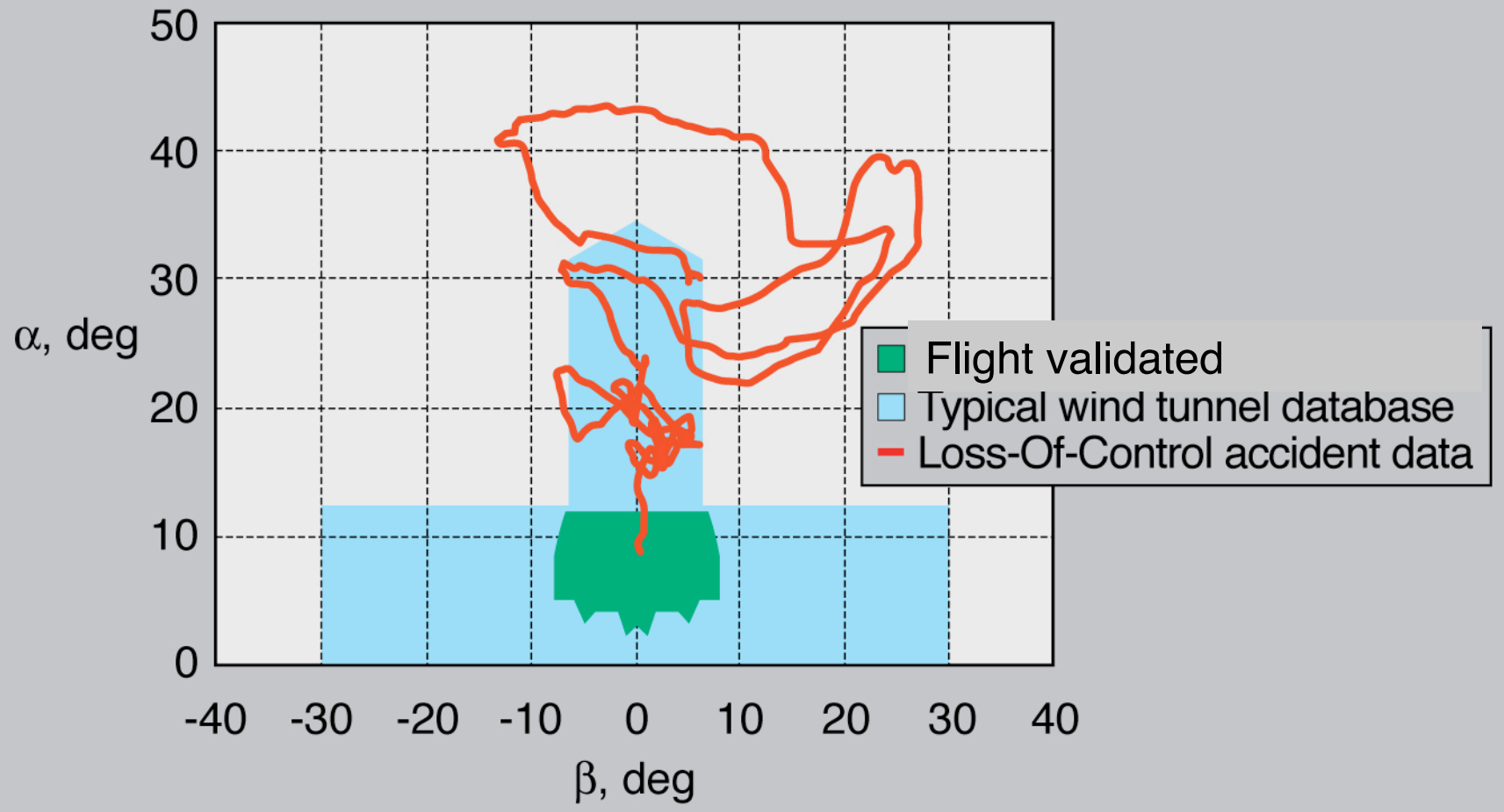


5.5% model on yaw forced oscillation rig
NASA LaRC 14x22 Ft Tunnel



Smoke/laser flow visualization in
NASA LaRC 12 Ft Tunnel

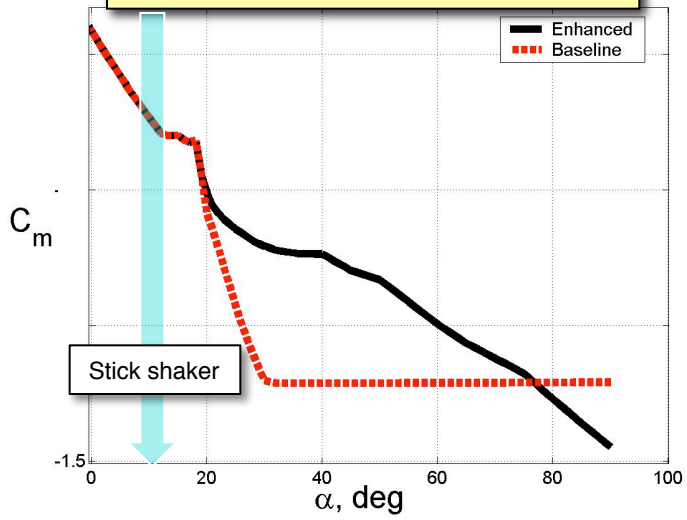
LIMITATIONS OF CURRENT TRANSPORT DATABASES



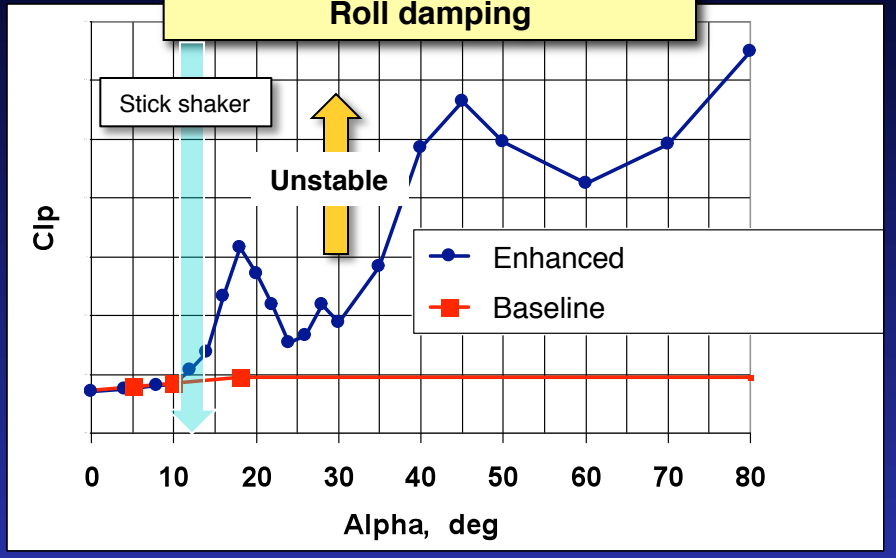
Current transport simulations not designed for upset conditions

IMPORTANT AERODYNAMIC CHARACTERISTICS FOR UPSETS

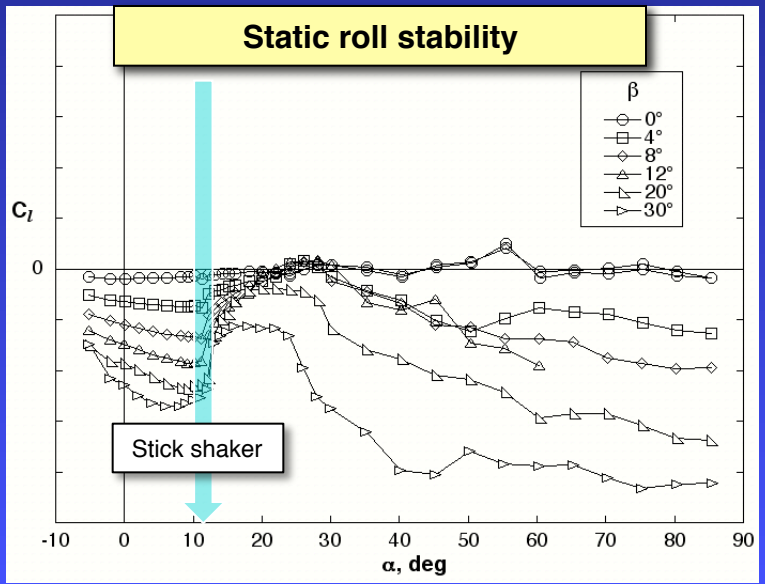
Static pitch stability



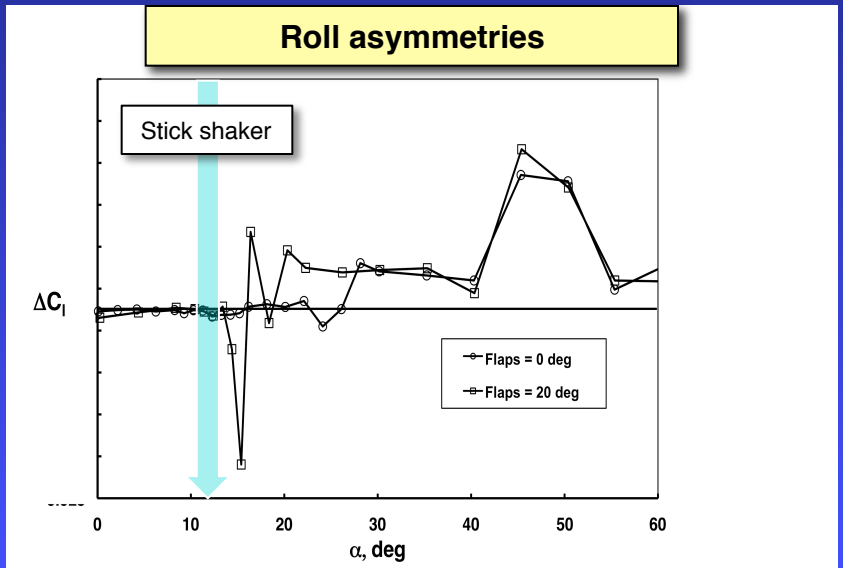
Roll damping



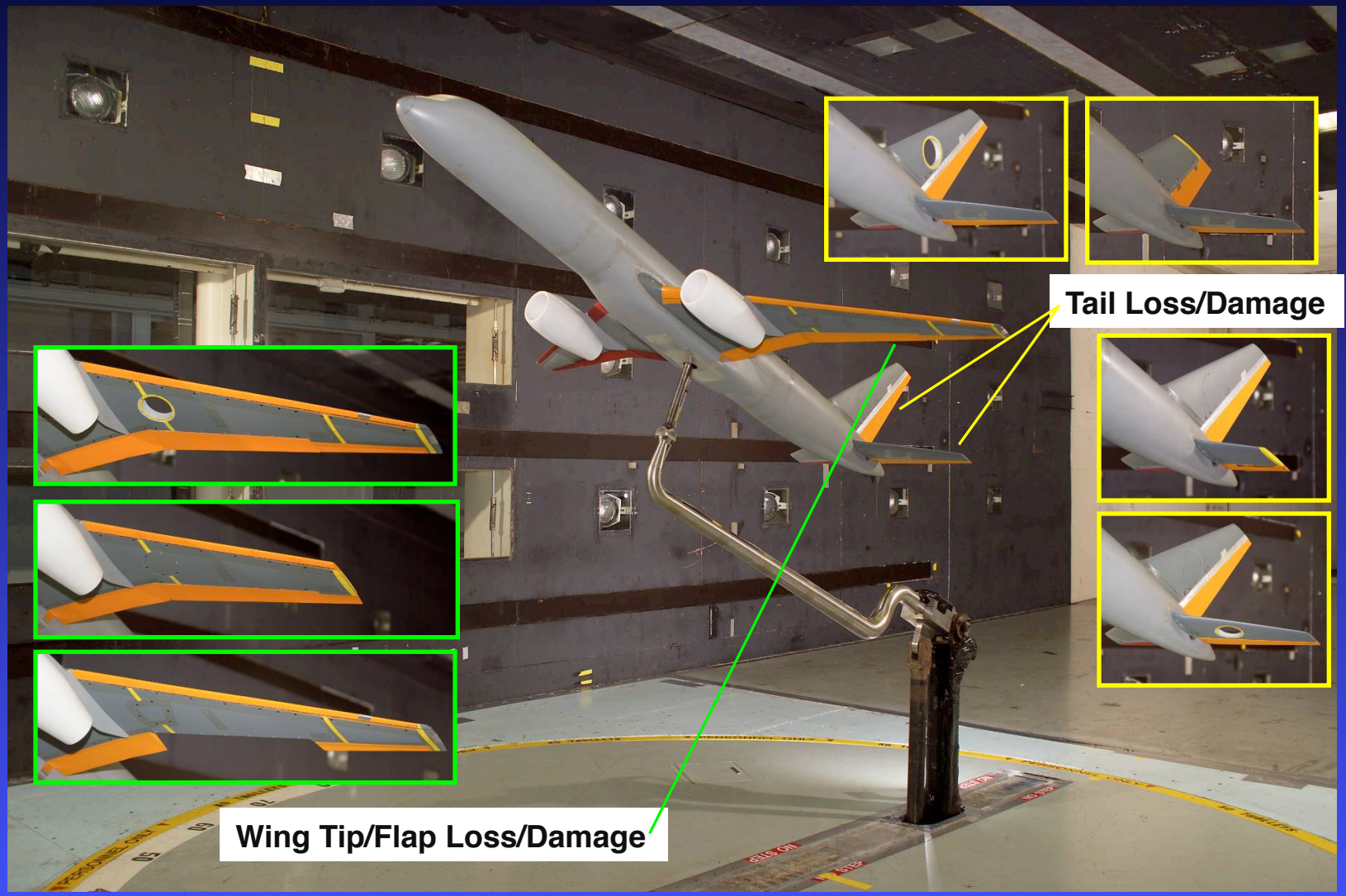
Static roll stability



Roll asymmetries

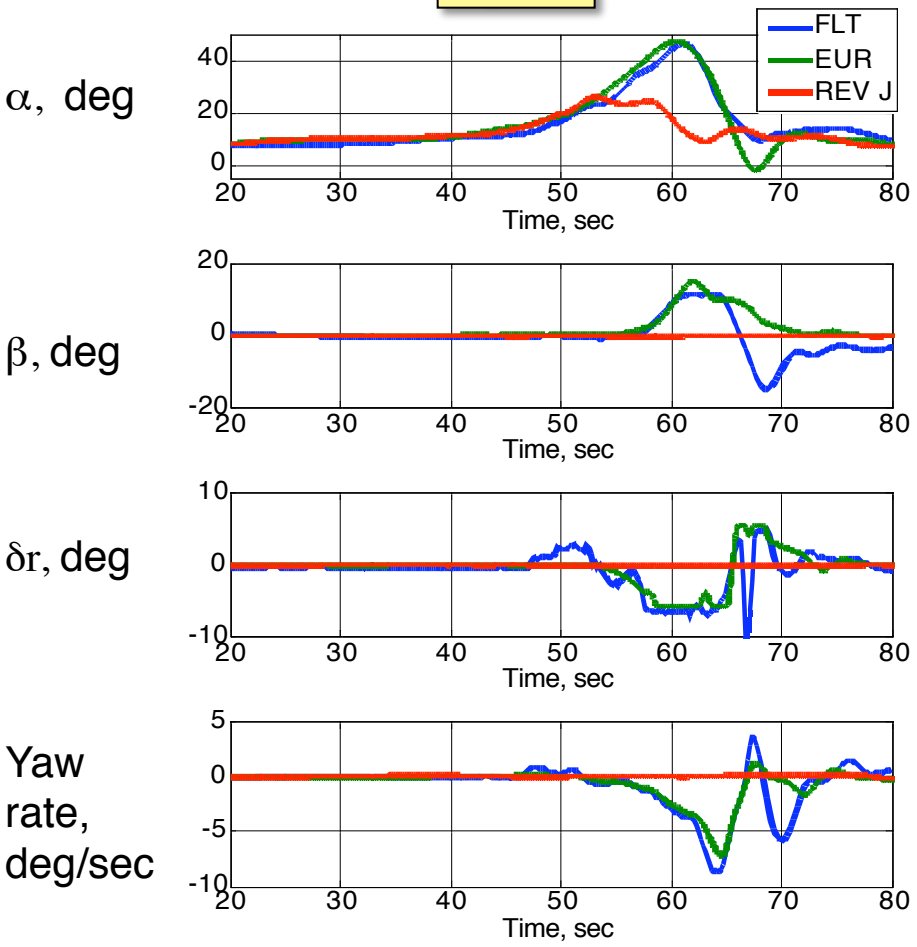


DAMAGE/FAILURE TESTING

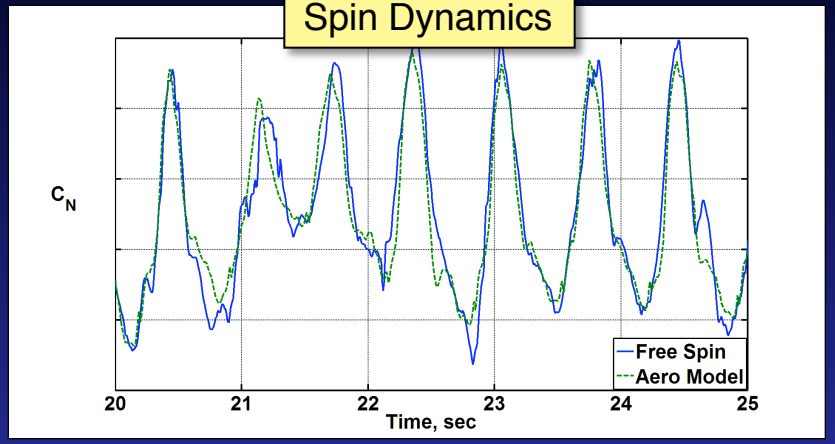


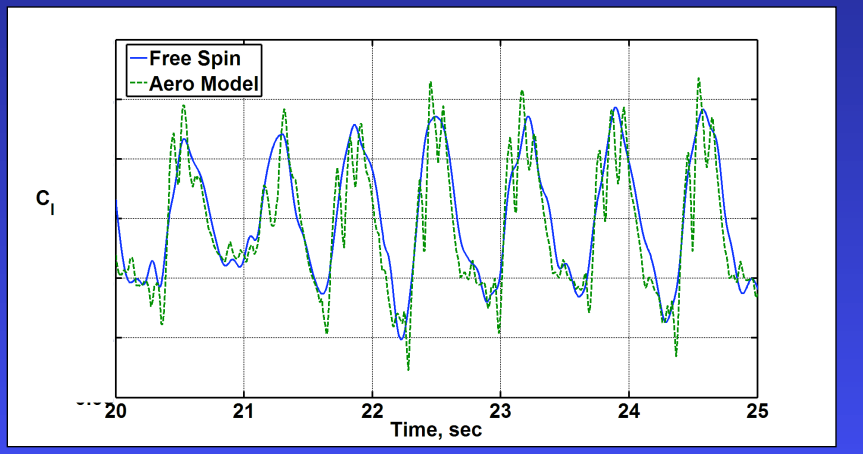
ADVANCED MODELING IMPROVES FIDELITY

1g stall

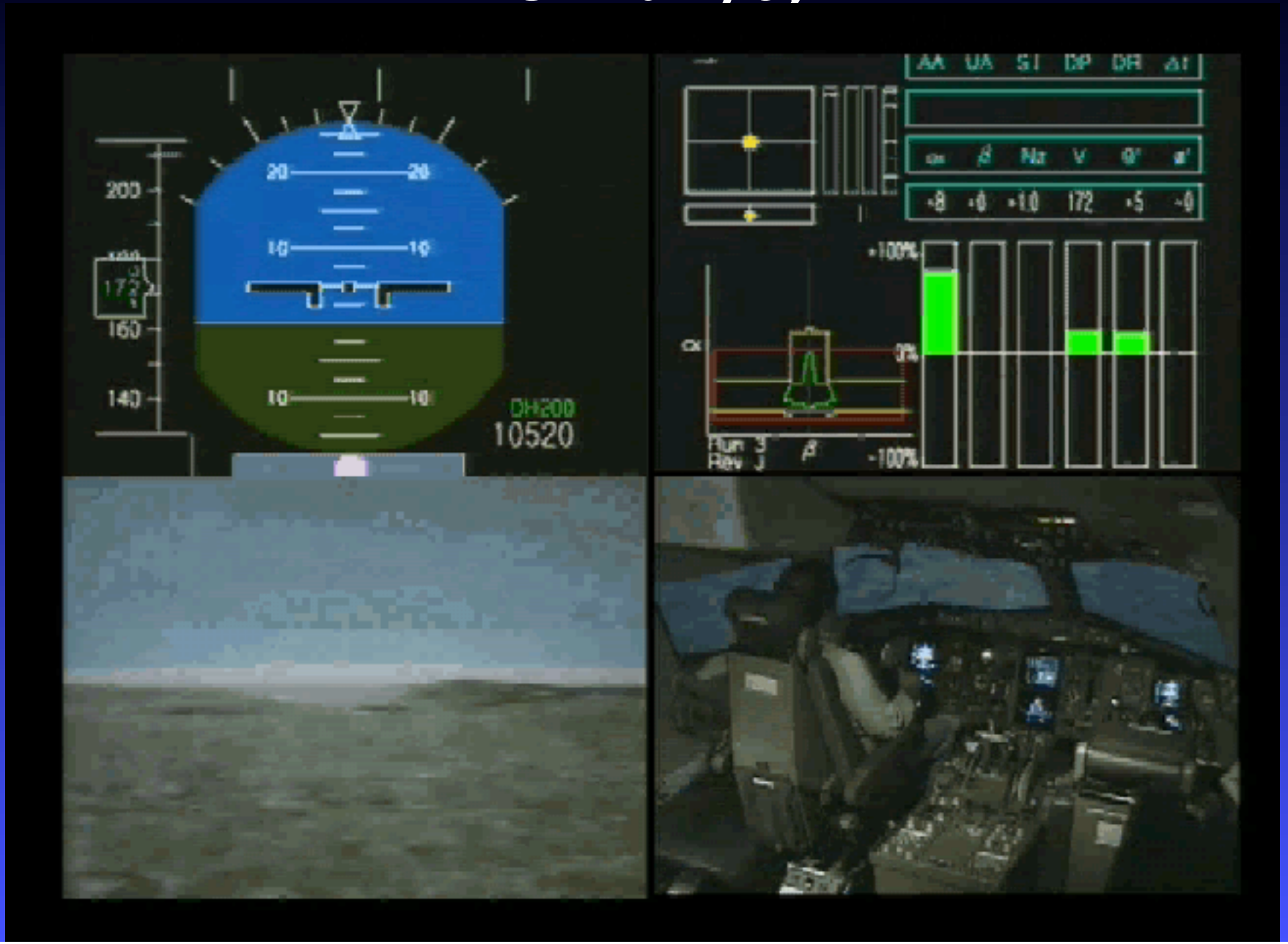


Spin Dynamics





BASELINE MODEL
NASA Langley IFD



ENHANCED MODEL

NASA Langley IFD

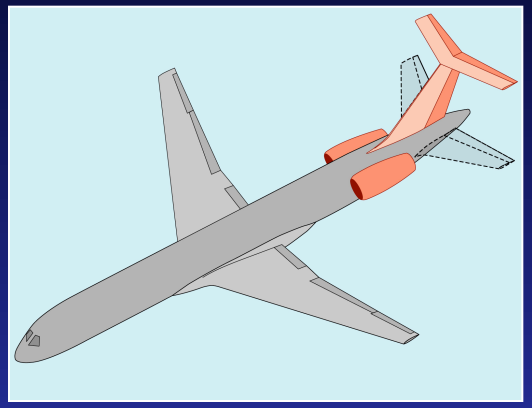


LESSONS LEARNED

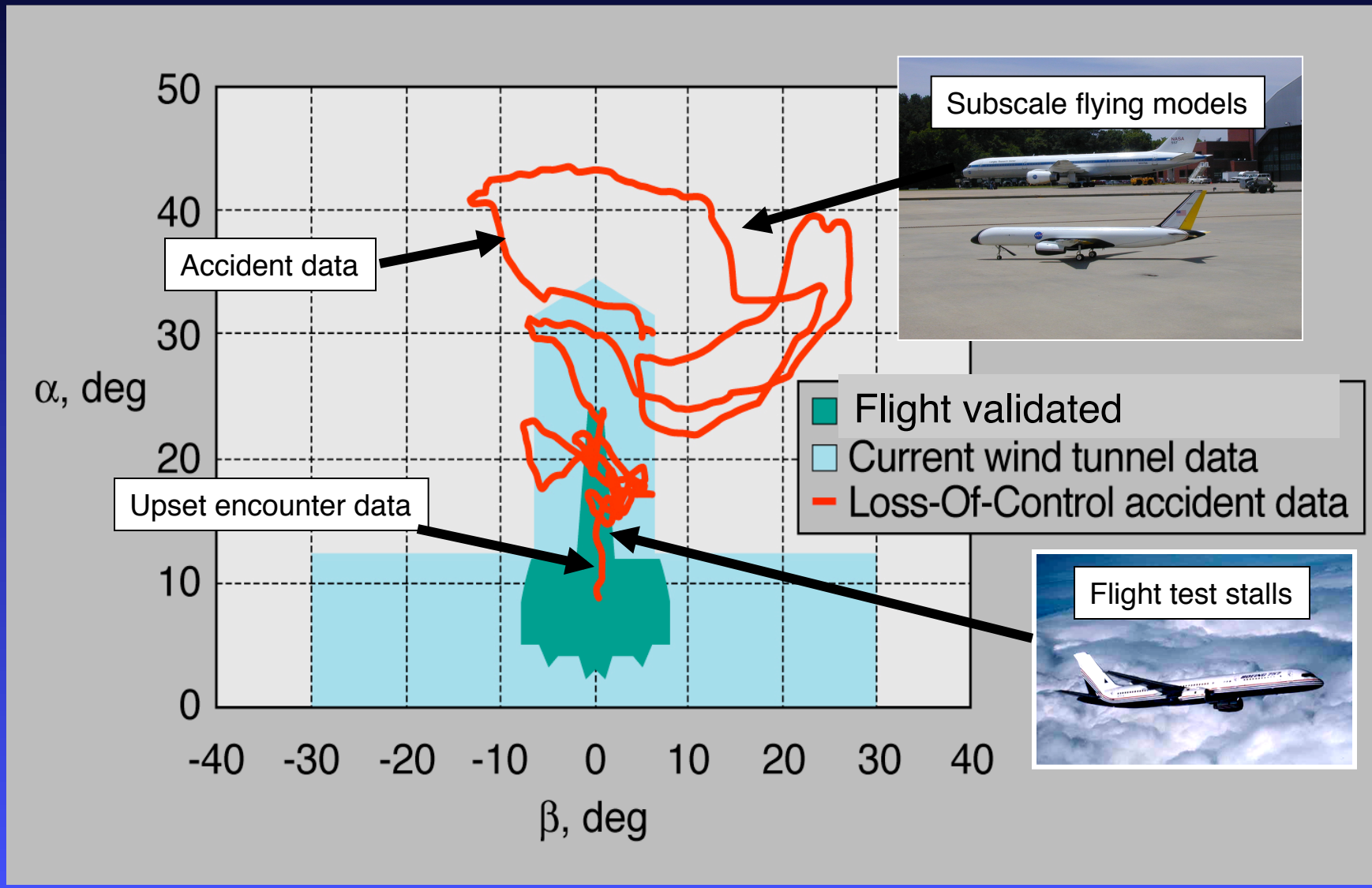
- Aerodynamic flow field is complex at high angles of attack
  - Nonlinearities can dominate
  - Aerodynamic asymmetries important (e.g. roll-off)
- Scaling effects remain an issue
  - Diminishes in separated flow
  - Modeling of flap effects is challenging
- Airframe damage/failure effects are measurable but complex
  - Non-linearities increased (e.g. directional effects)
  - Cross derivatives and mass asymmetries significant
- Important simulation features to be considered
  - Thrust characteristics during upsets
  - Control feel (including stall warning systems)
  - Noise and motion cues
- Existing simulations can be improved with existing methodologies

CHALLENGES

- Characterizing range of transport airframe configurations
  - Conventional vs T-tail
  - Engine configuration
  - Wing sweep
- Cost of acquiring experimental data
- Validation of upset models
  - Non-linear motions reduce ease of repeatability
  - May be driven by training requirements
- Modeling causal factors of upsets
  - Environment
  - Failures and damage
- Handling qualities and human factors issues



MODEL VALIDATION REMAINS A CHALLENGE



TRAINING NEEDS WILL INFLUENCE SIMULATION RESEARCH

- Modeling requirements for training may be unique
- Focus on database where training emphasized
  - Scenarios
- Flight dynamics fidelity
  - Generic or type-specific
- Motion effects
- Handling qualities influences



MOVING FORWARD

- Challenges should be addressed
- Important modeling issues remain
  - Further experimental-based testing needed
  - Integration of computational methods
- Use upset training requirements to help guide future upset modeling research
  - Define upset modeling envelope(s)
- Handling qualities issues should be addressed

Enabling research is in progress!



National Aeronautics and Space Administration

www.nasa.gov