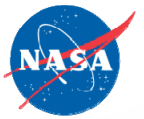
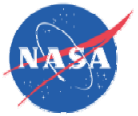


NASA Iced Aerodynamics and Controls Current Research

Gene Addy
Co-Associate Principal Investigator
Integrated Resilient Aircraft Controls Project
Aviation Safety Program



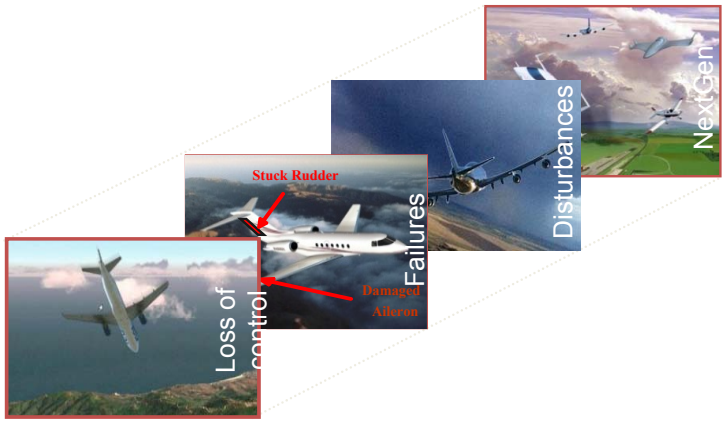
Current airframe icing research at NASA is funded through:

Aviation Safety Program
Integrated Resilient Aircraft Controls (IRAC) Project

- IRAC Scope:
  ...to advance the state of aircraft flight control to provide onboard control resilience for ensuring safe flight in the presence of adverse conditions.

- IRAC Goal:
  ...to arrive at a set of validated multidisciplinary integrated aircraft control design tools and techniques for enabling safe flight in the presence of adverse conditions.

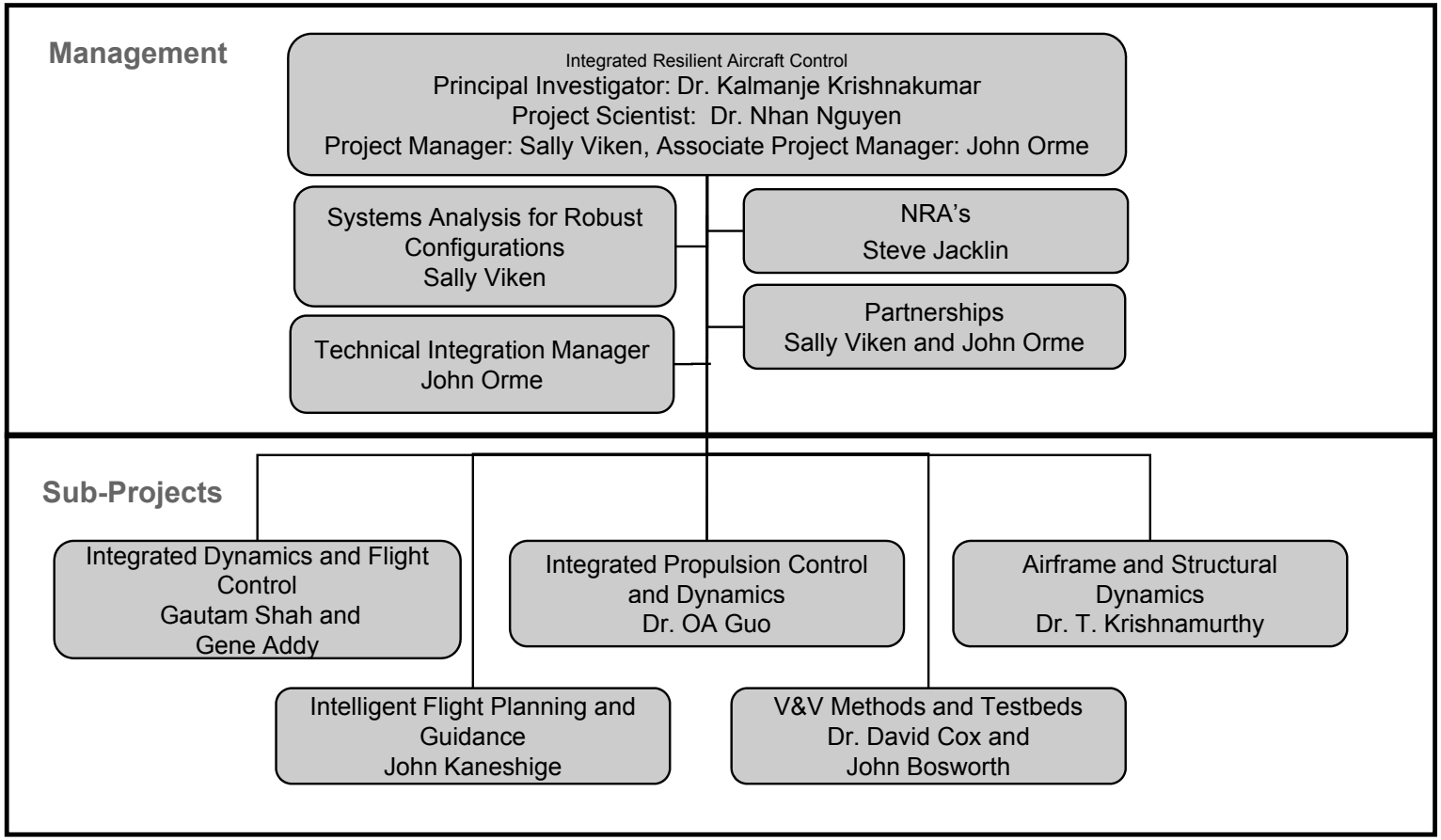
IRAC Project Plan



Adverse conditions categorized as:

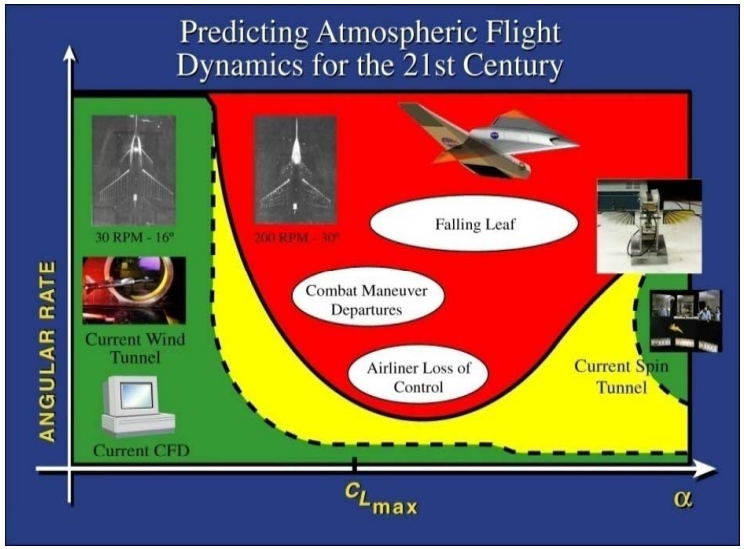
- **Failures** – Static and dynamic actuator failure effects (single and multiple)
  - ex.: locked stabilator (F-15), stabilator driven to local angle-of-attack, reduced control surface effectiveness due to icing
- **Damage** – aerodynamic and structural damage (wing and/or tail)
  - ex.: destabilizing angle of attack feedback to the canards, wing damage simulation (F-15), locked flaps (F-18), aerodynamic uncertainty caused by icing, engine degradation due to icing
- **Upset** – Unusual attitudes, stall/departure
  - ex.: elevated AOA (pre-stall), stall

Aviation Safety Program
Integrated Resilient Aircraft Control

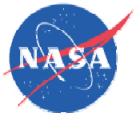


IDFC- Modeling Overview

- Objective
  - Develop experimental and computational methods to model and predict aircraft responses during IRAC adverse conditions: damage, upset, failures, including icing.
  - Develop models suitable for simulation, analysis, and flight control design
- Technical Challenge
  - Conventional modeling techniques provide limited to poor aircraft response prediction under IRAC adverse conditions where aerodynamics are characterized by separated flows, vortical flows, shock waves, or nonlinear-unsteady behaviors.



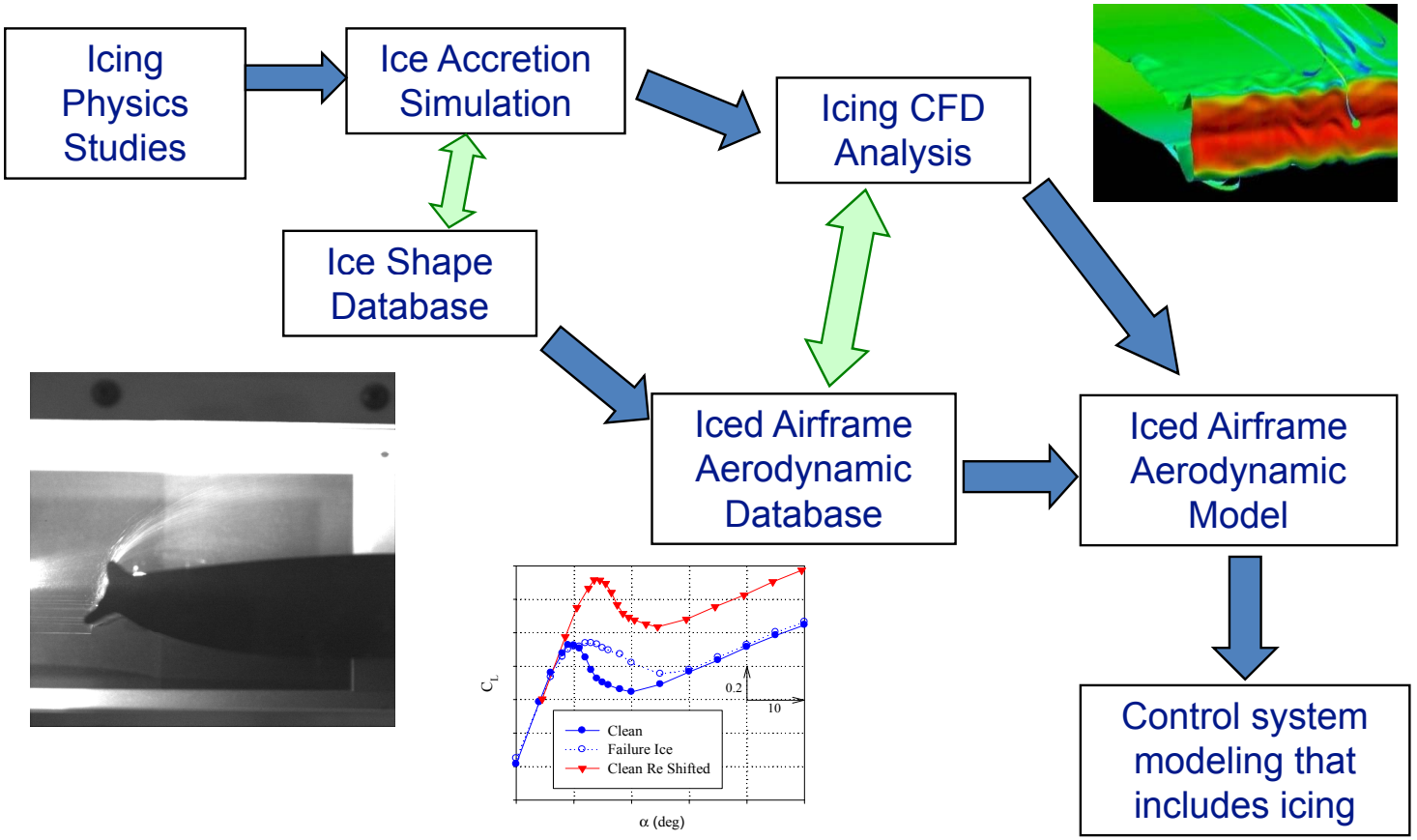
- Technical Approach
  - Develop advanced modeling and test techniques to characterize aircraft responses and validate via wind tunnel, simulation, and flight testing.
- Significance
  - Ensure scientific validation of models and control laws
  - Characterize uncertainties, reduce risks, increase efficacy of designs



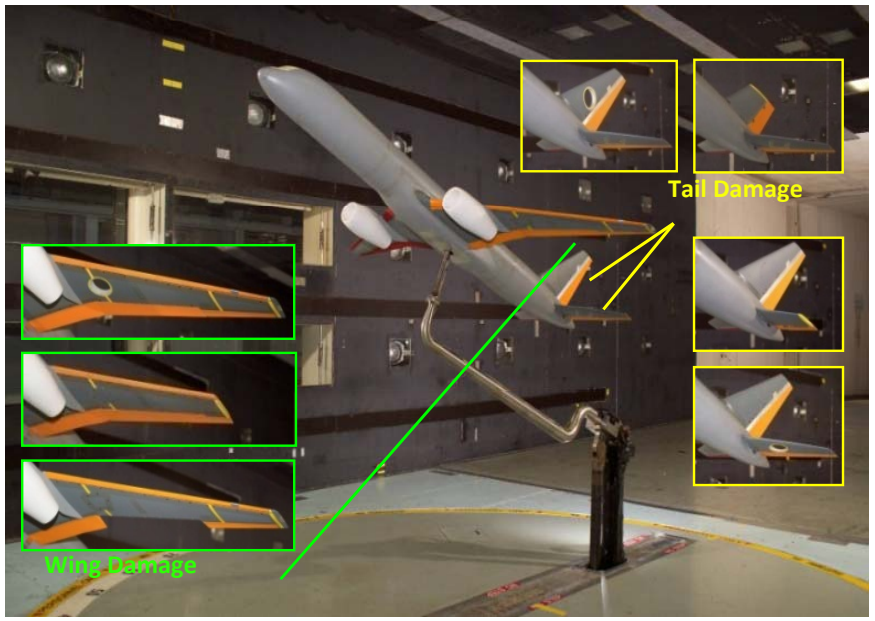
Icing research in support of IRAC Project:

- **Aircraft Icing Modeling**
  - **Ice-Contaminated Aerodynamics Modeling**
    - ❑ Effects of ice contamination on aircraft aerodynamics
    - ❑ CFD modeling of ice-contaminated aircraft aerodynamics
  - **Advanced Ice Accretion Process Modeling**
    - ❑ Physics of ice accretion on complex geometries
    - ❑ Computational modeling of ice accretions

Development of Iced Airframe Aerodynamic Parameters for Control Analysis Input

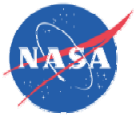


IRAC Testbed



GTM Wind Tunnel Testing, NASA Langley 14x22

- Generic Transport Model (GTM)
  - Small scale models of a large commercial transport – both wind tunnel (3.5%) and flight (5.5%) available



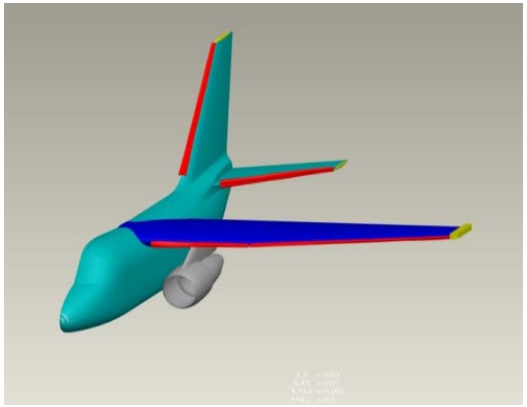
Iced GTM aerodynamics studies

Objective

- Investigate the effects of icing on GTM aerodynamics

Approach

1. Use LEWICE ice accretion codes to predict ice shapes for full scale GTM
2. Use ice shapes obtained from LEWICE in conjunction with CFD code USM3D to determine aerodynamic effects of ice on GTM
3. Scale, using geometric scaling and engineering judgment from previous icing scaling research, the ice shapes from LEWICE to obtain aerodynamically similar ice shapes
4. Manufacture these ice shapes, attach them to GTM wind tunnel model, and perform wind tunnel tests to study the effects of ice contamination on model aerodynamics
5. Perform CFD study of ice contaminated, subscale GTM
6. Provide data from wind tunnel study to researchers running GTM simulation for Intelligent Flight Planning and Guidance



LEWICE used to predict ice shapes

Artificial ice shapes attached to scale model S-3 wing

Scale model S-3 with ice shapes attached on wind tunnel force balance

GTM method is based upon prior research with S-3.

NASA/CP—2009-215797

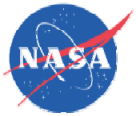
IRAC Icing Research Outcomes & Impact

Outcomes

- More thorough understanding and models, theoretical and empirical, of icing physics and ice accretion processes for complex (3D) airframe shapes
- Advanced 3D ice accretion prediction codes
- CFD methods for iced aerodynamics
- Better understanding of aircraft iced aerodynamics and its effects on control surface effectiveness

Marks of progress – impact on aircraft icing technology

1. 3D ice accretion codes more widely accepted and used by industry and government agencies for both design and development as well as aircraft icing certification
2. Iced aerodynamics methods are employed by industry for design, development, and certification
3. Perform validation exercises in order to achieve success
   - Ultimately, full-scale testing is needed to provide validation



Airframe Icing Research Collaborations

- Space Act Agreements
  - American Kestrel – LEWICE2D dissemination and support
  - Boeing – LEWICE3D development
  - Goodrich – icing physics
- International Agreements
  - INTA (Spain) – icing physics, droplet dynamics
  - ONERA (France) – iced aerodynamics
  - NRC-Canada – thermal scaling for IPS operation and runback icing
- NASA Research Announcements (NRA)
  - University of Tennessee Space Institute (UTSI) – aircraft health monitoring for icing