

# Introduction

*Smart Icing Systems Review, June 19-20, 2001*



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University of Illinois at Urbana-Champaign

Smart Icing Systems

NASA Review

June 19-20, 2001

# Outline

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- Background
- Objective
- Smart Icing System solution
- Timeline and research review
- Schedule of the presentations

# Illinois Icing Research



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## Iced Airfoil Aerodynamics

- AGATE residual ice and scaling study
- Sensing ice-induced separation and flow unsteadiness
- Iced airfoil aerodynamics of critical ice shapes
- Airfoil sensitivity to intercycle and SLD ice accretions
- Computational and experimental techniques
- Unsteady iced flowfields near maximum lift

## Ice Accretion Physics

- Turbulence measurements in icing conditions
- Hybrid model design for ice accretion scaling
- Influence of roughness on ice accretion
- Computational modeling of icing test facilities

## Smart Icing Systems

- Interdisciplinary research for flight safety

# Aircraft Icing Accidents

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## Accidents

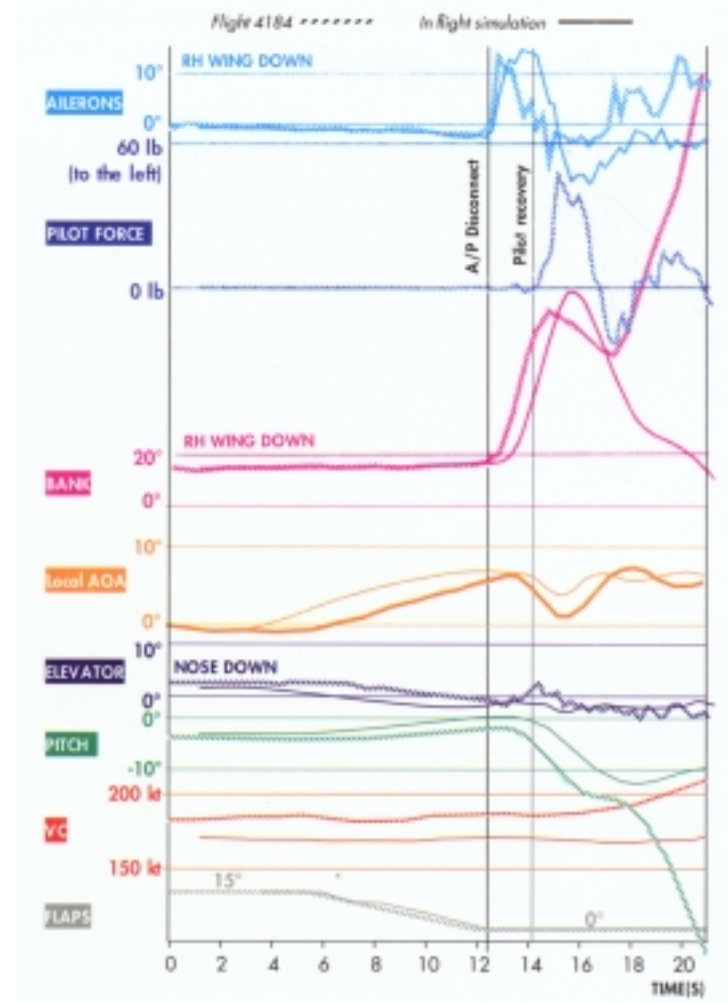
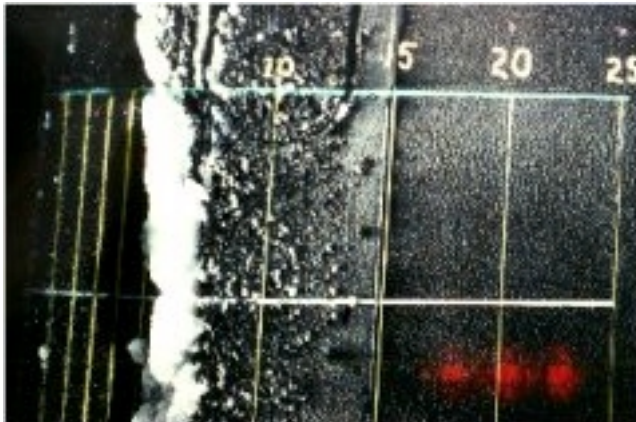
- Air Florida - takeoff accident - performance and S&C.
- United Express Jetstream - tail stall - longitudinal S&C.
- Roselawn ATR - roll upset - lateral S&C.

## Common Features

- Ice accretion.
- Aerodynamic effect leads to degradation in *performance and handling qualities*.
- Pilot is unaware of the full effect of ice on aircraft.
- Accident occurs.

# ATR 72 Roselawn Accident

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# Pilot's Perspective

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## **Steve Green (ALPA) UIUC April 29, 1999**

- When operating in icing conditions the flight crew should:
  - Monitor airspeed, rate of climb, fuel flow, SAT/TAT, cloud formation
  - Monitor aerodynamic surfaces, or representative surfaces for ice accretion
  - Allow some specified quantity of ice to build prior to operating the ice protection system
  - Determine whether the ice protection system is adequately clearing ice
  - Develop and update an opinion as to whether the icing conditions may adversely affect the safety of flight

# Pilot's Perspective (cont)



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## **Steve Green (ALPA) UIUC April 29, 1999**

- **Safe Operation in Icing**
  - Provide pilot with aerodynamic monitoring (proximity to  $C_L$  divergences)
  - The pilot must have reliably correlated data, measured in real time, with which to infer the proximity of divergences in  $C_L$  or  $C_h$  in a timely manner.

# Smart Icing Systems

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## Goal

- To improve the safety of aircraft operating in icing conditions.

## Objective

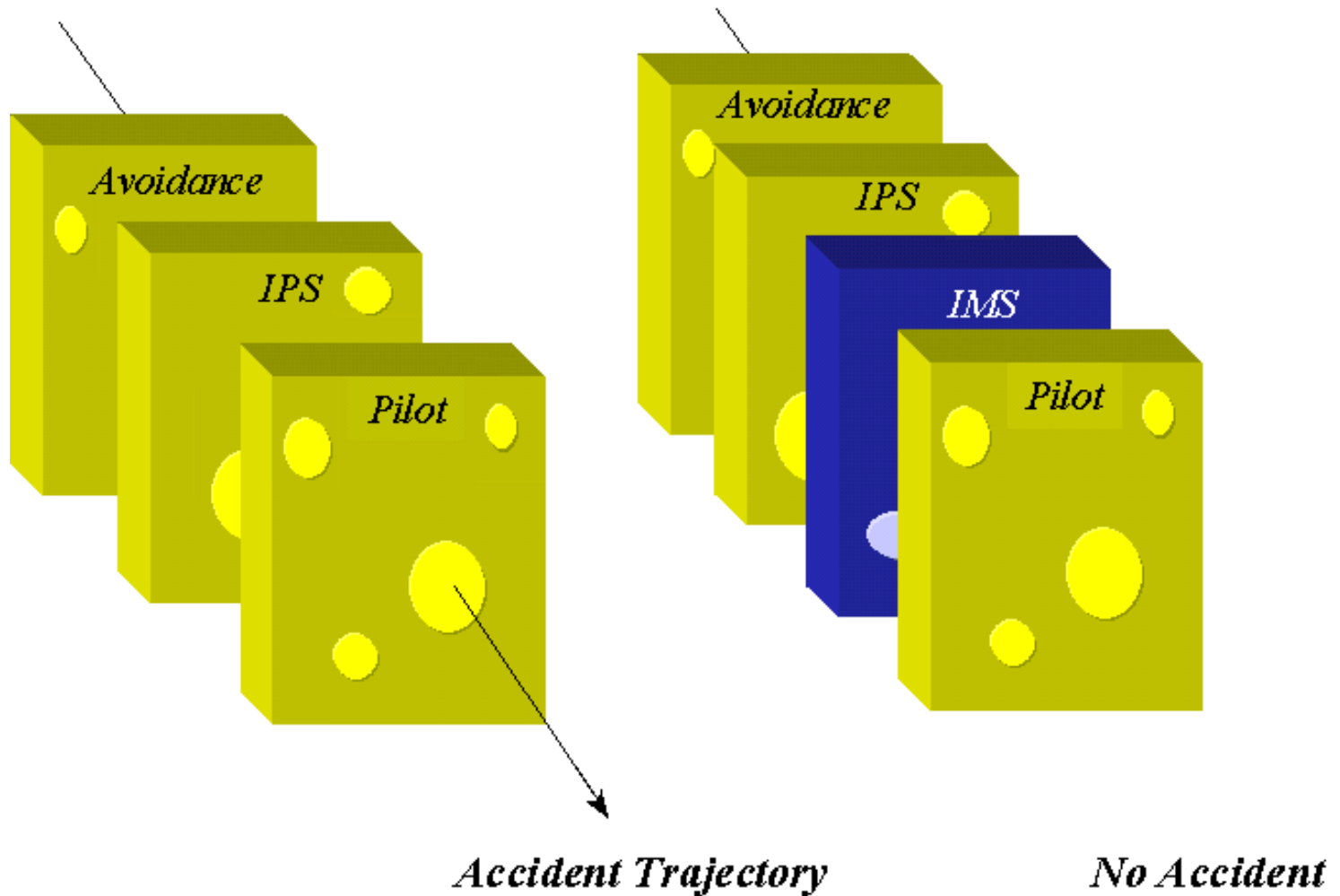
- To develop a human-centered automated system, to characterize icing effects, operate the IPS, provide envelope protection and control adaptation.

## Approach

- An interdisciplinary, systems approach is used to conduct the research in aerodynamics, flight mechanics, controls and human factors. Flight simulation and flight testing are used to develop the concept and validate the methods.

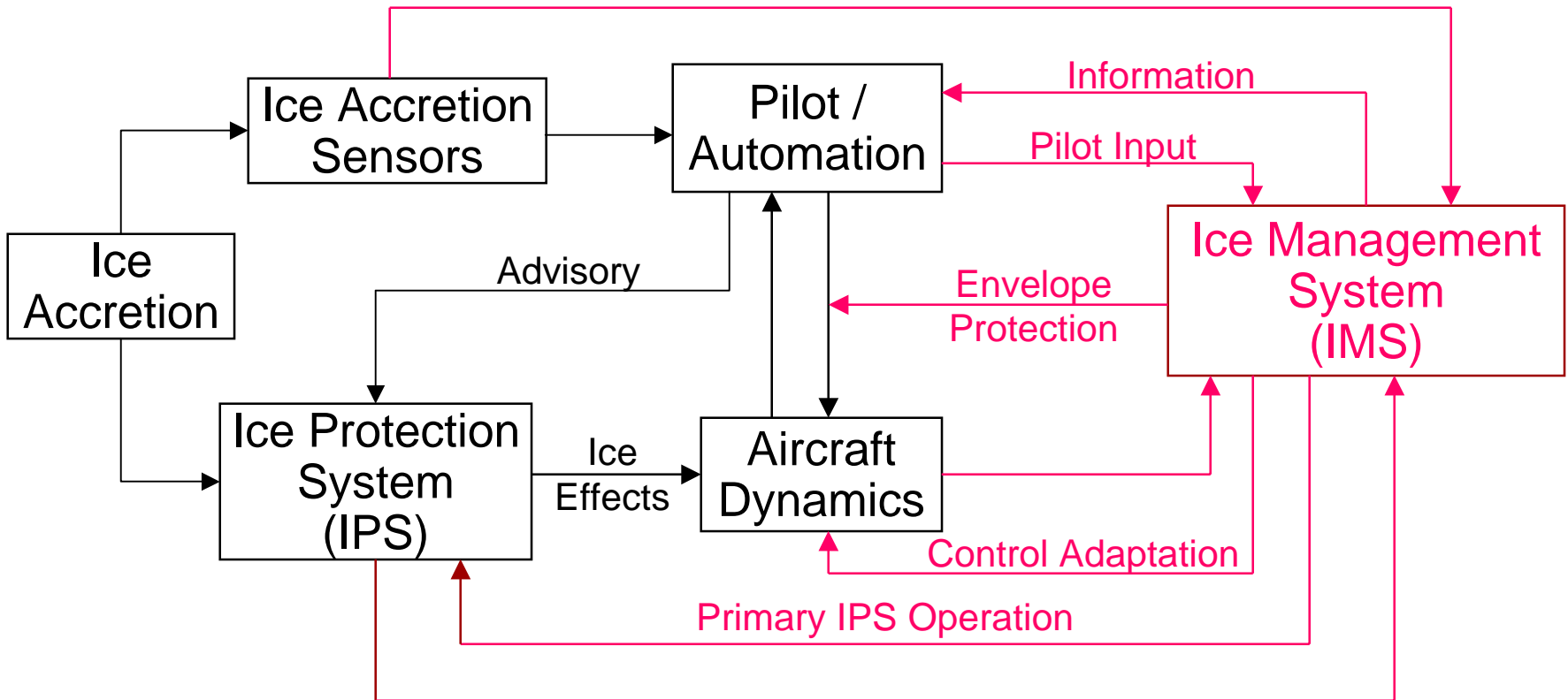
# Defenses in Depth

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# New Aircraft Icing Encounter Model

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# SIS Development Strategy

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- Incorporate Human Factors input throughout process
- Focus on technology and tools, not specifics of the IMS for a given aircraft
- Focus on icing effect characterization years 1 and 2
- Use flight simulator as system integrator with emphasis in later years of project
- Conduct envelope protection and control adaptation research years 3 and 4

# Major Program Changes

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- **Added**
  - Analysis of the effect of atmospheric effects
  - Flight test
- **Delayed**
  - Envelope protection research
  - Nonlinear aircraft model
  - CFD analysis of iced aircraft
- **Eliminated**
  - Construction of wind tunnel models and testing

# IMS Development



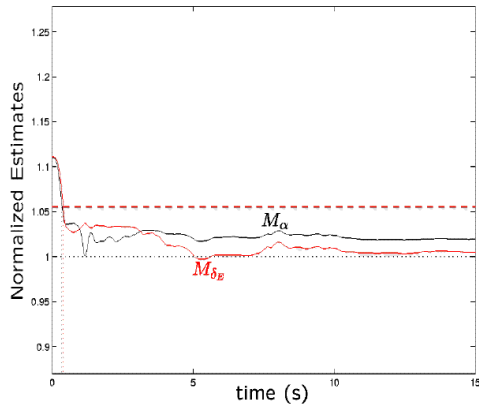
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- IMS development progressing in stages.
- First simple model presented at Reno 2000 used neural net to predict icing level from two dynamic characterization inputs.
- A more sophisticated neural net using dynamic and steady state characterization inputs as well as some sensor inputs presented Reno 2001.
- Nondimensional ID, improved neural networks, and envelope protection analysis presented here.

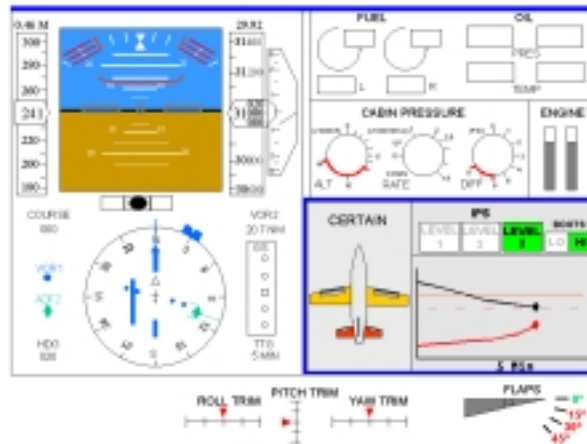
# NASA/University of Illinois Smart Icing Systems Program

## Technology Development

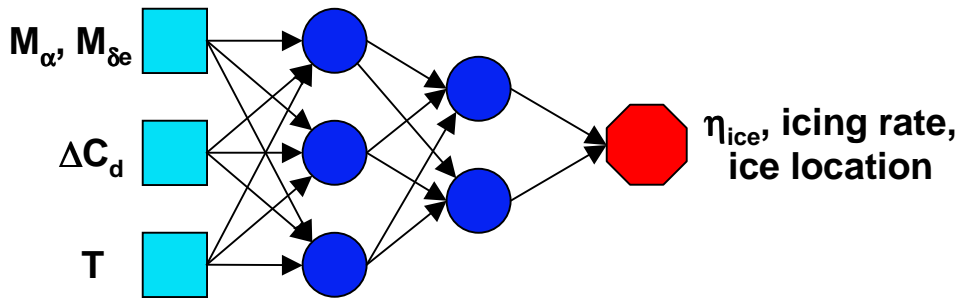
### Systems Identification



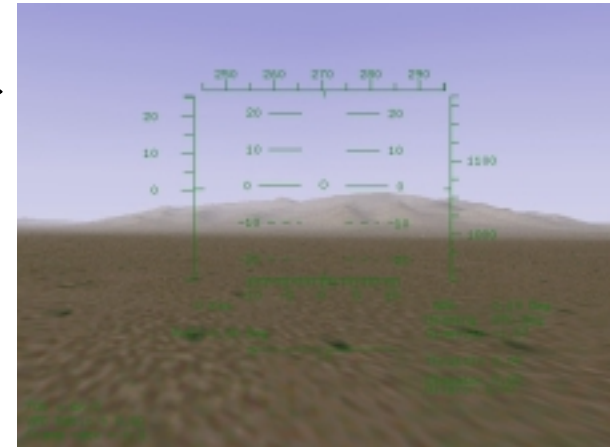
### Human Factors



### IMS Decision Making



## Piloted Flight Simulator Systems Integration



## Flight Test



# Faculty and Students

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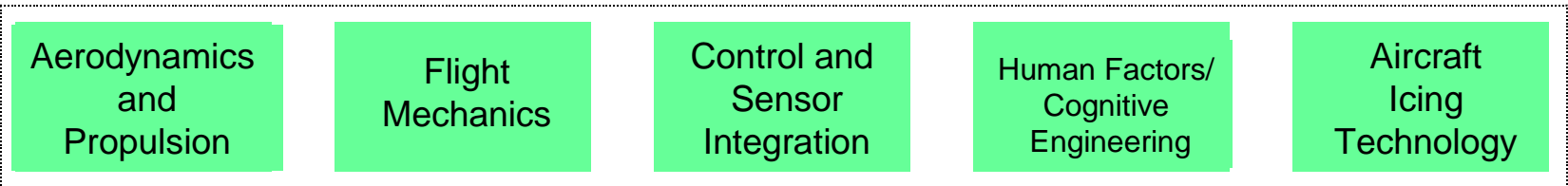
- **Aerodynamics, Propulsion and Flight Mechanics**
  - Profs. Mike Bragg (AAE) and Eric Loth (AAE)
  - Sam Lee, Andy Broeren, Jason Merret, Kishwar Hossain, Ed Whalen
  - Leia Blumenthal, Chris LaMarre, (AAE)
- **Control and Sensor Integration**
  - Profs. Tamer Basar (ECE/CSL), Bill Perkins (ECE/CSL), Petros Voulgaris (AAE/CSL)
  - James Melody (ECE/CSL), Vikrant Sharma (AAE/CSL), Paul Pawola (ECE/CSL)
  - Evgeniy Sklyanskiy (AAE)
- **Human Factors:**
  - Profs. Nadine Sarter (OSU), Chris Wickens (ARL)
  - John McGuirl (OSU)
- **Flight Simulation:**
  - Prof. Michael Selig (AAE)
  - Bipin Sehgal, Rob Deters (AAE)

# SMART ICING SYSTEMS Research Organization

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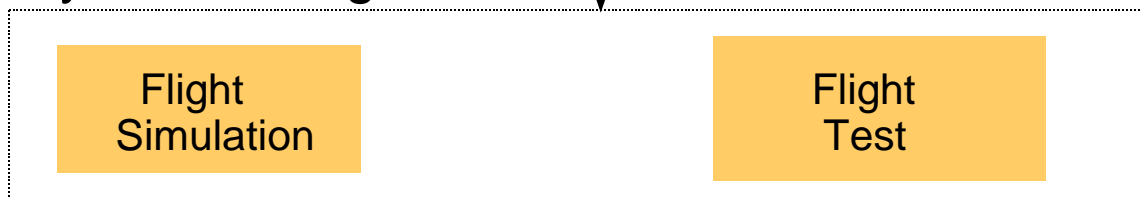
## Core Technologies



## IMS Functions

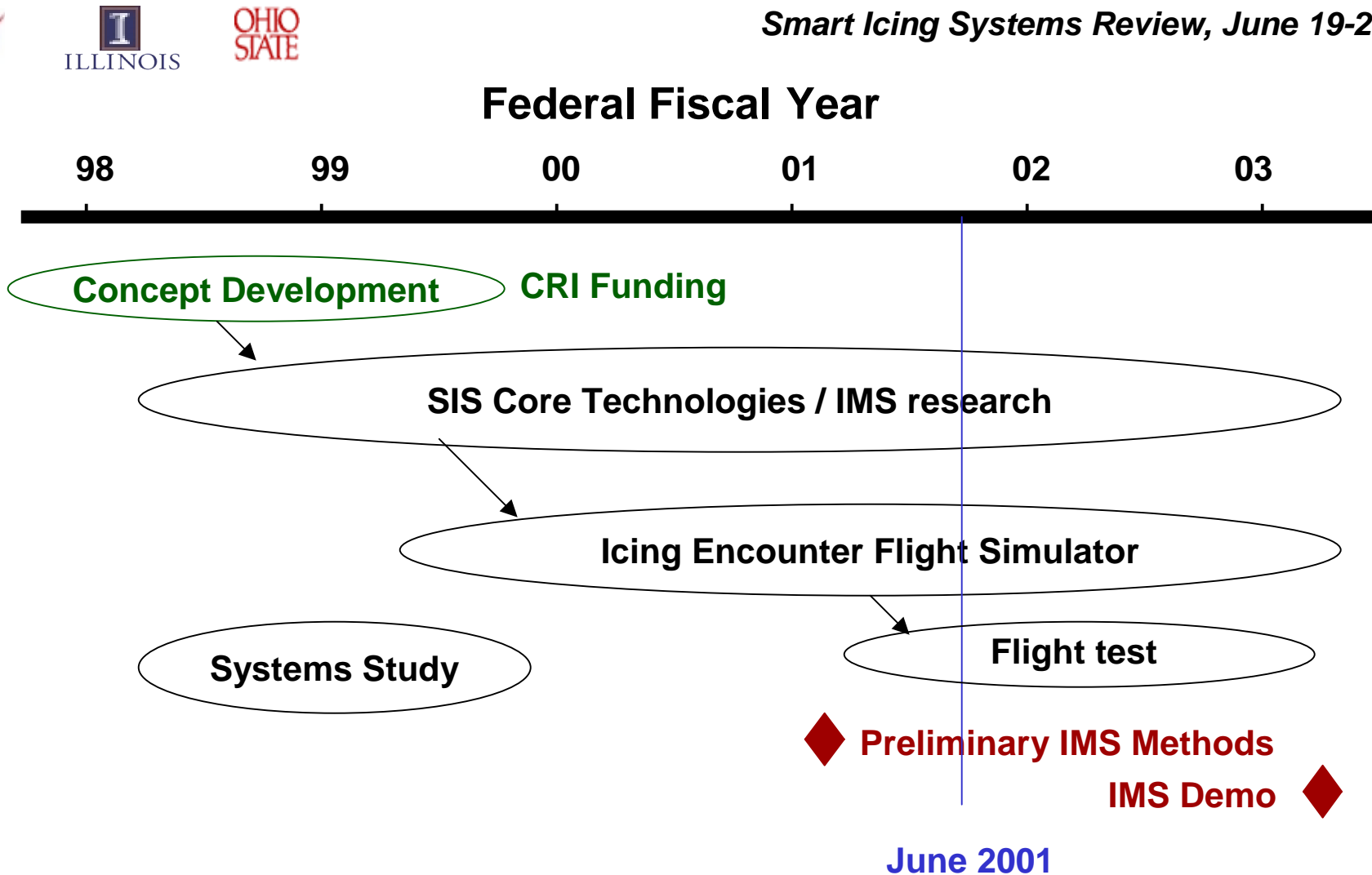


## Systems Integration



# SIS Schedule

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# Meeting Schedule

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## Tuesday June 19:

### **9:00 am – 9:45 am**

9:00 am – 9:05 am

9:05 am – 9:35 am

### **9:45 am – 11:00 am**

9:35 am – 10:20 am

10:20 am – 10:30 am

10:30 am – 11:00 am

### **11:00 am – 1:30 pm**

11:00 am – 11:45 am

### **11:45 noon – 1:00 pm**

12:30 pm – 12:45 pm

1:00 pm – 1:30 pm

### **1:30 pm – 3:15 pm**

1:30 pm – 2:00 pm

2:00 pm – 2:30 pm

2:30 pm – 3:00 pm

3:00 pm – 3:15 pm

### **3:15 pm – 4:15 pm**

3:15 pm – 3:45 pm

3:45 pm – 4:15 pm

### **6:30 pm – 8:30 pm**

### **Introductions**

Welcome

Smart Icing Systems Overview

### **Aerodynamics and Flight Mechanics**

Assessing Atmospheric Effects on Icing Characterization Merret

Break

Envelope Protection

### **Flight Controls and Sensors**

ID and Characterization with Nondimensional Derivatives Melody

### **Lunch**

College Summary

Autopilot Studies

### **Human Factors**

The IMS as a Decision Support Tool

Visual and Tactile Cues for Presenting In-flight Information McGuirl

Overview of IMS Interface and Planned Human Factors Activities Sarter

Break

### **Flight Simulation**

IMS Integration and Software Development Sehgal

Twin Otter Model and Validation

### **Reception**

Bond

Bragg

Hossain

Vojak

Voulgaris

Sehgal

Deters

**B02 CSRL**

**B02 CSRL**

**B02 CSRL**

**301 CSRL**

**B02 CSRL**

**B02 CSRL**

**Bragg Residence**

# Schedule (cont.)

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## Wednesday June 20:

8:30 am – 9:00 am	Flight Simulation Demonstration	Selig	
<b>9:00 am – 10:30 am</b>	<b>Twin Otter Flight Test Analysis</b>		<b>B02 CSRL</b>
9:00 am – 9:15 am	Flight Test Objectives and Plan	Bragg	
9:15 am – 9:45 am	Analysis of Quasi-Steady Data	Lee	
9:45 am – 10:00 am	Break		
10:00 am – 10:30 am	ID and Characterization with Flight Test Data	Melody	
<b>10:30 am – 11:00 am</b>	<b>Future Plans</b>		<b>B02 CSRL</b>
<b>11:00 am – 11:30 am</b>	<b>Open Discussion</b>		<b>B02 CSRL</b>
<b>11:30 am – 1:00 pm</b>	<b>Lunch</b>		<b>301 CSRL</b>
<b>1:00 pm – 2:00 pm</b>	<b>Government Meeting</b> (NASA/FAA only)		<b>469 CSRL</b>
2:00 pm – 2:15 pm	Break		
<b>2:15 pm – 3:30 pm</b>	<b>Review of SIS Research</b> (NASA/FAA/UTUC/OSU)		<b>469 CSRL</b>