National Aeronautics and Space Administration

NASA DFRC Practices for Prototype Qualification

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Outline

- Introduction
- Overview of Some UAV's, RPV's and Manned Prototypes Flown at DFRC
- Basic Safety of Flight Considerations and Available Processes
- Frequently Used Standards and References
- Typical Safety-of-Flight Approaches
- Other Considerations
- Summary

NASA DFRC's Mission

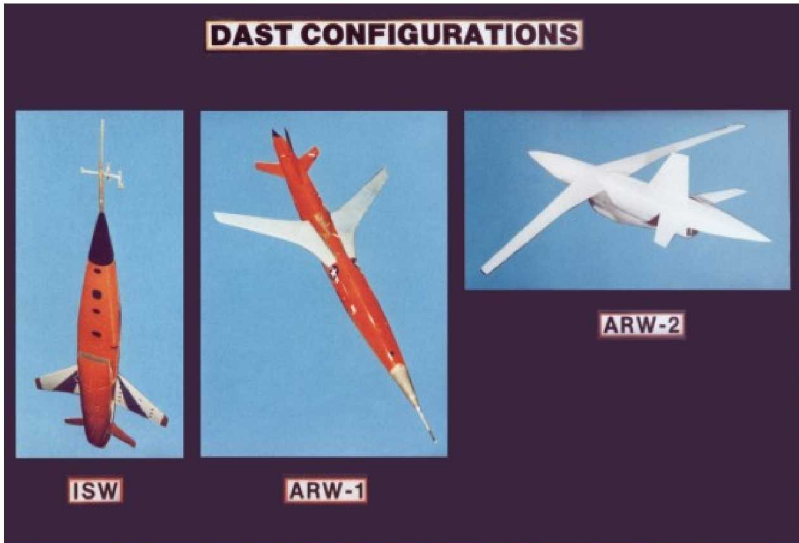
- The National Aeronautics and Space Administration is a civilian agency
- NASA was created from the National Advisory Committee for Aeronautics, NACA
- The Dryden Flight Research Center originally began as an offshoot of the Langley Research Center
- DFRC is the agency's premier flight research center and is located at Edwards AFB California

Air Vehicles Flown at DFRC

- UAV’s
- RPV’s
- Manned Prototypes
- Other

Mini Sniffer

Drones for Aerodynamic and Structural Testing



DAST Wing Flutter Testing

Spin Research Vehicle

Highly Maneuverable Aircraft Technology

HiMAT

PA-30 Twin Comanche

Controlled Impact Demonstrator

CID Touch Down

CID Post Impact Fireball

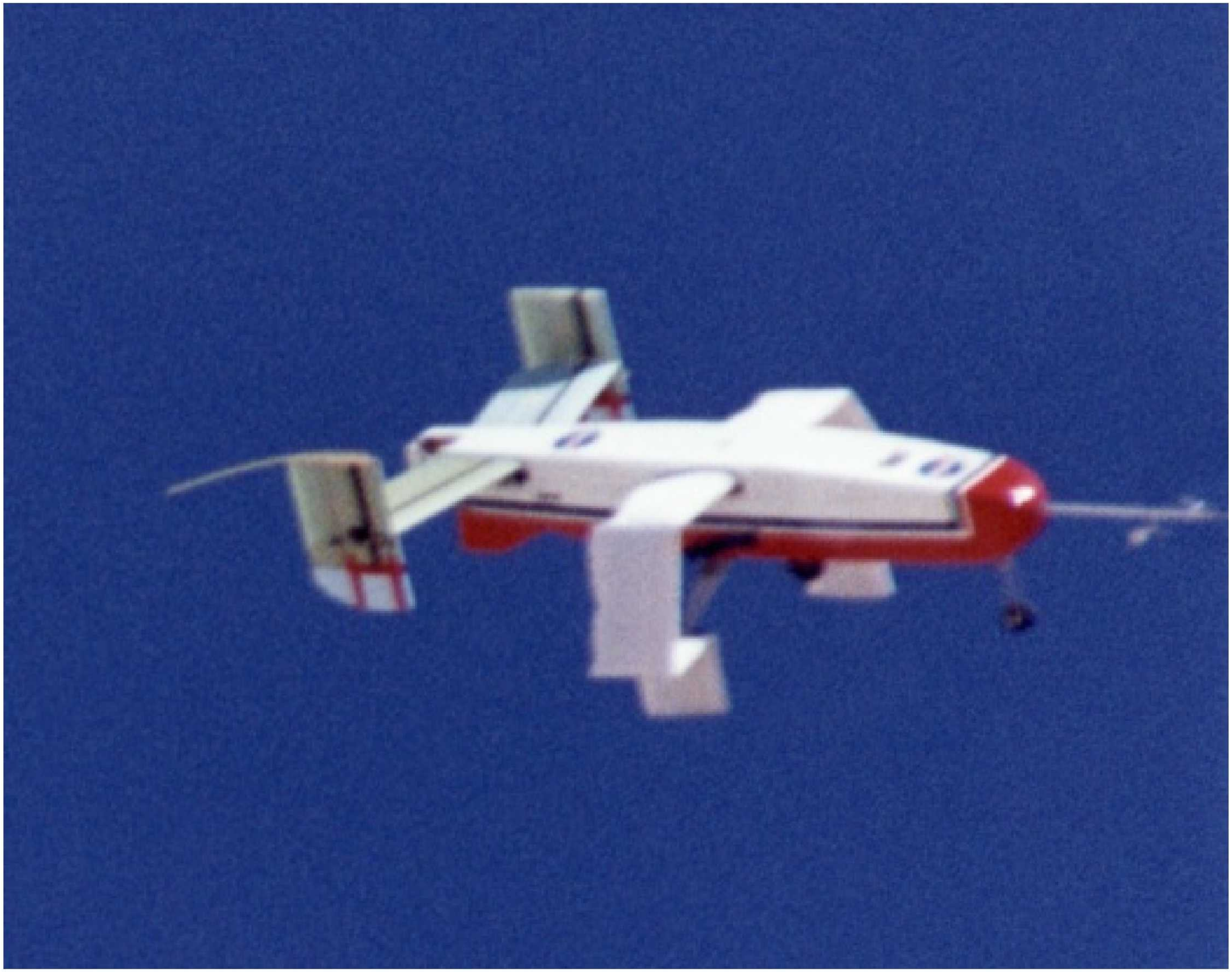
CID Video From Website

X-36

Inflatable Wing Demonstrator Being Carried Aloft

Inflatable Wing Aircraft Release

Wing Inflation



Inflated Wing in Controlled Flight

Autonomous Soaring Demonstrator

Autonomous Formation Flight

Automated Aerial Refueling Research

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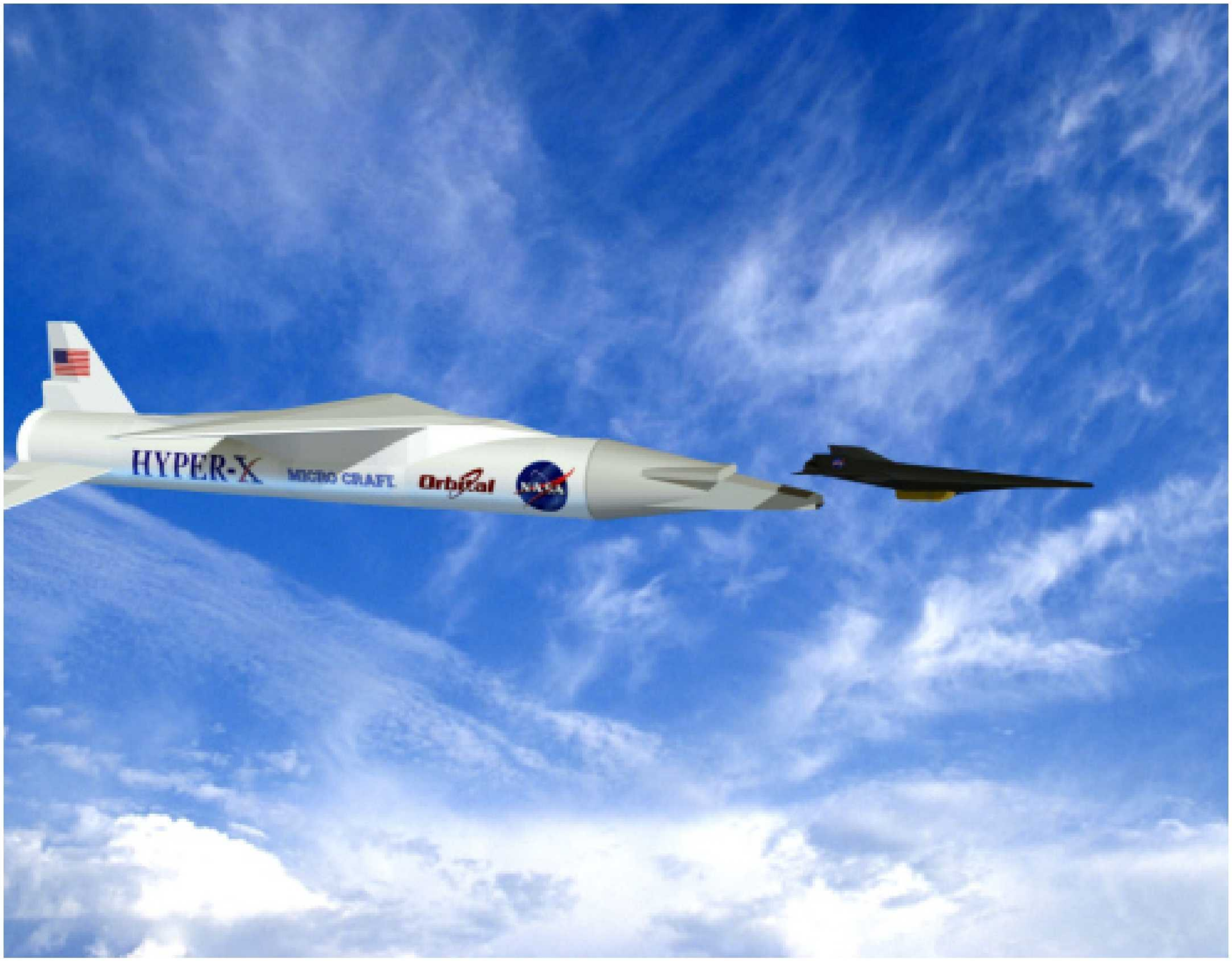
Autonomous Airborne Refueling Demonstrator

X-45A

Pegasus Light Satellite Launcher

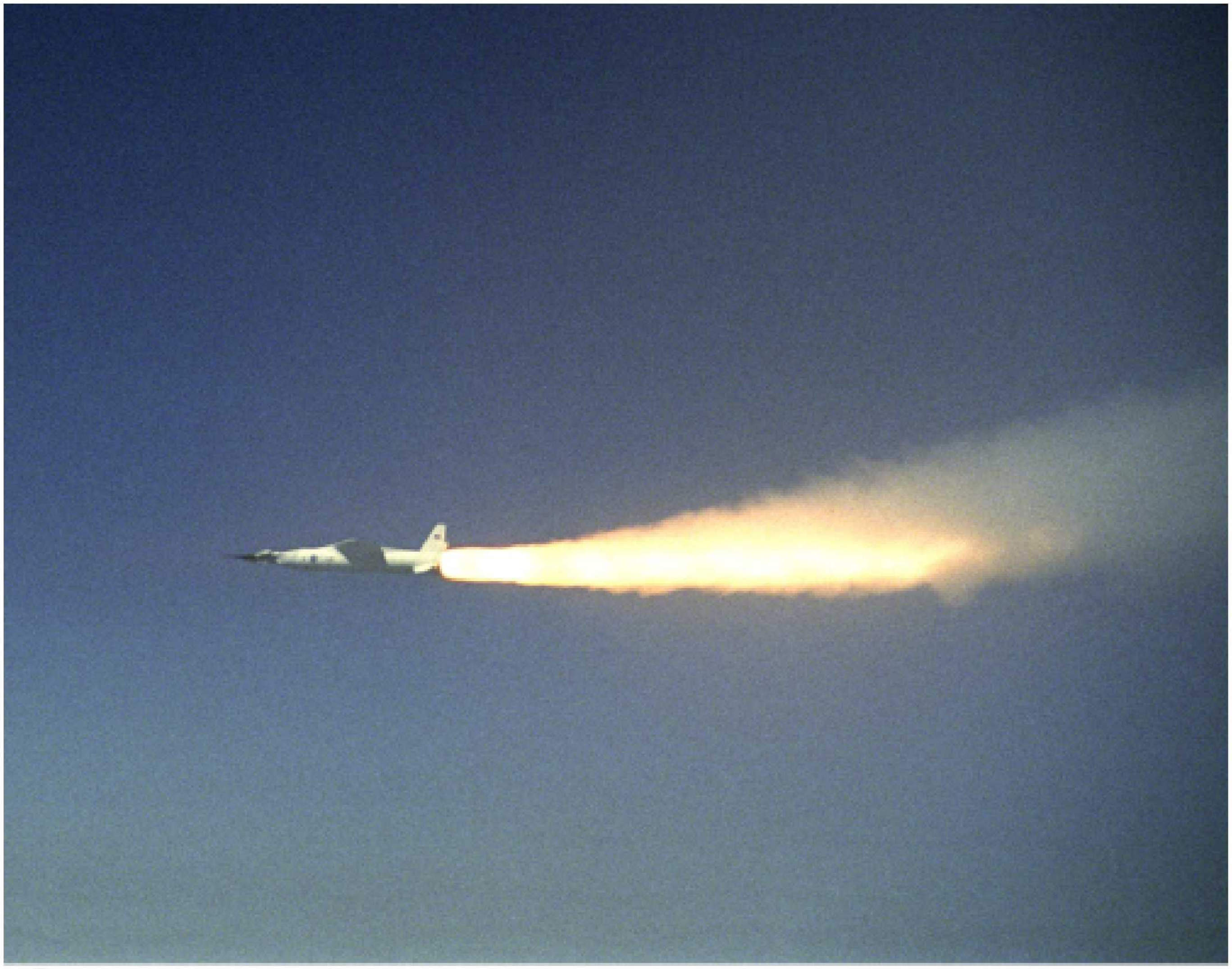
X-43A Hyper-X Illustrated Separation



Hyper-X Being Carried Aloft

Hyper-X Release

Hyper-X Booster Ignition



ERAST Demonstrator 2 (D-2)

Perseus B

Theseus

Proteus

Rans S-12 RPV Takes Off with Spacewedge

Spacewedge Landing

X-38 Crew Return Vehicle after Release

X-38 Landing

APV-3 Networked UAV Teaming Experiment

APV-3's

Helios

Altus II

Altair on a Fire Mapping Mission

IKHANA

X-48B Blended Wing Body

Global Hawk


NORTHROP GRUMMAN
NASA
DRYDEN FLIGHT RESEARCH CENTER
FIRE LANE

Basic Safety of Flight Considerations

- You don’t want it to break!
- So, you want the working strength to equal the max operating load.

Basic Considerations for Strength

- Traditional Design FS of 1.5 was probably developed from the ratio of Ftu to Fty of mild steel
- The Ftu/Fty ratio alone may have been acceptable for mild steel design as the toughness of mild steel covered stress concentration and fatigue issues
- For 7075 T6 aluminum alloy Ftu/Fty = 1.1 and we know this does not cover stress concentration and fatigue issues
- Therefore with modern materials we rely on empirically based design guidelines

Standards and References

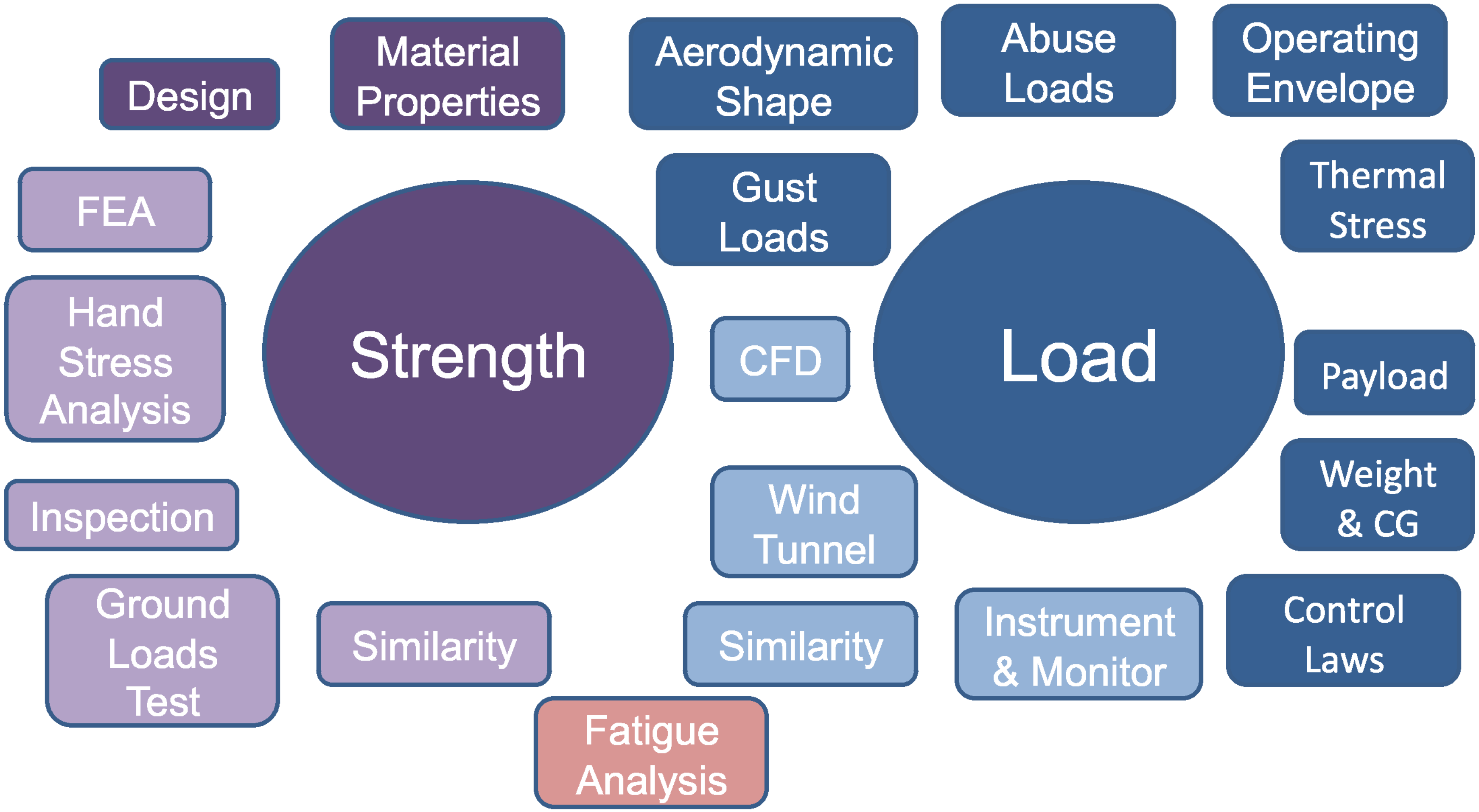
- NASA-STD-5001 “Structural Design and Test Factors of Safety for Space Flight Hardware”

- DHB-R-001 “Structural Design, Proof Test, and Flight Test Envelope Guidelines”
- DHB-R-006 “DFRC Flight Research Design Preparation Handbook”
- DHB-X-001 “Airworthiness and Flight Safety Review, Independent Review, Mission Success Review, Technical Brief and Mini-Technical Brief Guidelines”
- DCP-S-052 “Flight Termination System Requirements”
- DCP-S-002 “Hazard Management Procedure”

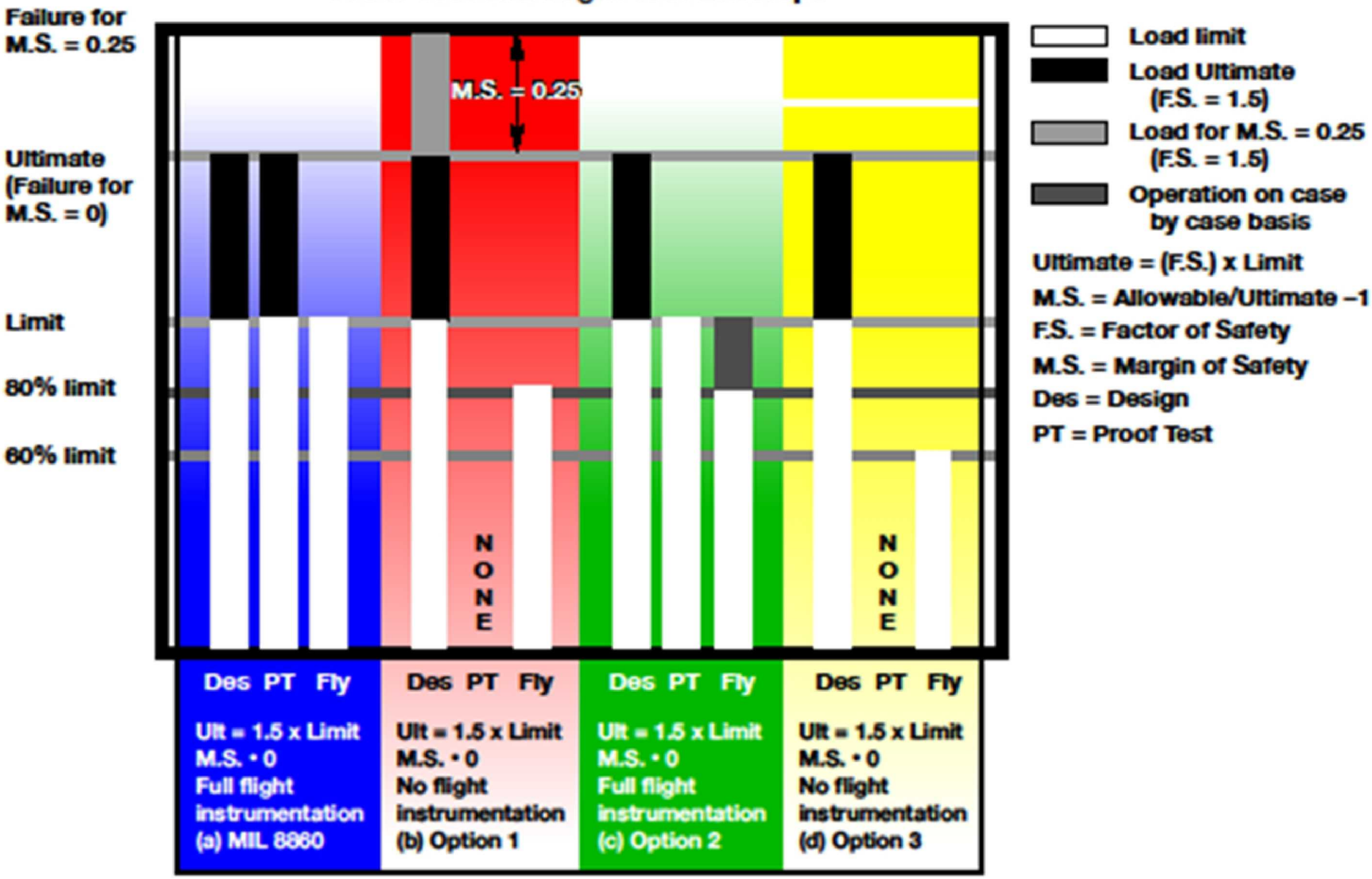
- FAR Parts 23 and 25 Reference

- Mil STD 8860 Reference
- Mil-A-8591 Reference

Required Knowledge and Available Processes



NASA DFRC Guidelines for Structural Design, Proof Test and Flight Test Envelope



Typical Safety-of-Flight Approaches

- Proven Aircraft
- New Prototype Design from Scratch
- Modified Aircraft
  1. New shape
  2. New control laws
  3. New operating envelope
  4. Limited scope add-on or substitute structure
  5. Extensively modified or replaced structure

Proven Aircraft

Examples: F-104, F-18, Predator-B, B-720

- Usually already designed and tested per Mil Std or FAR
- Operate within established envelope

All New Prototype Design

Example: X-29A

- CFD and Wind Tunnel Load Predictions
- Design to 1.875 Factor-of-Safety
- Install Structural Load Instrumentation
- Ground Load Test to ~110 % Design Limit Load (proof test and strain gage calibration)
- Fly to 80% DLL
- Post-flight Structural Inspections
- Expand Envelope Through Real-Time Monitoring
- Designed for 300 Hour Fatigue Life

X-29A

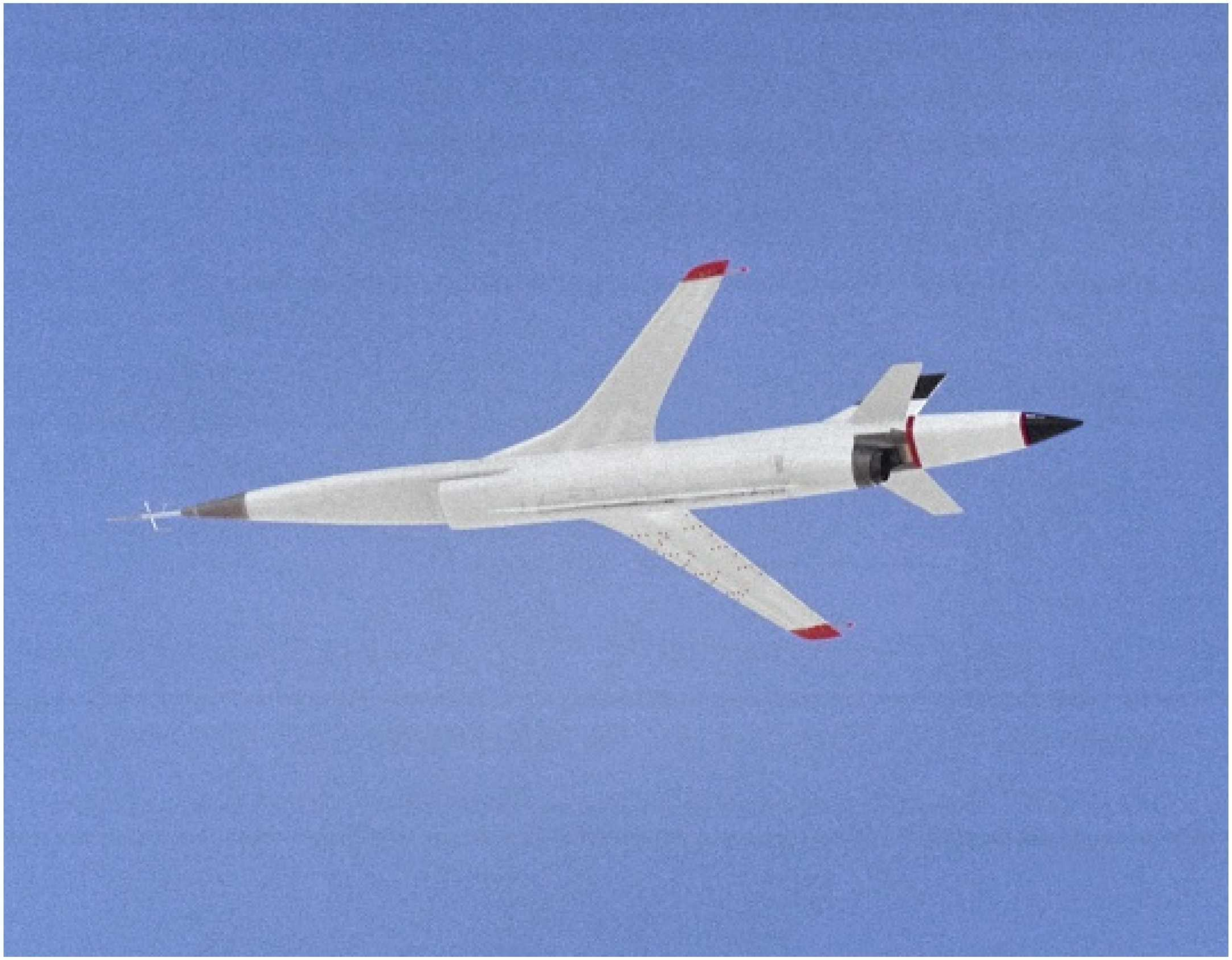
1) New shape

Examples:

DAST-ARW1, F-8 Super Critical Wing, AFTI/F-111 MAW

- Predict New Loads
- Installed Load Measurement Instrument
- Ground Load Calibration Test
- Load Test (driven by the structure also being new)
- Real-Time Monitor
- Post Flight Inspections

DAST ARW-1



F-8 Supercritical Wing

AFTI F-111 Mission Adaptive Wing

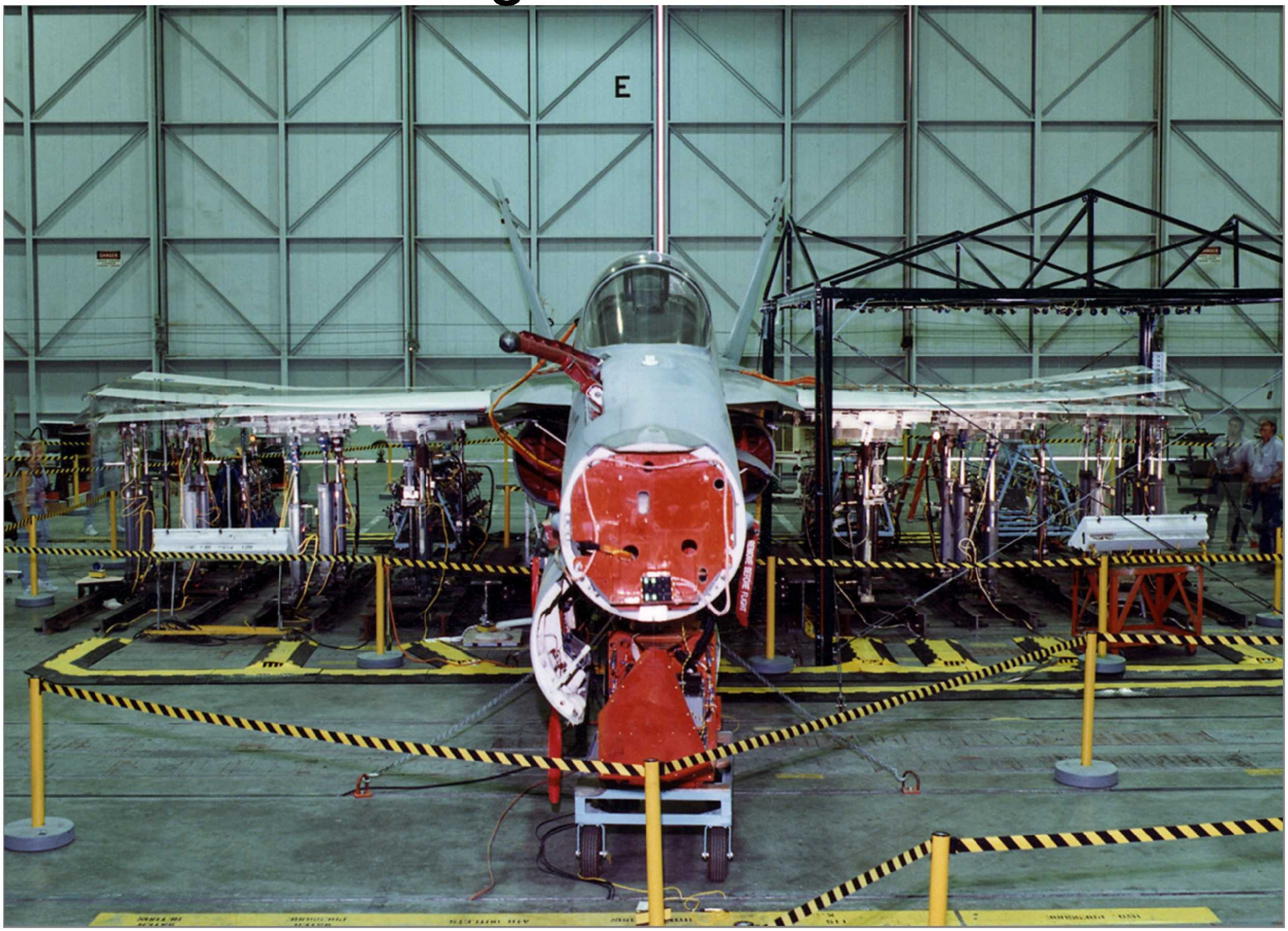
2) New Control Laws

Example: AAW F-18

- Installed Load Measurement Instrument
- Ground Load Calibration Test
- Real-Time Monitoring Against Established Component Load Limits
- Post-Flight Inspections

Active Aeroelastic Wing F-18

AAW Strain Gage Loads Calibration Test



AAW Loads Calibration Test Video (from Website)

3) New Operating Envelope

Example: F-18 HARV

- Instrument
- Real-Time Monitoring
- Post-Flight Inspections

F-18 High Angle of Attack Research Vehicle

F-18 HARV with Thrust Vectoring

F-18 HARV Engine Run

4) Limited Scope Add-On or Substitute Structure

Examples: SR-71 LASRE, ECLIPSE, F-16XL SLFC

- Predict Loads
- Design New Structure to 2.25 DLL
- Post-Flight Inspections
- Some Instrumentation
- Some Structural Sub-Component Load Tests
- Real-Time Monitoring
- Minimal Fatigue Consideration

Linear Aerospike SR-71 Experiment (LASRE)

Eclipse QF-106

Tow Hook Release Mechanism

Eclipse Aerotow Research Flight

F-16XL Supersonic Laminar Flow Control

5) Extensively Modified or Replaced Structure

Example: SOFIA B747SP

- CFD and Wind Tunnel Load Predictions
- Design to 1.5 Factor-of-Safety
  (With 10% material property knock down)
- Incrementally Validated FEM
- Install Extensive Structural Strain Instrumentation
- Baseline Flight Strain Survey
- Limited Ground Load Tests
  (Cabin pressure test, jacking test, door test)
- Expand Envelope Through Real-Time Monitoring
- Post-Flight Structural Inspections

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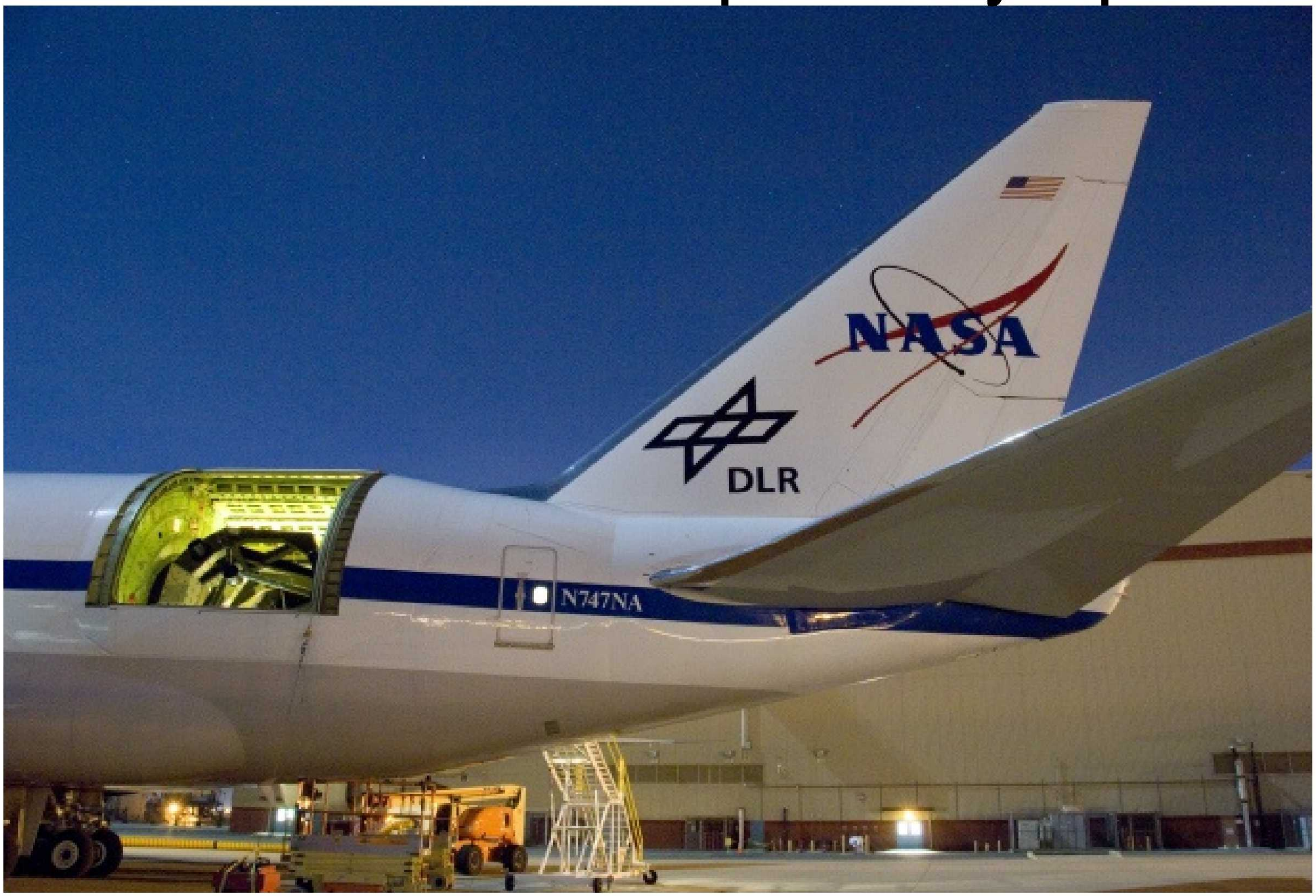
Stratospheric Observatory For Infrared Astronomy

SOFIA with Telescope Cavity Open



Non-Structural Mitigations

- Restricted Test Range
- Flight Termination System
- Hazard Analyses
- Independent Technical Review

Prototype Failure Causes

- Control System
  - Electronic Sub-Components
  - Mechanical Components
  - Software
  - Loss of Command Link
  - Sensors
- Other Causes
- Few Structural Related Catastrophic Failures

Concluding Comments

- A variety of combinations of structural processes can be used to produce good results
- Basic material properties limit the minimum design factor-of-safety that can be chosen
- Flight Terminations Systems do not always work
- Aircraft can leave controlled airspace
- Control systems can dominate structural loads
- Hazard analyses are great tools to identify weak links
- “Stakeholder” risk tolerance levels play a part in the big picture

Summary

- NASA DFRC uses Standard and Ad-Hoc Combinations of
  - Design Factors-of-Safety
  - Analyses
  - Ground Tests
  - Instrumentation and Monitoring During Flight
  - Inspection
- Hazard Analyses are Useful
- Airspace Restrictions
- Flight Termination Systems
- Independent Review and Management Approvals
- Catastrophic Structural Failures are Rare