EO-1 Advanced Land Imager (ALI) Technology Transfer Forum

Integration and Environmental Testing

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Outline

- Test Guidelines
- Structural Thermal Model
- Flight Unit Mechanical Tests
  - Electronics Box and Instrument Level
  - Mass Properties
  - Mechanism Life
- Thermal Tests
- Mechanical Ground Support Equipment
- Documentation and Summary

ALI Environmental Test Guidelines

- **ALI environmental testing guidelines established in Environmental Test Specification - 30 (ETS - 30)**
  - **Lincoln Document Number ALI-S1003**
  - **Release Date 31 July 1997**
- **Vibration Test Levels for ALI established in the "EO-1 Spacecraft to Advanced Land Imager (ALI) Interface Control Document (ICD)"**
  - **GSFC Document Number EO-1 ICD-018**
  - **Release Date 4 February 1998 (Rev A)**
- **Temperature Cycling Profile for ALI established by mutual agreement with the EO-1 Project Office at GSFC**
  - **Lincoln Document Number ALI-S1031**
  - **Release date 17 September 1998**

ALI Mechanical Design and Testing Philosophy

- Instrument design subjected to quasi-static loads of 12.5 g's axial & 10 g's lateral, applied simultaneously
  - Factors of Safety
    - 1.25 on microyield (telescope)
    - 1.60 on yield (ICD requires minimum 1.25)
    - 2.0 on ultimate (ICD requires minimum 1.4)
  - Design driven by minimum 65 Hertz instrument frequency requirement
- STM sine burst tested in each axis to qualify basic design
  - Qual-level quasi-static loads: 12.2 g's axial and 9.6 g's lateral
- Instrument random vibration inputs notched
  - 3 sigma g loads not allowed to exceed qual-level quasi-static load inputs at M1 or the focal plane (i.e. close to c.g.)
- No notching applied for electronics box testing

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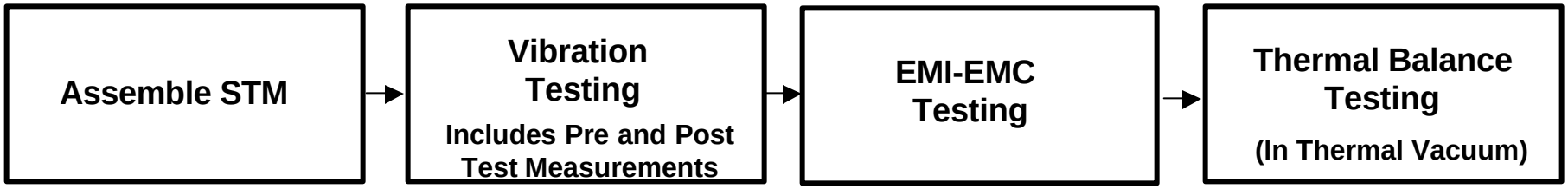
Structural Thermal Model (STM)

- **STM ALI Assembly Contains:**
  - **SSG STM Telescope and SBRS EDU Focal Plane Assembly**
    - **No optics or photon sensitive chips**
  - **SBRS Breadboard Focal Plane Electronics (FPE) and Lincoln EDU Mechanisms, Radiators and ALICE**
    - **Mass mock-ups of FPE and ALICE on pallet during vibration**
    - **Mass mock-up of ALICE in vacuum tank during thermal balance tests; EDU ALICE outside tank**

STM Phase Duration: 1/13/98 - 9/8/98



- **Verify Interfaces and Assembly Procedures**
- **Verify Structural Integrity and Computer Model Results**
- **Characterize potential for interference**
- **Verify Thermal Design**
  - **System**
  - **Focal Plane**

STM ALI Vibration Test Flow

Install Accelerometers in Pre-selected Internal & External Locations of STM ALI Assembly

Blue Test Elements Are Repeated for All Three Axes

Measure Mass & C.G.; Mount ALI Assembly on Vibration Fixture; Mount Fixture on Vibration Table

Low Level Random Survey @ 0.25 G rms; Verify Frequencies & Amplifications

Quarter, Half and Full Level Sine Burst Tests at Qualification Level

Low Level Random Survey @ 0.25 G rms; Verify Frequencies & Amplifications

Half and Full Level Sine Sweep Tests at Qualification Level

Low Level Random Survey @ 0.25 G rms; Verify Frequencies & Amplifications

-12 dB, -6dB and Full Random Vibration at Qualification Level with or without Notching

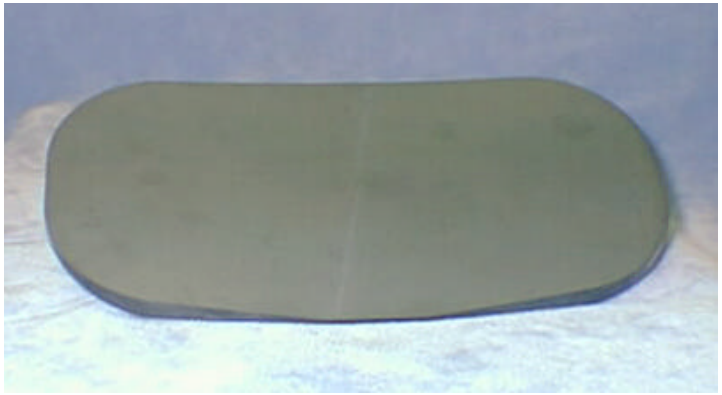
Low Level Random Survey @ 0.25 G rms; Verify Frequencies & Amplifications

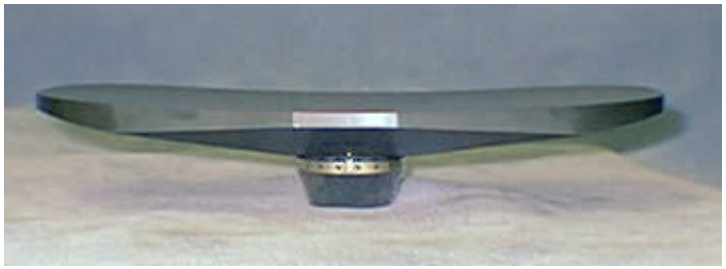
Remove ALI Assembly from Table and Fixture

STM Vibration Test Highlights

- Nothing broke; almost everything worked afterward
- Two anomalies found
  - Diffuser fail-safe did not operate properly
    - Torsion spring disengaged during vibration
    - Problem corrected by elongating spring tangs
  - F1 mirror blank shifted
    - Problem traced to defect in the adhesive joint between silicon carbide mirror and nickel plated invar mount
    - Recommended Action: Conduct vibration test of as delivered flight telescope and look for mirror frequency shifts (done)
- Post vibration diffuser fail-safe design/testing dilemma
  - Torque associated with deployment of diffuser fail safe exceeds maximum allowable back drive torque for motor gear head
    - i.e. “one time only” device works very well but can damage motor gear head during testing

ALI Silicon Carbide Mirrors





M1

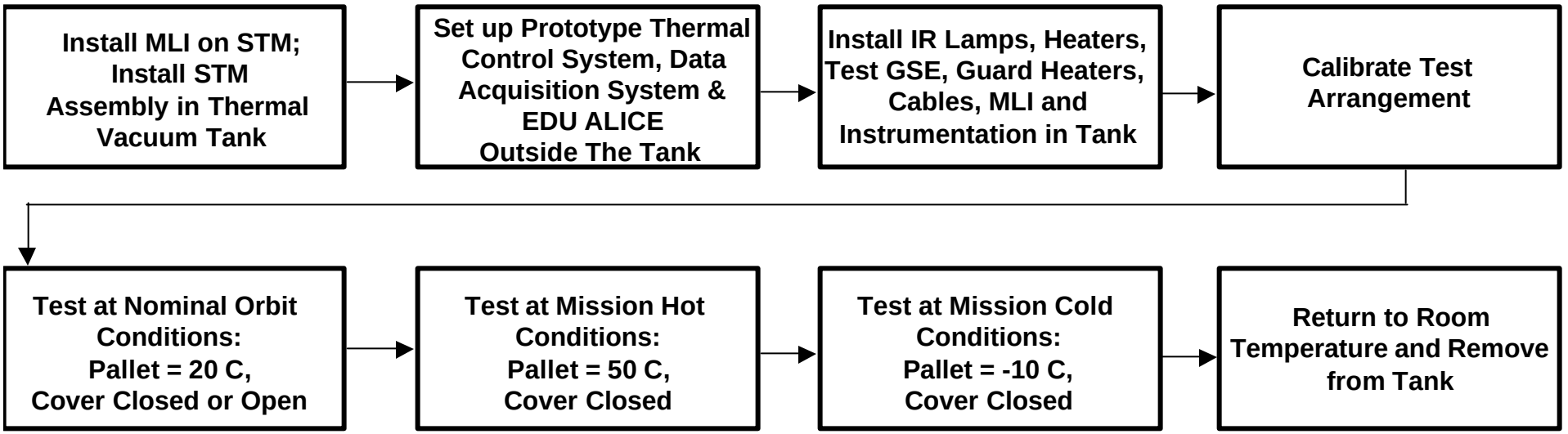
M2

M3

F1

STM Thermal Balance Testing

Objectives: Thermal Design Verification
Analytical Model Verification
Worst Case Condition Simulation
Establish Criteria for Flight System Testing



Mechanism Life Testing

- **Mechanism Life Tests conducted using EDU mechanisms**
  - **EDU units made from same drawings & materials as flight units**
    - **Different surface treatments for non-bearing parts**
- **Governing Document:**
  - **"Mechanism Life Test Plan"; LL Document ALI-S1017; last revised 28 September 1998**
- **Testing Details:**
  - **No. of Cycles = 1.5 times design life**
    - **Thermal survival cycle (-10 C to + 50 C) before and after operational cycles**
    - **Operational cycle temperatures: Cold = 0 C; Hot = 40 C**
  - **Testing successfully completed on Aperture Selector (240 cycles), Aperture Cover (3900 cycles) and Calibration Diffuser (240 cycles)**
    - **All cycles in vacuum; half hot, half cold**
- **No problems encountered**
- **EDU Mechanisms returned to STM after testing**

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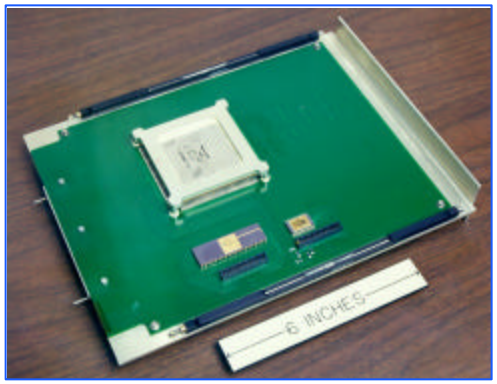
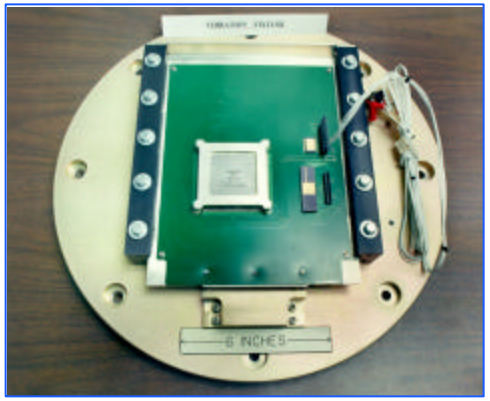
Board Level Qualification Testing

- **Objective: Qualify mounting of largest ceramic leaded components on ALI Control Electronics FR-4 boards**
  - **Issue: Fatigue due to mismatched coefficients of thermal expansion (CTE) between board sandwich and components**

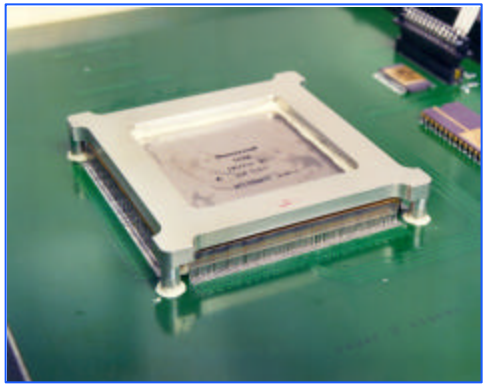
    Ceramic CTE ~ 6-7 ppm/C; Board sandwich CTE ~ 18-20 ppm/C
  - **Components: 392 lead Surface Mount Multi-Chip Module, 40 pin Dual In-Line Package & 28 pin Surface Mount Device**



Test Board Sandwich



Board Mounted for Vibration



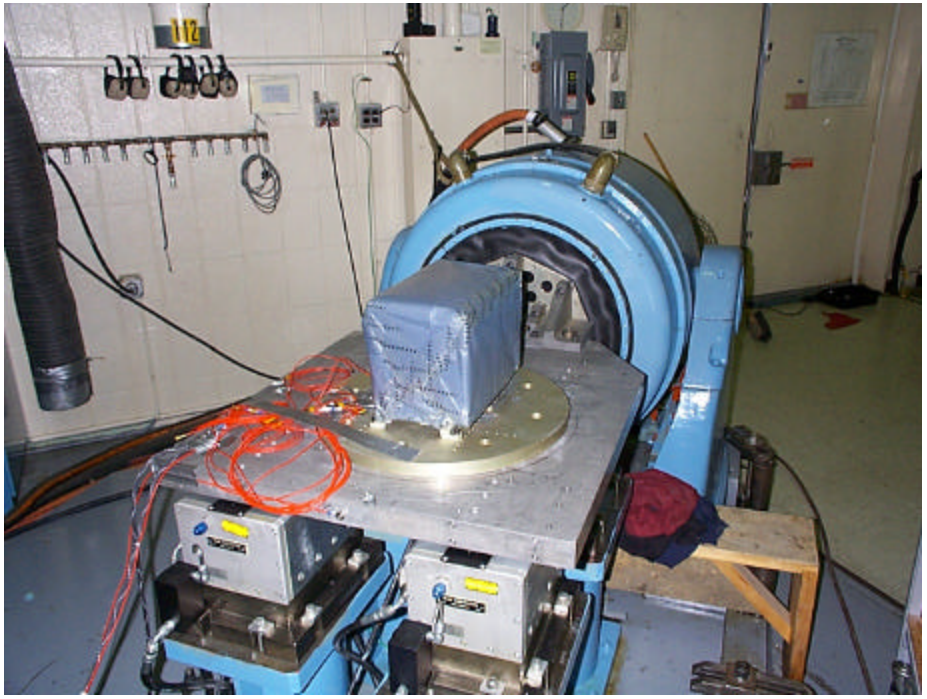
Replica of Multi-Chip Module

  - **Test Environments: Sine burst, sine sweep & random vibration**
  - **Thermal cycling: -50 to 50 C, 20 cycles; 0 to 100 C, 200 cycles**

Flight Control Electronics Vibration Testing

Protoflight Testing Suite - 3 Axes

- Sine Burst (quasi-static loads)
  - 12.2 g's axial
  - 9.6 g's lateral
- Sine Sweep (5-50 Hz)
  - 3.5 g's axial
  - 5.9 g's lateral (15-35 Hz)
  - 3.0 g's lateral (35-50 Hz)
- Random Vibration (20-2000 Hz)
  - 10.6 g rms for electronics
  - 5.8 g rms for instrument



ALICE on the Vibration Table

Box Level Testing

- **Vibration Tests**
  - **First ALICE protoflight vibration test (prior to PER)**
    - **Sine burst, sine sweep & random (for electronics)**
    - **Problem: 5 of 6 wedgelock screws loosened**
  - **Second ALICE protoflight vibration retest**
    - **Sine burst, sine sweep & random (for electronics)**
    - **No problems encountered**
      - **Wedgelocks remained tight over all tests**
      - **Primary fix: installation procedure changed**
  - **ALICE filter box protoflight vibration test**
    - **Sine burst, sine sweep & random (for electronics)**
    - **No problems encountered**

Flight ALI Integration and Testing

28 April 98

Flight Telescope Delivery from SSG

- Unit delivered without housing

28 April - 7 July

Telescope Vibration; Disassembly, Cleaning, Re-assembly & Realignment

19 June - 3 Aug

Focal Plane Delivery, Warm Testing, Integration & Alignment "Telescope Integration"

- Housing delivered 7 July

3 Aug - 2 Sept

Instrument Integration

- Pre- Environmental Review 5 Aug

3 Sept - 24 Oct

Vibration and Thermal Cycling in Vacuum

25 Oct - 22 Jan 99

Calibration

25 Jan - 22 Feb

Pre-Ship Activities, Reset Mechanisms, Clean, Pack & Ship

- Replace one 1773 transceiver
- Vibrate, thermal cycle ESN board
- Add contamination heaters
- Instrument outgassing

23 Feb

Deliver to Swales

10 March

Integrate with Spacecraft

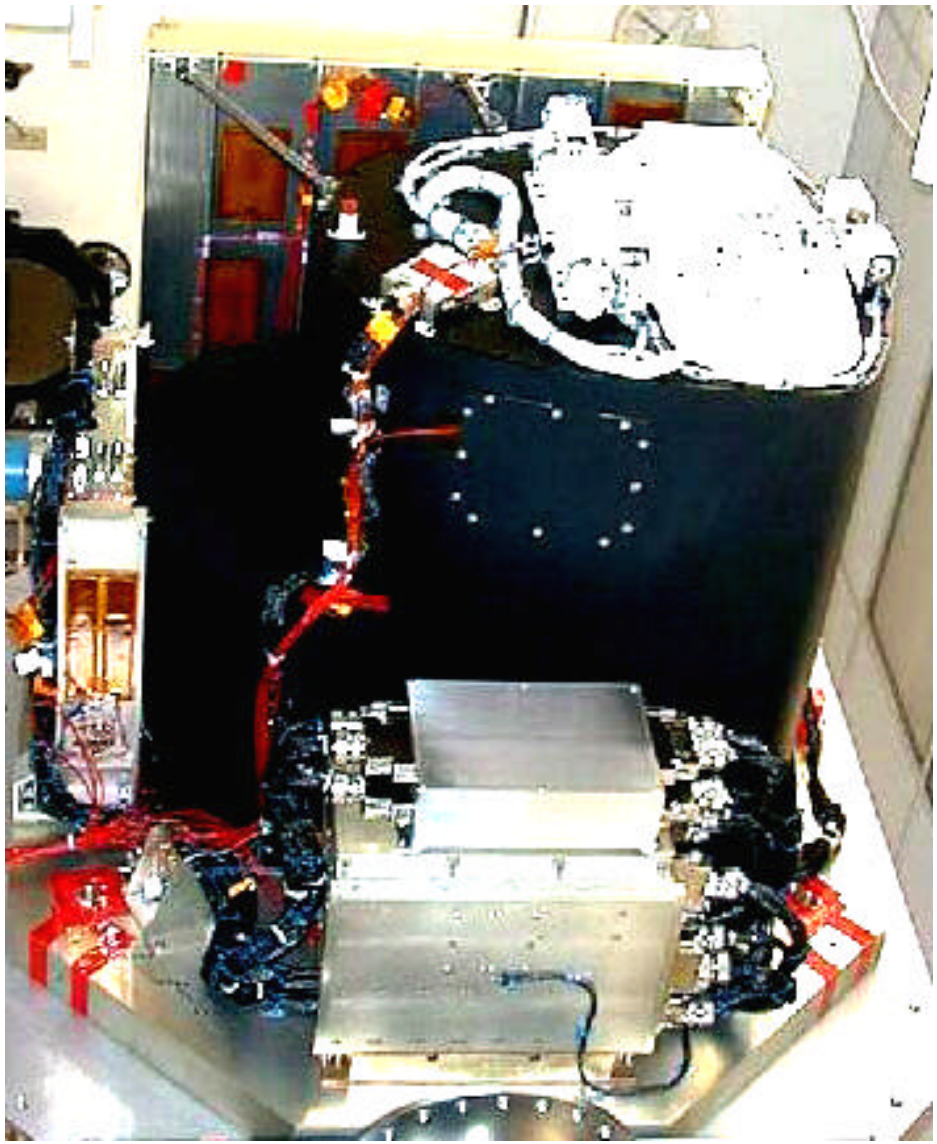
Environmental Test Dates (1998)

- Telescope Thermal Vacuum at SSG — 13-17 April
- Telescope Vibration at LL — 19-21 May
- Focal Plane (FP) Vibration at SBRS — 18-20 May
- Focal Plane Electronics (FPE) Vibration
  - at SBRS (sine sweep & random) — 8-12 May
  - At LL (sine burst only) — 1 July
- FP & FPE Thermal Cycles at SBRS — 21-25 May
- ALICE Thermal Cycles at LL — 13-17 July, 3 Aug

PER 5 Aug

- ALICE Vibration at LL — 7 July, 7 Aug, 17 Sept (FB)
- Flight ALI Vibration at LL — 3-4 September
- Flight Thermal Cycles at LL — 4-25 October

Vibration Test Configuration



Mass Properties

- **ALI weight & center of gravity**
  - **Weight 197.8 pounds (~90 kg)**
    - **FPE to WARP data cable not included**
  - **Center of Gravity at x = - 0.5 in., y = 5.7 in., z = 10.5 in.**
  - **All measurements within ICD allowables**
- **Weight Distribution**

– Telescope (Truss, Diffuser, Wiring)	76 pounds
– Housing (Structure, Mechanisms, Wiring)	30
– Pallet (Structure, Wiring)	40
– Focal Plane Radiator (Structure, Wiring)	16
– Focal Plane Electronics (Structure, Wiring)	17
– ALICE (Including Filter Box)	19

Flight ALI Vibration Testing

Protoflight Testing Suite - 3 Axes

(1) 0.5 Grms White-Noise Random Signature Test
(2) Half-Level Sine Sweep Test
(3) Full-Level Sine Sweep Test
(4) 0.5 Grms White-Noise Random Signature Test
(5) –12 dB down Random Level
(6) –6 dB down Notched Random Level
(7) Full-Level Notched Random
(8) 0.5 Grms White-Noise Random Signature Test

ALI on the Vibration Table

Instrument Vibration Testing

- **Test exceptions**
  - **Mass mock-up used for ALICE filter box**
  - **MLI not present**
- **Post-test results**
  - **All electrical, mechanical & optical checks successful**
    - **Optics in focus and all electrical & mechanical functions verified**
    - **Two anomalies found:**
      - **Aperture selector slightly ajar**
      - **Some black paint and lint particles on M1 & M3**
  - **Anomaly resolution**
    - **Aperture selector: Jam nut found loose; tightened and epoxy staked**
      - **Durability of fix verified through vibration testing of EDU selector**
    - **Particles: Feathered paint edges and thoroughly cleaned telescope at the truss level prior to instrument assembly**
      - **Considerably less particles found than after truss vibration test**

Vibration Test Data

Resonance Frequencies

Component	Frequency (Hz)
Telescope	68, 78, 170
Housing	68, 110
FPE	110, 180
ALICE	105, 180
Focal Plane Radiator	68, 100, 190

Sine Sweep Component Responses (g's)

Components	X peak		Y peak		Z peak	
	5-35 Hz	35-50 Hz	5-35 Hz	35-50 Hz	5-35 Hz	35-50 Hz
Input	5.9	3.0	5.9	3.0	3.5	3.5
Telescope	8.2	7.0	7.0	7.0	3.8	4.4
Housing	7.0	4.6	9.2	9.8	4.5	6.0
FPE	7.0	4.6	7.2	4.8	3.6	3.6
ALICE	5.8	3.3	6.0	3.2	3.9	4.1
FP Radiator	8.1	6.2	9.4	10.0	4.0	3.6

3s Random Peak Responses at f_n<200Hz (g's)

Components	X	Y	Z
Allowables @ c.g.	9.6	9.6	12.2
M1	9.5	9.5	11.0
Housing	2.7	6.6	9.8
FPE	3.7	2.8	4.2
ALICE	6.7	5.7	2.0
FP Radiator	4.6	6.8	6.4

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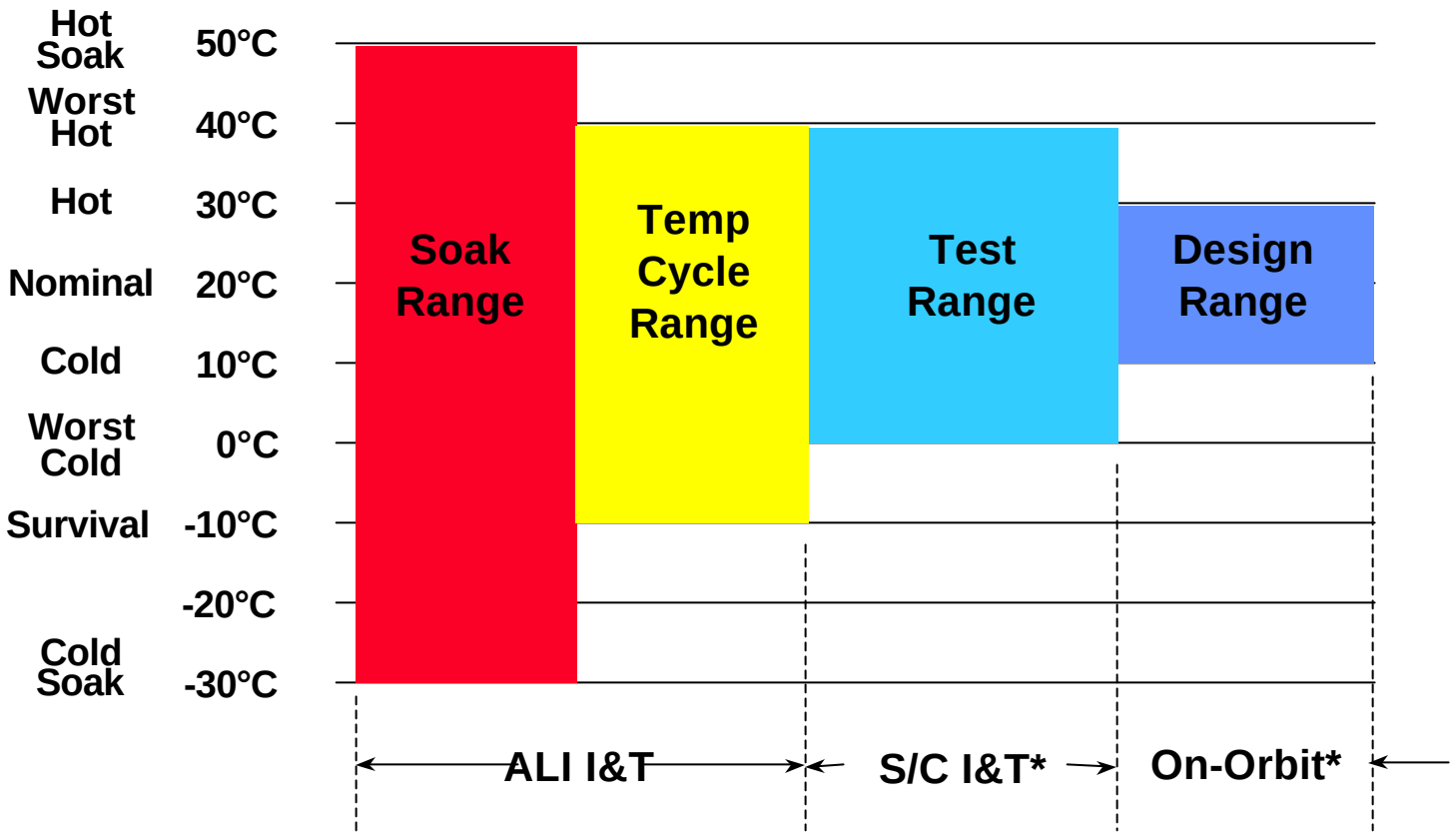
Control Electronics Thermal Cycling

Protoflight Temperature Limits

Survival -30 to +50 C Operating -20 to + 40 C

ALI in Tank with MLI

EO-1 Temperature Limits

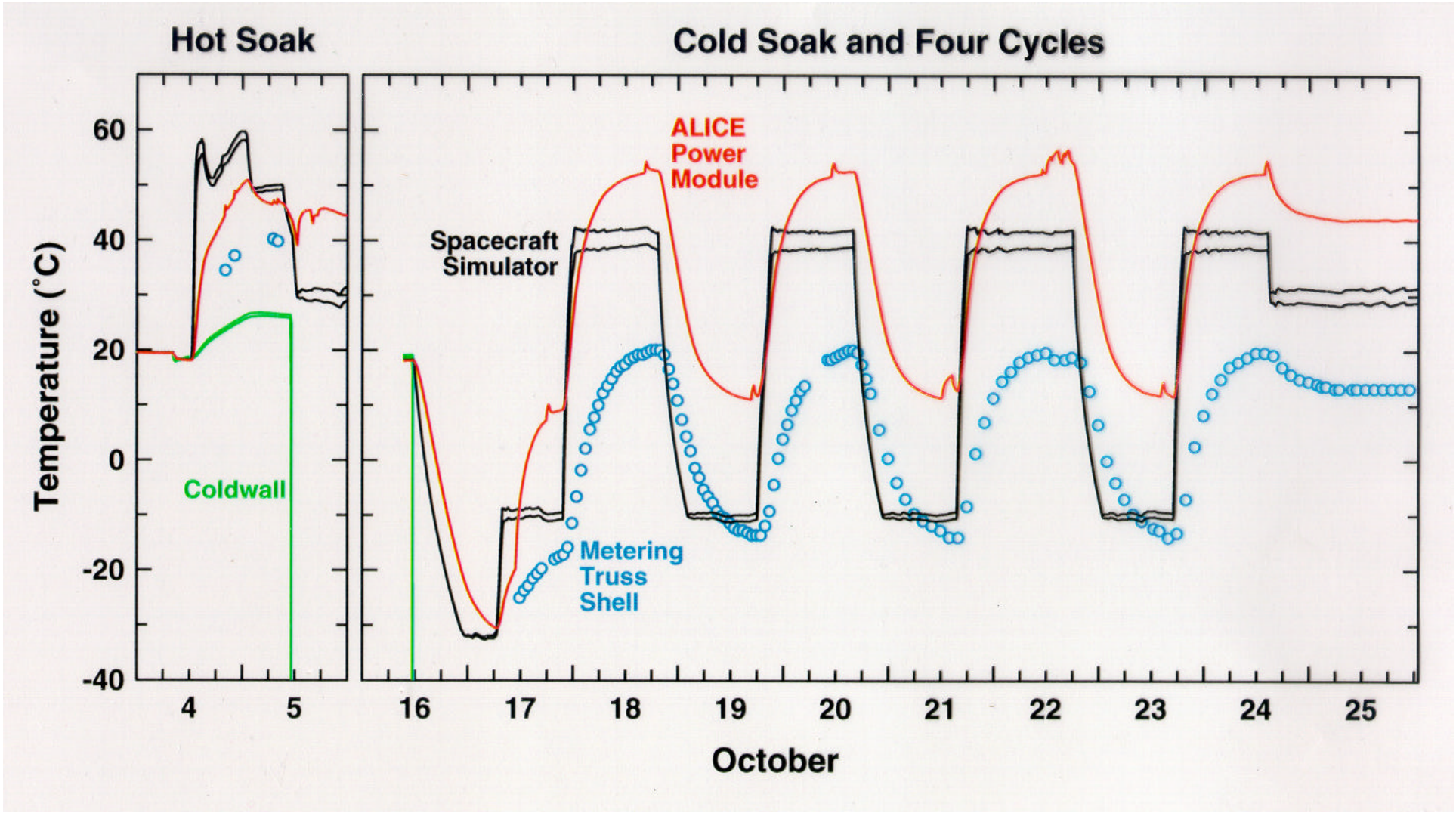


* Reference: Nick Teti (Swales) to Ralph Welsh (GSFC) memo of 13 August 1998

Instrument Thermal Vacuum Testing

- MLI installation 14-22 September
- ALI installed in vacuum tank 25 September
  - Pre-cycling optical focus measurements completed with ALI in tank at room temperature 28 Sept - 1 Oct
  - Thermal cycling initiated 4 Oct; completed 25 Oct
    - 50 C spacecraft simulator "hot soak"& "bakeout" conditions at start
    - 30 C spacecraft simulator "baseline" data condition established
      - All temperature sensors, heaters and mechanisms operated properly
      - Anomalies:
      - Focal plane thermal control system noisy & operating improperly; new system implemented in ALICE software
      - Best ALI focus position altered by tank window thermal gradients; optical test equipment adjusted to compensate for focus shift
    - Thermal cycling & data taking continued to completion
      - Cold soak at - 30C; data taking at -10C & 40C over 4 cycles
      - 1 week delay due to LN_2 plumbing problem outside clean room
  - ALI thermal computer model verified

ALI Thermal Vacuum Cycling



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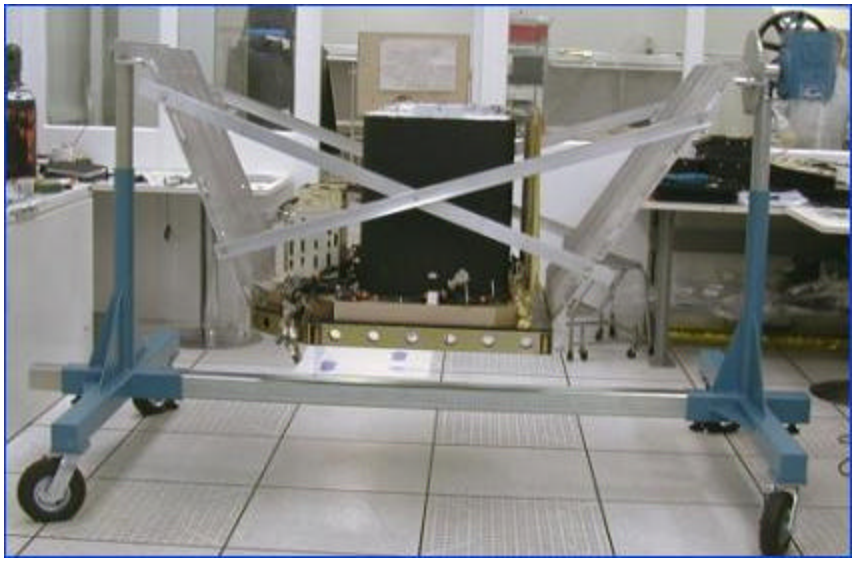
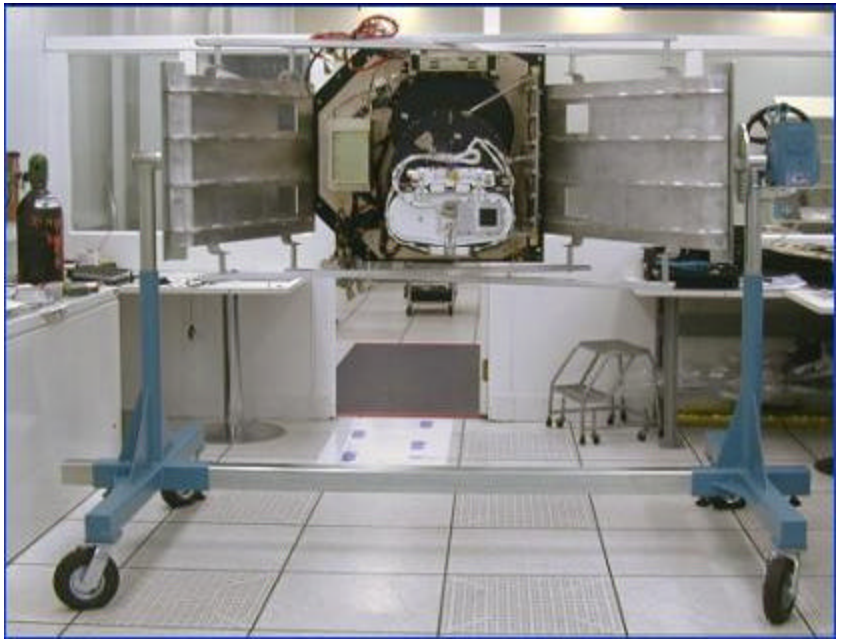
Mechanical Ground Support Equipment

- **Instrument lifting fixture**
  - **Successfully used throughout all I&T handling operations**
  - **Proof tested to 1000 pounds (5 X ALI weight)**
- **Instrument shipping container**
  - **Shock isolation system**
  - **External electrical and purge connections**

Vacuum Tank Handling Fixture

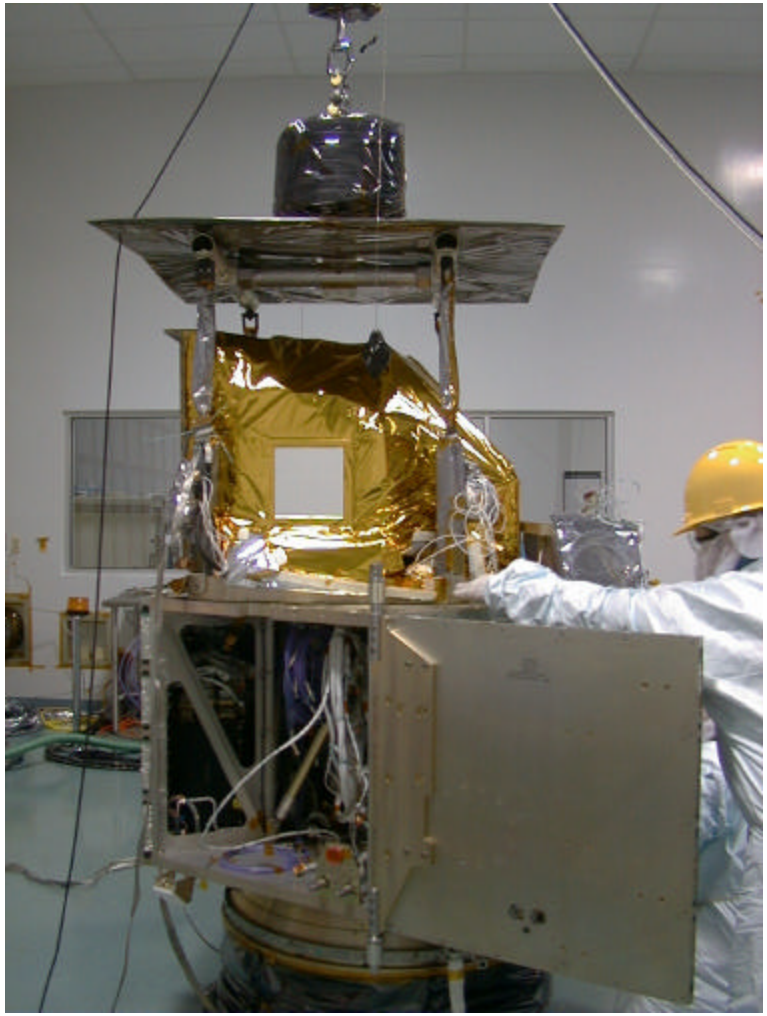


Upright



90° Rotation for
insertion in tank

Mounting ALI on EO-1 Spacecraft



EO-1 Spacecraft Integration at Swales Aerospace

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Documentation - 1

- **Drawings**
  - Detail drawings from LL, SBRS & SSG completed
  - Many assembly drawings red lined
  - LL Drawing Listing available
- **Vibration Test Reports**

– STM	21 April
– Telescope	19-21 May 98
– FPE Sine Burst	1 July
– ALICE	7 July, 28 July, 7 Aug
– ALI	3 Sept
– EDU Aperture Selector	15 Sept
– ALICE Filter Box	17 Sept
– Focal Plane & FPE at SBRS	8 May, 18 May

Documentation - 2

- **Thermal Cycle Testing**
  - **Instrument data files available**
  - **Mechanism Life Test summary report, 29 Sept 98**
- **Log Books**
  - **STM I&T activities**
  - **Flight unit I & T activities (not including calibration)**
- **Materials (ML) and Electronic Parts (EPL) Lists**
  - **ML submitted to GSFC 24 July, 17 Sept 97; approved 9 Oct 97**
  - **EPL submitted to GSFC 1 July, 1 Sept 98; not formally approved by GSFC Parts Engineer**
- **Computer Models**
  - **Pre-Hyperion ALI structural finite element model (NASTRAN)**
  - **Post- Hyperion ALI thermal models (SSPTA & LLTTA)**

Summary

- ALI integration and environmental testing successfully completed with few anomalies
  - All test-related anomalies documented and resolved
  - Test data documented in reports and at Web site
- ALI mass properties met ICD guidelines
- Design drawings mostly completed
  - Some red lined
- Handling and shipment MGSE available