Propulsion Controls and Diagnostics Research at NASA GRC – Status Report

Dr. Sanjay Garg
Branch Chief
Ph: (216) 433-2685
FAX: (216) 433-8990
email: sanjay.garg@nasa.gov
http://www.lerc.nasa.gov/WWW/cdtb

Presented at: Aerospace Guidance and Control System Committee Meeting
Cocoa Beach, FL, Oct. 2007

NASA Program Structure

Mission

- To pioneer the future in space exploration, scientific discovery, and aeronautics research
- **Values:** Safety, Teamwork, Integrity, Mission Success

Strategic Goals

1. Fly the shuttle safely till 2010.
2. Complete the International Space Station
3. Develop a balanced program of science, exploration and aeronautics
4. Bring a new Crew Exploration Vehicle into service ASAP
5. Encourage the pursuit of partnership with commercial space sector
6. Establish a lunar return program with utility for mission to Mars

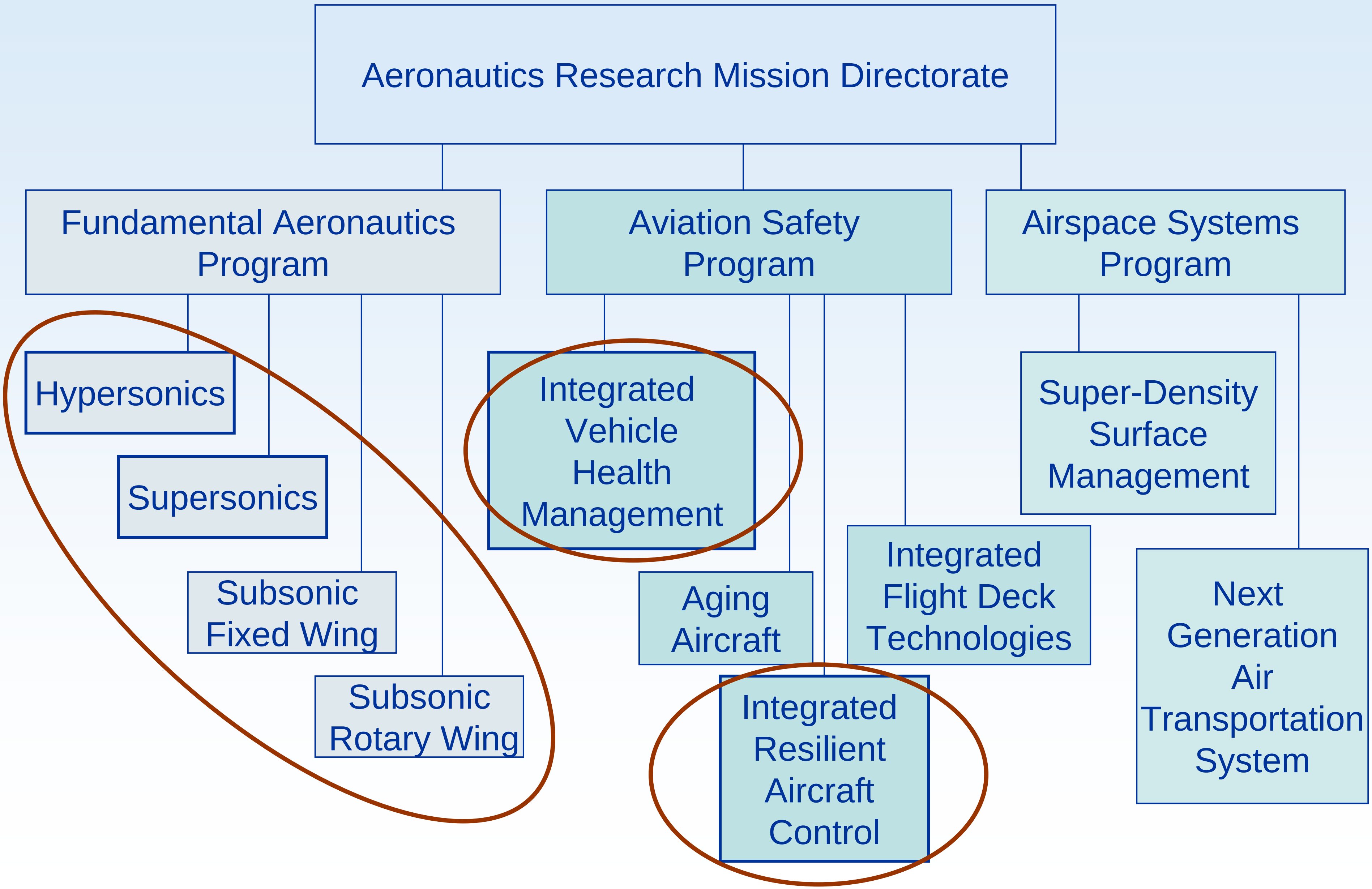
Mission Directorates

- Aeronautics Research
- Science
- Exploration
- Space Operations

Centers

Programs → **Projects** → **Sub-Proj.** → **Tasks**

NASA Aeronautics' Program Structure



Propulsion Control and Diagnostics Research Under NASA Aeronautics Research Mission Programs
November 6-7, 2007
Ohio Aerospace Institute

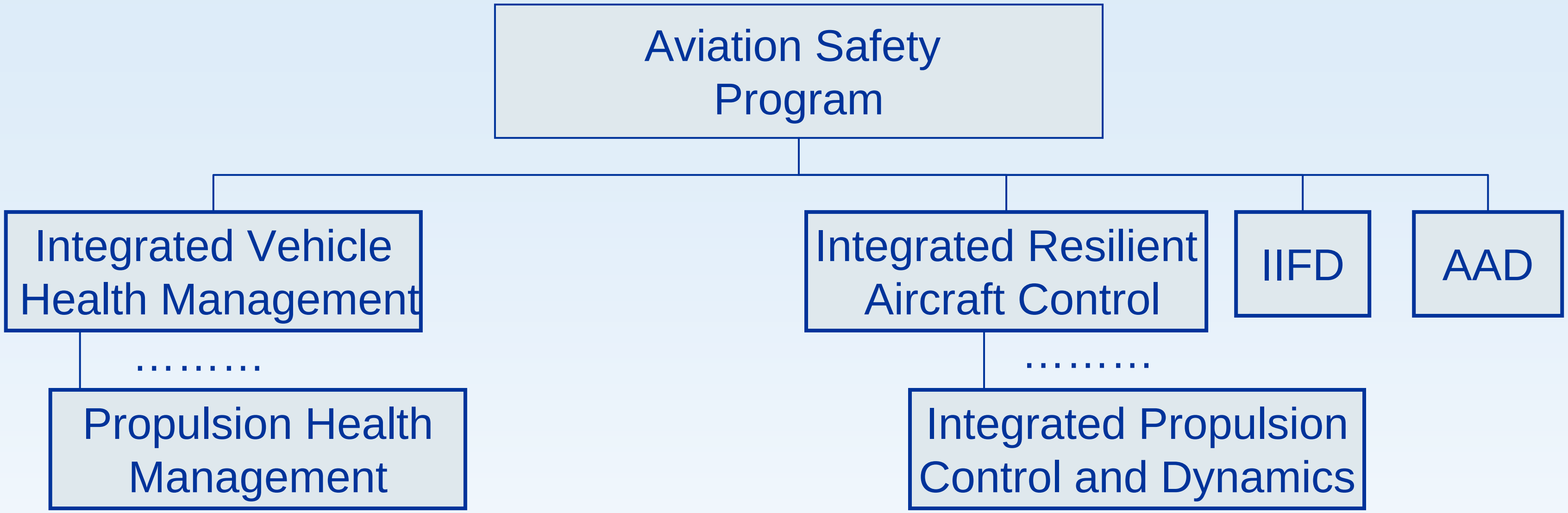
https://web1.oai.org/PCDR.nsf/

OBJECTIVES

- Disseminate information to the research community about the propulsion control and diagnostics research being done at NASA GRC in support of various projects under the NASA Aeronautics Research Mission programs.
- Get feedback from peers on value of the research and validity of the technical approach.
- Identify opportunities for potential collaboration and sharing of tools and methods.

http://www.grc.nasa.gov/WWW/ictd/content/5530.html

Propulsion Control and Diagnostics for Aviation Safety



- Self awareness and prognosis of gas path, combustion, and overall engine state; fault-tolerant system architecture
  - Gas Path health management
  - …..

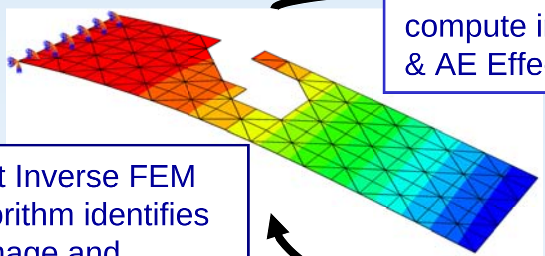
- How to use the propulsion system as an effective flight control actuator in abnormal situations – allow safe and controllable flight for limited time and safe landing in the presence of airframe damage

IRAC System Concept

Integrated Adaptive Flight/Structural/Propulsion Control

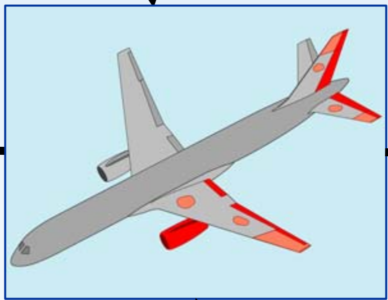
Adaptive Flight Control
- Decisions Based on Failures/Impairment/Damage, Remaining Control/Engine Capabilities, Risks Associated with Accommodation/Recovery, Flight Safety Margins
- Combinations of Internal & External Loss-of-Control Factors
- Includes Upset Recovery under Failures/Damage/Disturbance Conditions and Adaptive Guidance

Direct FEM models compute internal loads & AE Effects in real time

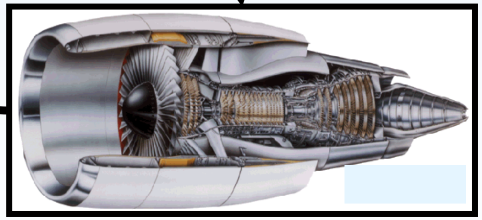


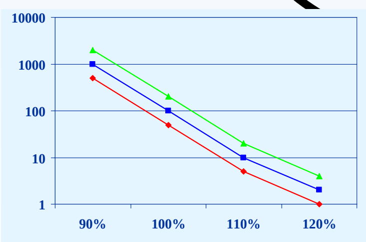
Fast Inverse FEM algorithm identifies damage and predicts deformations in real time

Strain sensors provide discrete measurements in real time



Flight Control Commands
- Engine Operation Mode
- Engine Performance Requirements





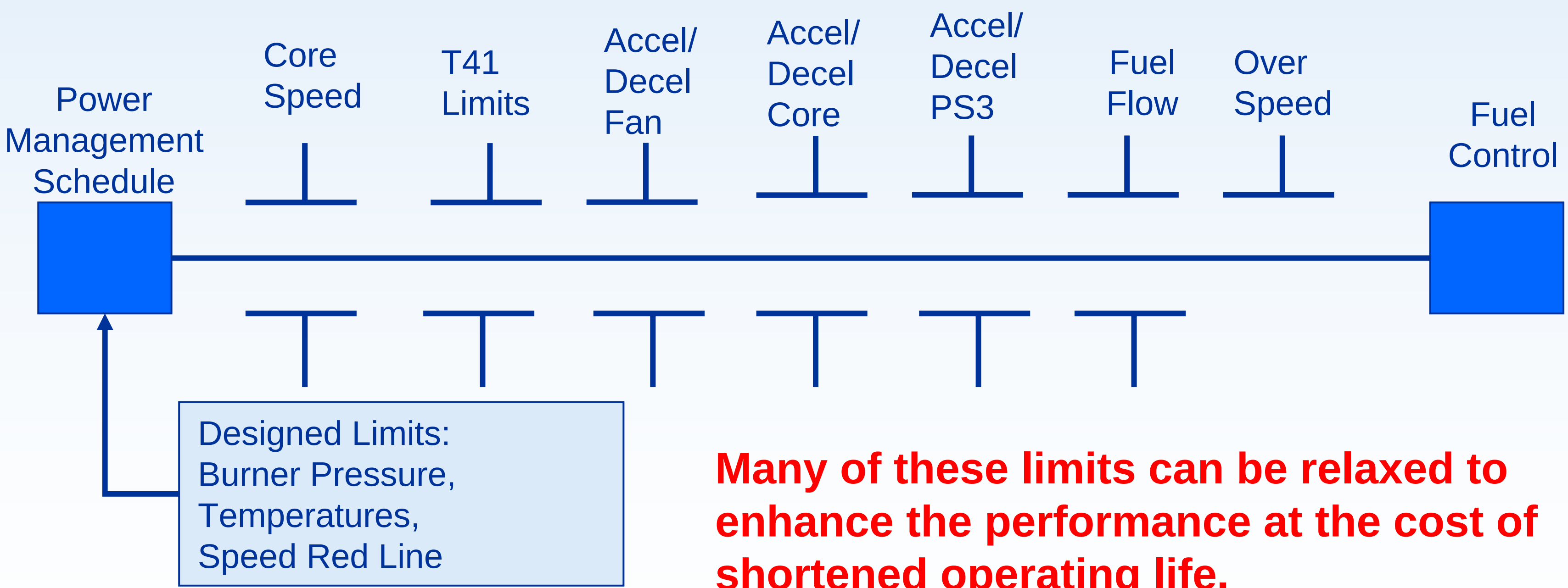
Engine Status Report
- Engine Failure/Damage Condition
- Engine Performance Limits
- Performance/Life Trade-off Curve

- Engine Failure/Damage Assessment
- Survival Operation Mode for Damaged Engine
- Optional Operation Beyond Designed Envelope

Current Engine Control and Limits

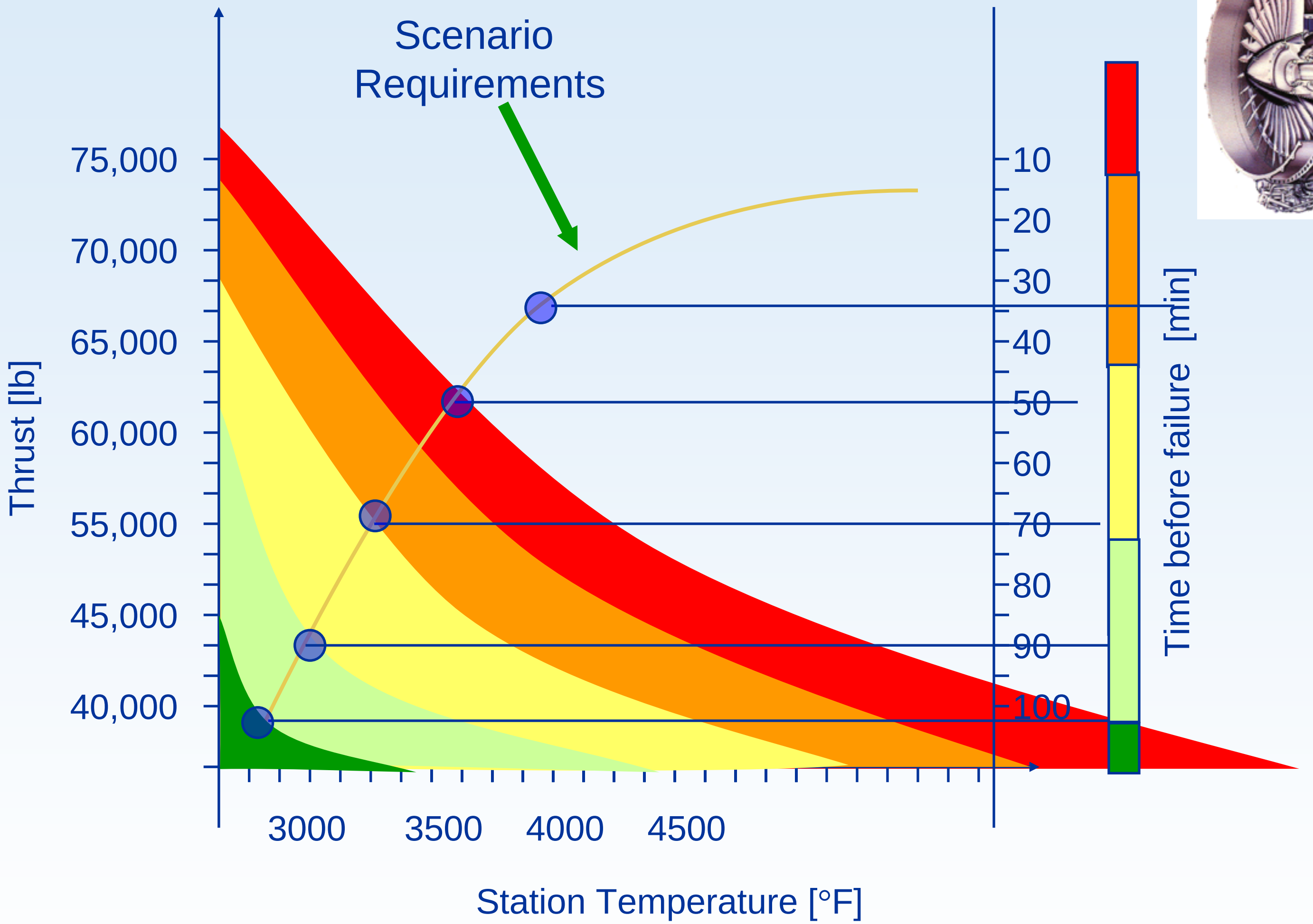
A Full Authority Digital Engine Control (FADEC) system adjusts fuel flow to set power management

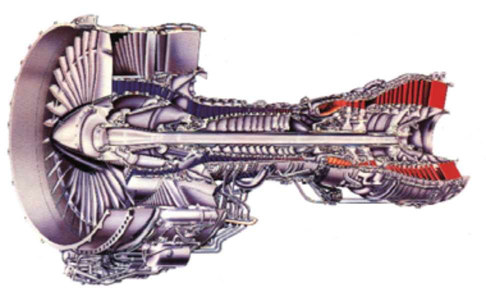
- Speed Control limits
- Acceleration/Deceleration speed limits
- Fuel Flow limits
- Pressure Control



Many of these limits can be relaxed to enhance the performance at the cost of shortened operating life.

Structural Damage Assessment





Example : Thrust → Station Temperature → Sustainable Time Duration

IRAC Approach

- **Baseline engine simulation to:**
  - Include representative engine control limits
  - Simulate engine response time throughout the flight envelope
- **Flight/propulsion study to determine high level requirements**
  - Concentrate on fast response engine control
- **Studies on:**
  - Effects of relaxing various control limits
  - Operating margin estimation and management
- **Engine life monitoring and prognosis**
  - Stochastic component life models
  - Prognostic model to predict risk
- **Control strategy for performance/life trade-off**
  - Risk management
  - Optimum control for selected acceptable risk level
- **Flight/propulsion integration**
  - Flight simulator implementation