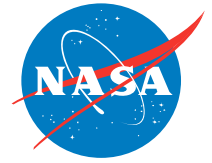


RECOMMENDATIONS FOR RULEMAKING

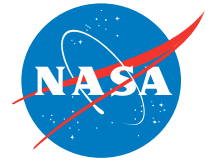
Presented to the
**Stick Pusher and Adverse Weather Training
Aviation Rulemaking Committee**
12-14 April, 2011

John V. Foster
NASA Langley Research Center



OUTLINE

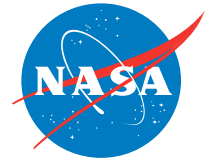
- NASA perspective on upset/stall training
- Risk reduction opportunity
- Simulation technology
- Integrated training benefits
- Future needs
- Recommendations
- Relevant publications



NASA ROLE IN UPSET TRAINING

- Aviation Safety Program(s)
 - AvSSP (2000 – 2005)
 - AvSAFE (2005-2010)
 - AvSP (2010-present)
- Technology development focused on loss-of-control accident prevention
- Technology provider via research, publications, databases and demonstrations
- Previous research portfolio has not included -
 - Training methodologies
 - Flight physiology

AVIATION SAFETY PROGRAM



System-Wide Safety Assurance Technologies (SSAT) Project

Provides knowledge, concepts and methods to proactively manage increasing complexity in the design and operation of vehicles and air transportation systems



Vehicle Systems Safety Technologies (VSST) Project

Provides knowledge, concepts and methods to *avoid, detect, mitigate and recover* from hazardous flight conditions, and to maintain vehicle airworthiness and health



Atmospheric Environment Safety Technologies (AEST) Project

Investigates sources of risk and provides technology needed to help ensure safe flight in and around atmospheric hazards



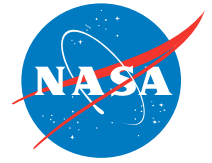
TECHNICAL CHALLENGES

- Assurance of Flight Critical Systems
- Discovery of Safety Issues
- Automation Design Tools
- Prognostic Algorithm Design
- Vehicle Health Assurance

- Crew-System Interactions and Decisions
- Loss of Control Prevention, Mitigation, and Recovery
- Engine Icing
- Airframe Icing
- Atmospheric Hazard Sensing & Mitigation

- Accident analysis to identify technology gaps
- Ground-based simulation technologies
- Flight dynamics and handling qualities
- Control system design

INVOLVEMENT IN UPSET TRAINING INITIATIVES

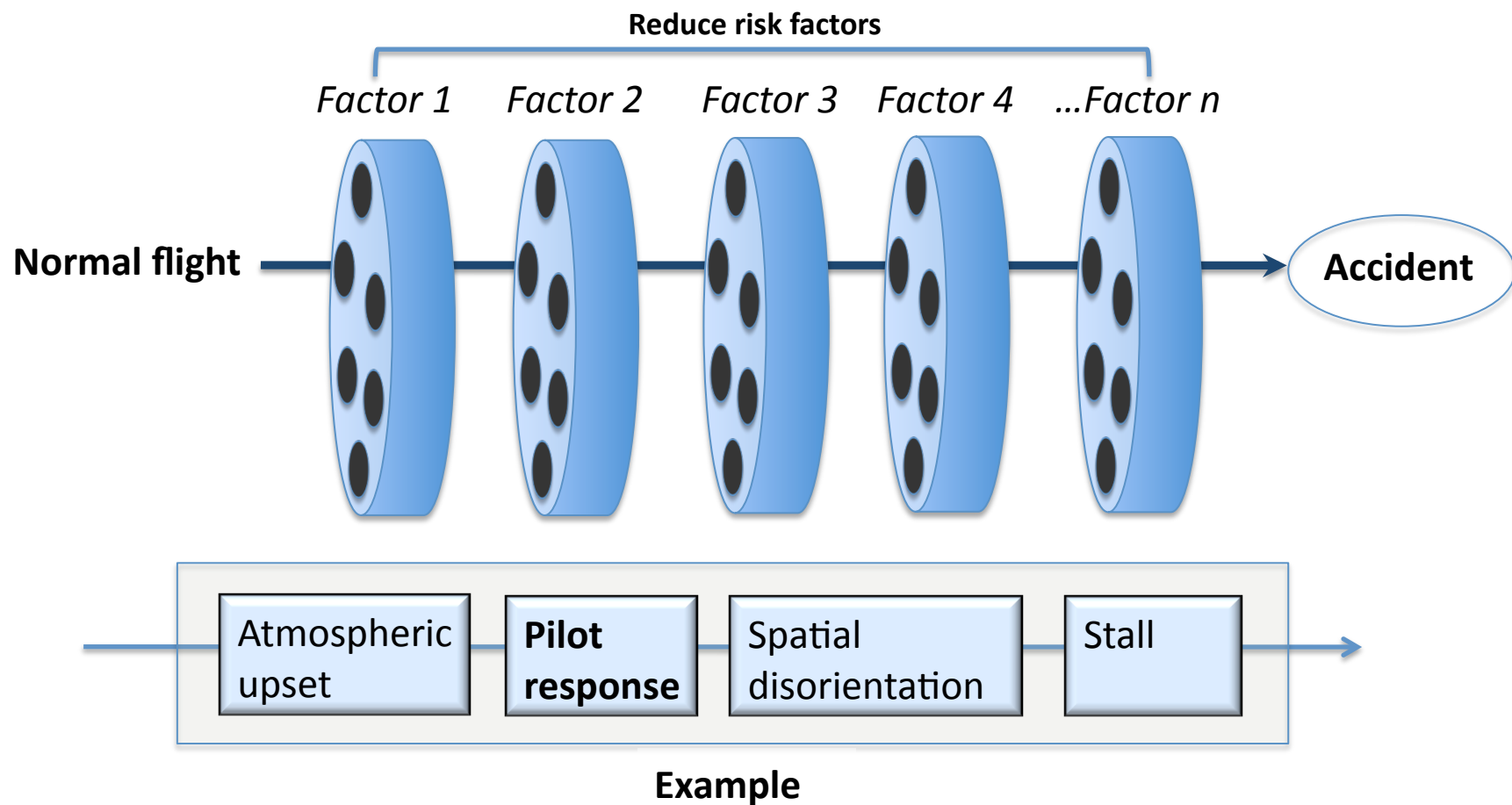


- Technical conferences addressing solutions related to loss-of-control accidents
 - NASA-sponsored invited sessions
 - Agency level program conferences
- Commercial Aviation Safety Team (CAST)
 - Identified simulation as an “intervention strategy”
 - Applications to training, control system design, accident analysis
- International Committee on Aviation Training in Extended Envelopes (ICATEE)
 - Training requirements
 - Simulation / flight implementation strategies
 - Looking ahead at R&T needs
- Simulation of Upset Recovery in Aviation (SUPRA)
 - Research driven
 - Filling in long-term technology gaps



ACCIDENT REDUCTION THROUGH RISK MITIGATION

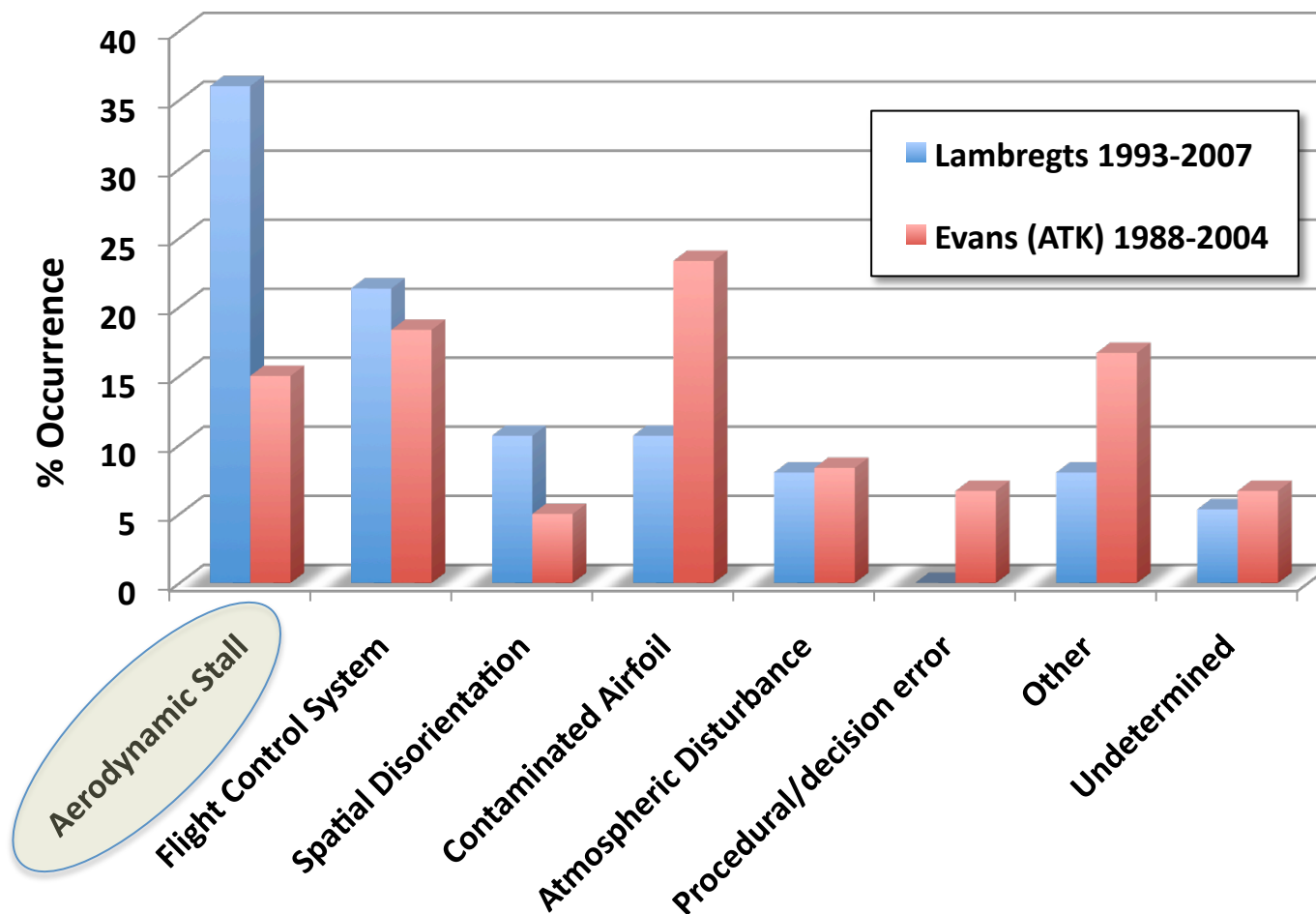
Research Strategy: Loss-of-control accidents have numerous causal factors and multiple intervention strategies are required



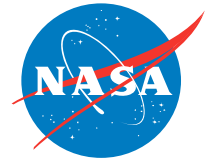


LOC ACCIDENT PRIMARY CAUSES

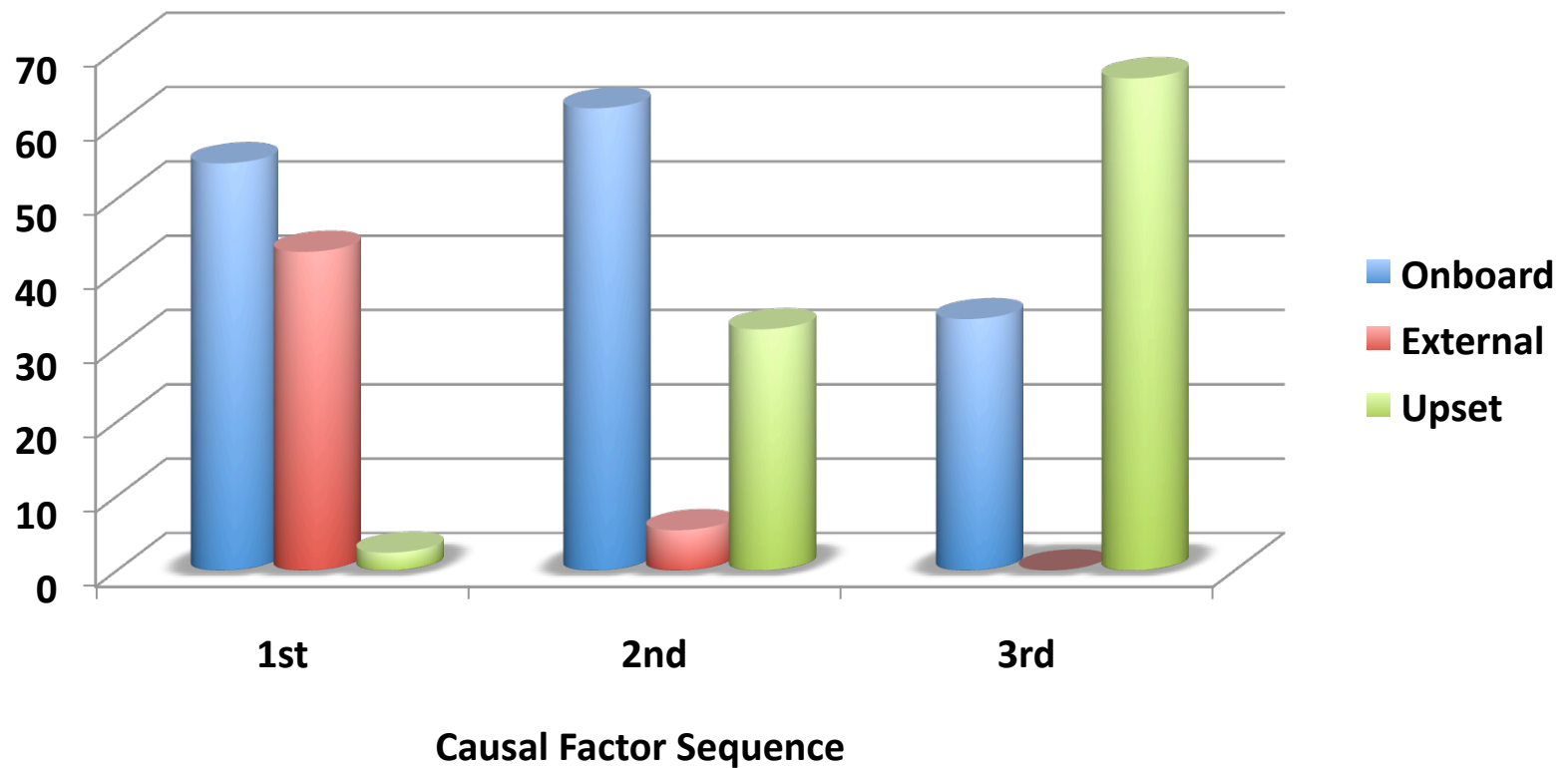
Part 121/135S



PART 121 LOC ACCIDENT SEQUENCES



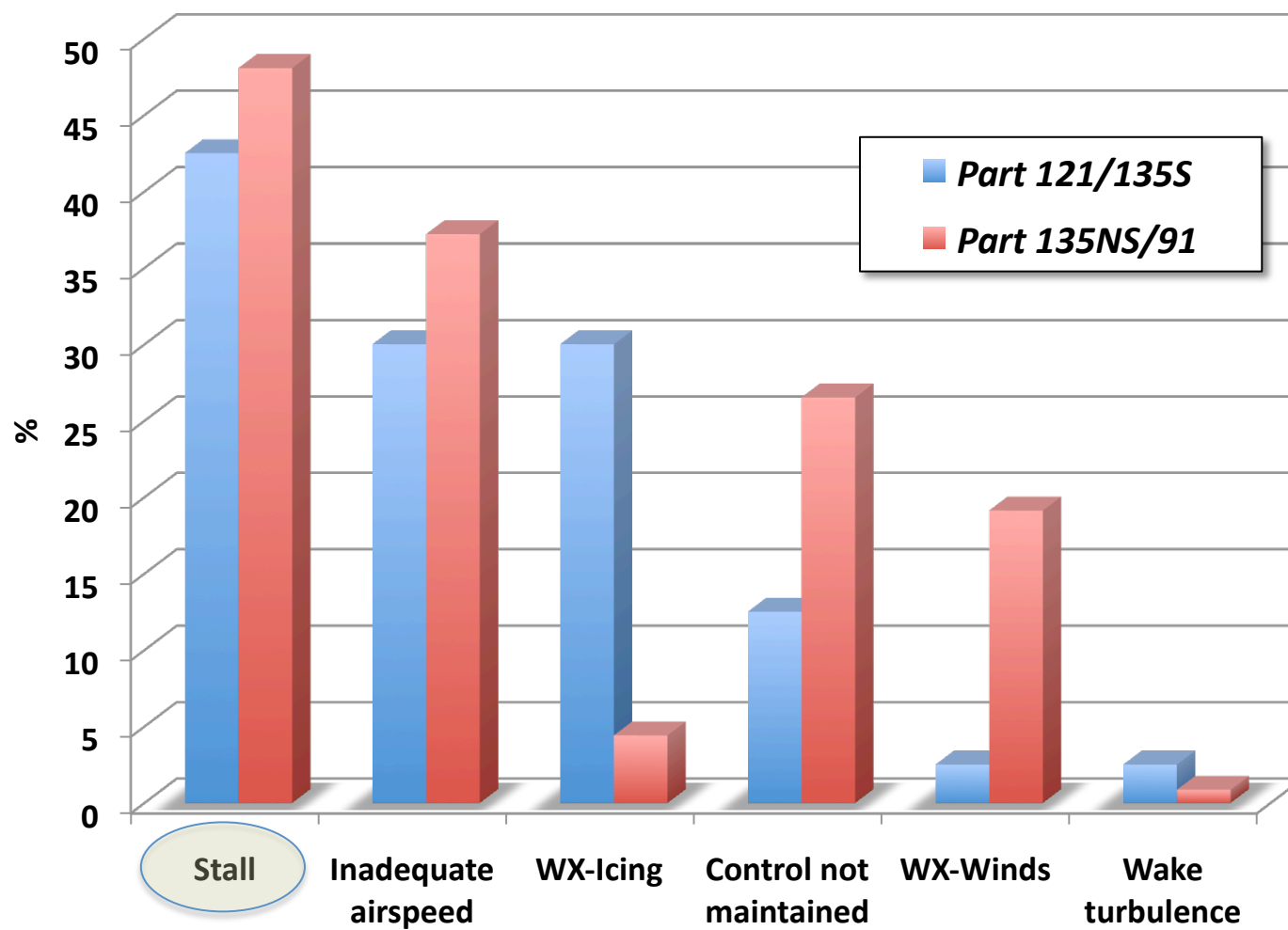
% Occurrence



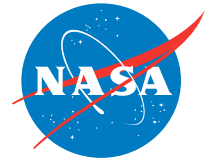
Source: Belcastro, et al; AIAA-2010-809429



CAUSAL FACTORS



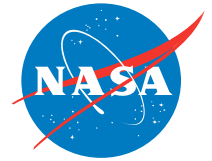
Source: ATK NNLO7AM99T



EXTERNAL FUNDED RESEARCH SIMULATOR TECHNOLOGY

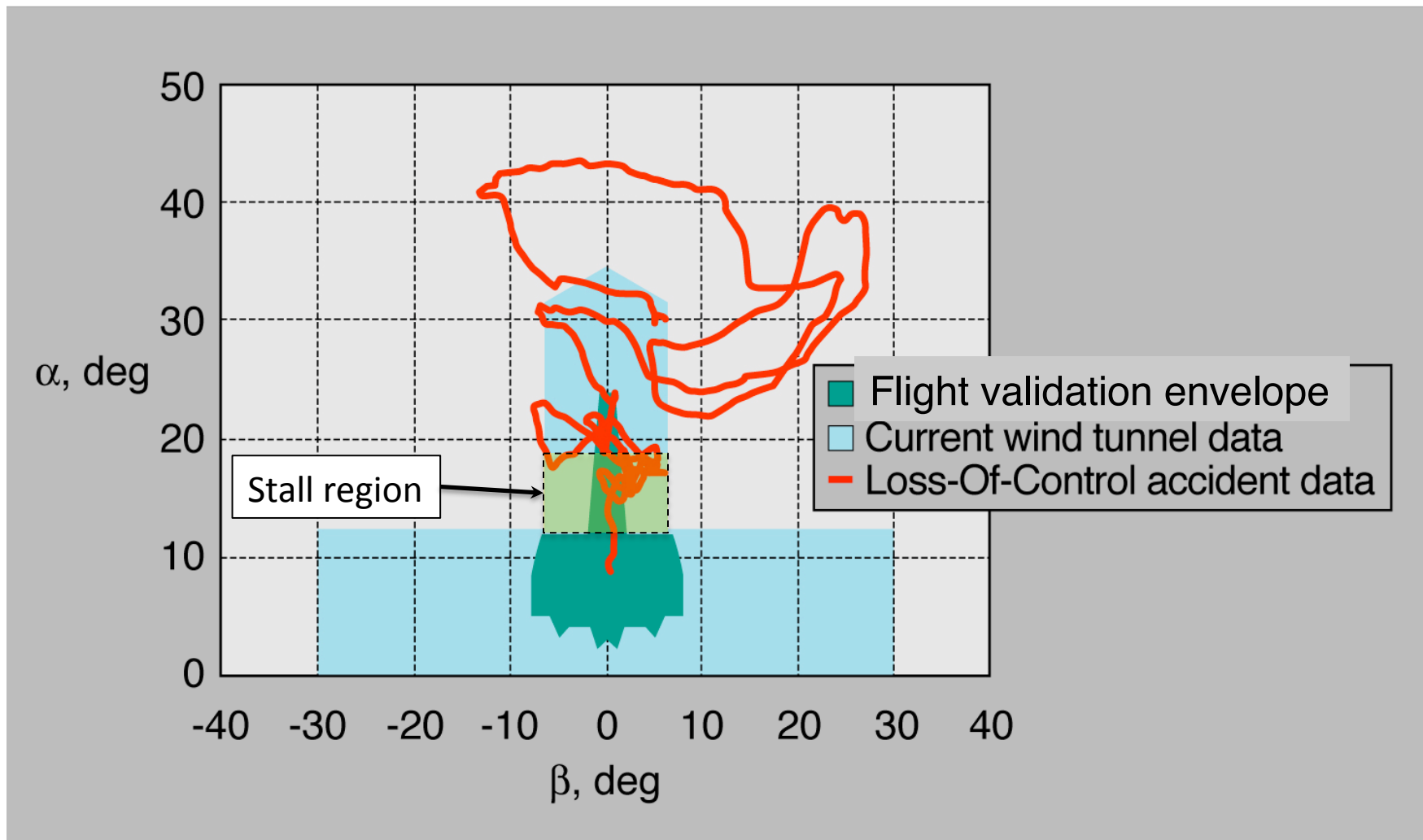
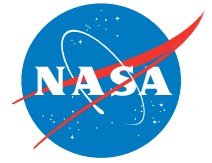
- Boeing
 - Aerodynamic modeling
 - Piloted handling qualities
- Environmental Tectonics (Congressional earmark)
 - Continuous-g motion system development
 - Training physiology
- CUBRC (Congressional earmark)
 - In-flight simulation
 - Currency requirements

R&D FOR AERODYNAMIC MODELING



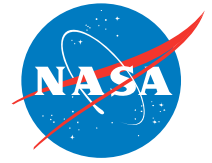
Category	60's	70's	80's	90's	2000
Military Fighter		Stall warning / spin training	High alpha airframe/controls technology		
Light GA		Spin resistant wing design	Stall awareness training		Envelope protection
Regional transport				Tail-plane Icing simulation	
Large transport			Envelope protection	Upset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

UPSET MODELING FOR TRANSPORTS



DATABASE DEVELOPMENT FOR HIGH AOA

Joint NASA/Boeing Partnership

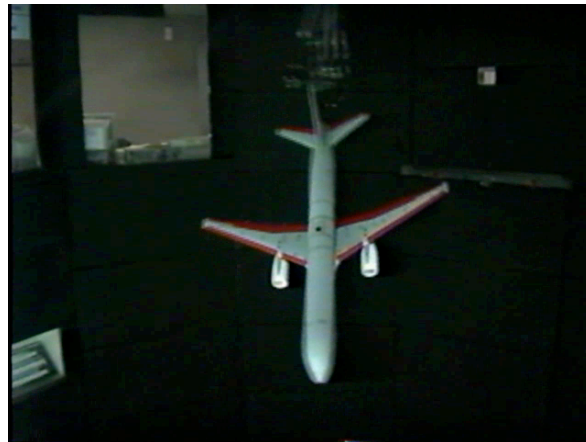


5.5% model on static mount
NASA LaRC 14x22 Ft Tunnel

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



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

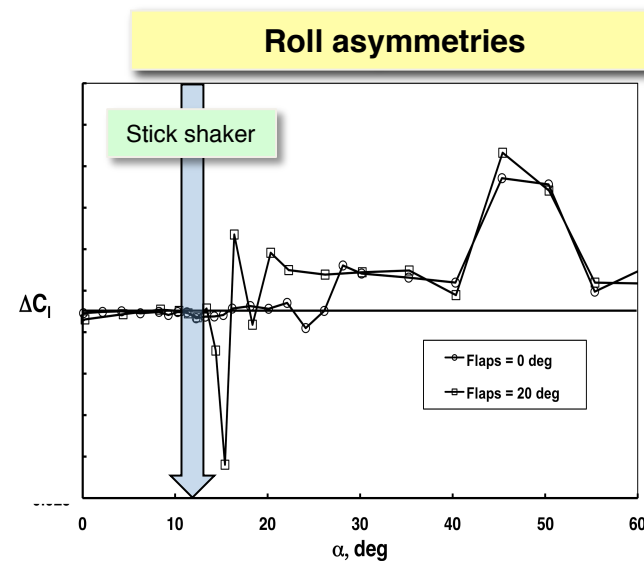
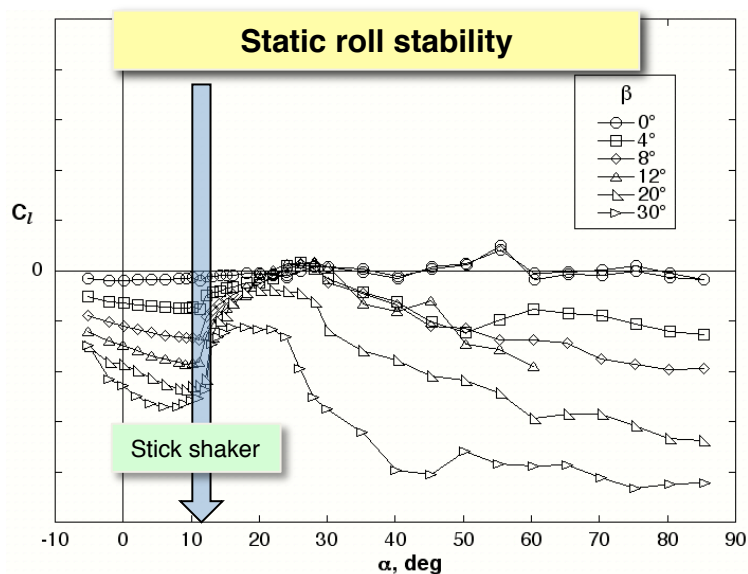
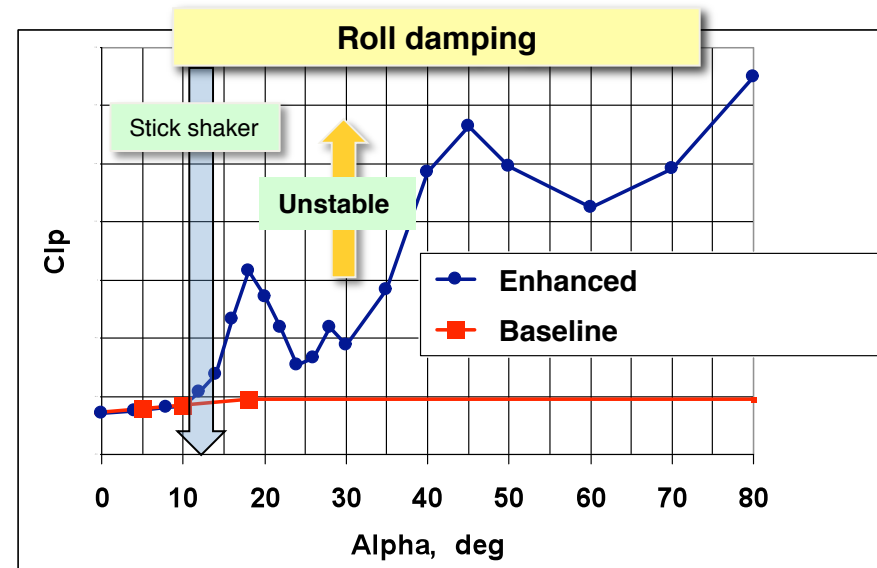
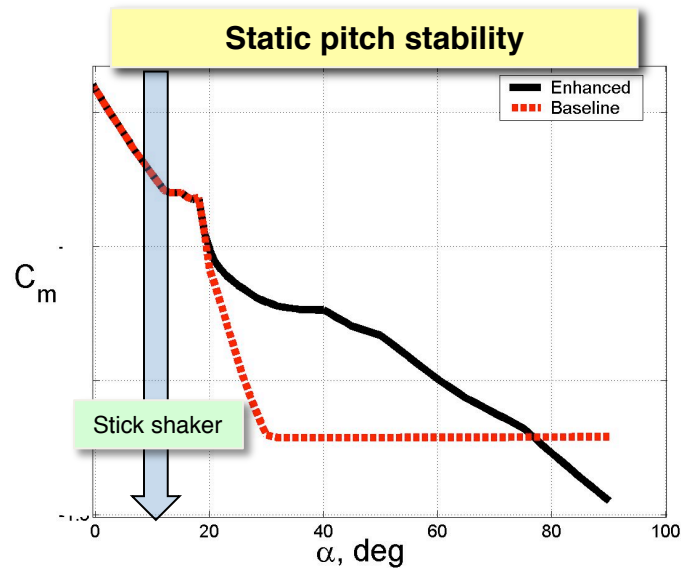
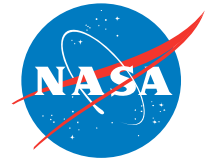


3.5% model on rotary balance rig
NASA LaRC 20 Ft Vertical Spin Tunnel



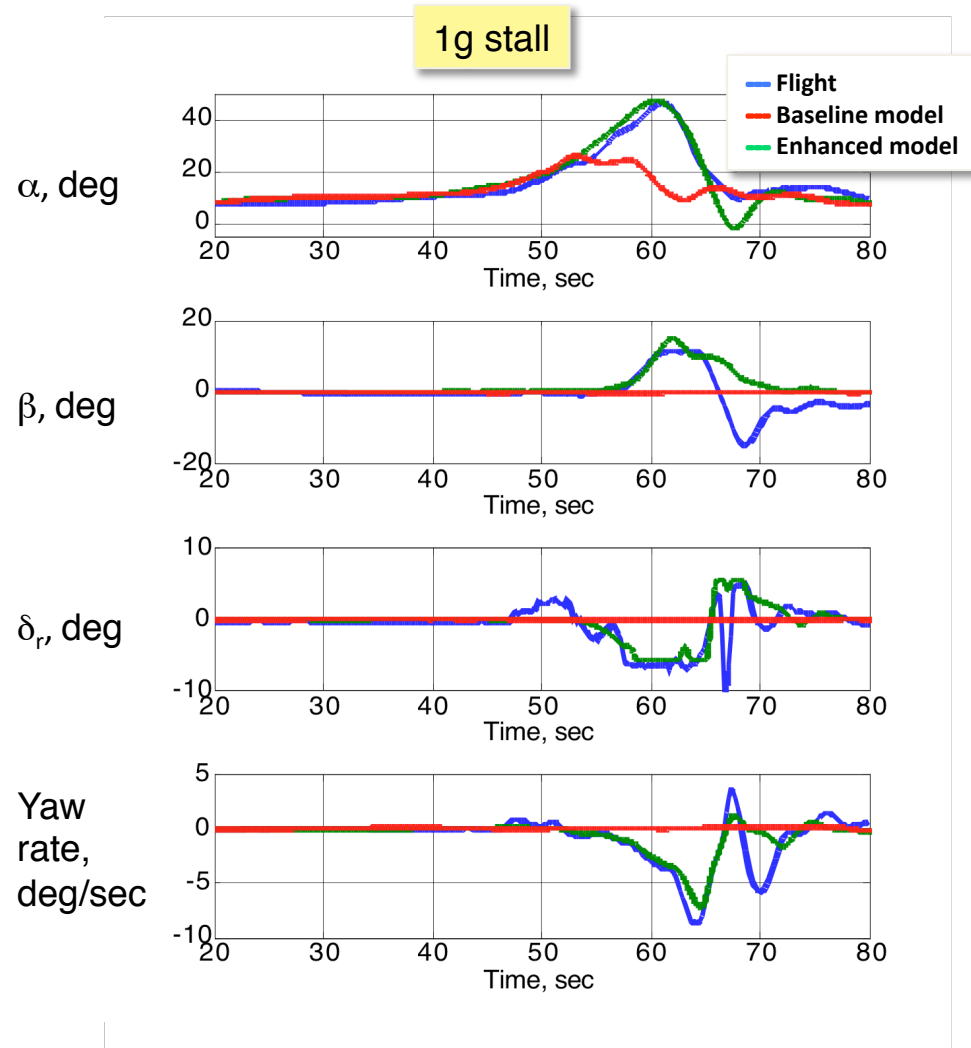
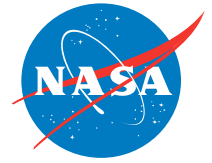
2% free-spin model
NASA LaRC 20-ft Vertical Spin Tunnel

IMPORTANT AERODYNAMIC CHARACTERISTICS FOR UPSET MODELING

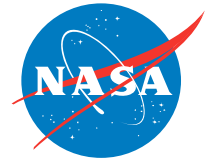


SIMULATION FIDELITY

CURRENT STATE-OF-THE-ART

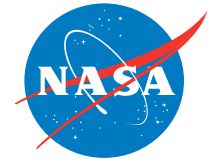


SIMULATION TECHNOLOGY FOR UPSET TRAINING

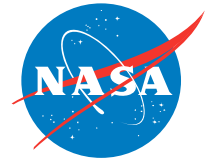


- Current training simulators provide very good fidelity up to first indication of stall
- URTA upset maneuvers can be conducted in current simulators
 - Potential to exceed database for certain cases
- A “representative” aerodynamic model provides important characteristics for stall training
 - Degradation in control effectiveness
 - Degradation in stability (all axes)
 - Apparent randomness
 - Stall roll-off
- Majority of proposed training maneuvers up to full stall can likely be conducted in current training simulators
- State-of-the-art aerodynamic modeling methods can be used to improve simulator fidelity for stall/post-stall conditions when required
 - “Generic” modeling approach may satisfy many of the modeling requirements
 - Availability of data is growing
- Benefits of simulator motion are promising but no consensus

TRAINING TECHNOLOGY INTEGRATION

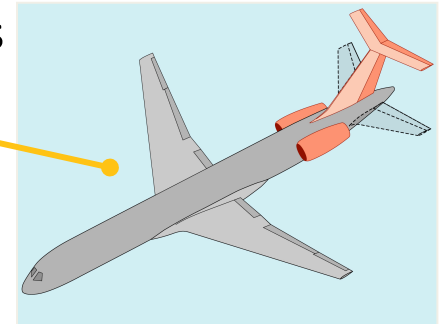


Purpose of Training	Method		
	Academic	Ground Simulation	Flight
Technical Awareness 		• Flight dynamics • Aerodynamics • Causal factors	
Muscle memory 		• Awareness of control forces • Handling qualities	
Visual Perception 		• Dynamic motions • Angle of attack and attitudes	
Motion Effects 		• Large amplitude maneuvers • Cockpit accelerations	

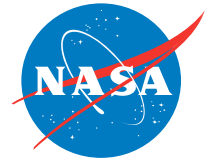


CURRENT/FUTURE NASA RESEARCH SUPPORTS STALL TRAINING

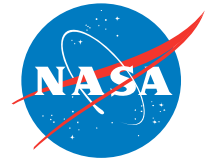
- Characterizing range of transport airframe configurations
 - Wing, tail, engine arrangement
 - Generic database development
- Model fidelity requirements
 - Address training needs
 - Generic models vs type specific
 - Cost of acquiring data
- Validation of models
 - Stall / post-stall behavior
 - “Non-linear” effects
- Human factors issues
 - Handling qualities
 - Simulator motion effects



SUMMARY AND RECOMMENDATIONS



- Implementation of effective upset training is likely to reduce the risk factor of inadvertent stalls; a common precursor to LOC accidents (applies to Part 121 and Part 135)
 - Increased awareness of precursors and risk factors
 - Improved manual handling skills
 - Emphasis on prevention
- There are no technical barriers to implementation of effective ground-based simulation for upset training
 - Modeling methods and data
 - “Representative” models suitable for training
 - Proposed certification methods (ICATEE)
 - Envelope monitoring recommended
- An integrated training approach is warranted
 - Comprehensive academic material
 - Ground-based piloted simulation with “representative” characteristics
 - In-flight training addresses limitations of simulators
 - The potential for “negative training” can be mitigated with qualified instructors
- Additional research and development recommended for future needs
 - Simulator motion
 - Generic modeling for stall conditions



RELEVANT NASA PUBLICATIONS

- Dynamics Modeling and Simulation of Large Transport Airplanes in Upset Conditions, AIAA-2005-5933, August 2005.
- Wind-Tunnel Investigation of Commercial Transport Aircraft Aerodynamics at Extreme Flight Conditions, SAE 2002-01-2912.
- Simulation Study of a Commercial Transport Airplane During Stall and Post-Stall Flight, SAE 2004-01-3100.
- Simulation Study of Flap Effects on a Commercial Transport Airplane in Upset Conditions, AIAA 2005-5908, August 2005.
- NASA Grant NNL06AA21G, Final Report, National AeroSpace Training and Research (NASTAR) Center, 23 Sep 2009.
- Defining Commercial Transport Loss-of-Control: A Quantitative Approach, AIAA-2004-4811-776, August 2004.

