Flight Simulation

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SMART ICING SYSTEMS
Research Organization

Smart Icing Systems Review, May 28, 2003

Core Technologies

- Aerodynamics and Propulsion
- Flight Mechanics
- Control and Sensor Integration
- Human Factors
- Aircraft Icing Technology

IMS Functions

- Characterize Icing Effects
- Operate and Monitor IPS
- Envelope Protection
- Adaptive Control

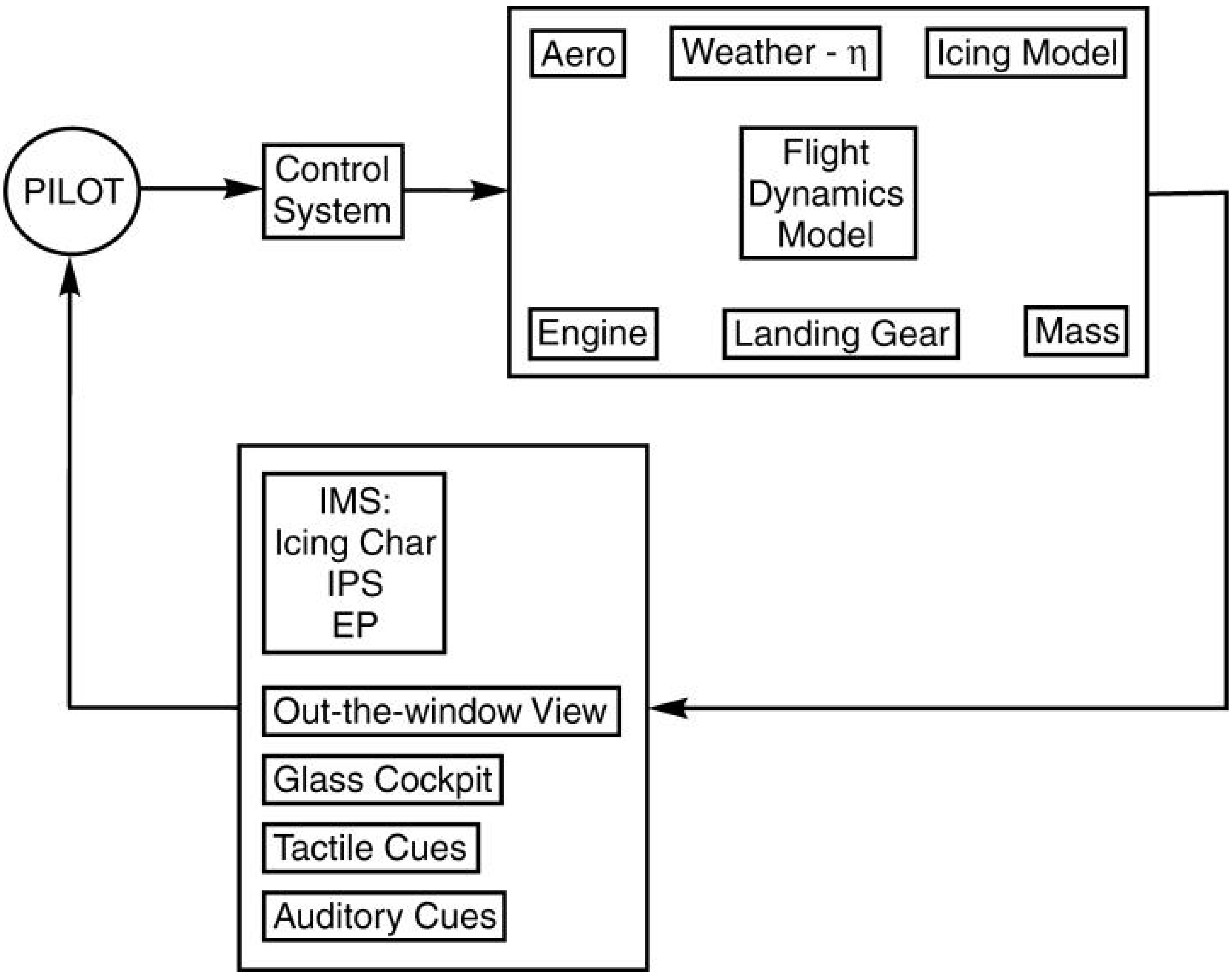
System Research/Integration

- Flight Simulation
- Flight Test

Flight Simulation

- Objectives:
  - Function as a systems integrator by bringing together the various flight simulator components: flight mechanics, aircraft model (weights, aerodynamics, propulsion, etc), controls, glass cockpit, scenery, and the Smart Icing System (Sensors, Ice Protection System, Envelope Protection System, and interfaces)
  - Demonstrate the functionality of the Smart Icing System and its potential benefit in the cockpit
- Approach:
  - Develop an Icing Encounter Flight Simulator (IEFS)
  - Apply the simulator to icing scenarios for demonstration

IEFS – Simple Representation



Aerodynamics Model - Twin Otter

- Nonlinear model
- Lookup tables for all aero coefficients
- In body axis
- 3D interpolation
- Data usage follows

Aerodynamics Model - Twin Otter

- Component build-up

$$C_Z = C_Z^*(a, b) + \Delta C_Z^*(a, d_e) + \Delta C_Z^*(a, q)$$

$$C_X = C_X^*(a, b) + \Delta C_X^*(a, d_e) + \Delta C_X^*(a, q)$$

$$C_m = C_m^*(a, b) + \Delta C_m^*(a, d_e) + \Delta C_m^*(a, q)$$

$$C_Y = C_Y^*(a, b) + \Delta C_Y^*(a, d_a) + \Delta C_Y(a, d_r) + \Delta C_Y^*(a, p) + \Delta C_Y^\dagger(a, r)$$

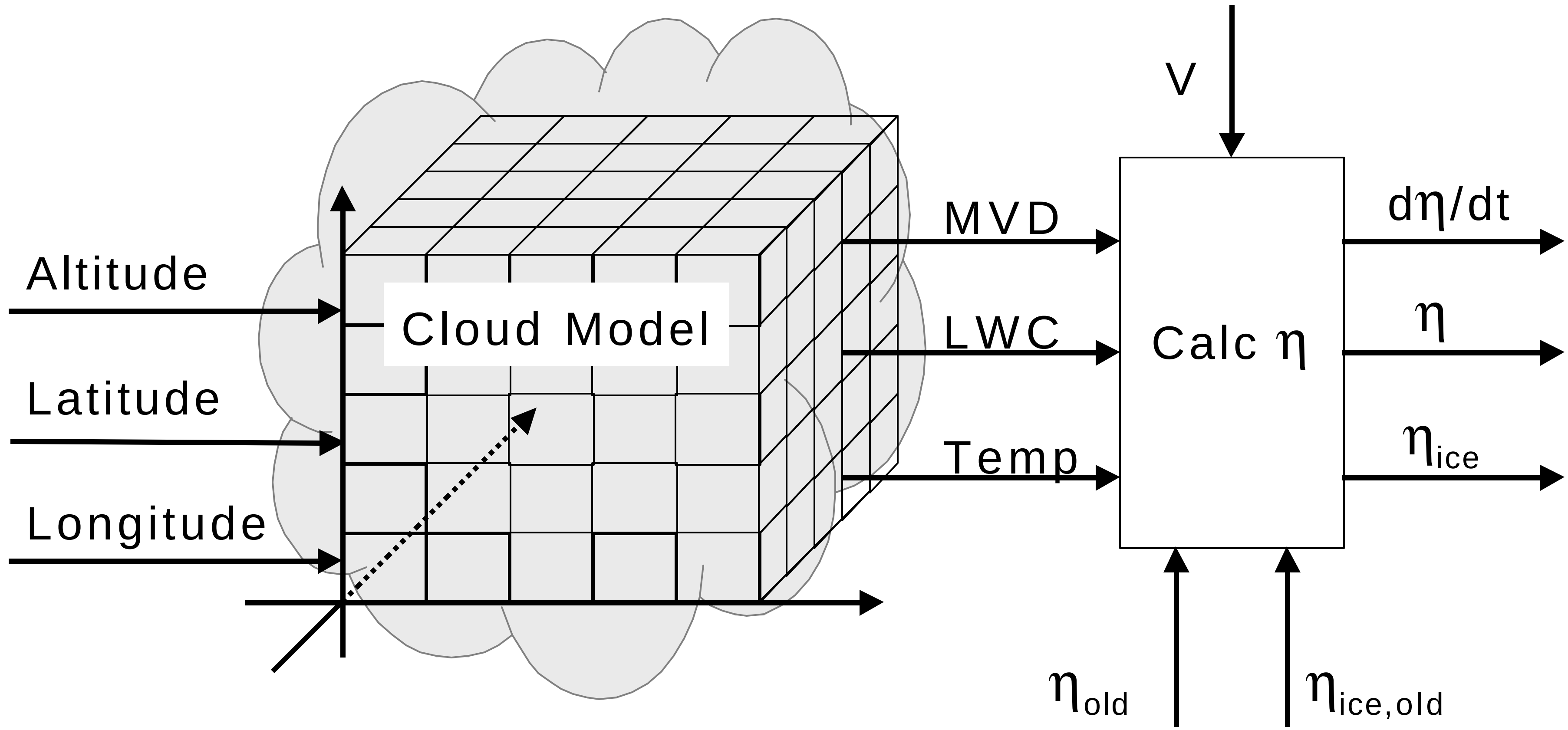
$$C_l = C_l^*(a, b) + \Delta C_l^*(a, d_a) + \Delta C_l(a, d_r) + \Delta C_l^*(a, p) + \Delta C_l^\dagger(a, r)$$

$$C_n = C_n^*(a, b) + \Delta C_n^*(a, d_a) + \Delta C_n(a, d_r) + \Delta C_n^*(a, p) + \Delta C_n^\dagger(a, r)$$

* function of flap (0, 20, 40 deg)

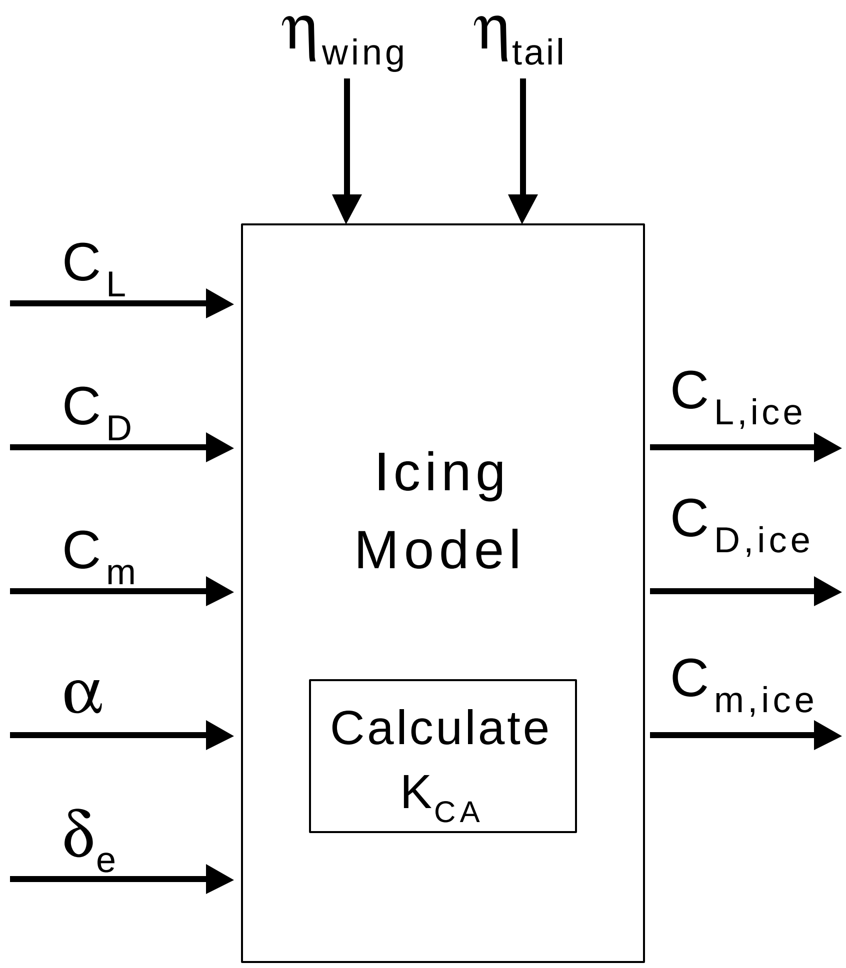
† function of flap (0, 40 deg)

Weather Model



- Also used as an “icing characterization” surrogate

Longitudinal Icing Model

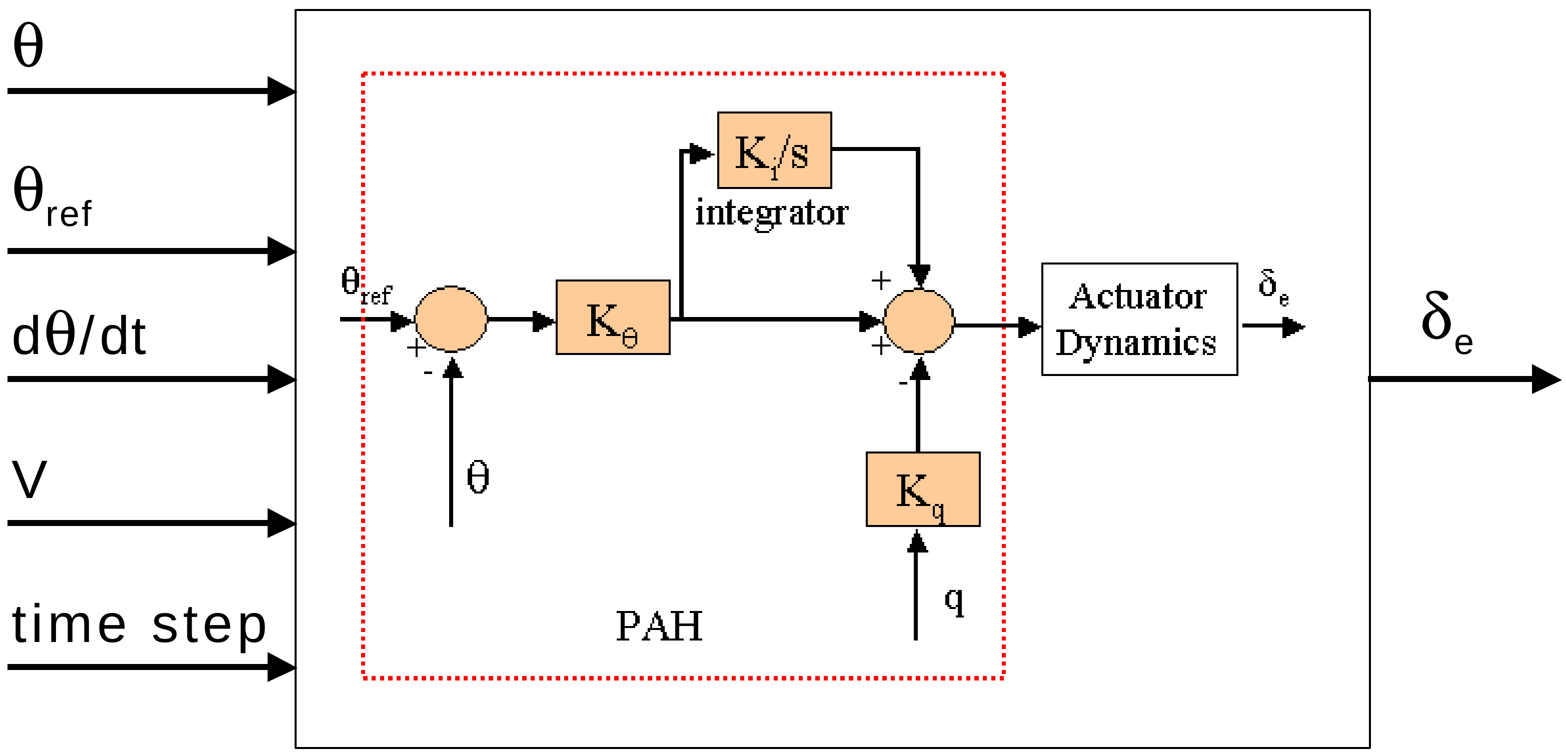


More Models and Parameters

- Simple engine model
- Ground reactions (landing gear) model
- Mass data
- Control deflection limits

Autopilot - PAH

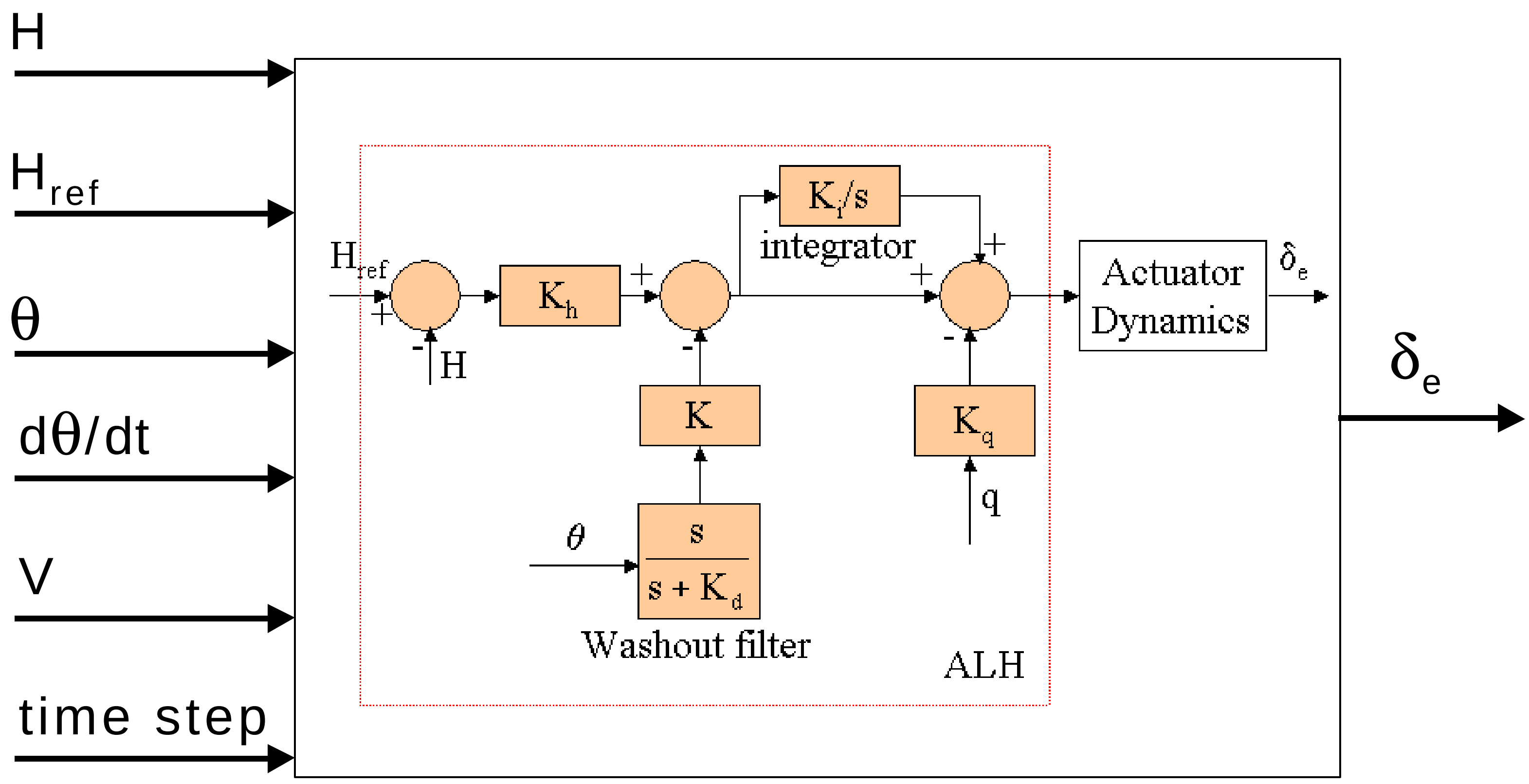
- Pitch Attitude Hold Autopilot



Airspeed V is used to set the gains.

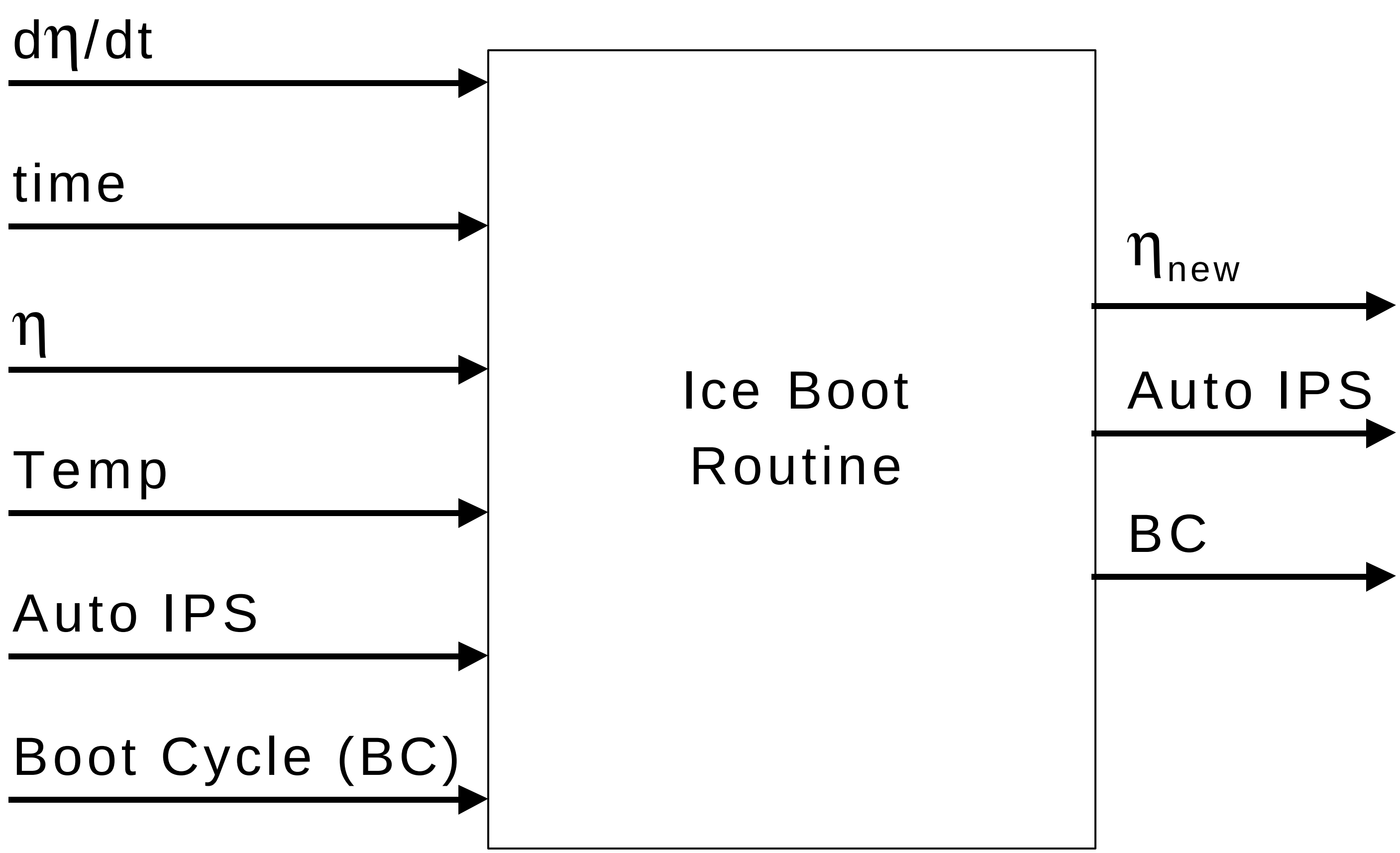
Autopilot - ALH

- Altitude Hold Autopilot



Airspeed V is used to set the gains.

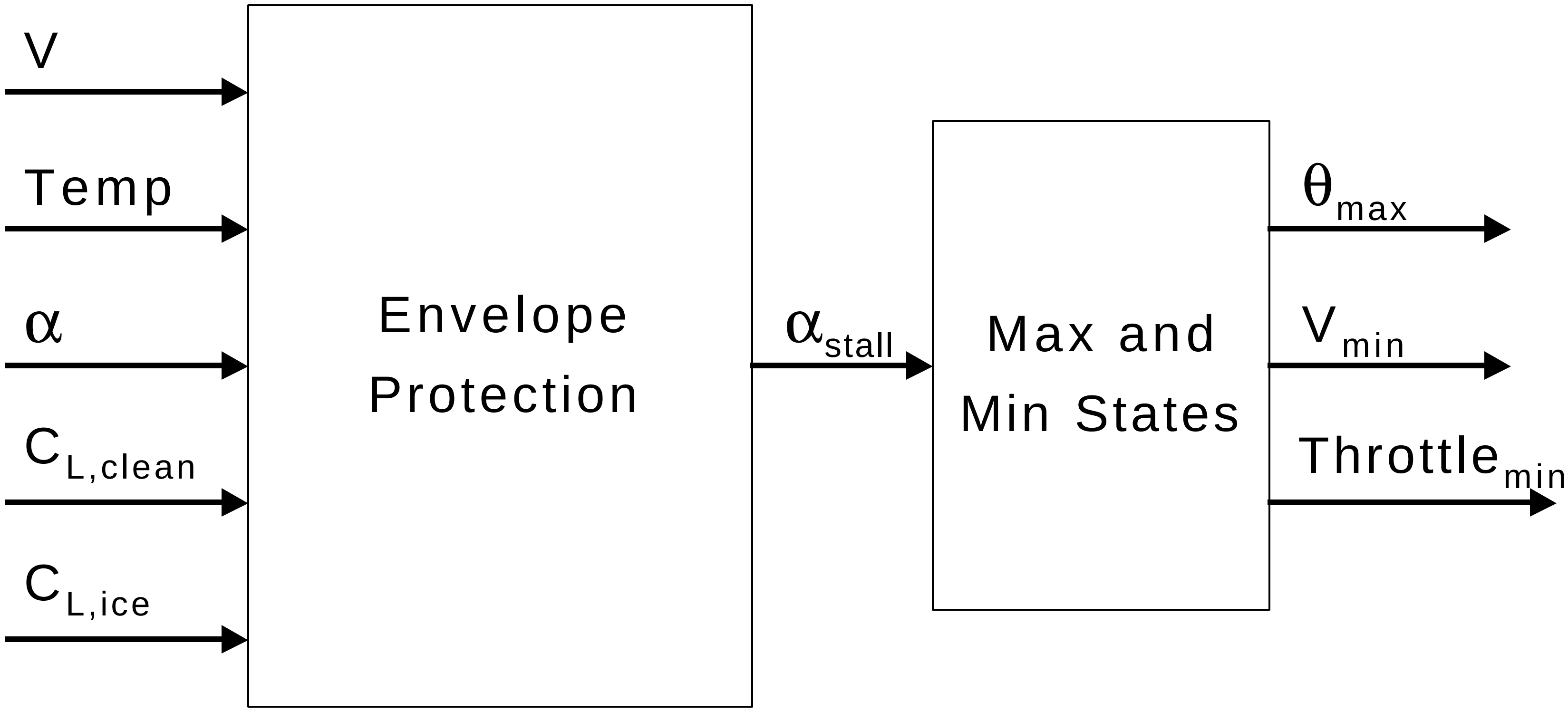
Ice Protection System



BC = 0, off unless overide
BC = 1, 1-min cycle
BC = 3, 3-min cycle
BC = -1, failure

Envelope Protection

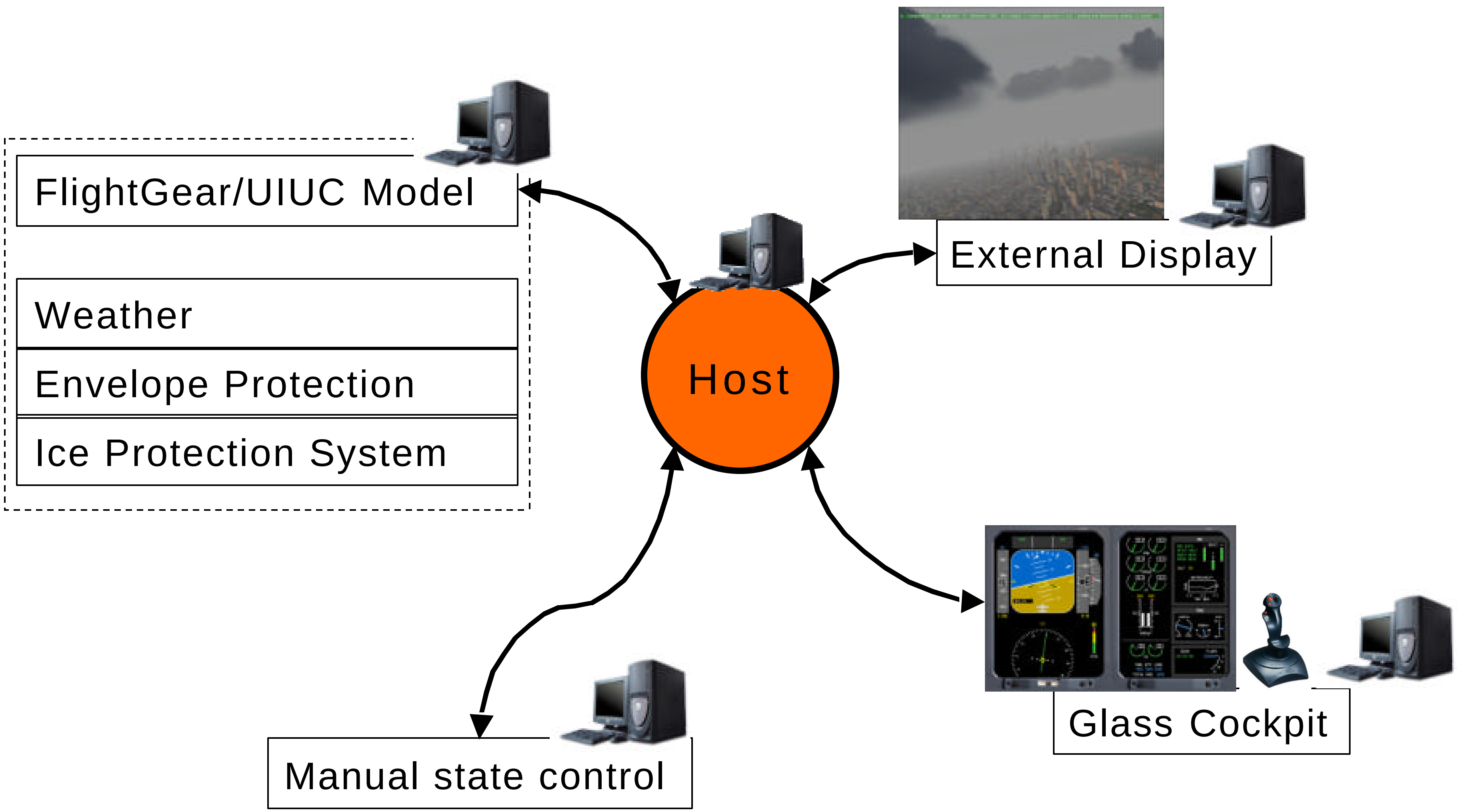
- Longitudinal Model – 0th order



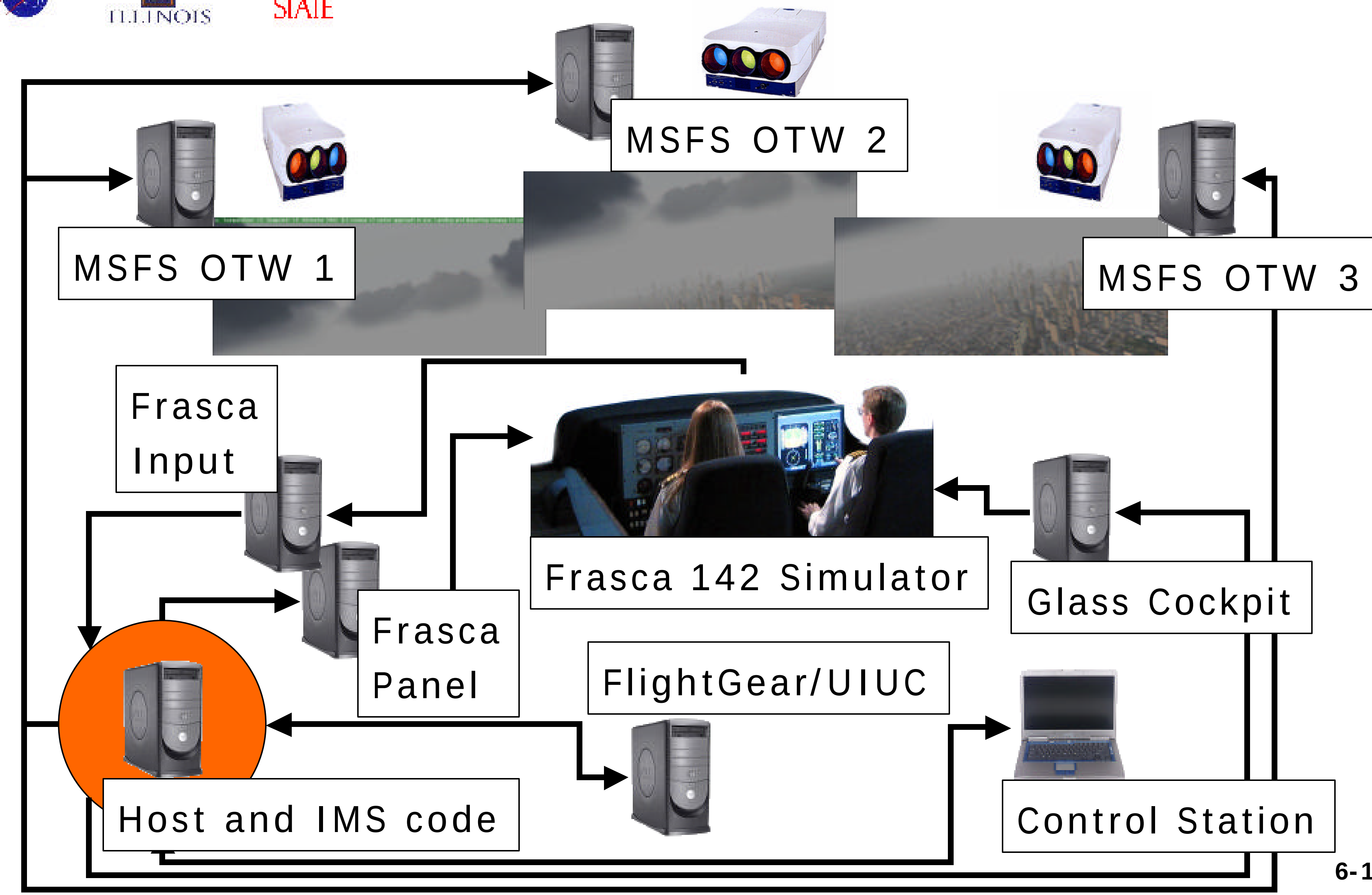
Real-time Flight Simulation

- Problem: A single computer is too slow to run all IEFS components in real-time
- Solution: Distribute processor-intensive models (software) across multiple CPUs

Networked IEFS Components - I



Networked IEFS Components - II



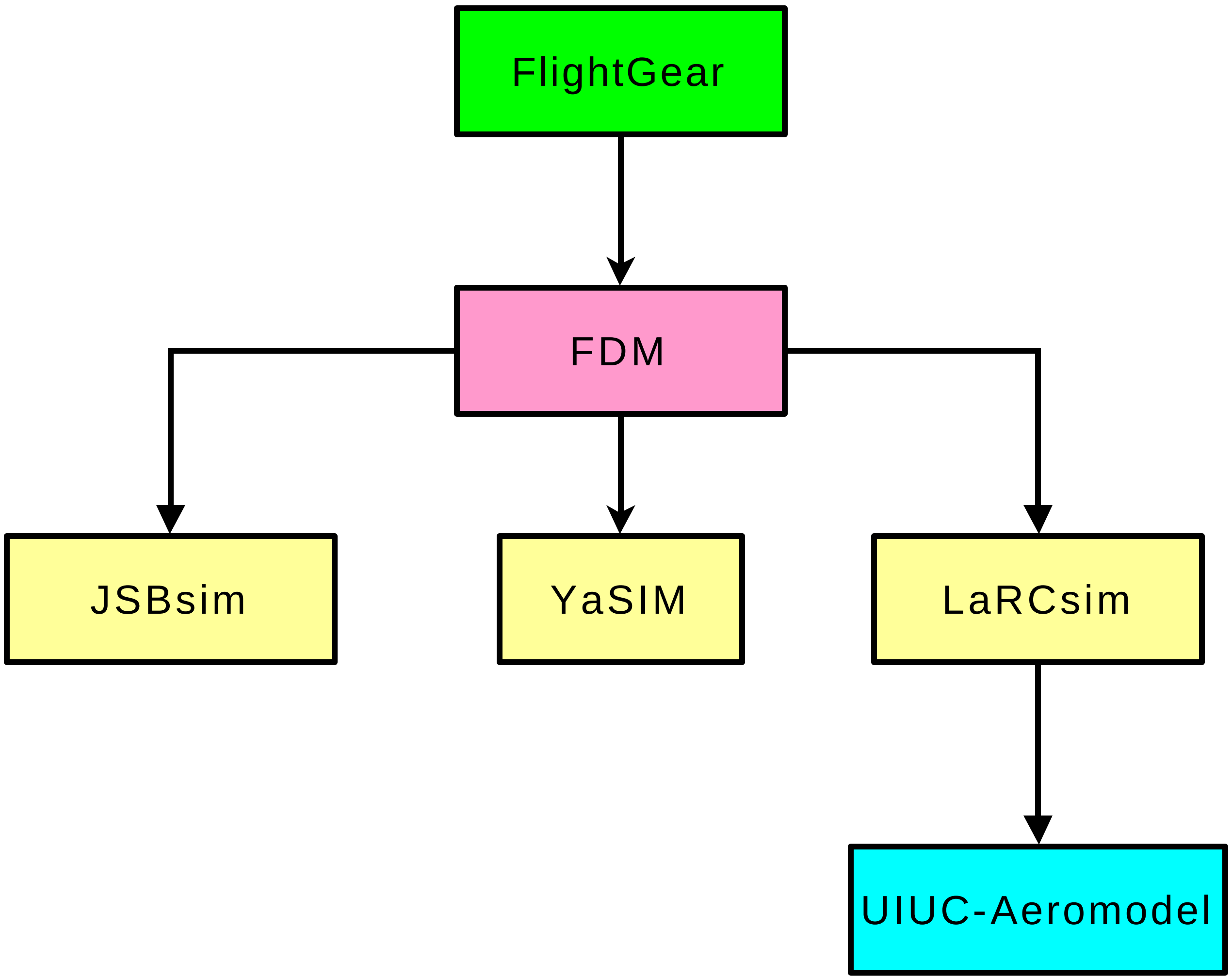
FlightGear Baseline Code

- Open-source flight simulator http://www.flightgear.org
- C/C++ code, OpenGL graphics, Multi-platform
- Includes several flight dynamics model (FDM) solvers and associated aircraft flight models
- SIS IEFS uses the NASA Langley LaRCsim FDM (Bruce E. Jackson, NASA TM-110164, April 1995)

UIUC Modifications to FGFS

- Integrate of SIS components
- Design reconfigurable aircraft model description
- Accept multiple aero-data formats
  - Linear, nonlinear table lookup, mixture
  - Wind and/or body axis data
  - Full aircraft or component based data
- Network with other components
- Implement force feedback for envelope protection (stick shaker and soft limits on control surface deflections)

FGFS/UIUC Code Architecture



FGFS/UIUC Code Architecture

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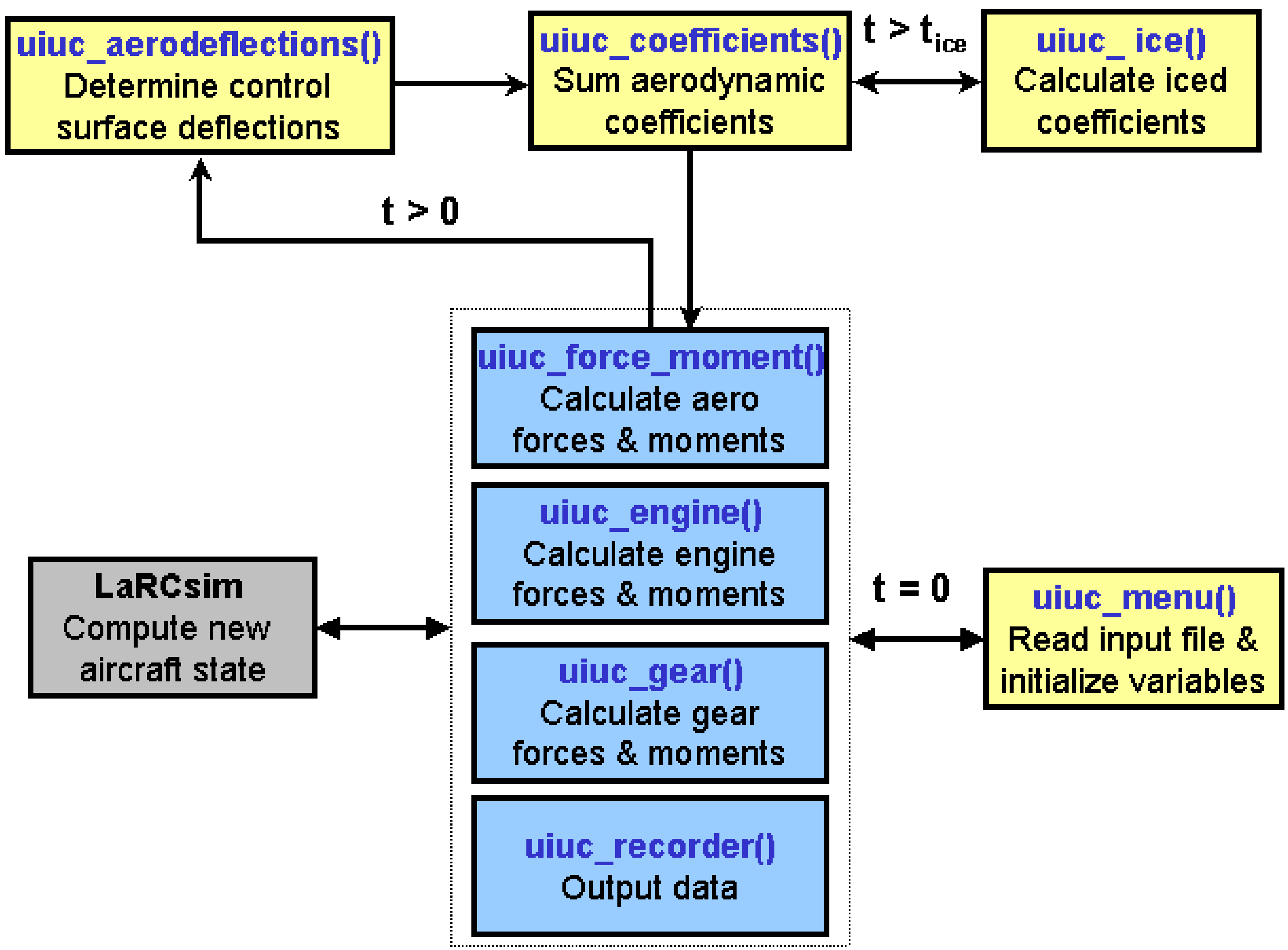


Out-the-Window View (OTW)

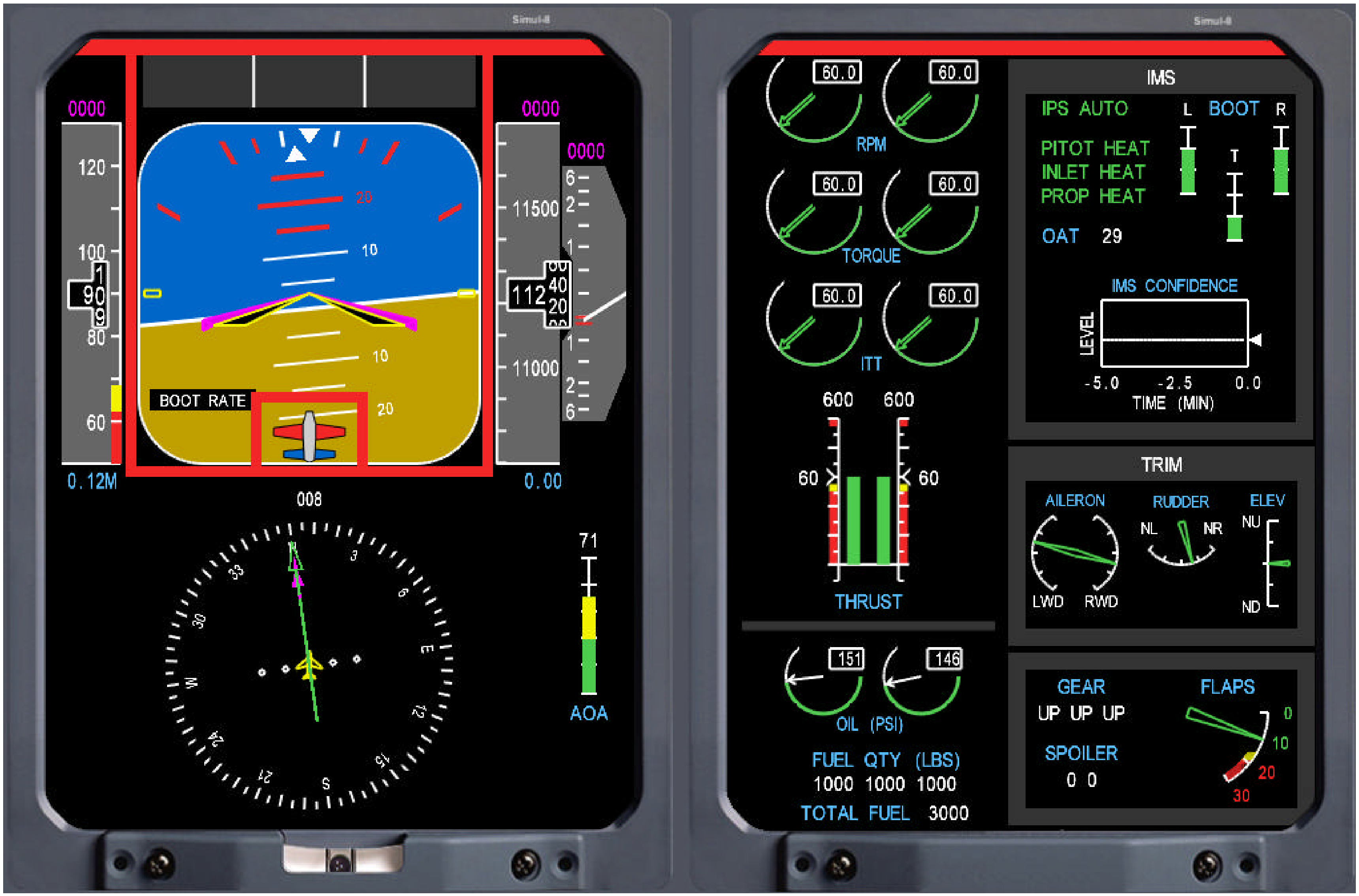
- Microsoft Flight Simulator 2002 (MSFS) used in display mode for the out-the-window view.
- Driven over the network in so-called "slew mode" using aircraft state data from FGFS
- FSUIPC DLL required
- Note: MSFS cannot be adapted to simulate aircraft icing


n. Temperature: 15. Dewpoint: 15. Altimeter 2992. ILS runway 13 center approach in use. Landing and departing runway 13 center . . V

Glass Cockpit

- Has gone through several iterations
- Based partly on code by Brian Fuesz, Frasca International
- Uses OpenGL and DirectX
- Incorporates SIS components: IPS and Envelope Protection
- Includes force-feedback joystick support

Glass Cockpit Demonstration



Scenarios

- Developed historically-motivated icing encounter accident/incident (event) scenarios to demonstrate Ice Management System (IMS) capabilities and benefits
- Enacted scenarios on UIUC PC-based flight simulator, with and without IMS active
- Designed two scenarios based on historical event data:
  - Tailplane stall
  - Roll excursion

Scenario 1: Tailplane Stall

- Aircraft in approach configuration
- Partial or full use of flaps
- Steep and/or nonstandard approach
- Aircraft in high-weight, forward-CG configuration – creating a high tail down-force
- Crew unaware of icing severity

Scenario 1: Tailplane Stall

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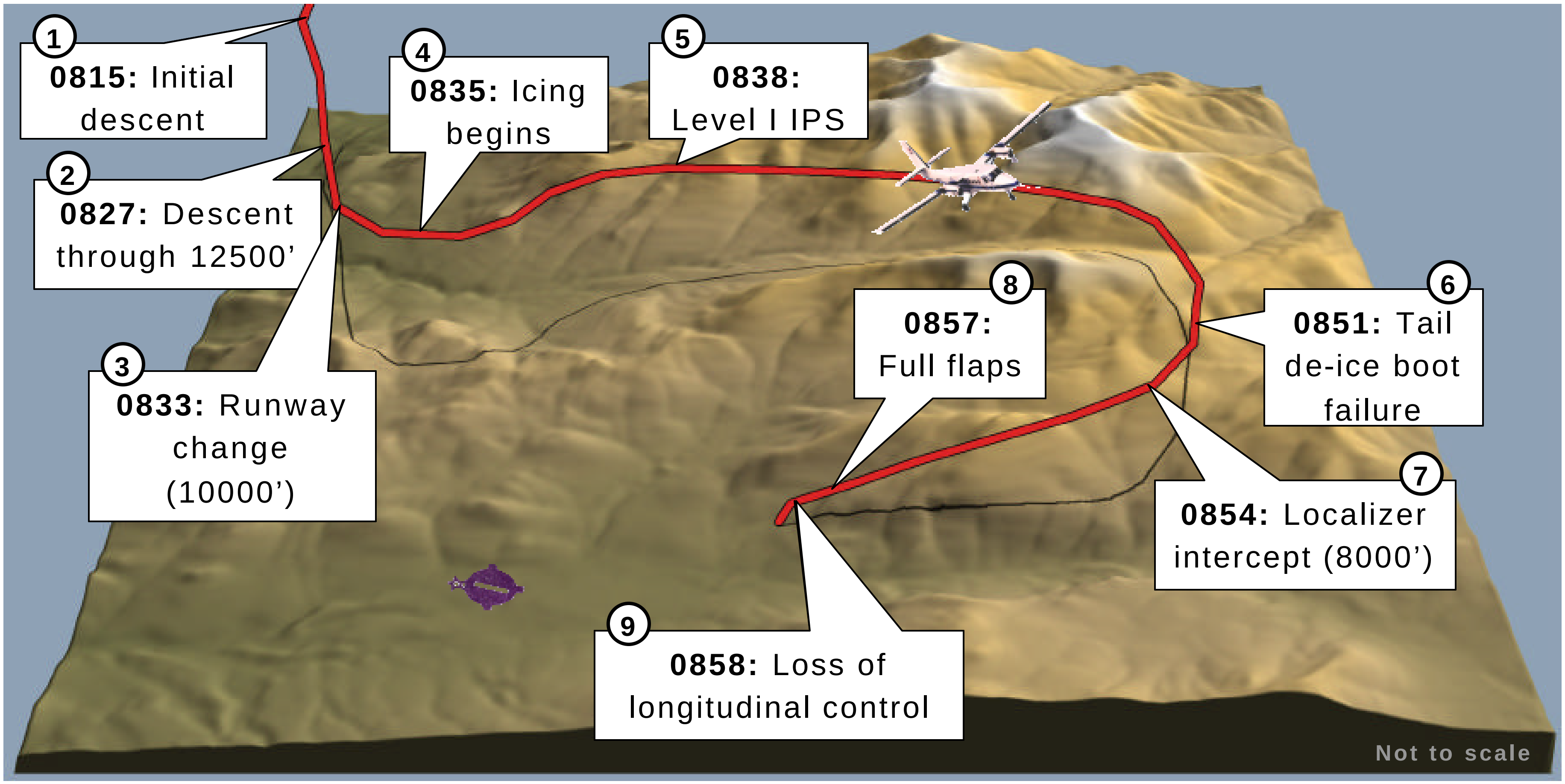

Scenario 2: Roll Upset

- Aircraft in approach configuration
- Large droplet icing conditions
- Crew distracted by engine failure
- Crew unaware of icing severity
- Ice accumulation behind de-ice boots

Scenario 2: Roll Upset

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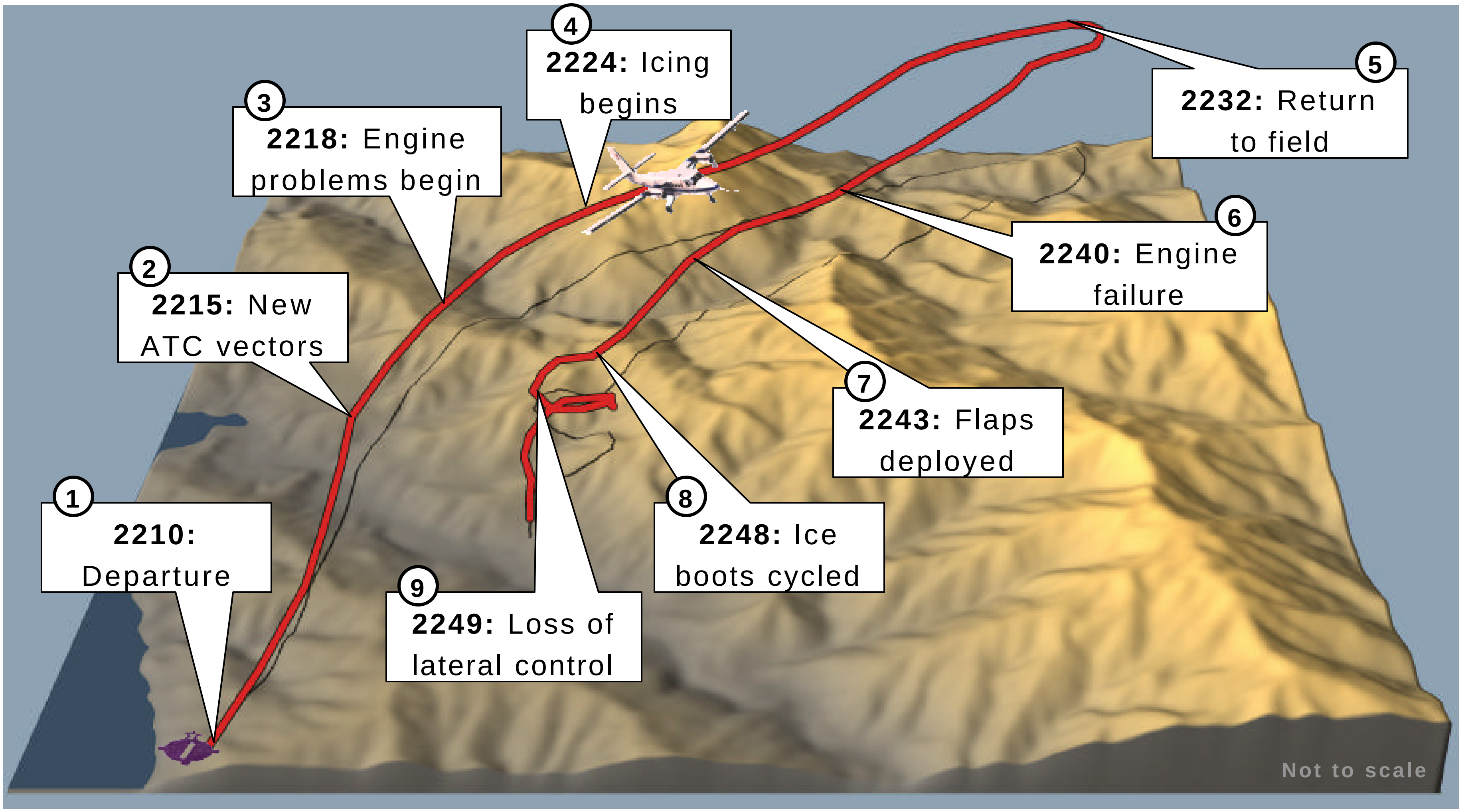

Smart Icing System DVD

- *Producer / Director:*
  Bill Fletcher
  InDyne Inc.
  NASA GRC
- *Location:*
  UIUC Campus
- *Hardware / Software:*
  Frasca Model 142 w/ UIUC/IEFS SIS software

Summary

- An Icing Encounter Flight Simulator (IEFS) has been created
- A network of computers was used to enable real-time simulation
- UIUC SIS software was integrated with the Frasca 142 simulator
- The IEFS was used in the DVD to highlight SIS functions and their potential benefits in the cockpit