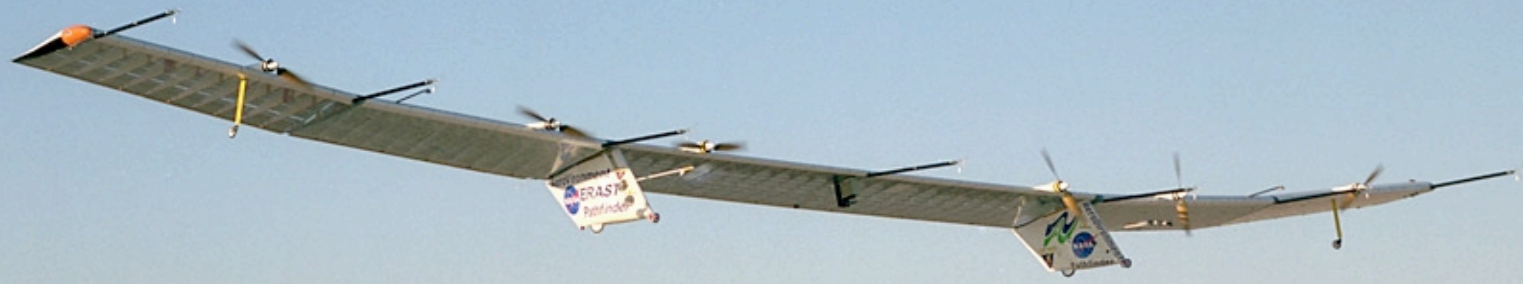
2005 Pathfinder+ Aero-Elastic Research Flight



31st MAES Symposium

San Jose, California

Presented by Robert Navarro, NASA Dryden Flight Research Center

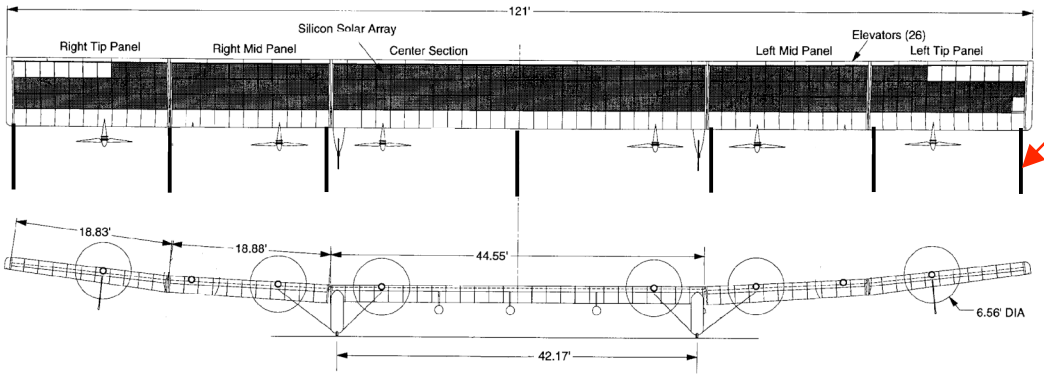
November 1– 6, 2005

HALE Class of Vehicles

Aero-elastic Research Flights Overall Objective

- **Investigate aero-elastic response of low-stiffness, lightweight, high-aspect ratio class of vehicles and improve existing analytical tools.**
  - **Improve modeling of Pathfinder+ type aircraft by instrumenting and flying the aircraft in turbulence along the lakebed edge and into the shear layer**
    - a. Improve analytical tools to look at data between flights in a timely manner
    - b. Characterize/measure the turbulence the aircraft is flying in
    - c. Measure the turbulence response of the aircraft (strains, accelerations & shape)
- **AeroVironment, Inc., Pathfinder+ Aircraft was instrumented with sensors to collect turbulence and A/C dynamics data**
  - **Two low altitude flights were conducted at NASA-DFRC, Edwards, CA in late summer of 2005.**
  - **Obtained good turbulence and A/C dynamic data sets**
  - **Data reduction phase has started**

GENERAL ARRANGEMENT



Atmospheric Turbulence Boom

(1 of 7)

Aircraft:

- **Five Wing Sections**
- **Two Landing Gear Pods**
- **3 Main Payload Attach Points Between Pods**
- **Six 2hp Electric Motors**
- **Six Helios propellers**
- **2 battery packs**
- **Carbon/Kevlar Fiber Construction**

- **Takeoff weight ~ 710±5 lbs**

Landing Gear Pods:

Fixed Landing Gear

ATMS Payload

Redundant Flight Computers

Redundant Data Links

Redundant Flight Critical Sensors

Redundant GPS Receivers

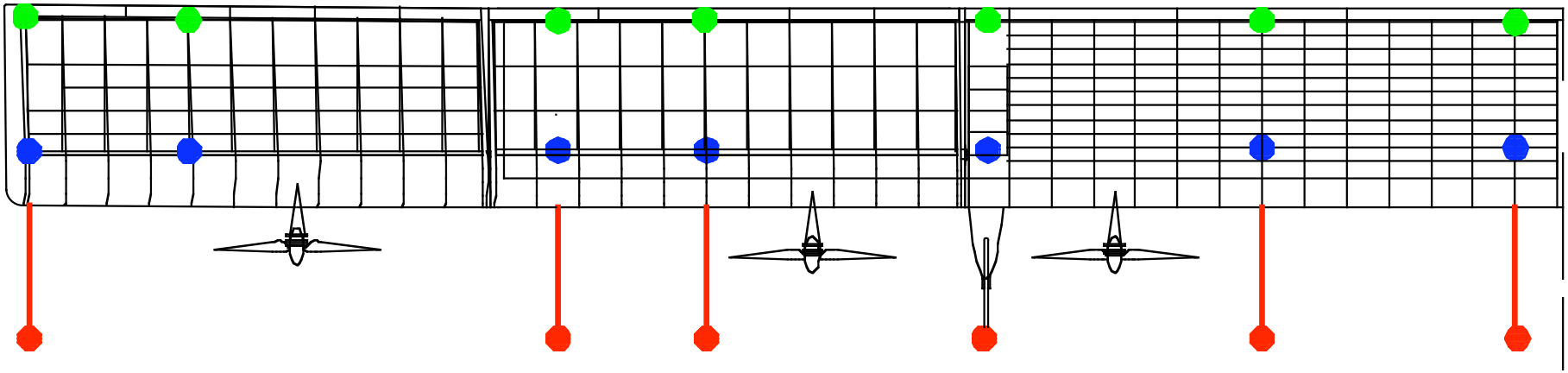
Mode 3C Transponder

Primary Lithium Battery Packs

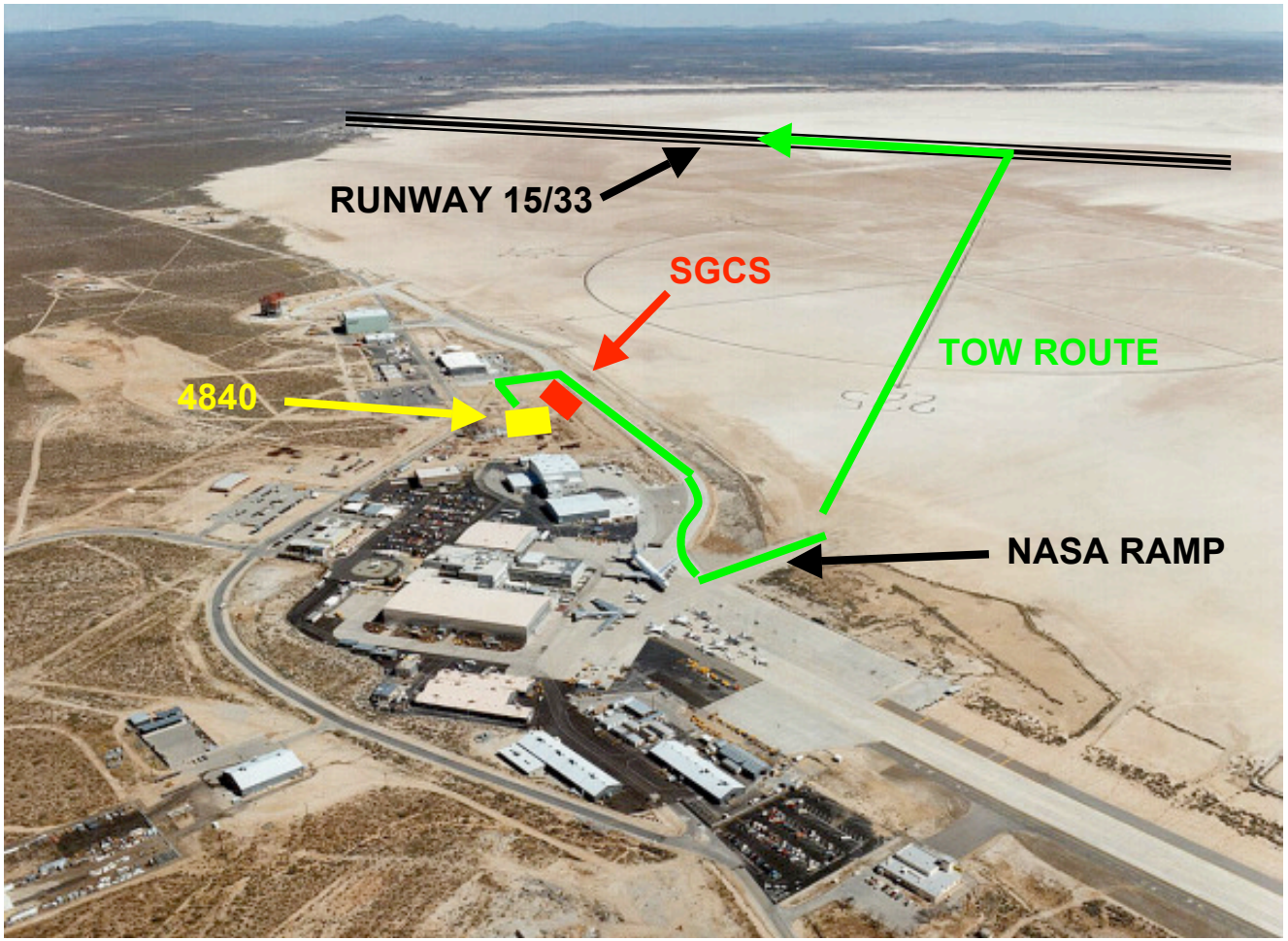
Flight Termination System

Sensor Locations

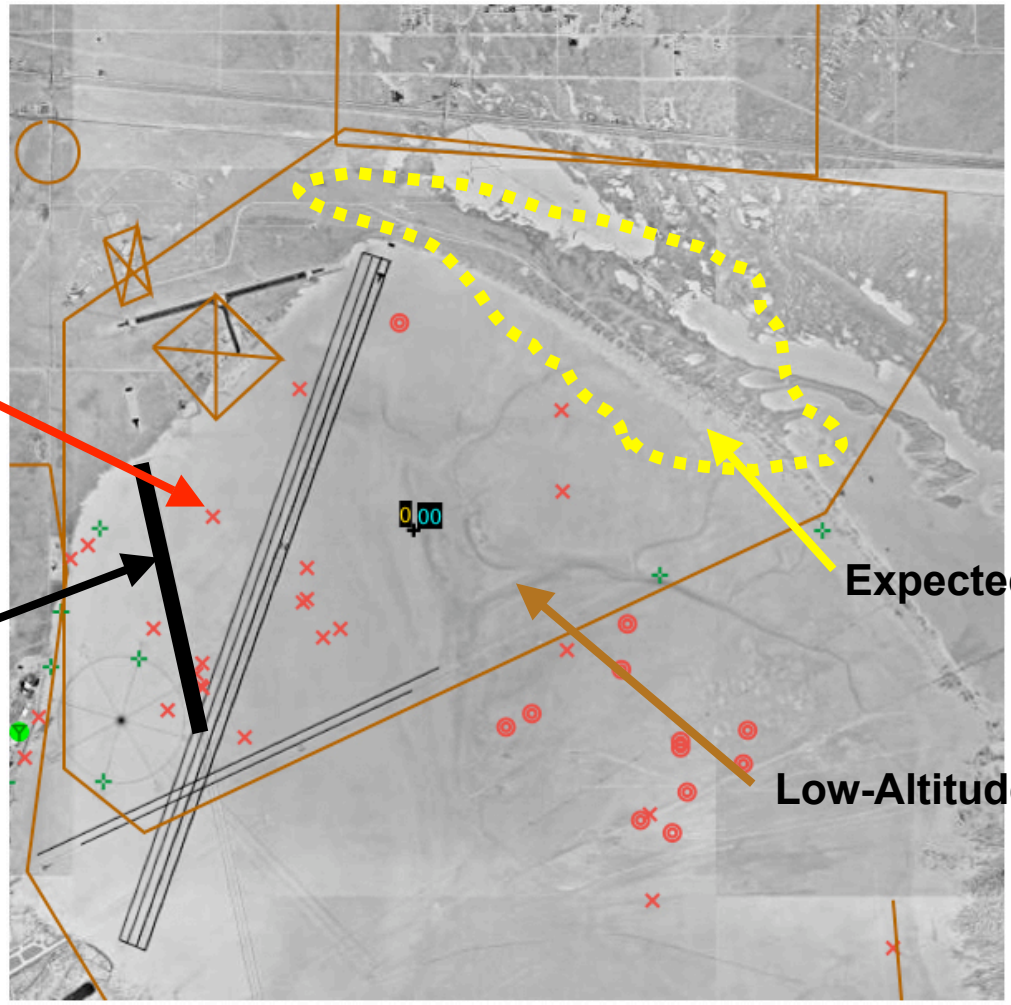
- Trailing Edge - Strain, Acceleration, Temperature
- Spar - Strain, Acceleration, Rod Position, Temperature
- Air Data - Acceleration, Pressure, Wind Data, Temperature



NASA RAMP OPERATIONS

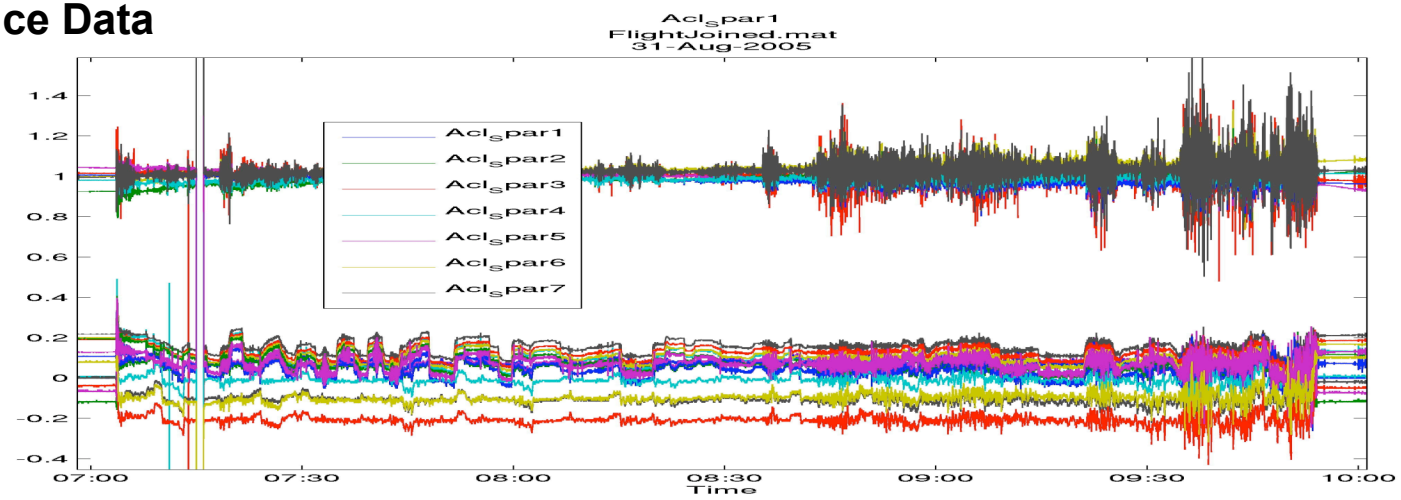


LAKEBED OPERATIONS

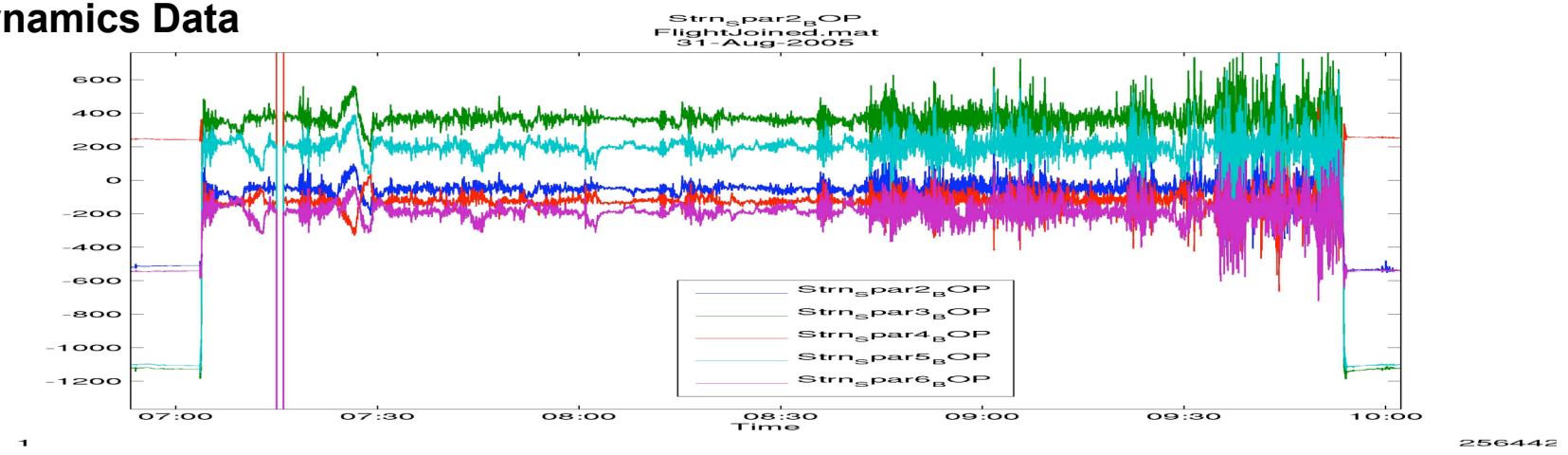


1st Flight Data Set

Turbulence Data



A/C Dynamics Data



Tool development / data usage

- **Flight test / turbulence data used for:**
  - ASWing
    - Steady-state dihedral correlation
    - Low-frequency dihedral sensitivity (spanwise turbulence, power and elevator response, configuration)
    - Spanwise gust correlations / time histories
  - NASTRAN
    - Steady state trim shape correlation
    - RMS turbulence transfer function estimates
    - Gust response spanwise and transfer function correlations
  - Mathematica
    - RMS transfer function estimates (moment, deflection, accelerations)
  - Turbulence Database
    - Requires turbulence velocities in inertial space
  - Database of flight data available for tool development and validation.
- **Data sets available to develop improve and validate models and analytical tools to better predict performance of low-stiffness, lightweight, high-aspect ratio class of vehicles**

HALE Tool Development & Validation

The Wright Flyer awakened the world to powered flight, but formal methods were required to develop the DC-3

- **Advance multidisciplinary (structures, aeroelastic, aerodynamics, materials, propulsion, controls, etc) "time-domain" analysis methods appropriate to highly flexible, "morphing" vehicles.**
- **Develop HALE ground/flight test techniques and procedures to validate new models.**
- **Capitalize on Helios knowledge-base and lessons learned.**
- **Improve criteria for a more rigorous assessment of the probability of identified hazards occurring as the vehicle migrates away from the original design concept.**

Building a HALE Foundation

HALE's of the Future

Foundational Tool Set
Transition from empirical methods to public domain design tools.

Use a representative HALE ROA to validate tool development for light-weight nonlinear aerostructures

Validate new tool sets

Better understanding of the flight environment

Test novel control schemes or lightly loaded airframes

Characterize the effects of different load distributions

Understand the inter-relationship between aeroelastic and stability & control modes

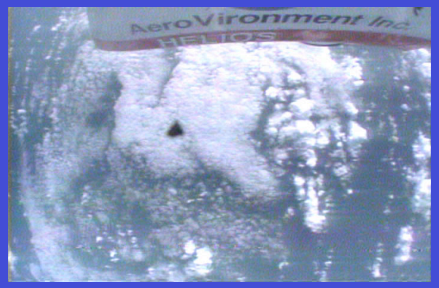
Evaluate human factors

Compelling Needs Drive HALE Efforts

Commercial

- Conquer the "Digital Divide"
- Provide global low cost high quality communications that truly connect the world

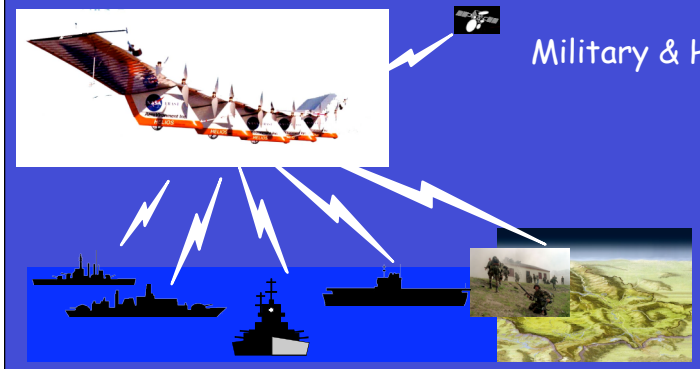
Science



- In-Situ Real-Time Global Atmospheric Information 24/7
- Sharply reduce uncertainties in atmospheric and weather models & forecasting

Disaster Mitigation

- People suffer because of the disaster information vacuum.
- Ameliorate human misery by providing communications and imagery before, during & after crisis



Military & Homeland Defense

- Fill the large gap in existing military & domestic security capabilities
- Reliable, low cost, flexible surveillance and communications platform

Land & Sea Resource Management

- Agriculture, water resources, forests, etc. suffer from lack of current information
- World-wide low-cost coverage would revolutionize resource management

Team Photo