SIS II Future Research: Envelope Protection Research

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Envelope Protection Summary

- Linear and nonlinear aircraft S and C models and EP simulation capabilities developed
- Open loop and closed loop methodologies developed
- Longitudinal envelope critical parameters set based on correlation from airfoil data
- Simulations show good performance

Envelope Protection Challenges

- Human factors issues for the open loop case have not been addressed
- Open loop method needs more sophisticated implementation
- Closed loop method needs further testing with nonlinear aero model
- Method for setting the critical parameters (envelope boundaries) needs major improvements to provide accurate and reliable protection

Future EP Research

Goal Provide accurate envelope protection in real time

Objective Develop a better method to characterize the aircraft state including the aerodynamics

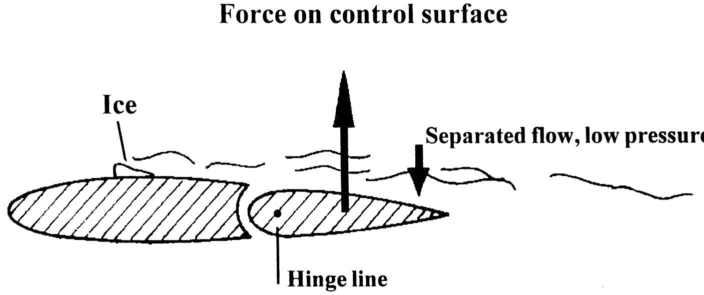
Determine the edges of the envelope as a function of aircraft configuration and the icing condition

Approach 1. Evaluate aerodynamic performance monitors and other sensors and techniques for iced aircraft characterization through wind tunnel and flight test

2. Develop sensor fusion techniques to combine several different kinds of data, including data vs time or aircraft state, to determine the edges of the envelope

1. Aerodynamic Sensors

- SIS characterized icing using stability and control data and trim data

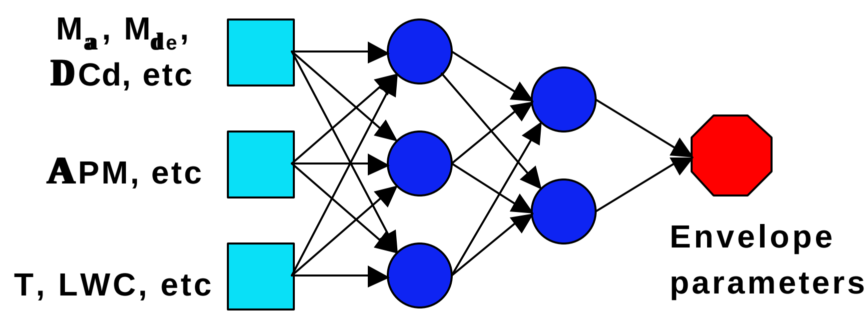


- In this study explore the use of aerodynamic sensors to predict the flow separation that sets envelope boundaries for aircraft in icing conditions
- Examine techniques such as UIUC C_h sensor, APM pressure-based methods, and potentially other concepts

- Conduct wind tunnel tests and examine existing data to prepare for a Twin Otter flight test program
- Test aerodynamic stall/separation detection sensor methods in flight with simulated shapes or natural icing

2. Flight Envelope Prediction

- Focus on longitudinal envelope bounds due to aircraft stall and loss of longitudinal control (tail stall)
- Conduct sensitivity studies based on data gathered in part 1 to identify the most promising sensors
- Gather flight data to edge of envelope to acquire a realistic data set for method development
- Develop envelope limit prediction method incorporating key aircraft and icing data. Flight test if possible in natural conditions.



SIS II Future Research:
Envelope Protection and Robust Autopilot Operation

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Research Topics

- Full scale analysis of traditional EP/AP schemes for safe operation in icing conditions
- Development of new, more adaptive and more robust EP/AP techniques
- Analysis and development of EP/AP schemes in single and multiple UAVs flying in icing conditions

Full scale analysis of traditional EP/AP

- Initial study showed that the operation of standard PAH schemes is safe provided that an appropriate EP module is active
- Lateral EP schemes that limit lateral critical variables in coordination with RAH need to be analyzed
- Implementation and testing of the entire EP/AP scheme based on 6-dof reliable nonlinear iced-models to provide confidence in utilizing the EP/AP modules

Robustness and Combined EP/AP Adaptation

- Current analysis of EP and AP modules assumes ice-characterization is accurate. Need to investigate robustness to erroneous estimates of ice accretion

- Currently only EP module adapts pilot inputs to the system. Gain adaptation of the AP itself can provide extra performance, robustness and safety within the varying envelope

UAVs

- UAVs susceptible to icing
- Effectiveness and robustness to icing of AP systems need to be analyzed
- Distributed control architectures for UAV formations in icing conditions need to be analyzed

SIS II - Future Research:
Cognitive Engineering

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Cognitive Engineering: Summary

- Pilot survey was conducted to identify critical icing situations and crew's information requirements
- Various IMS interface components and functions were developed:
  - attention capture/guidance
  - visual and tactile status display
  - decision support
  - system confidence/trust calibration
  - envelope protection
- These display elements were shown to be effective in supporting pilots in detecting/handling icing encounters

Cognitive Engineering: Challenges

- Some IMS interface components (e.g., IMS/IPS information, envelope protection) have not been tested
- Other IMS interface components (attention capture and guidance, decision support) have been tested individually
- Testing has occurred in the context of a medium-fidelity simulation
- Main focus has been on problem of sudden rapid ice accretion and performance effects

Cognitive Engineering: Proposed Research

- Design and testing of envelope protection indications, including aspect of confidence and shifts in control authority
- Conduct operational evaluation of overall SIS concept to ensure robustness of design
  - Higher-fidelity full-mission simulation study
  - Airline pilots as participants
  - Both sudden onsets and slowly developing ice accretion
  - Include wide range of competing attentional demands

SIS II Future Research: Flight Simulation

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Flight Sim Research - Summary

- We developed a real-time Icing Encounter Flight Simulator (IEFS) that incorporates key SIS technology. This infrastructure is a tremendous resource that should be further exploited.
- IMS functions are integrated into the framework and interact with the pilot through an OTW-view / glass-cockpit environment with tactile and auditory cues.
- The simulator is based on PC technology (low-cost) and open-source software (free).
- It is reconfigurable.
- The IEFS has been used in icing scenarios that were recorded to DVD to demonstrate the potential advantages of SIS technology in the cockpit.

Flight Sim Research - Challenges

- The flight dynamics model and icing model applied specifically to the DHC-6 Twin Otter. A range of aircraft should be considered from General Aviation to Commuter Jets.
- Asymmetric ice shedding / stall should be modeled.
- The icing characterization algorithm is one component of a potential smart icing system. Other data collection approaches could augment this approach, e.g. individual sensors and existing flight data recorder information (previously mentioned).
- Several of the human-factors glass-cockpit elements that were featured in the DVD remain untested.

Flight Sim Research - SIS II

Proposed Research:

- Develop a methodology for synthesizing aircraft flight dynamics models, including nonlinear aerodynamics and post-stall effects on a lifting-surface component basis.
- Include in the approach a model for characterizing asymmetrical icing effects and consequently stall-spin.
- Create new flight models to exercise the method.
- Incorporate “edge-of-the-envelope” detection sensors and data into the flight simulator for testing the new “SIS-II” functionality in real-time
- Support testing of these new SIS cockpit interfaces.
- Collaborate in the SIS Demonstration Project

SIS II Future Research: Demonstration Project

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SIS System Challenges

- System ID in turbulence must be enhanced or alternative characterization approach developed
- Improved envelope protection critical parameter determination needed
- Application to other aircraft needed
- SIS system needs a focused flight demonstration

Demonstration Project Introduction

- Current SIS program took a systems approach to problem while developing some key technology
- SIS program was a technology development program. TRL up to 4 (Component and/or breadboard validation in laboratory environment)
- Need to continue system development with flight demonstration project to TRL 6 or 7 (6. System/subsystem model or prototype demonstration in relevant environment; 7. System prototype demonstration in an operational environment.)

Project Plan

- Propose a university/industry/government partnership
- Possible steps:
  - Determine subset of SIS features/functions that are desirable
  - Identify appropriate aircraft platform
  - Develop detailed program plan
  - Perform necessary method development research
  - Design/build necessary hardware and software
  - Develop/test system components
  - Conduct validation flight testing

Possible Project Scenarios

- Government/Industry/University consortium
  – Research focus with NASA/industry funding
  – Applied research with military or other funding
- Industry proprietary program (university participation?)
- Industry/university program with NSF funding (GOALI program) with possible NASA role