https://ntrs.nasa.gov/search.jsp?R=20070035890 2018-07-26T08:35:49+00:00Z

National Aeronautics and Space Administration
Ames Research Center

SOFIA Stratospheric Observatory for Infrared Astronomy

SOFIA

Stratospheric Observatory For Infrared Astronomy

Nans Kunz, NASA Ames Research Center
Al Bowers, NASA Dryden Flight Research Center

Outline

SOFIA Stratospheric Observatory for Infrared Astronomy

- Heritage & History
- Level 1 Requirements
- Top Level Overview of the Observatory
- Development Challenges
- Highlight Photos

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

The Great Observatories

SOFIA Stratospheric Observatory for Infrared Astronomy

- Mt Wilson
- Mt Palomar
- Keck (Hawaii)

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

Hubble

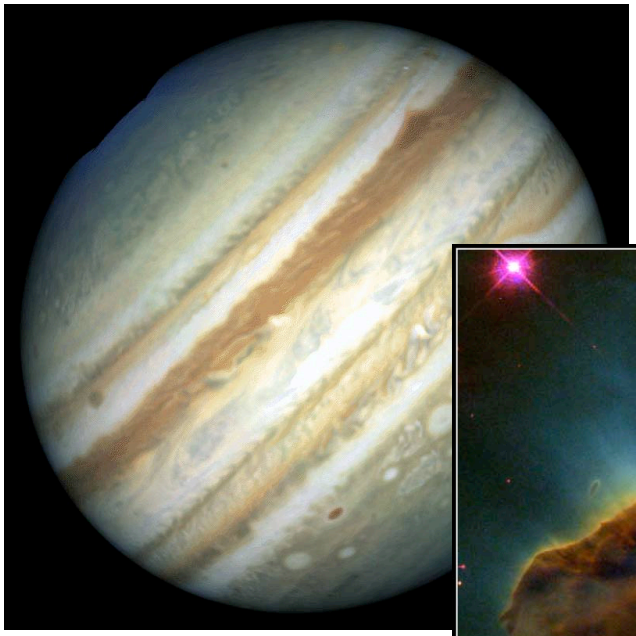
SOFIA Stratospheric Observatory for Infrared Astronomy

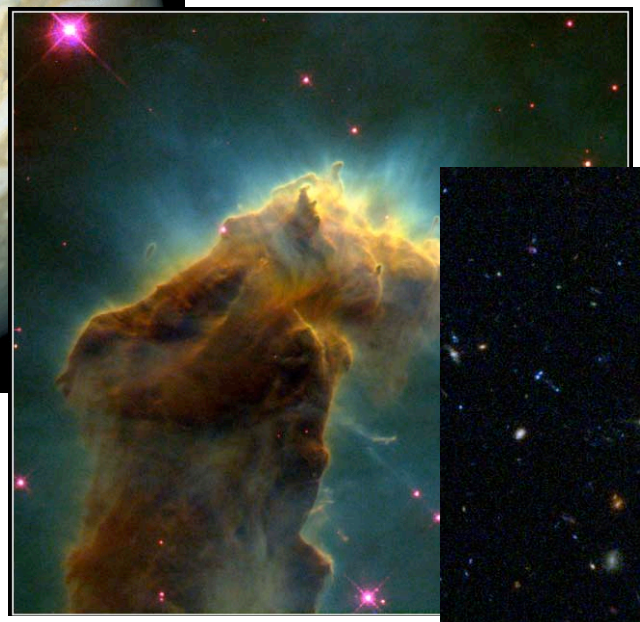
Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

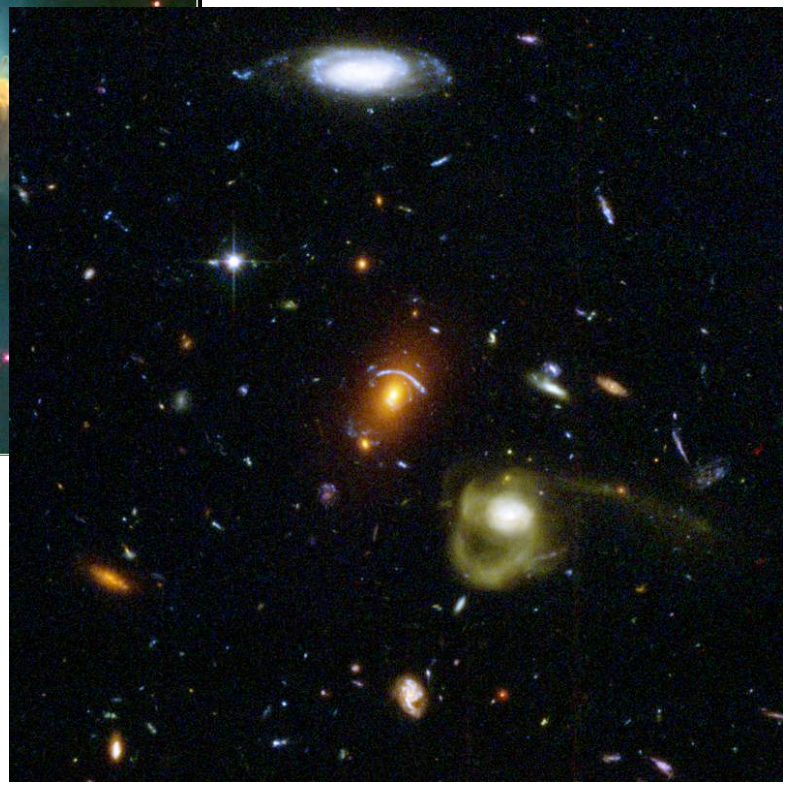
National Aeronautics and Space Administration
Ames Research Center

Hubble Discoveries

SOFIA Stratospheric Observatory for Infrared Astronomy







Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

HISTORY OF SOFIA

SOFIA Stratospheric Observatory for Infrared Astronomy

1965-1985

- **1965-1969** First use of NASA aircraft for infrared (IR) astronomy(CV-990 & Lear Jet)
- **1969** Planning started for installation of 36-inch telescope in a CV-990
- **1969** First astronomy community interest in a Boeing 747
- **1971** National Academy of Sciences (NAS) Decade Survey (Greenstein) Report recommended study of Large Airborne Telescope (LAT)
- **1974** First research flight of Kuiper Airborne Observatory; Initial studies on larger system
- **1983-1984** Success of Infrared Astronomy Satellite (IRAS) shows need for follow-up/exploitation
- **1984** "Stratospheric Observatory For Infrared Astronomy (SOFIA) Preliminary Feasibility Study" report issued (10th KAO Anniversary)
- **1985** SOFIA study funding provided – partnership with Germany started

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

HISTORY OF SOFIA

SOFIA Stratospheric Observatory for Infrared Astronomy

1986

- **JANUARY** Ames Research Center (ARC) establishes SOFIA Study Office
- **JANUARY** Challenger accident
- **MAY** SOFIA technology workshop at Ames;
- **MAY-NOVEMBER** Boeing-Military Aircraft Company Phase I Study; Confirms feasibility of installing a 2.5 meter telescope in a 747SP
- **JULY** Draft of the Memorandum of Understanding (MOU) for Telescope System study established with Germany
- **OCTOBER** Ames in-house Conceptual System study begins
- **NOVEMBER** Collaborative agreement made with DFVLR (Deutsche Forschungsanstalt für Luft und Raumfahrt)
- **NOVEMBER** German Phase A Telescope System studies kickoff

1987

- **FEBRUARY** Telescope System Phase A Study midterm review at ARC
- **FEBRUARY-SEPTEMBER** Boeing-MAC Phase II Study
- **MAY** German Phase A studies completed
- **JULY** SOFIA concept review held at ARC
- **SEPTEMBER** Ames Conceptual System study finished; SOFIA "Phase A System Concept Description" (The Red Book) published

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

HISTORY OF SOFIA

SOFIA Stratospheric Observatory for Infrared Astronomy

1988

- **JUNE** Space and Earth Sciences Advisory Committee (SESAC) recommends that SOFIA proceed into definition phase
- **JUNE** – Began planning for wind tunnel tests
- **OCTOBER** Phase B (Definition Study) kickoff for Aircraft System at Ames
- **OCTOBER** Phase B (Definition Study) kickoff for Telescope Assembly at Zeiss

1989

- **JANUARY** Telescope fixed at 2.5 meters by NASA HQ/DFVLR agreement
- **FEBRUARY** Wind tunnel model design complete and fabrication begins
- **MAY** Project Definition Review completed at ARC; Found SOFIA well planned and defined and approved the project to proceed into the development phase contingent on a successful completion of wind tunnel test
- **JUNE** Draft MOU for development & operations phases reviewed by Ames & DLR
- **JULY** Non-Advocate Cost Review successfully completed, Affirmation of project readiness for 1991 start; FRG listed as responsible for telescope assembly
- **JULY** Definition studies completed by NASA
- **SEPTEMBER** Telescope and Aircraft System Phase B final reviews are completed and reports published
- **OCTOBER** Boeing re-organizes; No longer interested in "one-off" mods like SOFIA
- **NOVEMBER** Berlin wall falls; Reunification of East and West Germany considered

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

HISTORY OF SOFIA

SOFIA Stratospheric Observatory for Infrared Astronomy

1990

- **MARCH** SOFIA I wind tunnel model tests start
- **MAY** DARA budget cuts begin
- **JUNE** Non-Advocate Review is held for SOFIA in accordance with the agency's new start-gate policy; SOFIA deemed ready to proceed to development again and recommended for 1992 start
- **JUNE** Preliminary engineering study of SOFIA Ground Support Facility
- **JUNE** Aircraft System modification procurement activities underway, Source Evaluation Board (S.E.B.) established
- **JULY** Wind tunnel tests successfully completed; A low drag passive shear layer control device derived that exceeds performance expectations
- **OCTOBER** Reunification of Germany, requires reduction of German government agencies' budgets

1991

- NAS Decade Survey (Bahcall) Report recommends SOFIA as the top priority moderate new missions for NASA
- **MAY** With the realization of DARA budget cuts, SOFIA plans FY92 to prepare for an all U.S. program with optional help from DARA in FY94
- **MAY** Aircraft Modification Contractors road trip to find companies w/interest/capability to perform the SOFIA aircraft modification
- **JULY - SEPT** In-house descope studies,to reduce total cost; 5 cases considered, one considers an aft cavity location to reduce aircraft modification costs
- **OCTOBER** Aft cavity location adopted as new baseline for the Aircraft System

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

HISTORY OF SOFIA

SOFIA Stratospheric Observatory for Infrared Astronomy

1992

- **JANUARY** IR measurements made of the Shuttle Carrier Aircraft (SCA) engine plumes using IR cameras mounted in Lear jet
- **DECEMBER** Final reports of Aircraft Systems NRA concur with Ames in-house study regarding feasibility and cost savings for the aft cavity configuration

1993

- **JUNE** ARC Code R agrees to de-mothball 14 ft wind tunnel for SOFIA test; Test entry planned for 1994
- **AUGUST** Headquarters OSS proposes SOFIA as an FY95 new start to Administration/Comptroller

1994-1995

- SOFIA New Start approved
- Headquarters mandates Privatization concept:
  - "Government owned, contractor operated"
  - "Better-Faster-Cheaper"
- Procurement proceeds for development & operations phase
  - Science organization prime - Government work packages

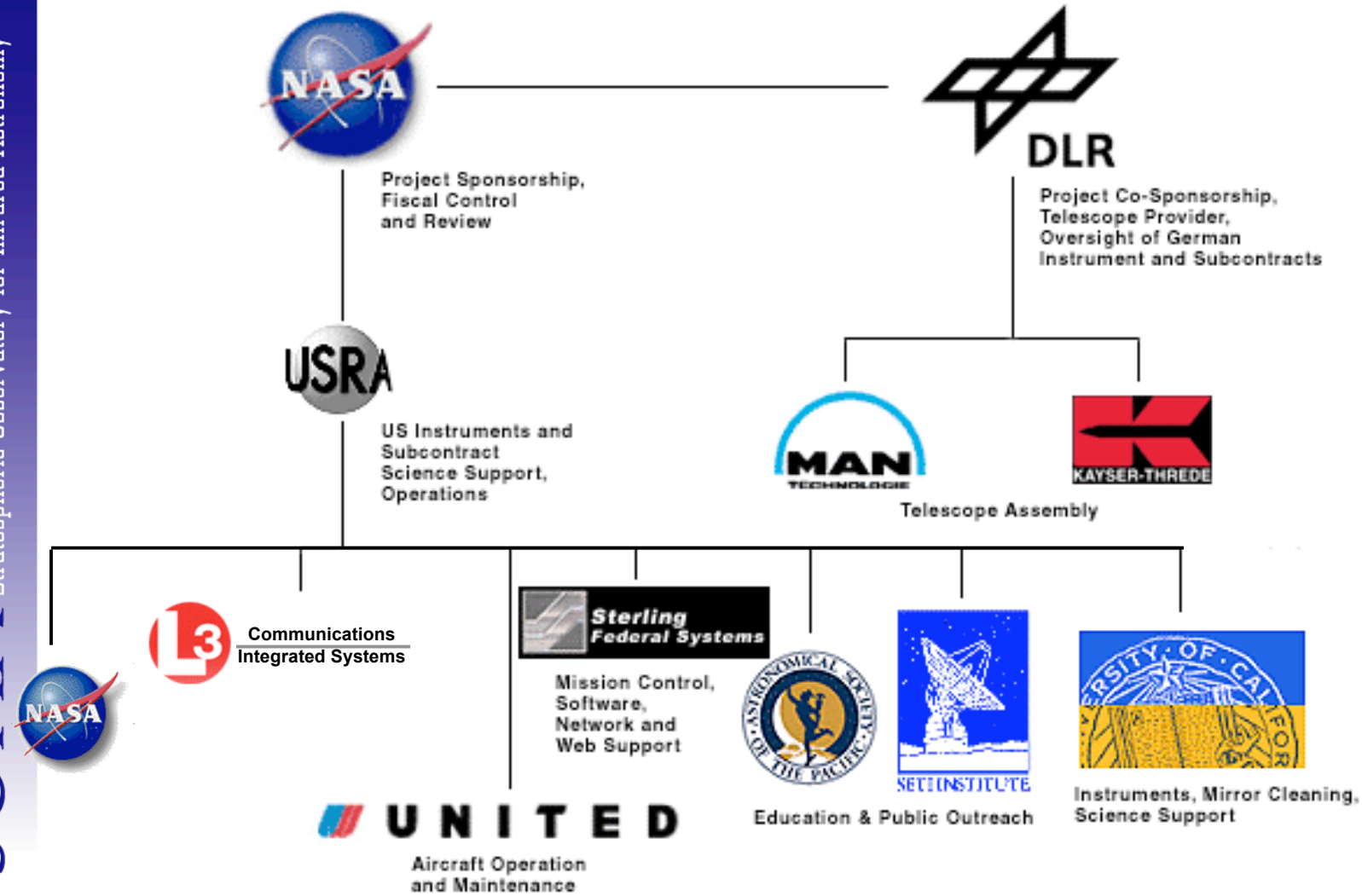
1996

- **December -** SEB process complete - NASA contract awarded to USRA-UAL-Chrysler Tech Team
- **December -** DLR awards contract to team of MAN-G, MAN-T, & KT

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

SOFIA Stratospheric Observatory for Infrared Astronomy

The Org structure for majority of the development phase



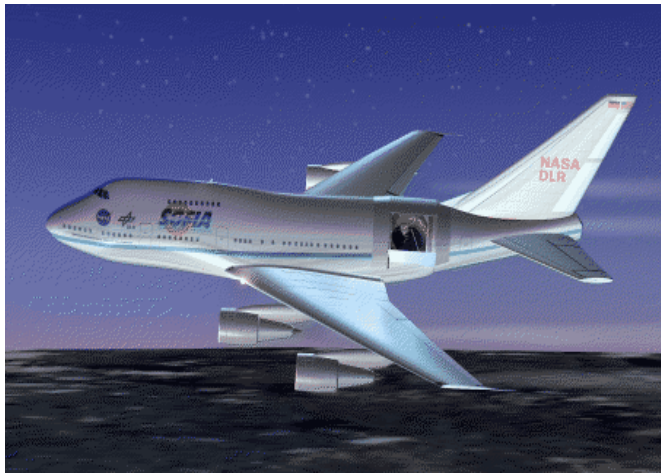
Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

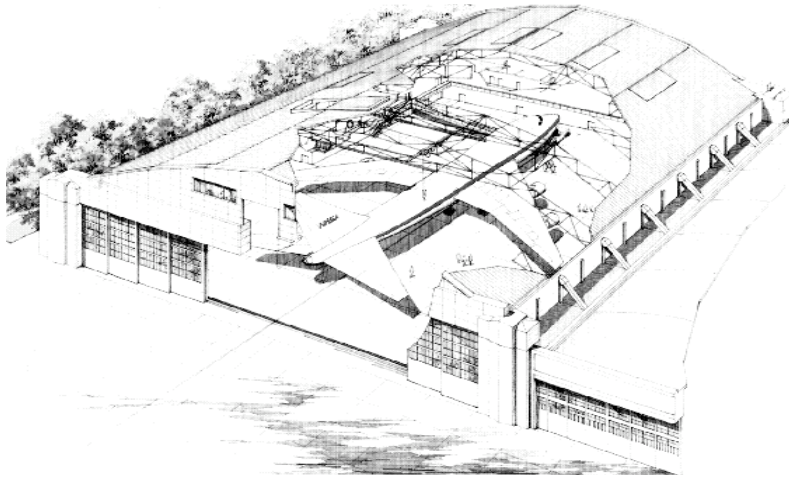
National Aeronautics and Space Administration
Ames Research Center

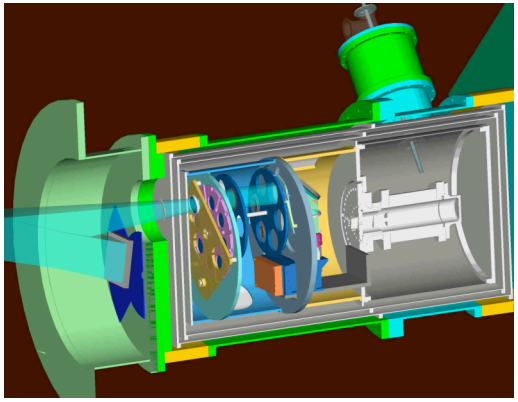
Major Components of SOFIA

SOFIA Stratospheric Observatory for Infrared Astronomy

Observatory







Science Instruments

Science and Mission Operations Center

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

HISTORY OF SOFIA

SOFIA Stratospheric Observatory for Infrared Astronomy

Milestones

- 1997
  - System requirement reviews completed (2)
  - Baseline Flight test completed
  - SOFIA V Wind Tunnel test completed
- 1998
  - TA PDR completed
  - AS PDR completed
- 1999
  - Schedule slips
  - 3% S&C wind tunnel tests completed
- 2000
  - TA CDR completed
  - AS CDR completed
  - Schedule continues to slip
- 2001
  - TA ground I&T begins
  - September 11 attack - impacts US airlines

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

HISTORY OF SOFIA

SOFIA Stratospheric Observatory for Infrared Astronomy

Contract Milestones

- 2002
  - TA ground testing & Project Final Review completed
  - TA shipped to Waco September 2002
- 2003
  - TA integration into aircraft begins
  - Columbia accident
  - UAL departs SOFIA program under bankruptcy protection (9/11)
- 2004
  - TA functional, SI mounted, First Light August 2004
  - Aircraft Proof pressure test completed
  - DSI selected in Germany to support SOFIA Ops
- 2005
  - Push for flight leads to multiple mishaps then work stoppage
  - Mod audit conducted
  - Per ICSMR recommedations Re-baseline & new approach begins

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

HISTORY OF SOFIA

SOFIA Stratospheric Observatory for Infrared Astronomy

Contract Milestones

- 2006
  - SOFIA Budget zeroed for FY07 budget
  - SORT commissioned to consider options for future
  - GVT conducted on aircraft in June per IMS established 8/2005
  - HQ dropped requirement for FAA certification (Public Use)
  - Budget rebaselined & program office transferred to Dryden
  - Flight Readiness Review started in Oct
- 2007
  - Airworthiness Flight Safety Review Board on 15 Mar 07
  - First Flight on 26 Apr 07
  - Ferry Flight of SOFIA to Dryden 31 May 07
  - Begin Phase 1 flights (door closed envelope expansion) Sep 25 07?

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

Heritage

SOFIA Stratospheric Observatory for Infrared Astronomy

- Kuiper Airborne Observatory is the direct Predecessor to SOFIA
  - Modified C-141 with 36” Diameter Telescope
  - Flew w/open port cavity 1974-1995
  - Cavity in forward fuselage
  - Porous fence was primary Shear Layer Control device
  - Aft Ramp augmentation based on SOFIA development wind tunnel test results was implemented in 1993
    - Flow attachment significantly improved
    - Internal Cabin noise significantly reduced for Open cavity flight
    - Cavity Environment significantly improved
    - Allowed fence position to be lowered from 30° to 10°
    - Reduced drag - improved flight performance

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

Kuiper Airborne Observatory (KAO)

SOFIA Stratospheric Observatory for Infrared Astronomy

1974-1995

Lockheed C-300
(Modified C-141)

36” Telescope

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

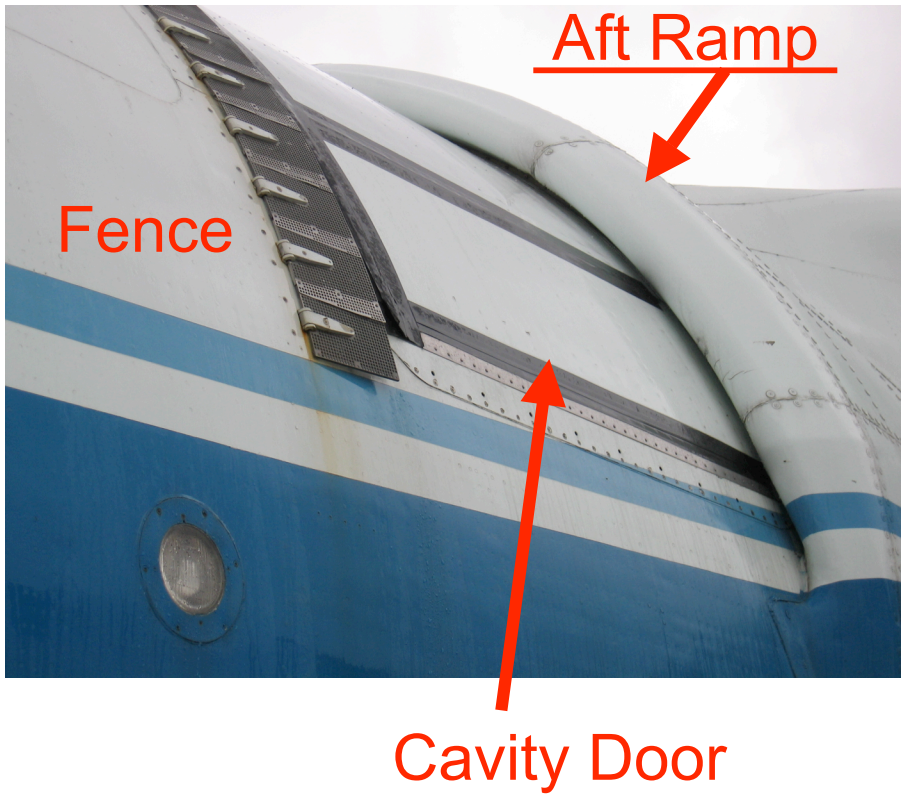
KAO Aft Ramp - Passive Flow Fairing

SOFIA Stratospheric Observatory for Infrared Astronomy

- Installed in 1993
- Developed from wind tunnel test data and research performed during initial development of the SOFIA Shear Layer Control System
- KAO design represents a compromise due to existing OML & cavity door constraint

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

KAO Aft Ramp - Passive Flow Fairing



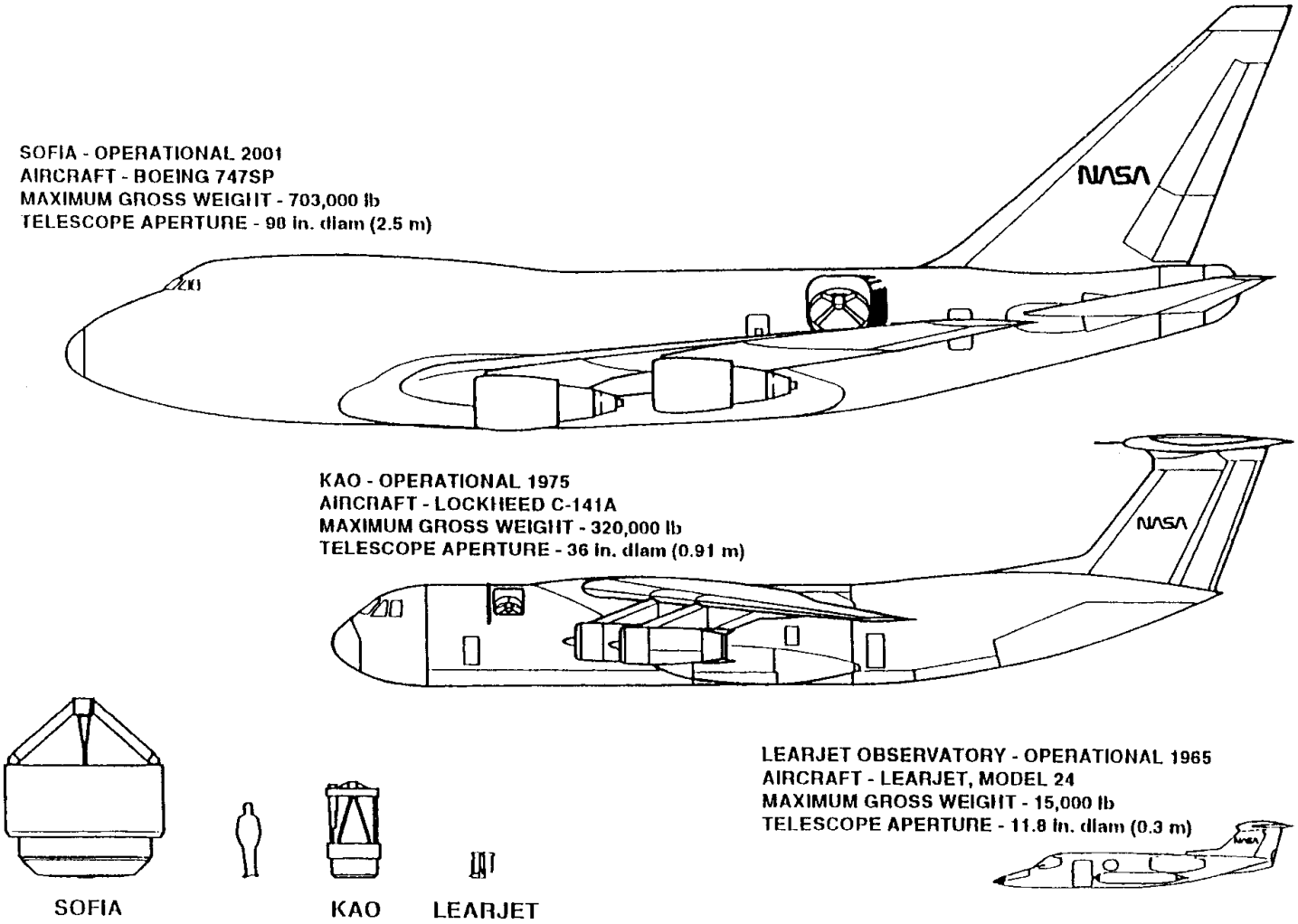
- Designed to stabilize the shear layer re-attachment downstream of the open cavity.
- Enabled KAO to fly with the cavity fence at 10° instead of 30°
- Reduced Shear layer thickness
- Significant improvements in "Seeing"
- Reduced cavity aero-acoustics
- Reduced structural fatigue in and around cavity
- Pilot noticed improvements in open door flight

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

SOFIA - Airborne Astronomy Size Comparison

SOFIA Stratospheric Observatory for Infrared Astronomy



Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

SOFIA - Requirements/Specifications

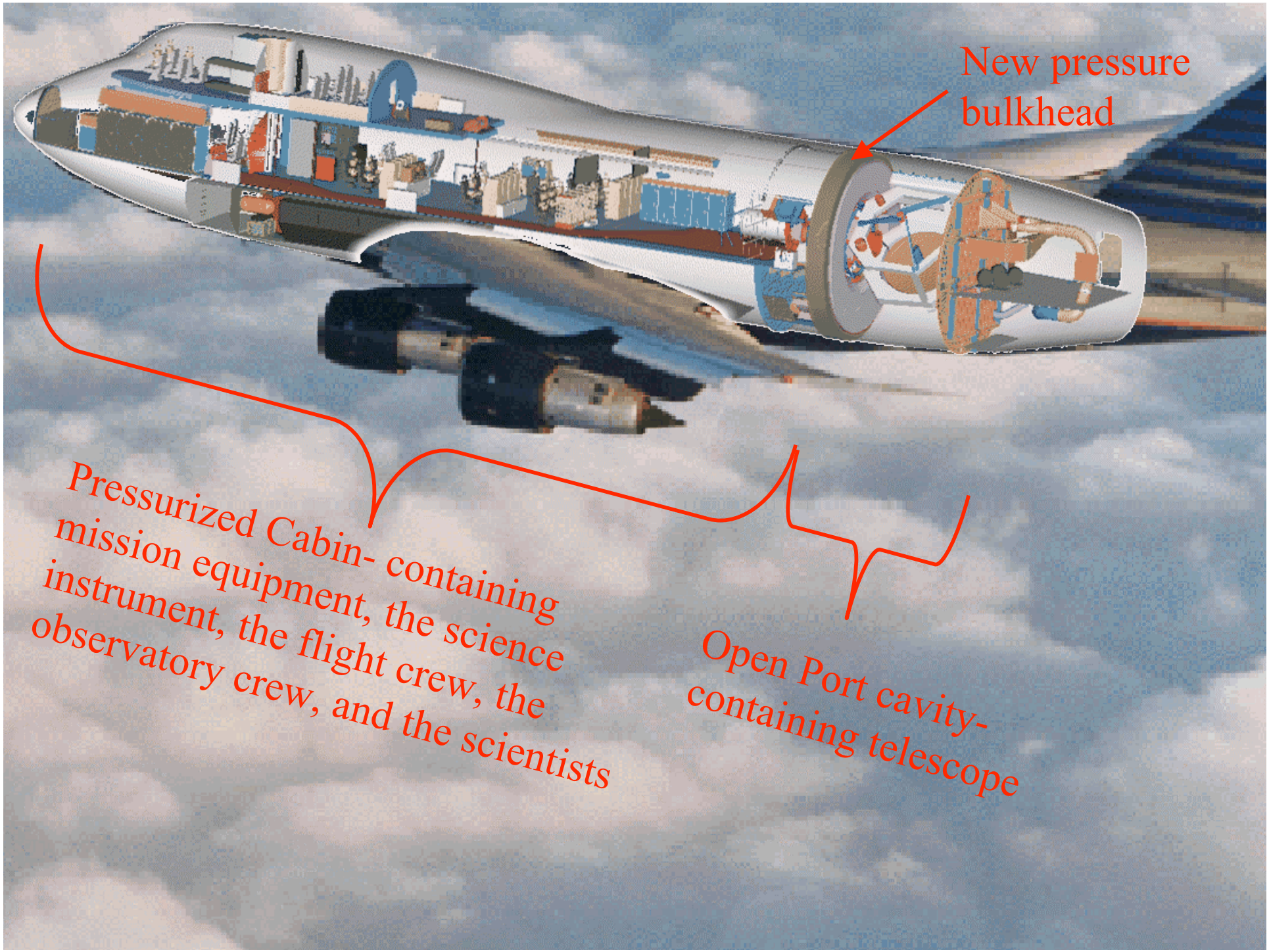
SOFIA Stratospheric Observatory for Infrared Astronomy

- Wavelength Range 0.3 - 1600 microns
- Unvignetted elevation range 20° to 60° above the horizon
- Configuration: Instrument Access in Cabin
- Telescope effective Aperture Diameter 2.5 meters
- Time at ≥ 41,000 feet ≥ 6 hours
- Observing hours per year ≥ 960
- Lifetime≥ 20 years
- PI Teams per year capability ≥ 40
- Education Goals: NASA OSS Guidelines
- ~~Airworthiness: FAR FAA Certification~~
- IR functional capabilities: chopping, nodding, & scanning
- Image quality 80% encircled energy within 1.5 arcsec at visible wavelength
- Image stability at focal plane 0.2 arcsec rms

Combined to 80% encircled energy within 5.3 arcsec diameter image size at First Science Flight improving to 1.6 arcsec within 3 years.

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

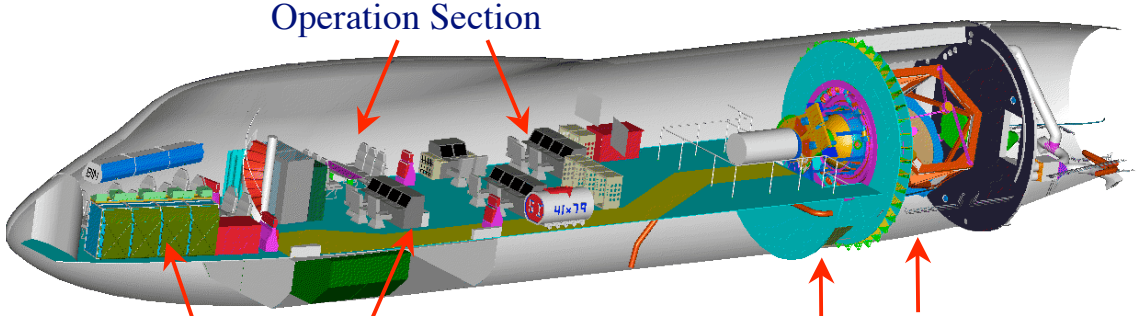
SOFIA
Location of future cavity opening

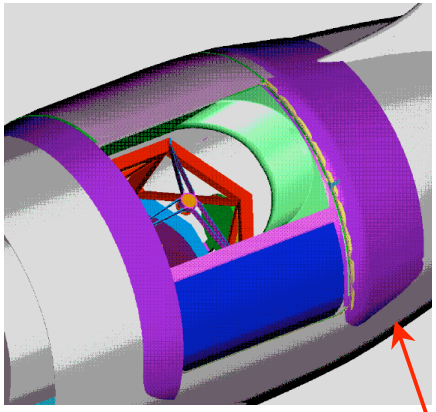

New pressure bulkhead
Pressurized Cabin- containing mission equipment, the science instrument, the flight crew, the observatory crew, and the scientists
Open Port cavity- containing telescope

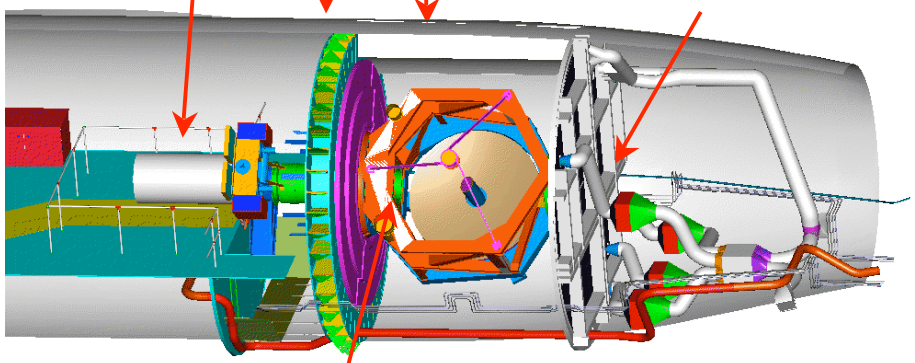
National Aeronautics and Space Administration
Ames Research Center

Airborne Observatory Layout

SOFIA Stratospheric Observatory for Infrared Astronomy



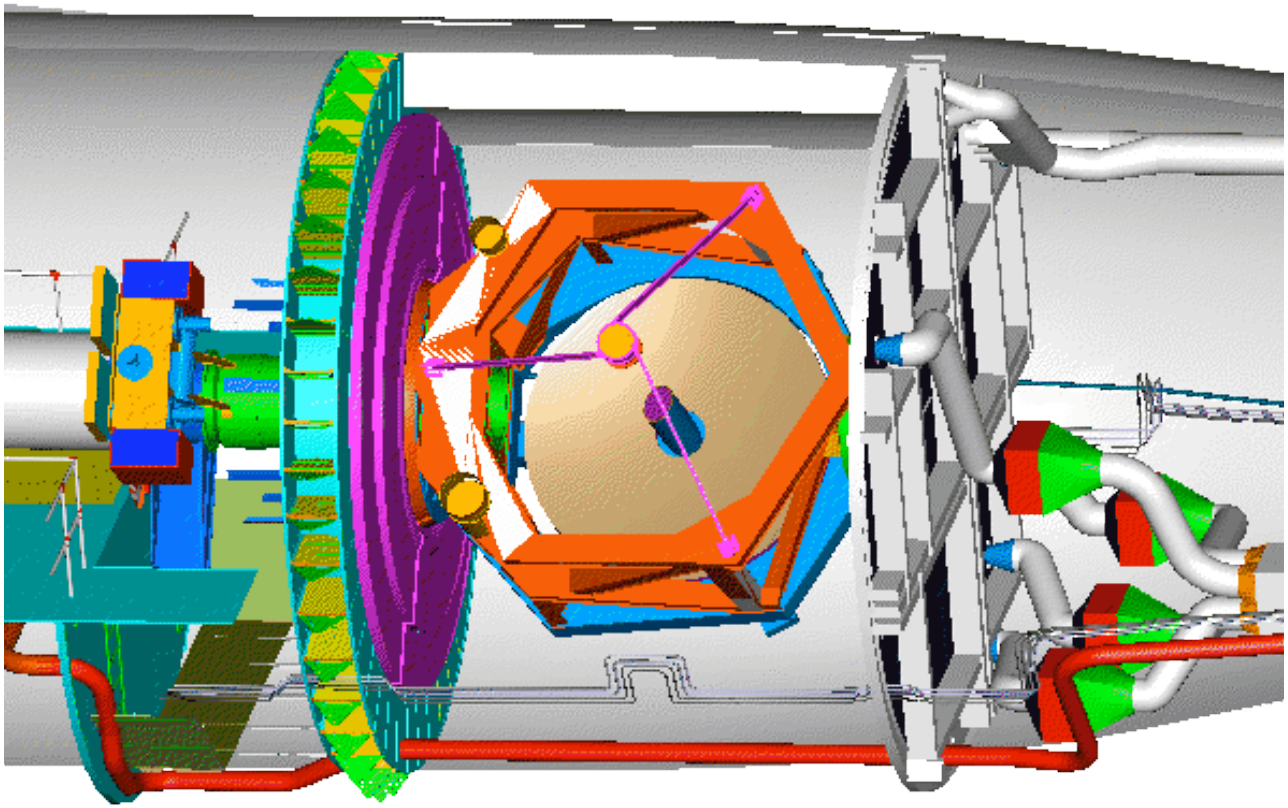




Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

2.5 Meter effective aperture

- Aircraft Size
- Large 2.7 Meter Primary Mirror
- "Fast" Mirror to fit within aircraft
  - Drives alignment/stiffness requirements

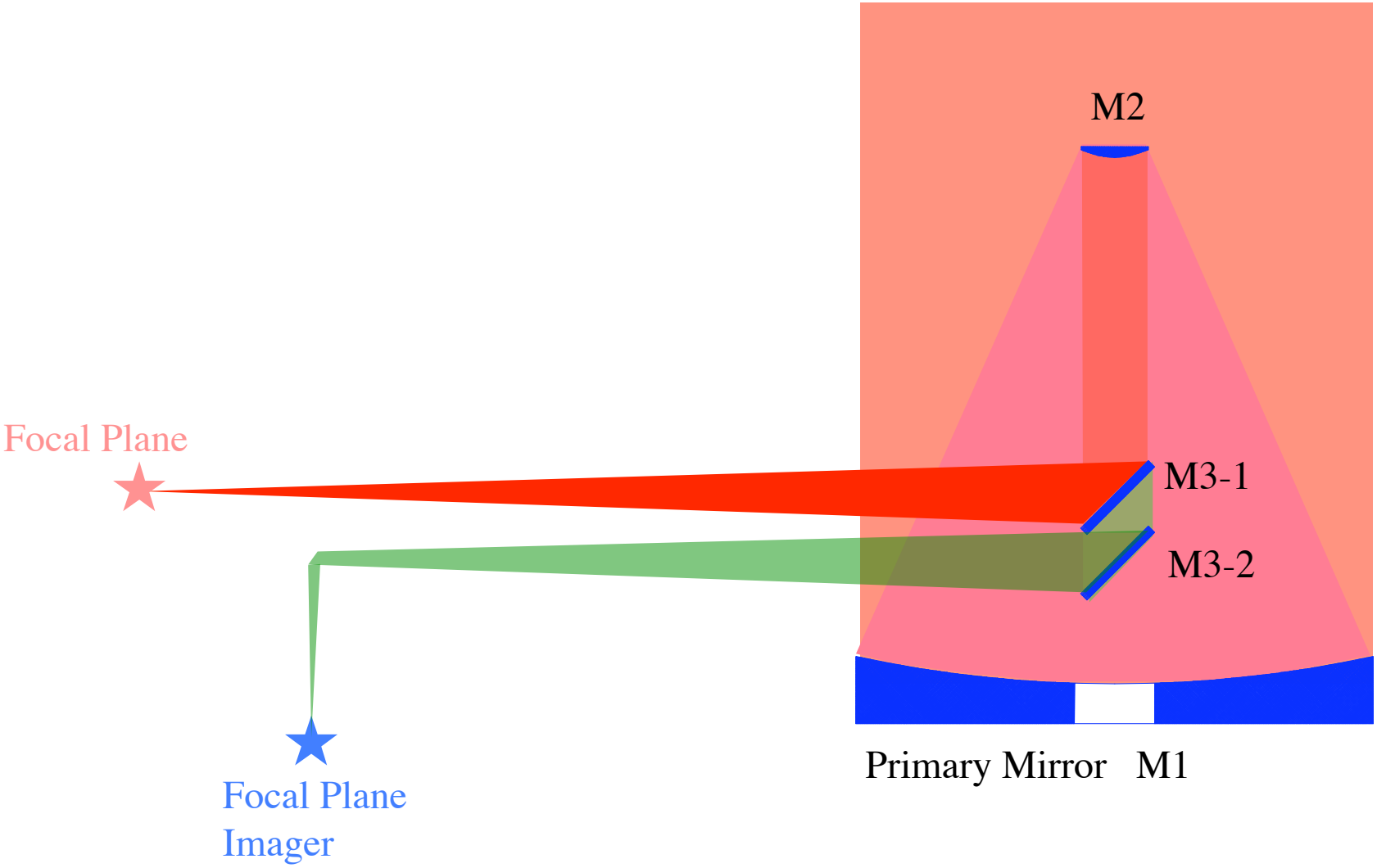


Telescope Size is Maximum that can fit Available Volume

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

Telescope Optical Layout

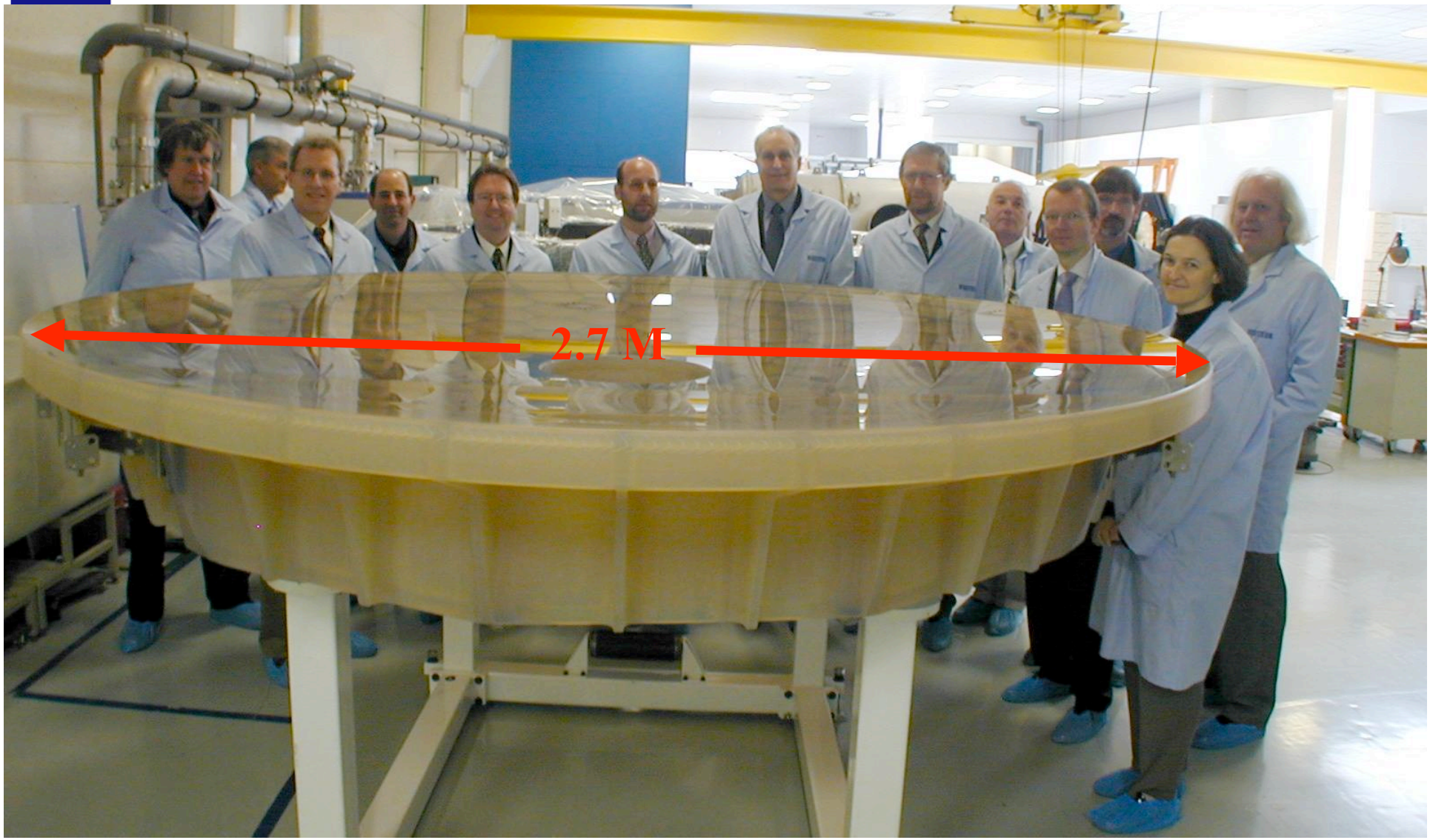
SOFIA Stratospheric Observatory for Infrared Astronomy



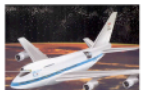
Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

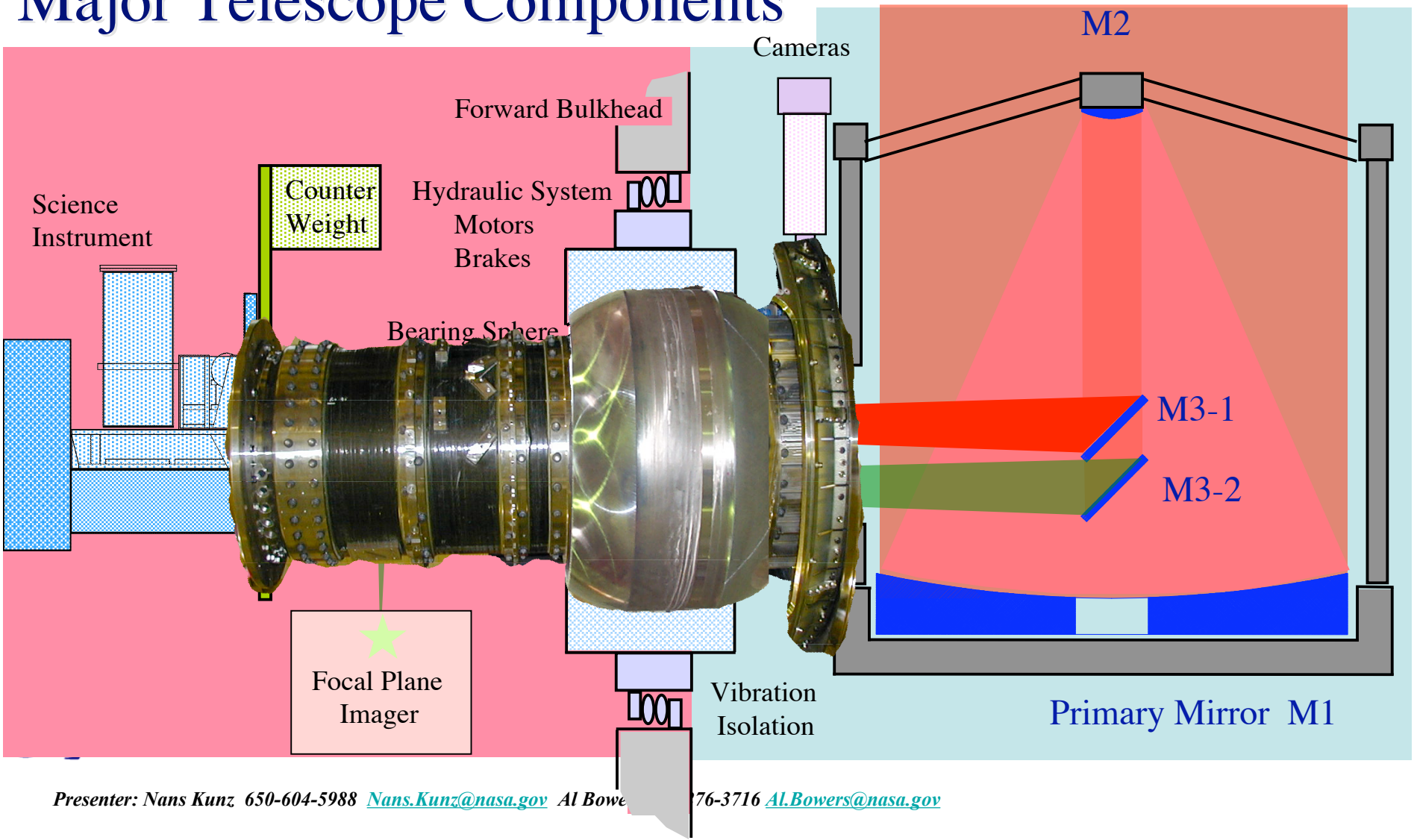
2.5 Meter effective aperture



Major Telescope Components

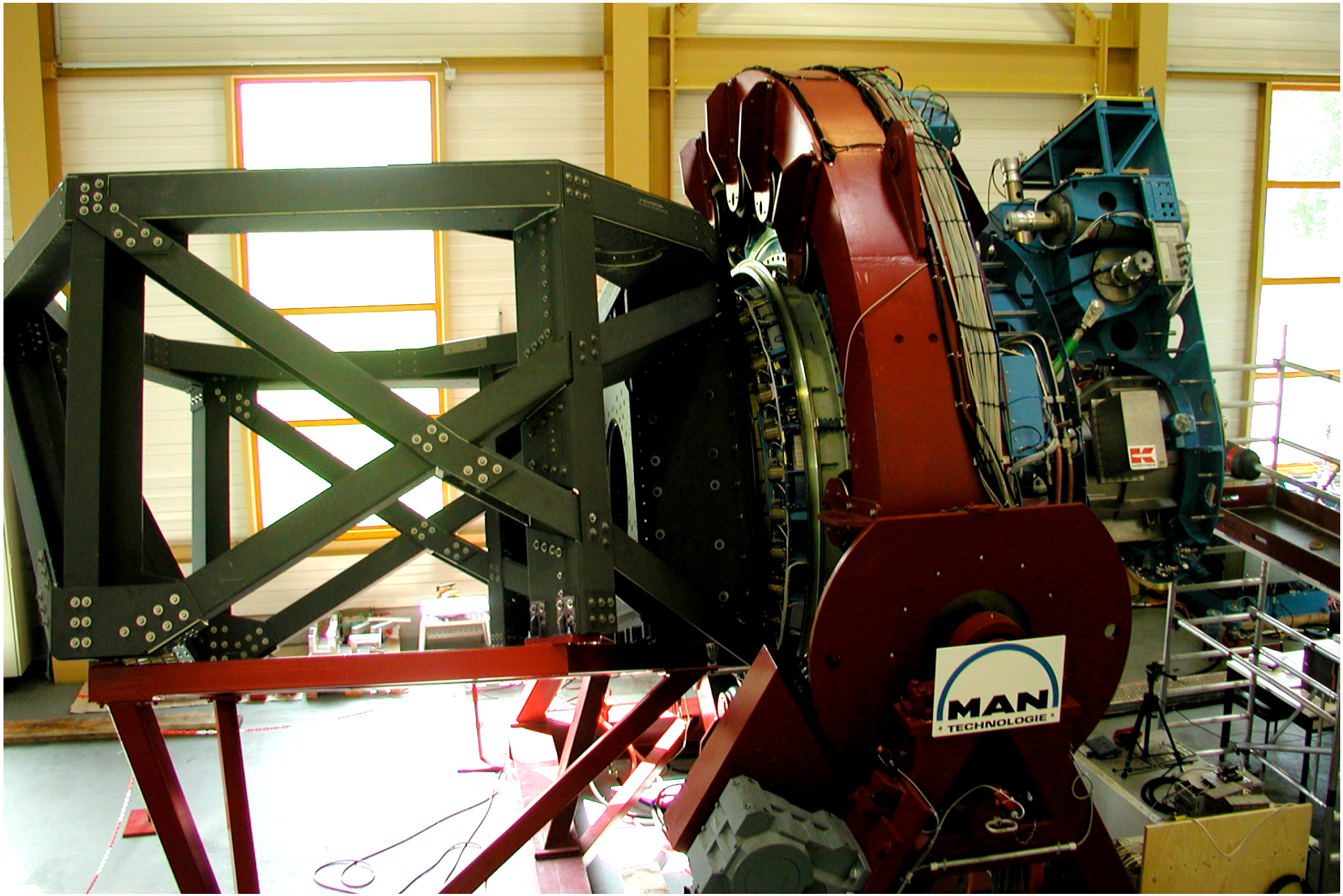


Major Telescope Components



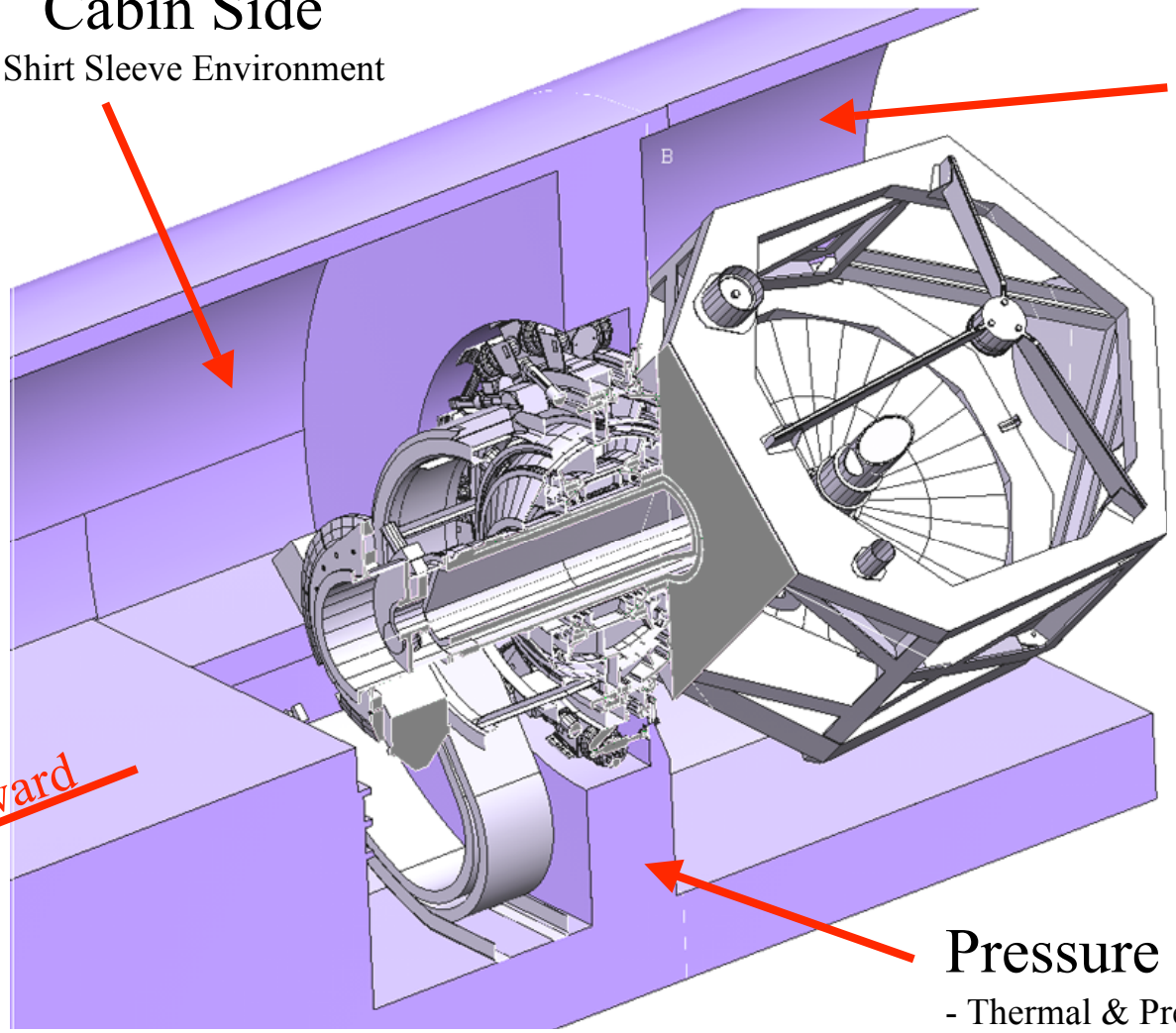
Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowe 76-3716 Al.Bowers@nasa.gov

Telescope pre-ship integration



Configuration: Instrument Access in Cabin

SOFIA Stratospheric Observatory for Infrared Astronomy

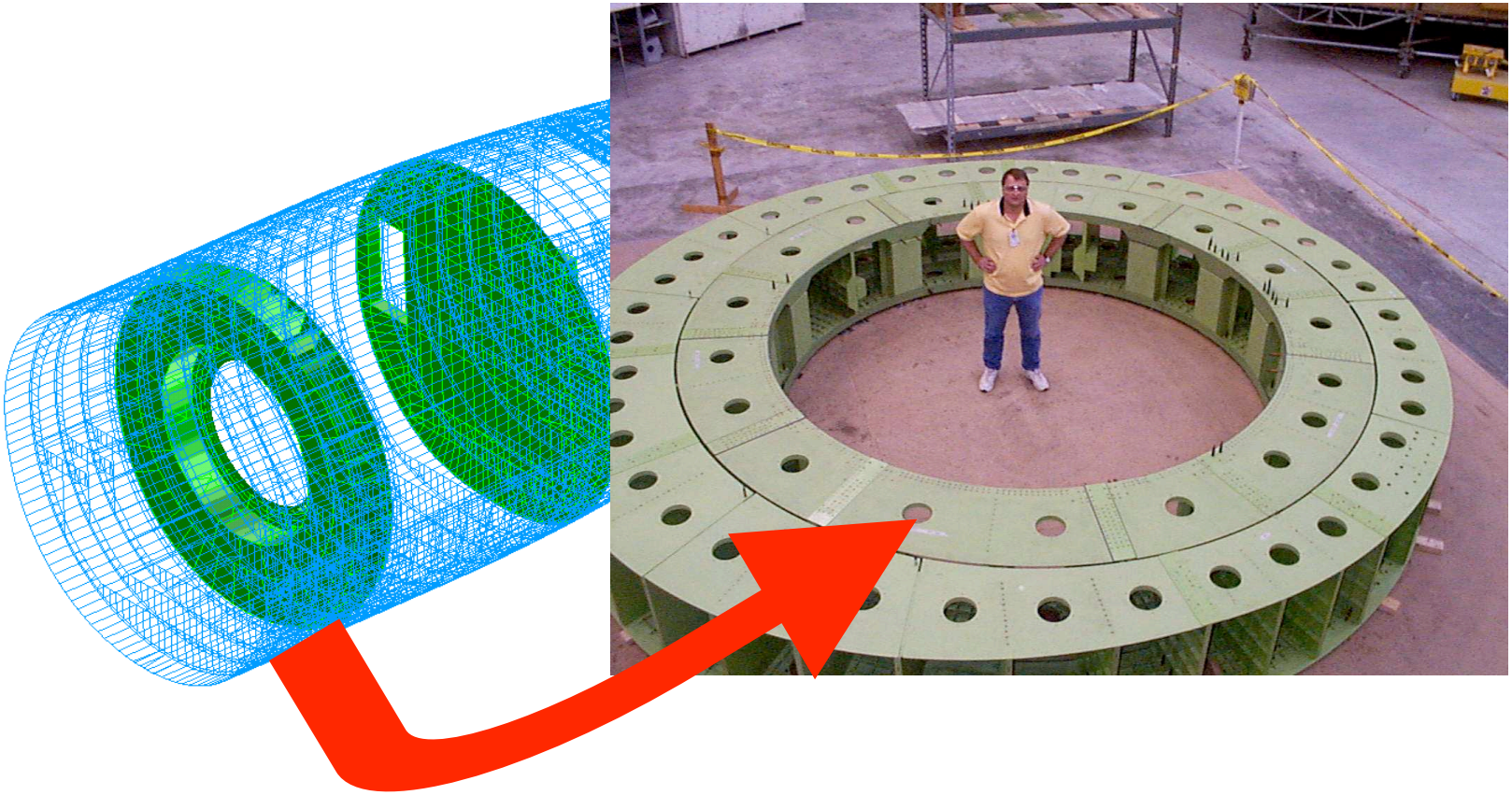


Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

Bulkhead - Flight Hardware

SOFIA Stratospheric Observatory for Infrared Astronomy

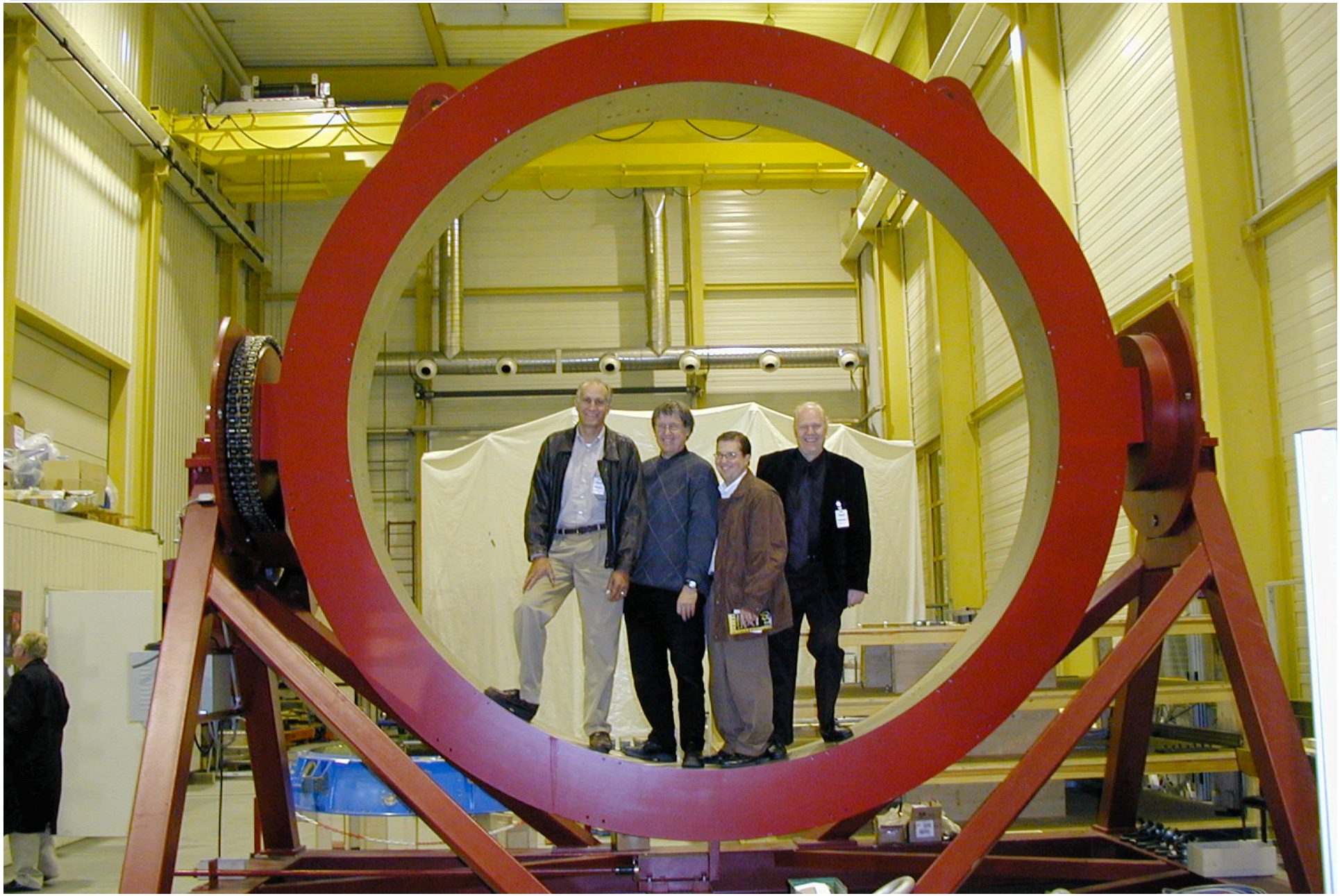
New Pressure Bulkhead



Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

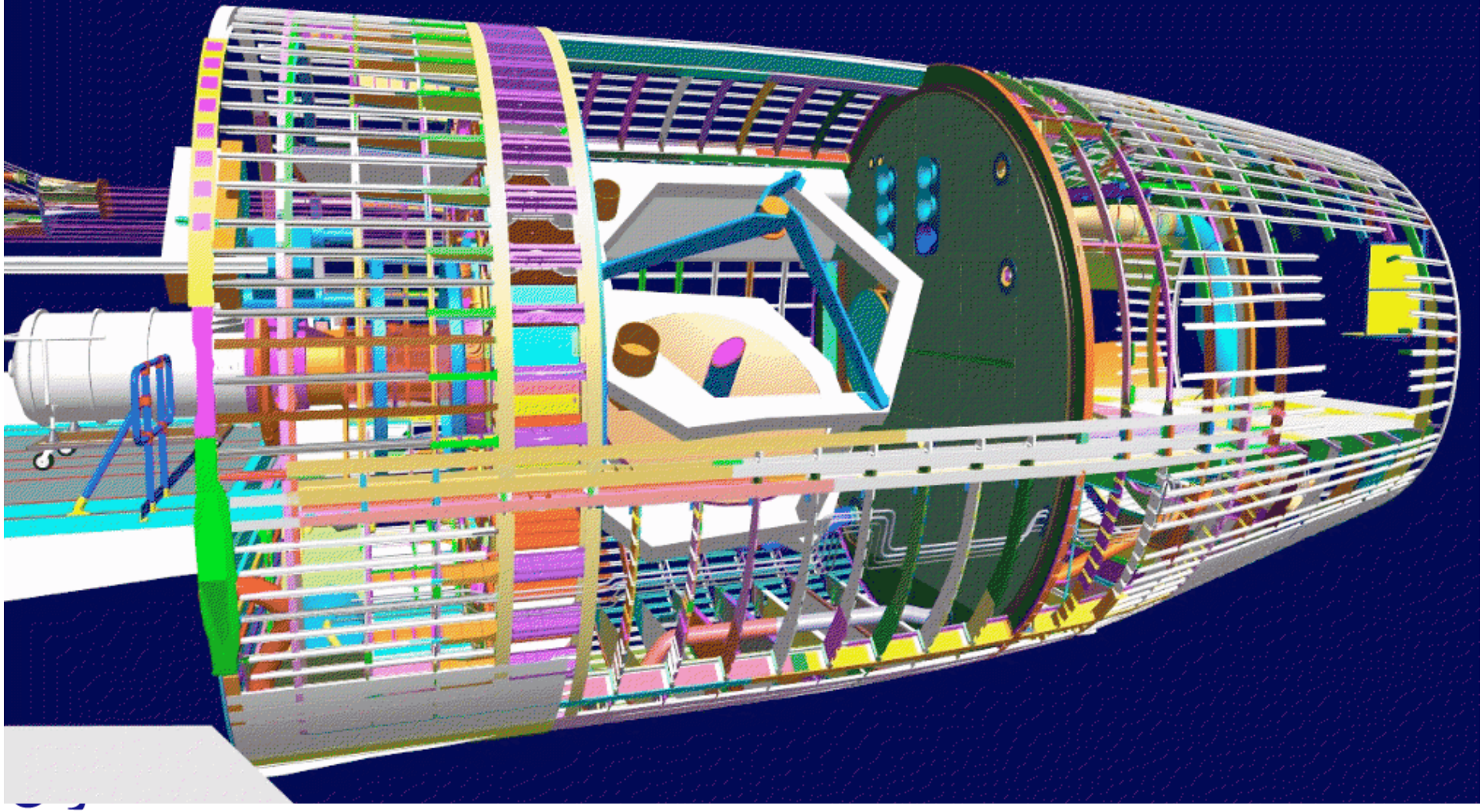
National Aeronautics and Space Administration
Ames Research Center

Bulkhead Simulator for TA Integration



Large Structural Opening

- Unvignetted Elevation Range (20° - 60°)

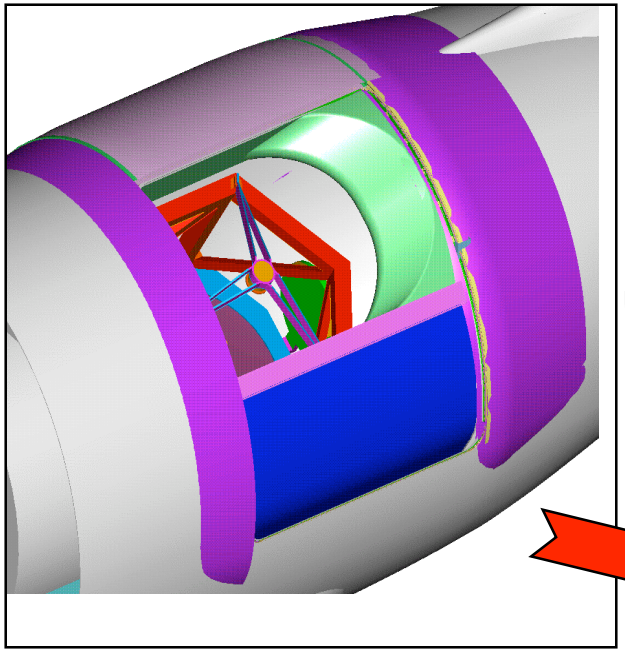


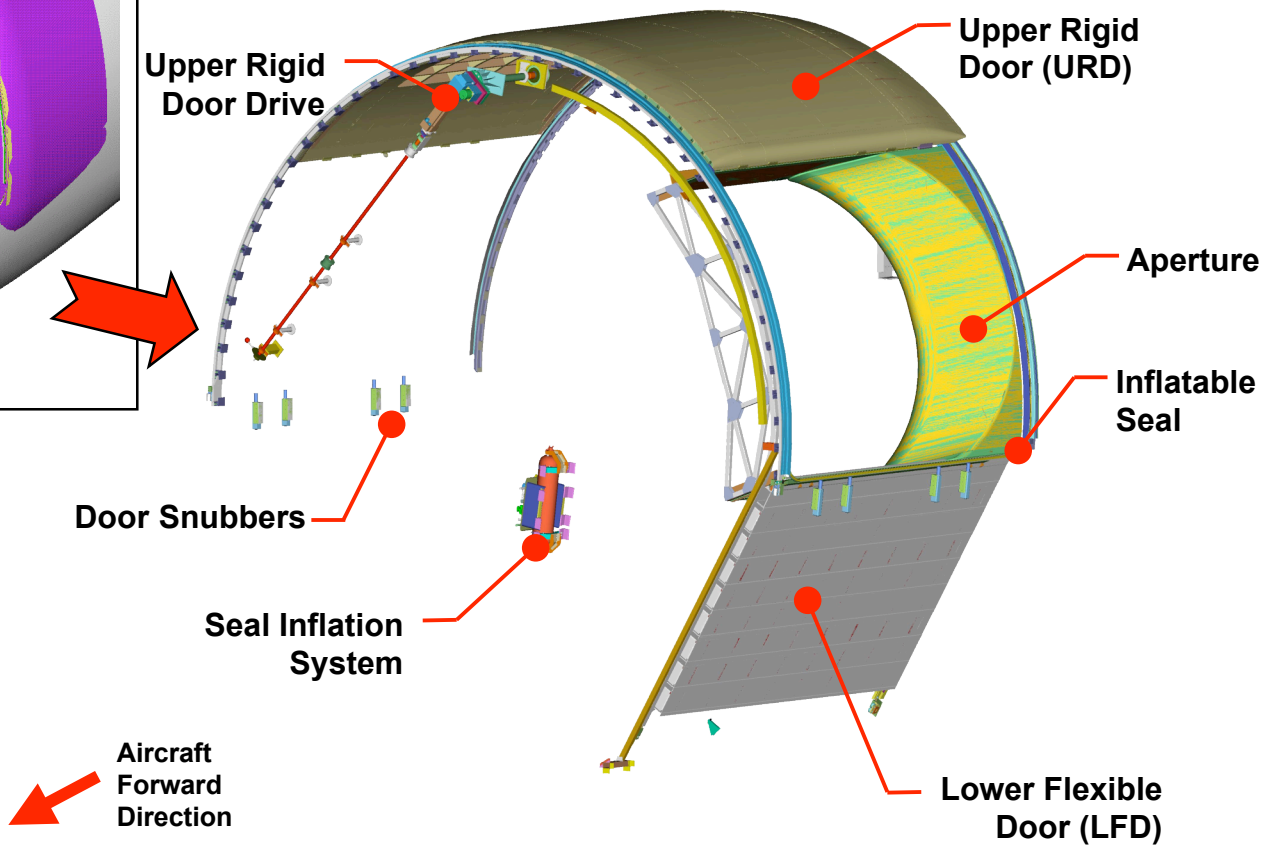
Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

Cavity Door System

SOFIA Stratospheric Observatory for Infrared Astronomy





Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

Technical Challenges

SOFIA Stratospheric Observatory for Infrared Astronomy

- Open Port cavity
- = Final Verification pending completion of Flight Tests
  - Influence on aircraft Stability & Control
  - Acoustic Issues
    - Resonance
    - Structural Fatigue
    - Environment for Telescope Performance
  - Drag (aircraft performance)
- Structural Modification
  - Strength
  - Stiffness
  - Transition to unmodified areas

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

Technical Challenges

SOFIA Stratospheric Observatory for Infrared Astronomy

- Thermal Environment
  - Systems exposure
  - Science performance
- Cavity Door
  - Accommodate fuselage deformation
  - Track Telescope motion
  - Drive system safety
- Lightweight Primary Mirror
- Rotational Isolation System
  - KAO used air bearing but this technology does not scale well…

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

SOFIA Wind Tunnel Testing Overview

SOFIA Stratospheric Observatory for Infrared Astronomy

7% Scale Tests

- SOFIA I - March 1990 to July 1990 - Forward Cavity configuration
- SOFIA II - June 1994 to August 1994 - Aft Cavity configuration
- SOFIA III - February 1995 -SP only -Aperture Geometry -TA loads
- SOFIA IV - Sept 1995 to Dec1995 Door design space evaluation
- SOFIA V - November 1997
  - Adjustment of Boundary Layer profile to match Baseline Flight tests
  - Verification of Final Partial External Door (PED) Design
  - Measurement of loads on Final Telescope design (pointing performance)
  - Measurement of loads for use in PED design

3% Scale Tests

Stability & Control - measure aero-coefficients between baseline 747-SP and SOFIA and provide substantiation for reduced flight test program

- Low Speed Tests - University of Washington Kirsten Wind Tunnel
  - Part 1 Sept 1998 to Oct 1998 & Part 2 Jan 1999 to Feb 1999
- High Speed Tests - Boeing Transonic Wind Tunnel
  - November 1998

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

SOFIA 7% model in Ames 14ft Transonic Wind Tunnel

SOFIA Stratospheric Observatory for Infrared Astronomy

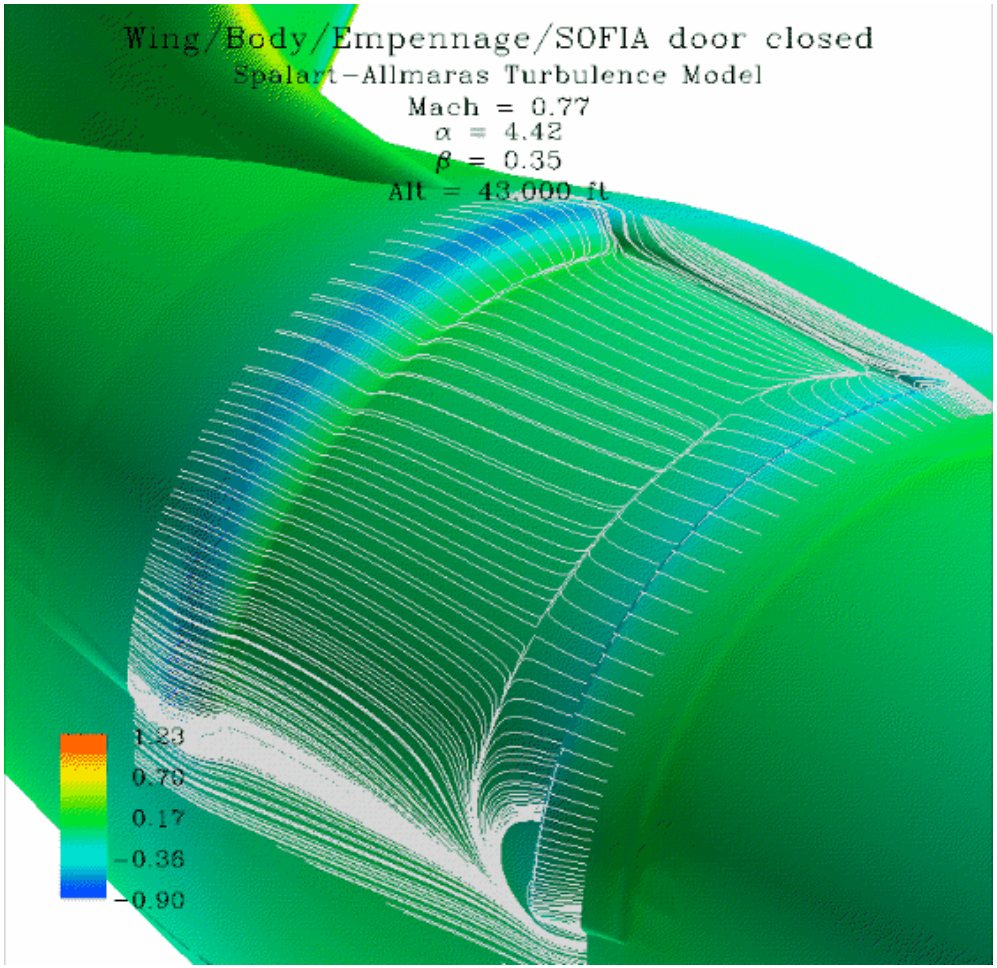
Primarily used to development shear layer control design technology and to determine cavity acoustic environment and resultant loads on Telescope

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

SOFIA CFD Predictions

SOFIA Stratospheric Observatory for Infrared Astronomy

- Example of CFD flow over the mod

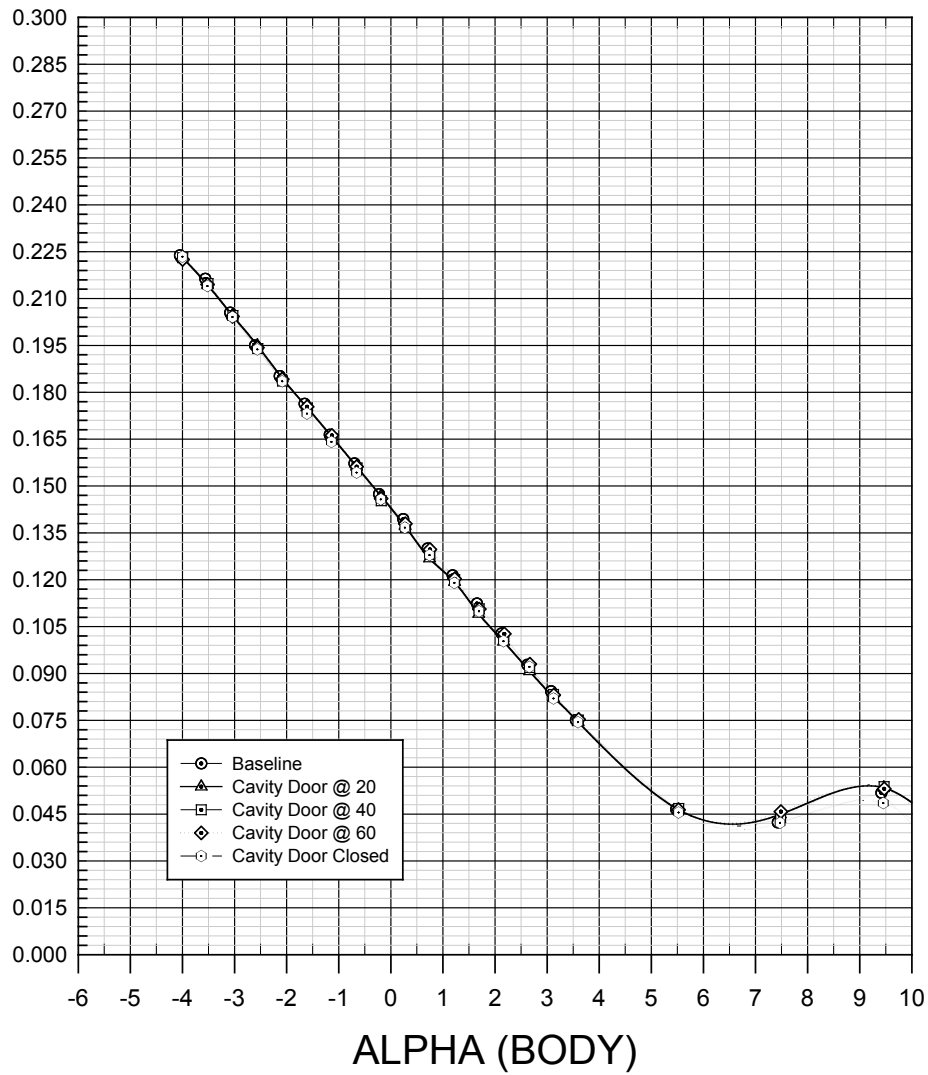


Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

SOFIA Wind Tunnel Data

SOFIA Stratospheric Observatory for Infrared Astronomy

- Stab & Control
- Negligible change in drag and pitching moment
- No other F&Ms affected



Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

Objectives

SOFIA Stratospheric Observatory for Infrared Astronomy

- Per all Test and Analyses completed, data indicates Objectives will be met
  - Minimal impact on Stability & Control of Aircraft
  - Robust - Non resonating cavity (structural/safety)
  - "Quiet" cavity for optimum TA pointing performance
  - Minimize drag to maintain Aircraft performance
  - Optimize Aero-Optic performance "seeing" for short wave length image quality performance
- Flight Testing is remaining step to Verify

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

Summary

SOFIA Stratospheric Observatory for Infrared Astronomy

- SOFIA SLC development began with KAO heritage
- Open port cavity/SLC issues identified early (1980's) as risk areas
  - Risk reduction activities were planned & completed accordingly
- Eight Separate Wind Tunnel Test Series Completed
  - Results Indicate:
    - Shear layer control implementation will provide quiet well behaved cavity acoustic environment
    - Stability & Control of aircraft will be essentially unaffected
- Multiple CFD and other analyses completed
  - Results concur with wind tunnel tests and provide additional data
- Multiple Independent Reviews Concur with approach
  - Latest NESC review extensively examined test and analysis data and planned program approach and recommend proceeding to flight test
- **All data indicates that SOFIA will fly like an unmodified 747-SP**

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

SOFIA Stratospheric Observatory for Infrared Astronomy

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

SOFIA Stratospheric Observatory for Infrared Astronomy

Telescope arrival in Waco- Sept 2002

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

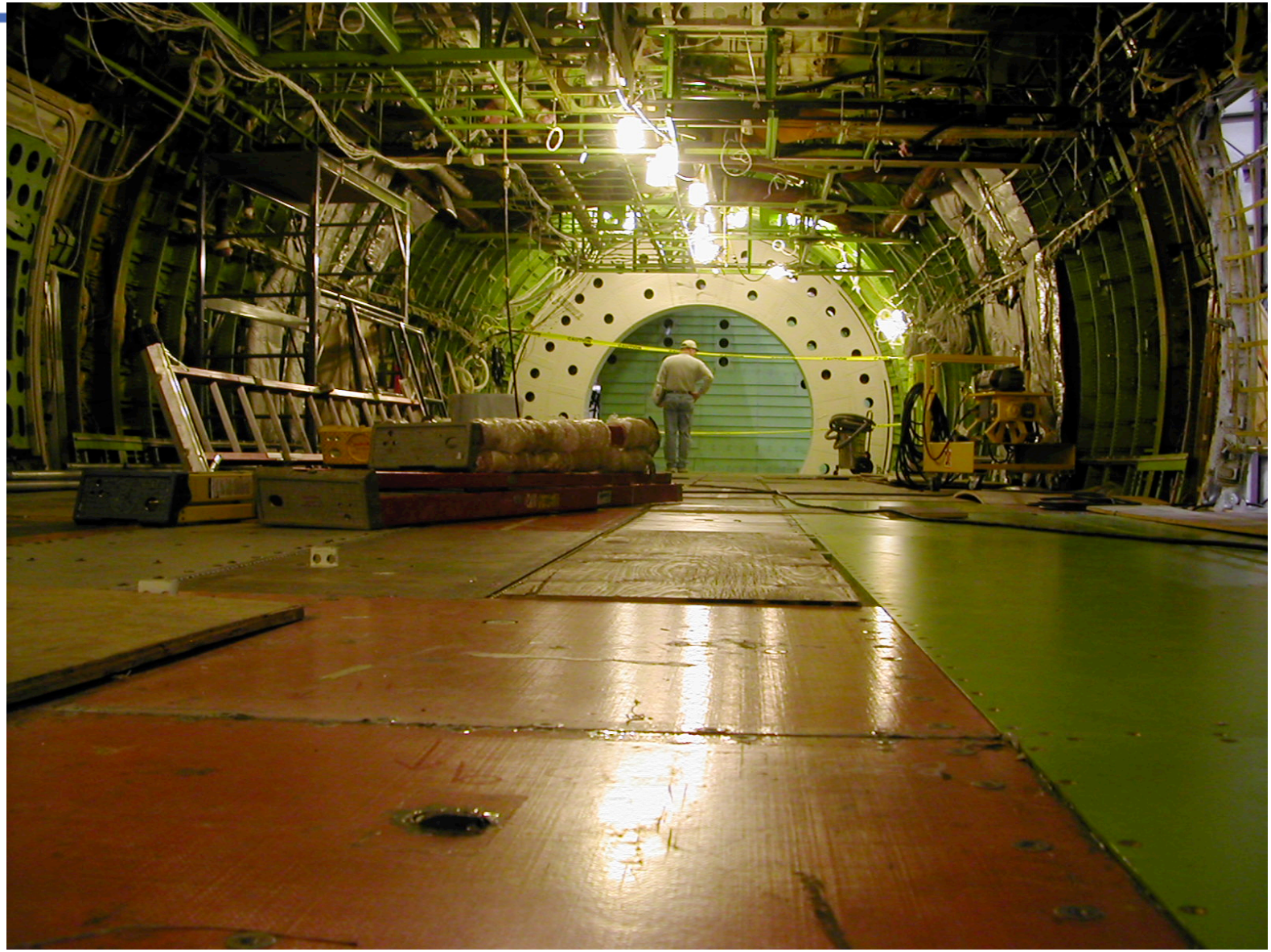
SOFIA Stratospheric Observatory for Infrared Astronomy

Unloading Telescope Pieces

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

SOFIA Stratospheric Observatory for Infrared Astronomy



Inside aircraft just before SUA installation

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

Lowering SUA into cavity 2/2003

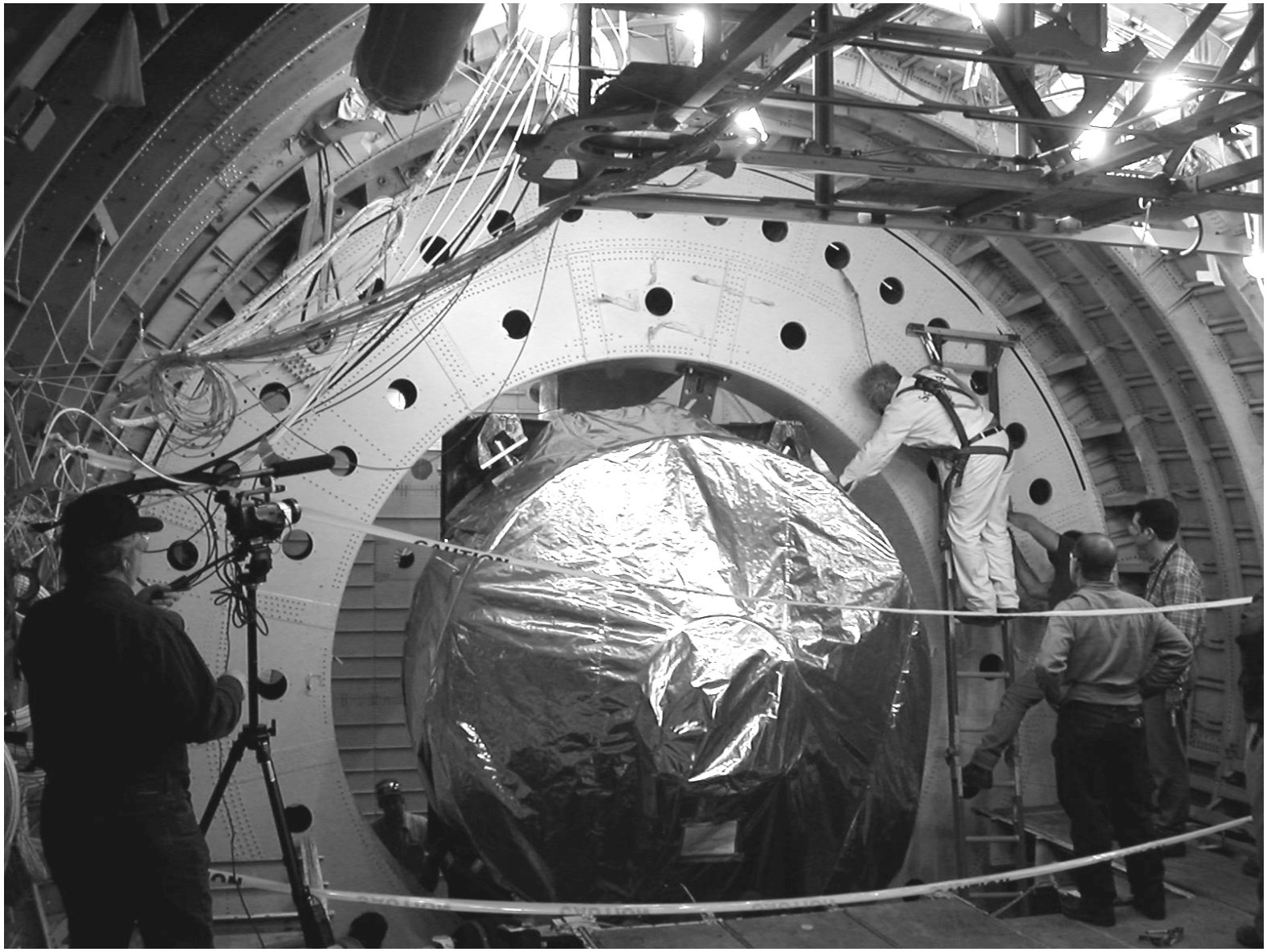
National Aeronautics and Space Administration
Ames Research Center

SOFIA Stratospheric Observatory for Infrared Astronomy

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

SUA in place

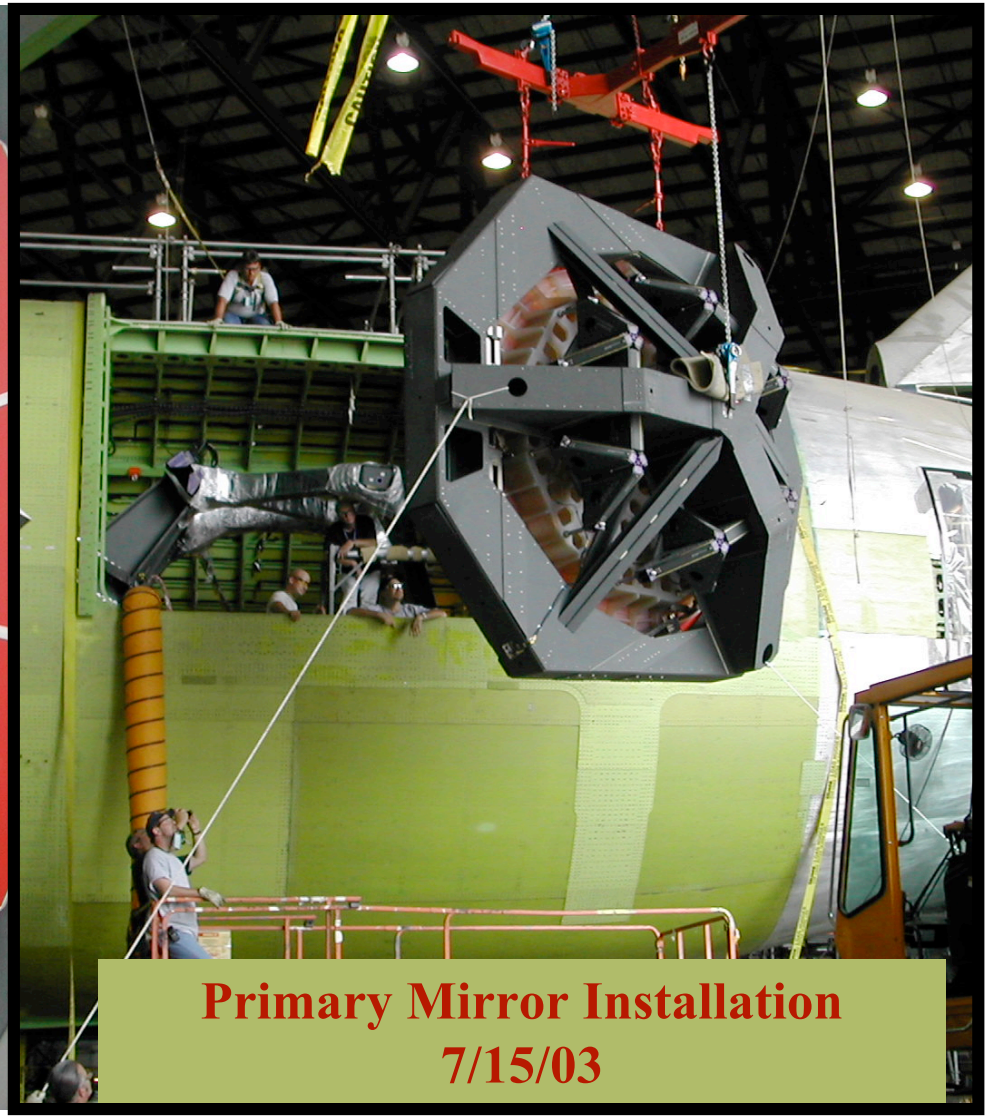
SOFIA Stratospheric Observatory for Infrared Astronomy



Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

SOFIA Stratospheric Observatory for Infrared Astronomy

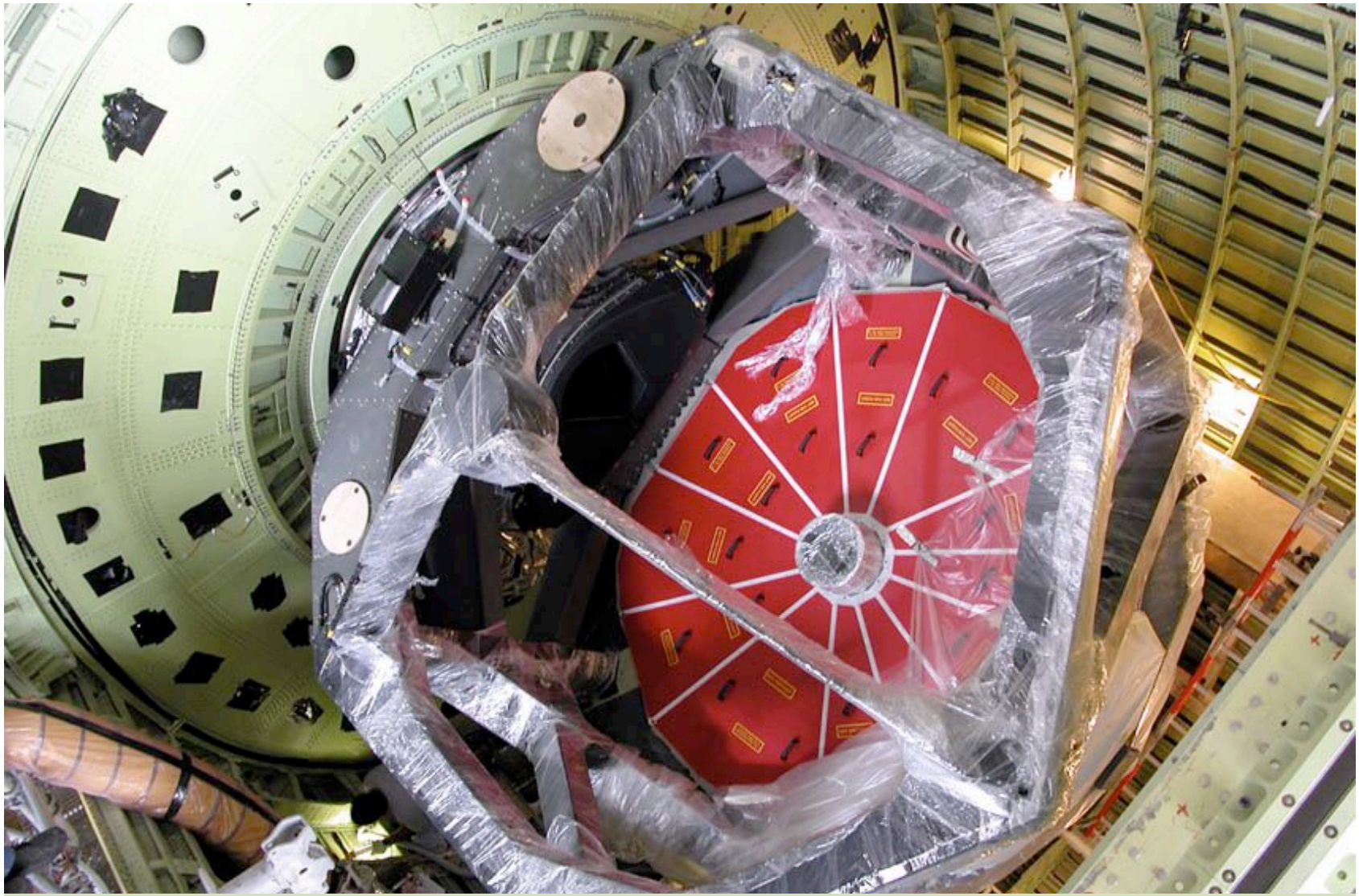


Primary Mirror Installation
7/15/03

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

SOFIA Stratospheric Observatory for Infrared Astronomy

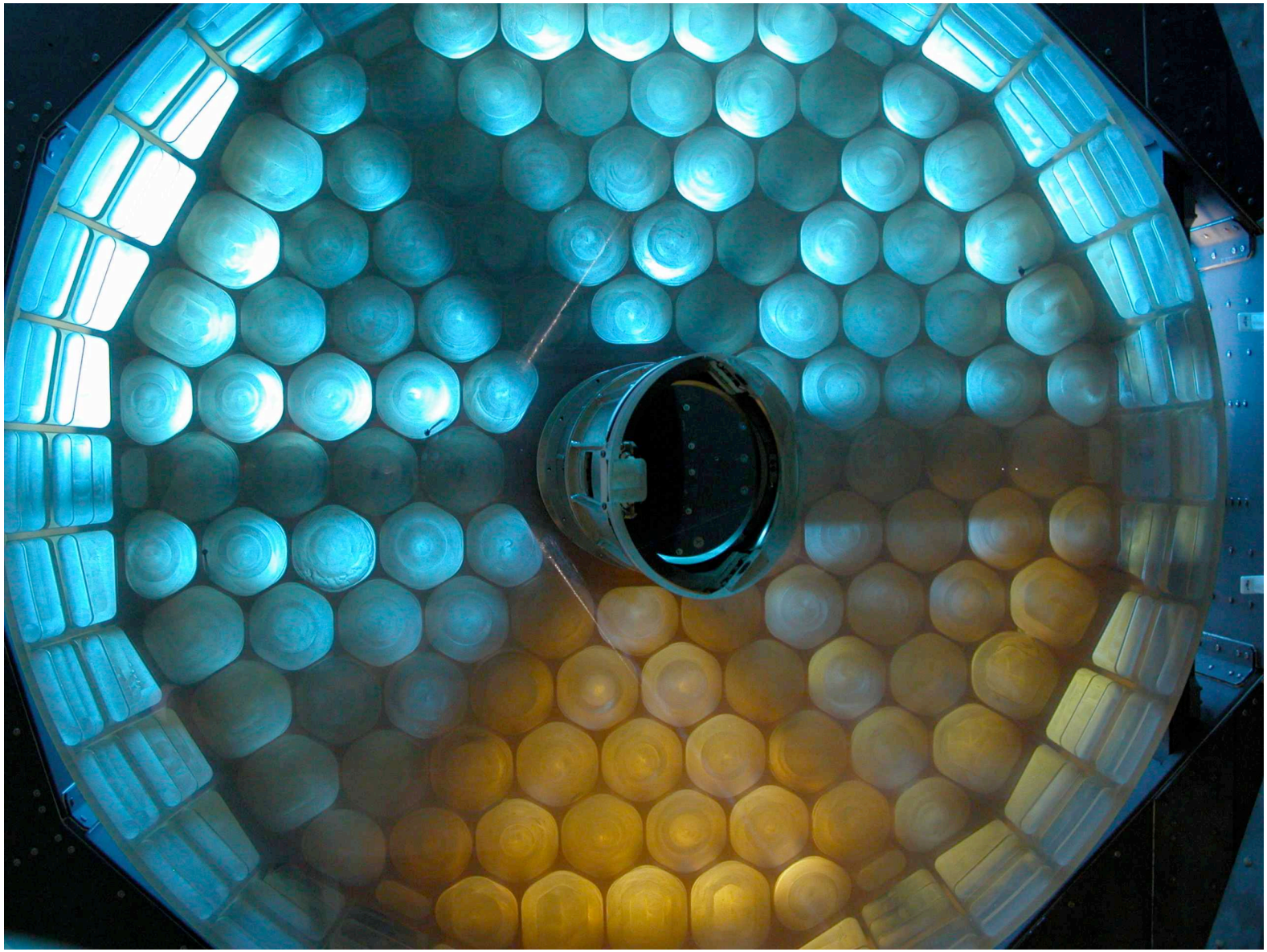


Telescope inside Aircraft Cavity

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

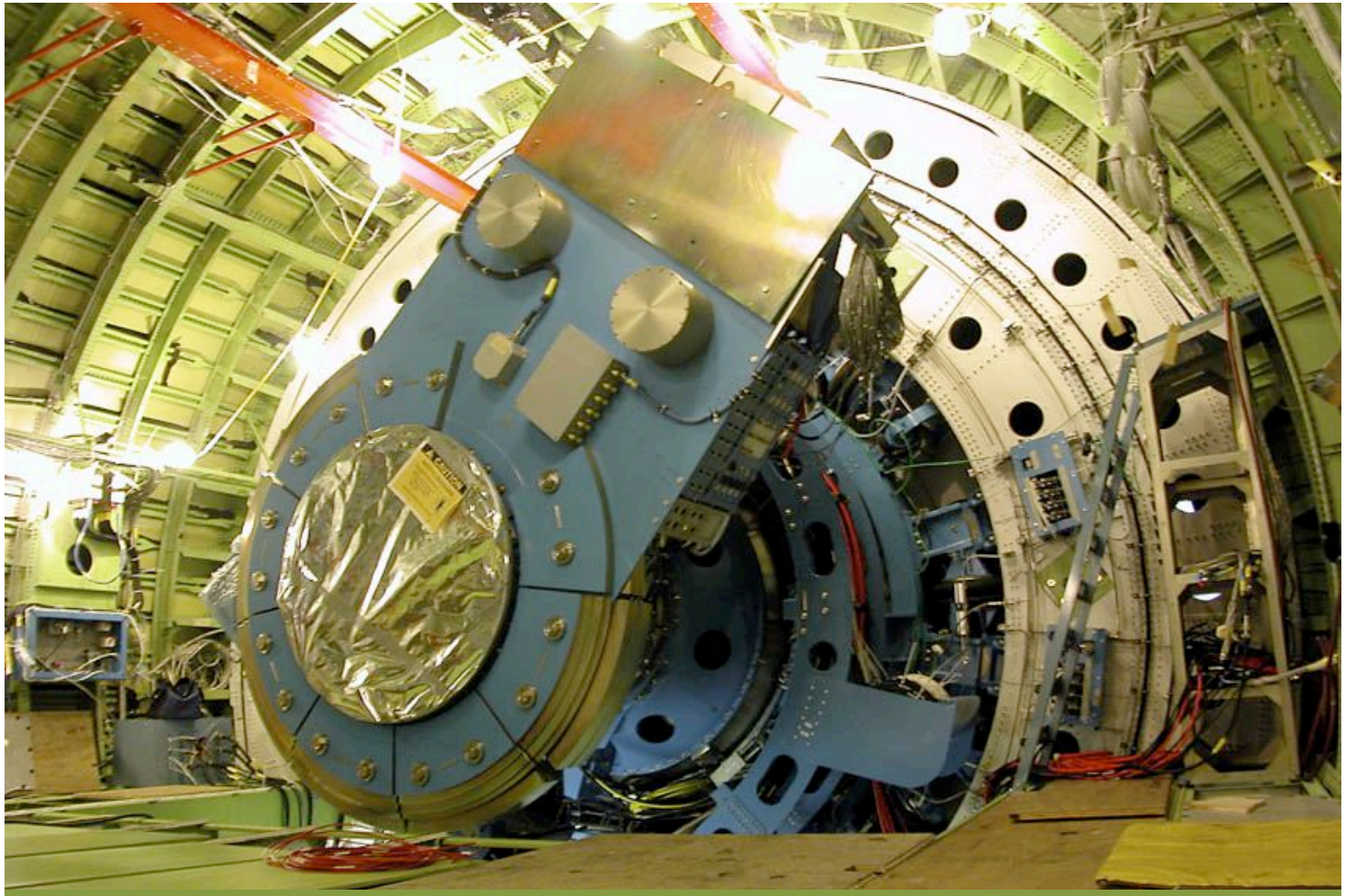
SOFIA Stratospheric Observatory for Infrared Astronomy



Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

SOFIA Stratospheric Observatory for Infrared Astronomy



Inside the aircraft - Fall 2003

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

SOFIA Stratospheric Observatory for Infrared Astronomy

First Light
August 2004

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

SOFIA Stratospheric Observatory for Infrared Astronomy

Roll out from paint hangar September 2006

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

First Flight

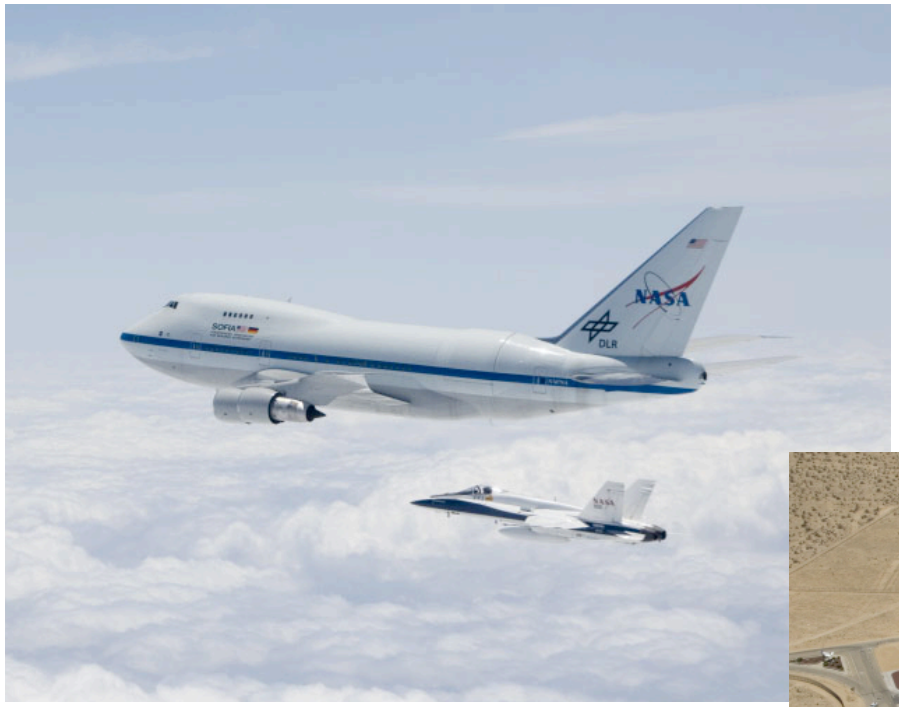
SOFIA Stratospheric Observatory for Infrared Astronomy

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

Ferry to Dryden

SOFIA Stratospheric Observatory for Infrared Astronomy



Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov

National Aeronautics and Space Administration
Ames Research Center

Questions?

SOFIA Stratospheric Observatory for Infrared Astronomy

Presenter: Nans Kunz 650-604-5988 Nans.Kunz@nasa.gov Al Bowers 661-276-3716 Al.Bowers@nasa.gov