Alpha Magnetic Spectrometer – 02

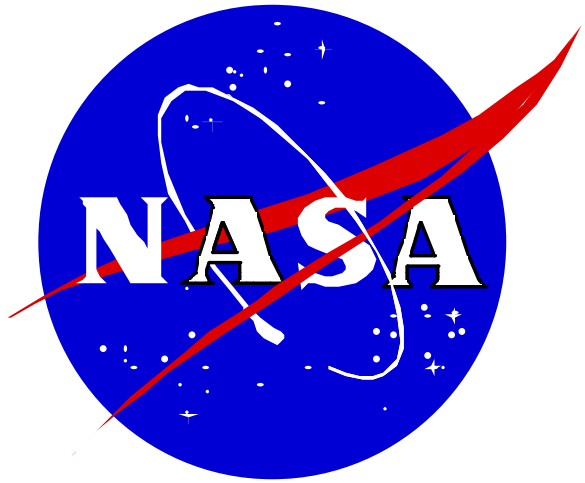
AMS Payload Overview & Experiment Components Summary

Critical Design Review

May 13-16, 2002

Ken Bollweg

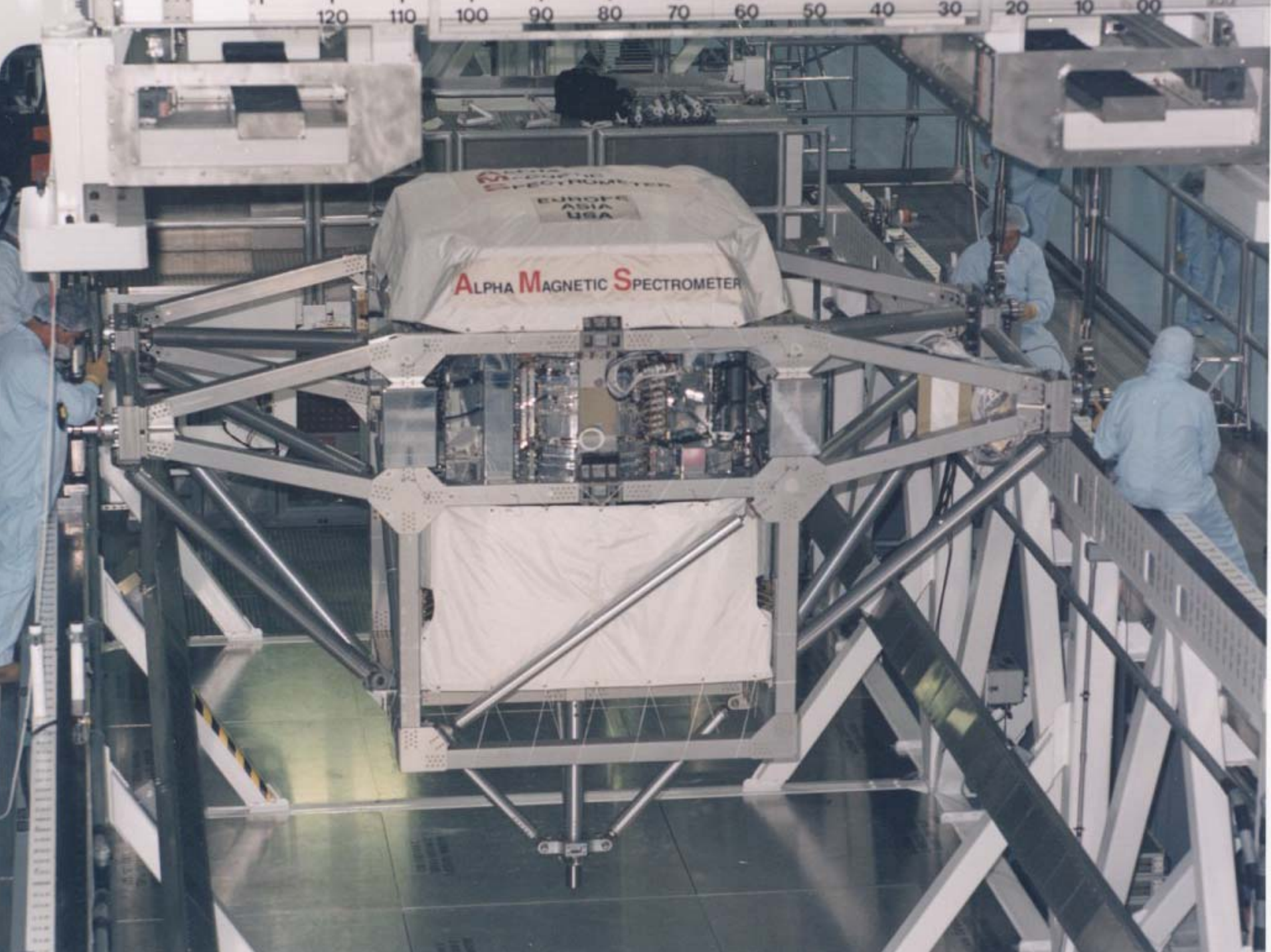
Trent Martin

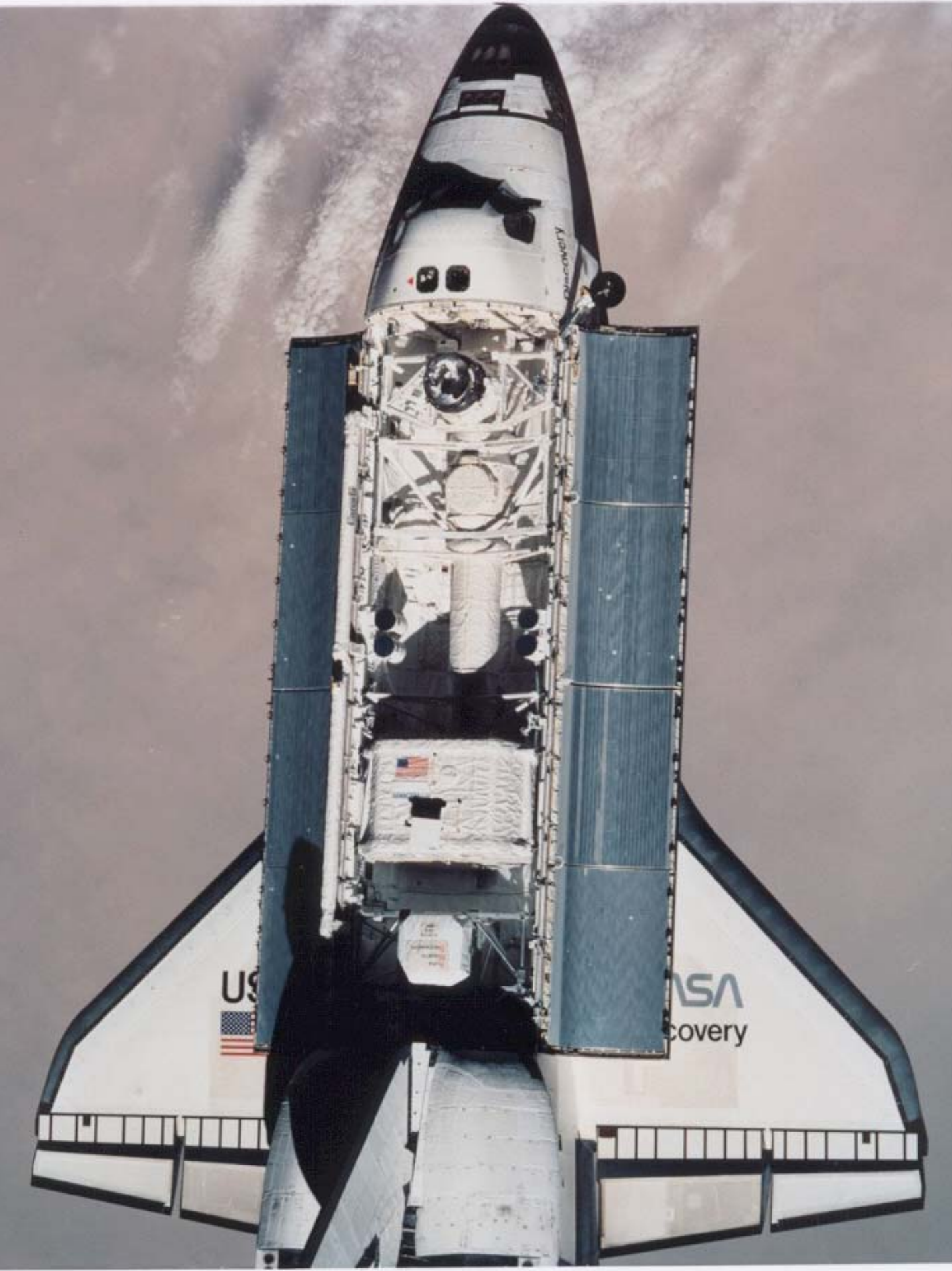


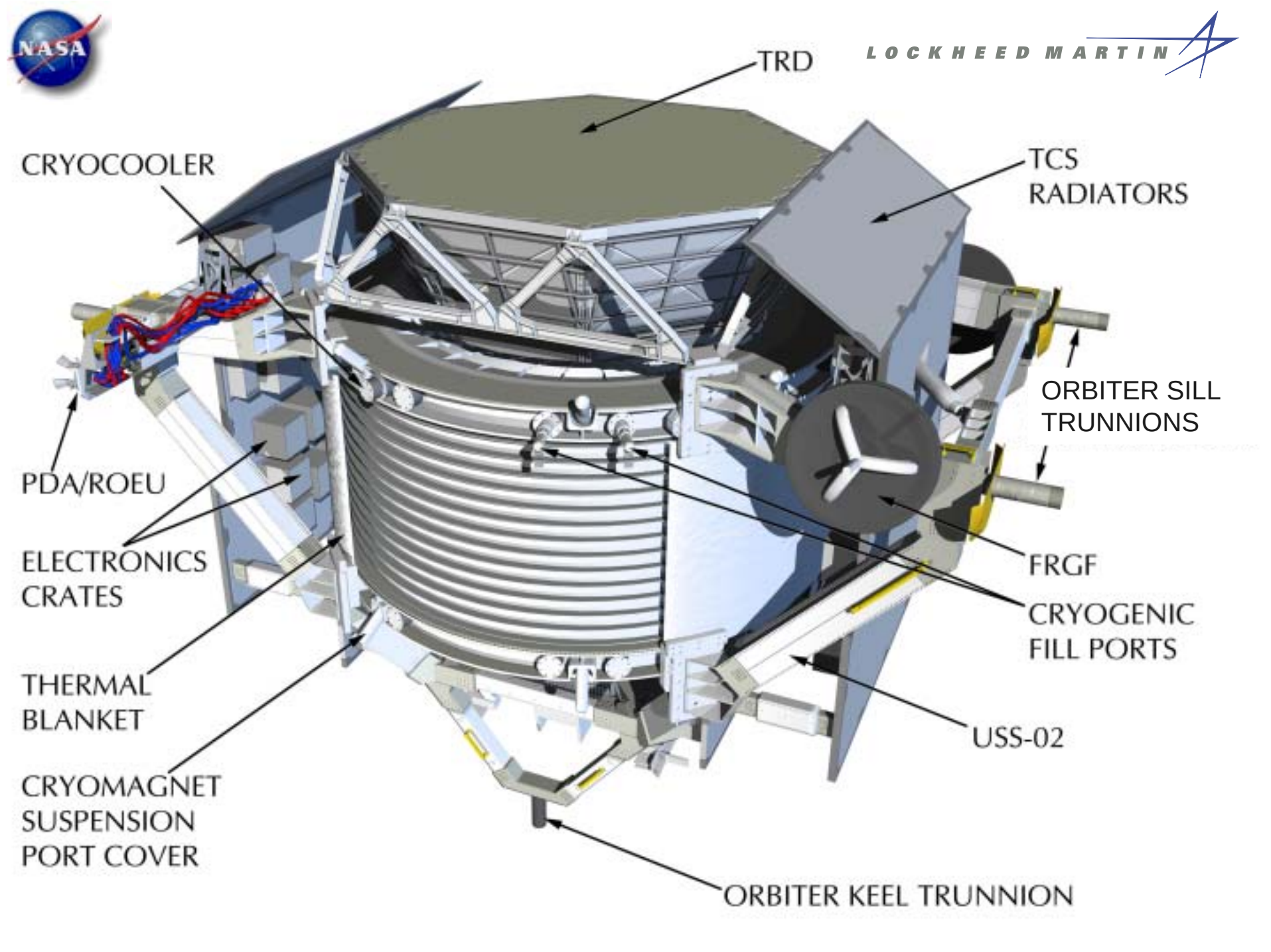
LOCKHEED MARTIN

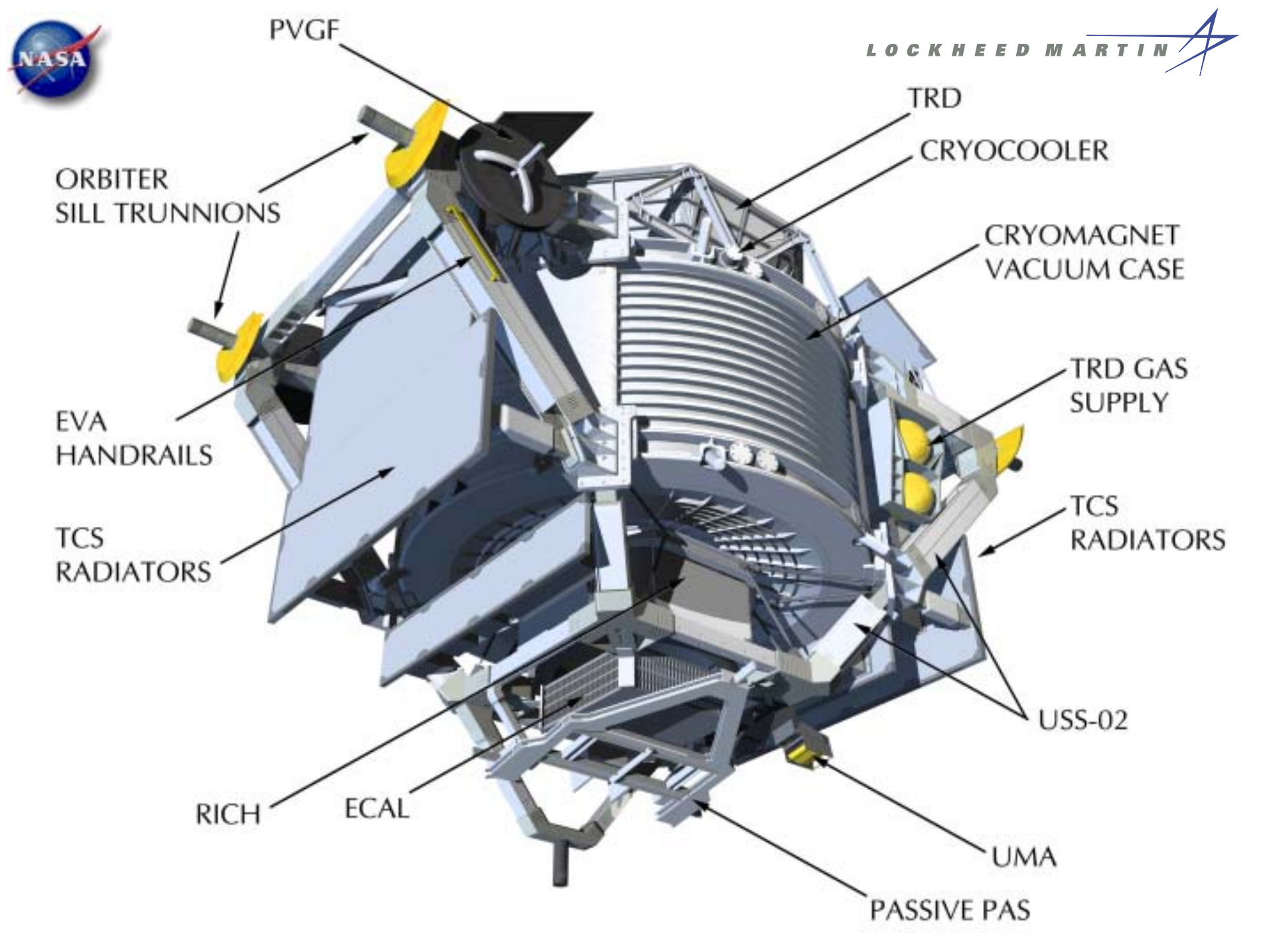
Discussion Topics

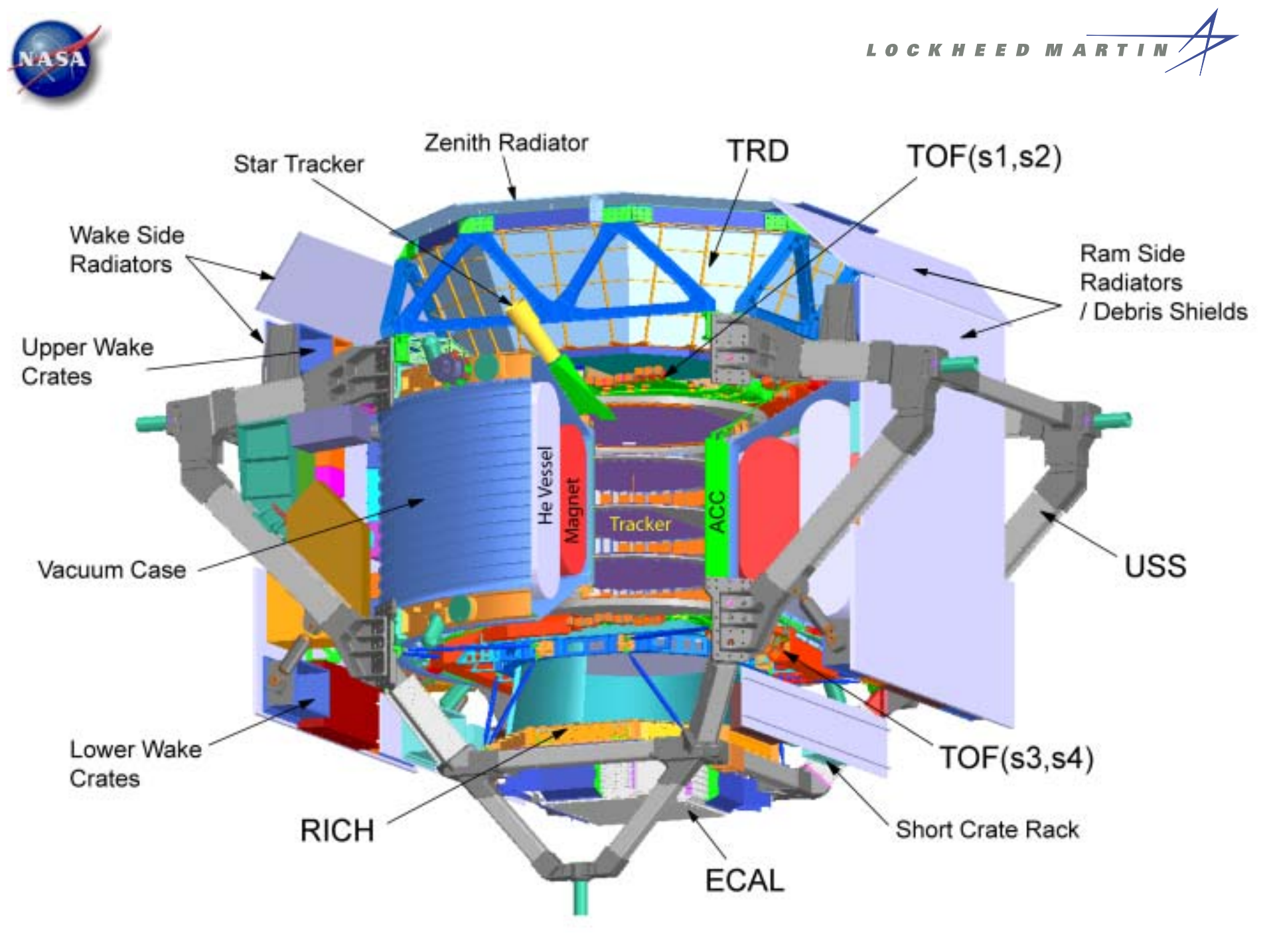
- AMS-02 Payload Overview
- Cryomagnet System
- Transition Radiation Detector (TRD)
- Time of Flight (TOF)
- Silicon Tracker & Star Tracker
- Anticoincidence Counter (ACC)
- Ring Imaging Cherenkov Counter (RICH)
- Electromagnetic Calorimeter (ECAL)
- Electronics Crates
- Thermal Control System (TCS)
- Weight Summary

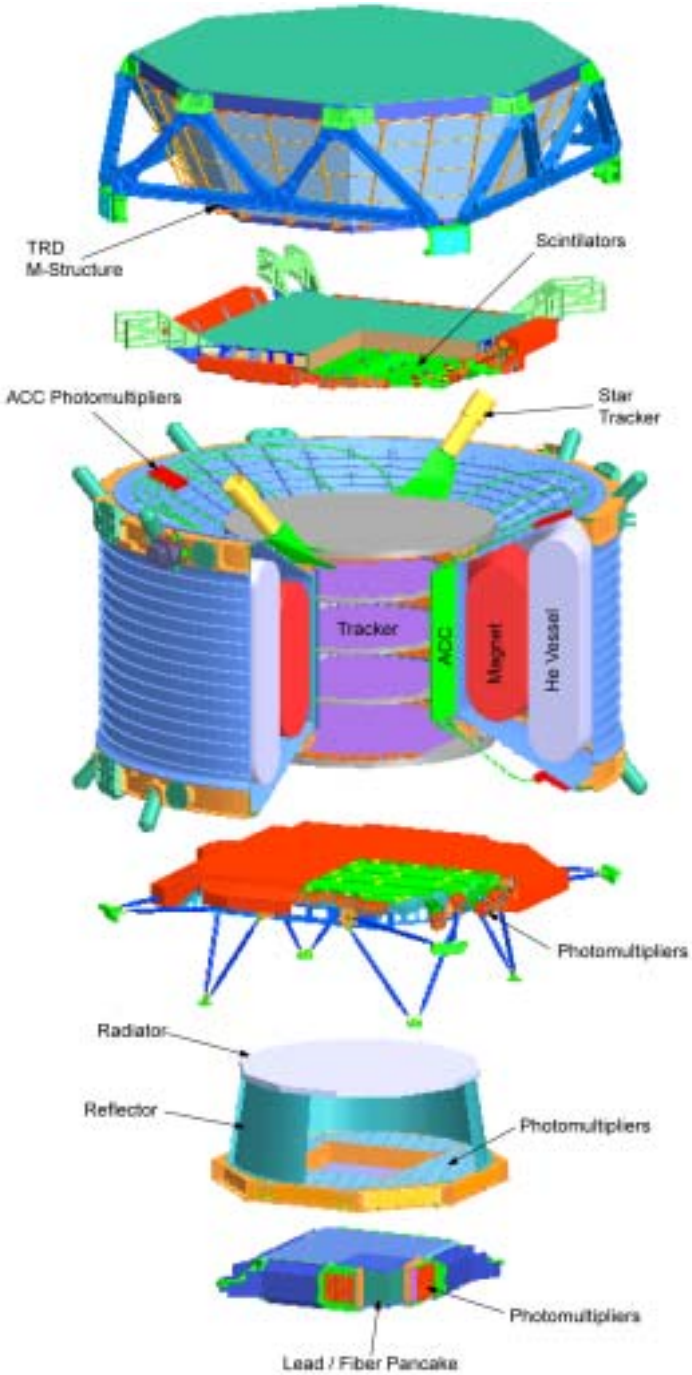

EUROPE
ASIA
USA
ALPHA MAGNETIC SPECTROMETER


DISCOVERY
NASA


TRD
CRYOCOOLER
TCS
RADIATORS
ORBITER SILL
TRUNNIONS
PDA/ROEU
ELECTRONICS
CRATES
FRGF
CRYOGENIC
FILL PORTS
THERMAL
BLANKET
USS-02
CRYOMAGNET
SUSPENSION
PORT COVER
ORBITER KEEL TRUNNION


PVGF
TRD
CRYOCOOLER
ORBITER
SILL TRUNNIONS
CRYOMAGNET
VACUUM CASE
TRD GAS
SUPPLY
EVA
HANDRAILS
TCS
RADIATORS
TCS
RADIATORS
USS-02
RICH
ECAL
UMA
PASSIVE PAS


Star Tracker
Zenith Radiator
TRD
TOF(s1,s2)
Wake Side Radiators
Ram Side Radiators / Debris Shields
Upper Wake Crates
He Vessel
Magnet
Tracker
ACC
Vacuum Case
USS
Lower Wake Crates
TOF(s3,s4)
RICH
Short Crate Rack
ECAL



TRD

Upper TOF

Vacuum Case,
SFHe Tank,
Cryomagnet,
ACC, Tracker,

Lower TOF

RICH

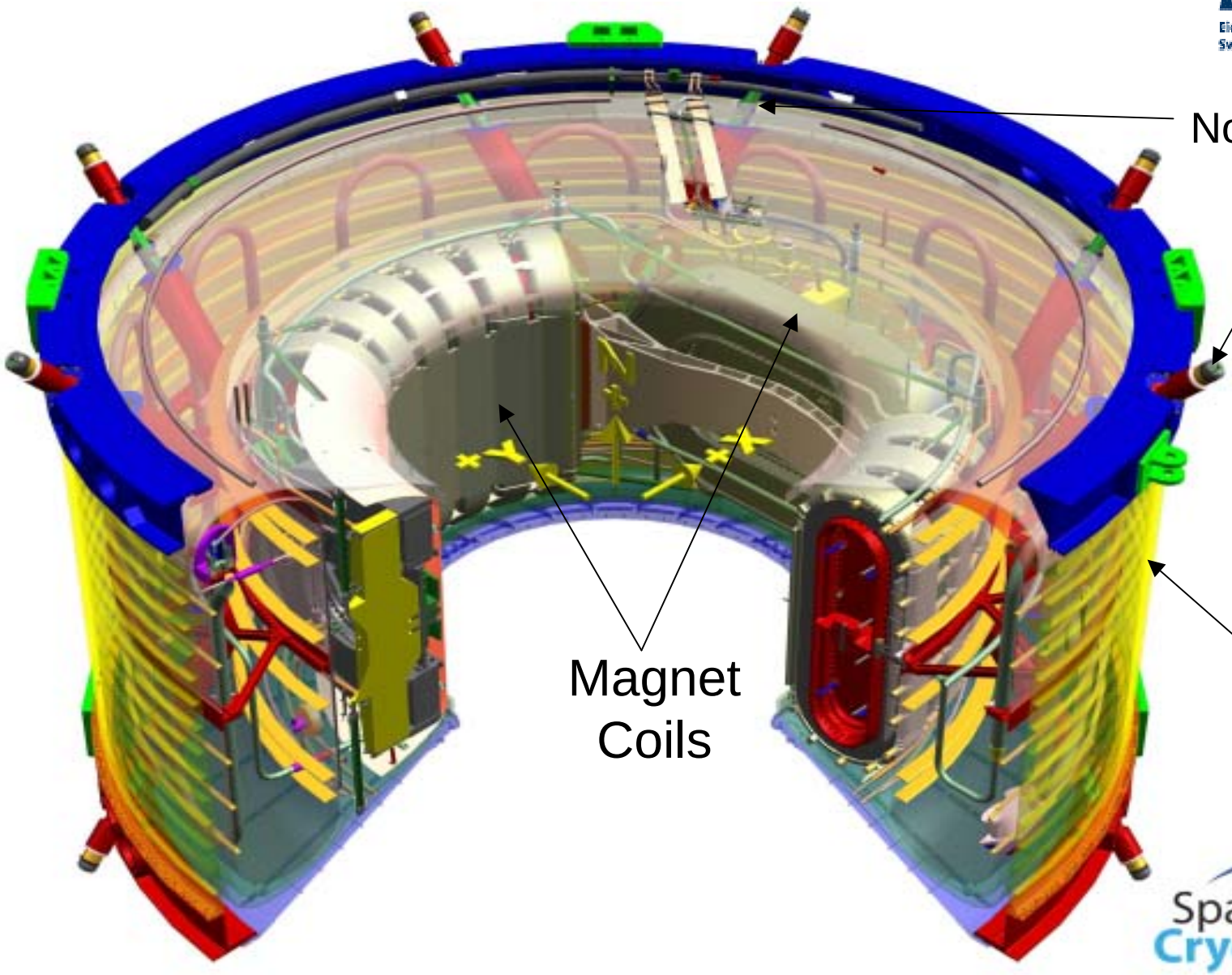
ECAL

AMS-02 Full Scale Mockup

Superconducting Super Fluid Helium Cryogenic Electromagnet System

Cryogenic Super-Conducting Magnet

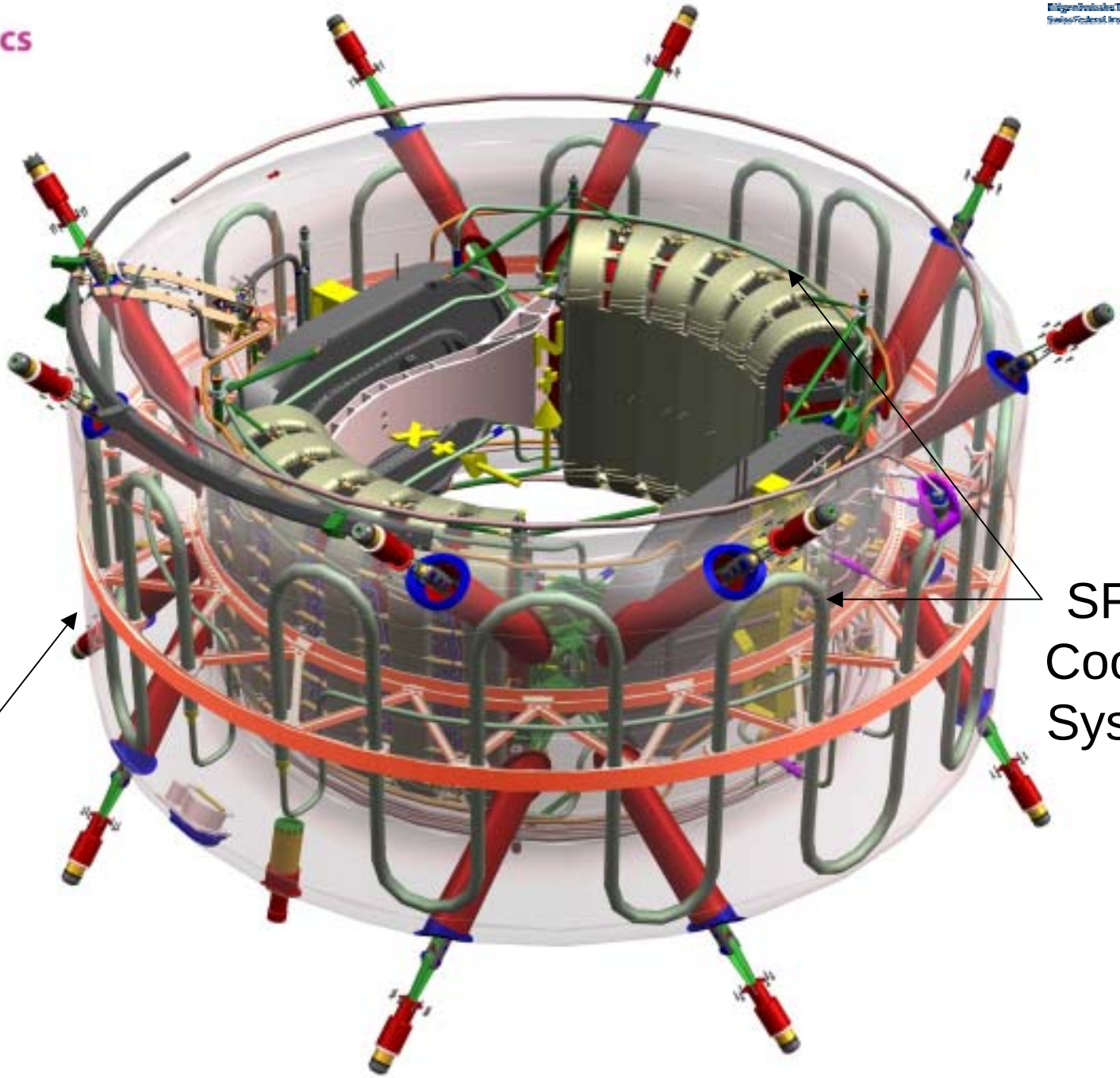
- Summary *(Entire Magnet System will be discussed in more detail in later presentations)*
  - Provides Magnetic Field for AMS Experiment
  - Components include:
    - Magnet
    - Superfluid Helium (SFHe) Tank
    - Cryogenic System (Insulation, Plumbing, Valves, Sensors, etc.)
    - Vacuum Case and Port Covers
    - Cryomagnet Support System
    - Cryomagnet Avionics Box (CAB)
    - Warm Helium Supply Tank
    - Cryocoolers and Controller
  - Size and Location
    - ~2.8 m (110 in) Diameter, ~1.5 m (60 in) Tall – Toroidal Shape, in center of AMS-02 Payload
  - Weight Estimate
    - 3077 Kg (6784 lbs) (including VC)



Space Cryomagnetics

Space Cryomagnetics

ETH



Cryomagnet, Cont.

- Primary Materials
  - VC - Structural Test Article (STA) & Flight Units
    - Aluminum 2219 and 7050
    - Viton O-rings
  - SFHe Tank - STA & Flight Units
    - Aluminum 5083
  - Magnet - Cold Mass Replica (CMR) & Flight Units
    - Aluminum 6061
  - Non-Linear Support Straps – for STA & Flight Units
    - Stainless Steel Fittings and Composite Straps
  - Cryosystem Plumbing & Supports - for STA & Flight
    - Stainless, Aluminum, & Copper
    - Aluminum Honeycomb supports for Vapor Cooled Shields

Cryomagnet, Cont.

- Structural Verification
  - Magnet verification by analysis & test with Fs_{ult}=1.5 and Fs_{yld}=1.1
    - Liftoff
      - Nx= ±5.7g, Ny= ±1.6g, Nz= ±5.9g
      - Rx=±10 rad/sec^2, Ry= ±25 rad/sec^2, Rz= ±18 rad/sec^2
    - Landing
      - Nx= ±4.5g, Ny= ±2.0g, Nz= ±6.5g
      - Rx=±20 rad/sec^2, Ry= ±35 rad/sec^2, Rz= ±15 rad/sec^2
  - SFHe Tank & Support System verification by analysis & test
    - Liftoff
      - Same as above
    - Landing (includes sloshing loads)
      - Nx= ±6.0g, Ny= ±3.7g, Nz= ±6.5g
      - Rx=±20 rad/sec^2, Ry= ±35 rad/sec^2, Rz= ±15 rad/sec^2

Cryomagnet, Cont.

- Components Minimum Margin of Safety:
  - Magnet = .071 on magnet bands
  - Superfluid Helium (SFHe) Tank = 0.17 on inner cylinder
  - Cryogenic System = TBD
  - VCS Support = 0.03
  - Vacuum Case and Port Covers = 0.03
  - Cryomagnet Support System = 0.03 on Clevis between strap and magnet
  - Cryomagnet Avionics Box (CAB) = >1
  - Warm Helium Supply Tank = TBD
  - Cryocoolers and Controller = 0.17 (titanium ring flexure)
- Components First Dynamic Frequency:
  - Magnet - >50 Hz
  - Superfluid Helium (SFHe) Tank - ~25 Hz
  - Cryogenic System - TBD
  - Vacuum Case and Port Covers – Part of overall AMS Primary Structure
  - Cryomagnet Support System – Part of overall AMS Primary Structure
  - Cryomagnet Avionics Box (CAB) - > 50 Hz
  - Warm Helium Supply Tank - > 50 Hz
  - Cryocoolers and Controller - >> 50 Hz
  - UPS - TBD

Cryomagnet, Cont.

- Certification Testing
  - Small Dewar Vent Testing
  - Magnetic Field Mapping
  - Magnetic Field Testing
    - US EMU – 300 Gauss set as new limit
    - Russian Orlan Suit – 175 Gauss set as new limit
    - Pistol Grip Tool (PGT) & Simplified Aid For EVA Rescue (SAFER)
  - Non-linear Strap Assembly Testing
    - Static & Dynamic @ room temp., Fatigue @ 77 K, Static @ 4 K
  - Pressure Testing of SFHe tanks and VCs
  - Vacuum Leak Testing of SFHe tanks and VCs
  - Cold Shock Testing on SFHe tanks
  - Cryogenic System Pressure & Leak Testing

Cryomagnet, Cont.

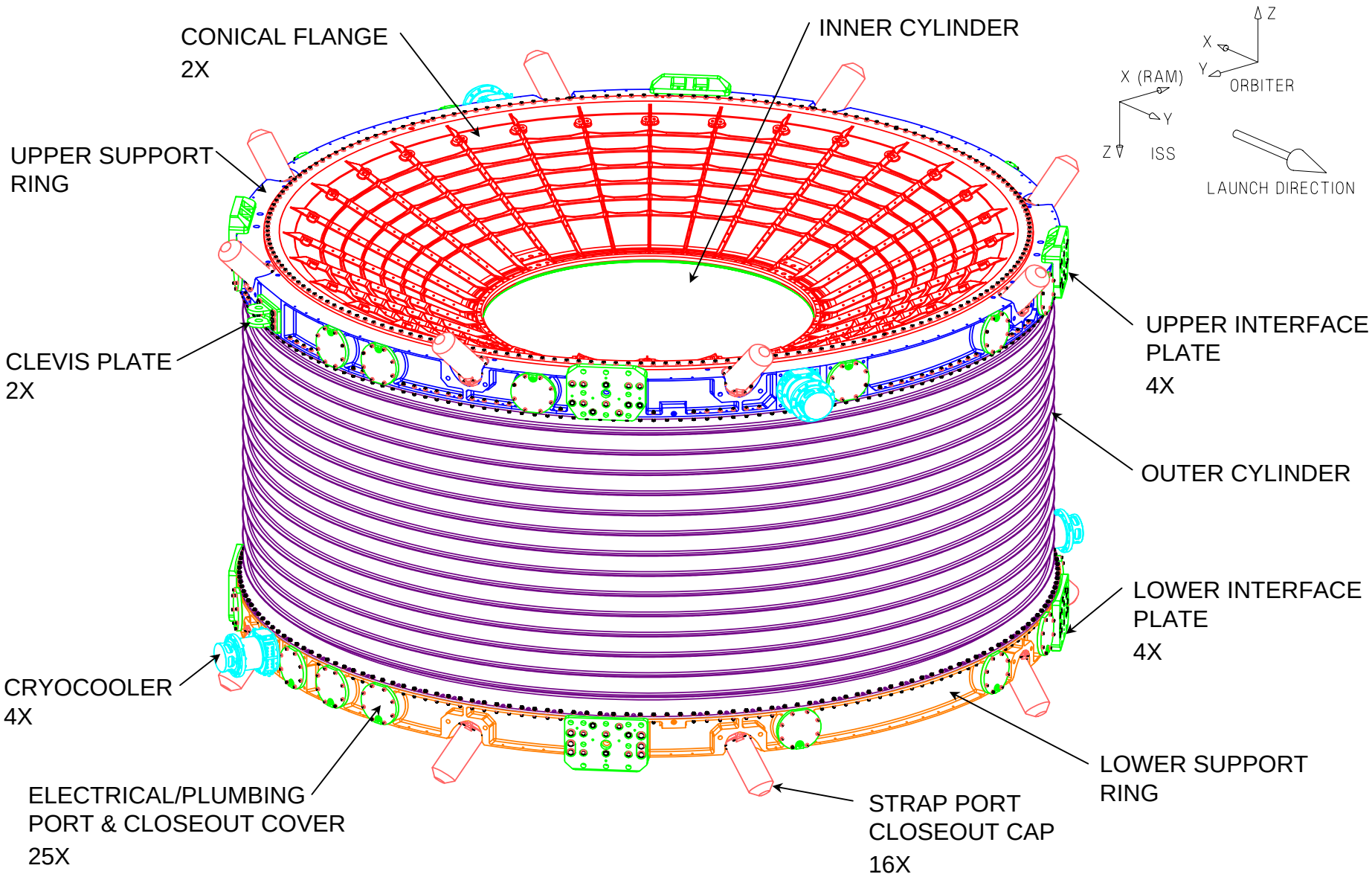
- Certification Testing, Cont.
  - Micrometeoroid and Orbital Debris Testing
  - Bolted Interface testing for VC
  - VC/USS-02 Interface Plate Static Test
  - O-ring Test Fixture testing for VC
    - Positive Pressure and Vacuum Leak Checks
  - Materials certification testing on VC, magnet structure, and supports, and SFHe tank ring forgings and plates
  - Sine Sweep of STA VC and STA CMR
  - Acoustic testing of STA VC and STA CMR
  - Cryosystem development and pressure & leak testing
  - Vibration testing of cryosystem components
  - Thermal Vacuum testing of overall AMS-02 Payload

Cryomagnet, Cont.

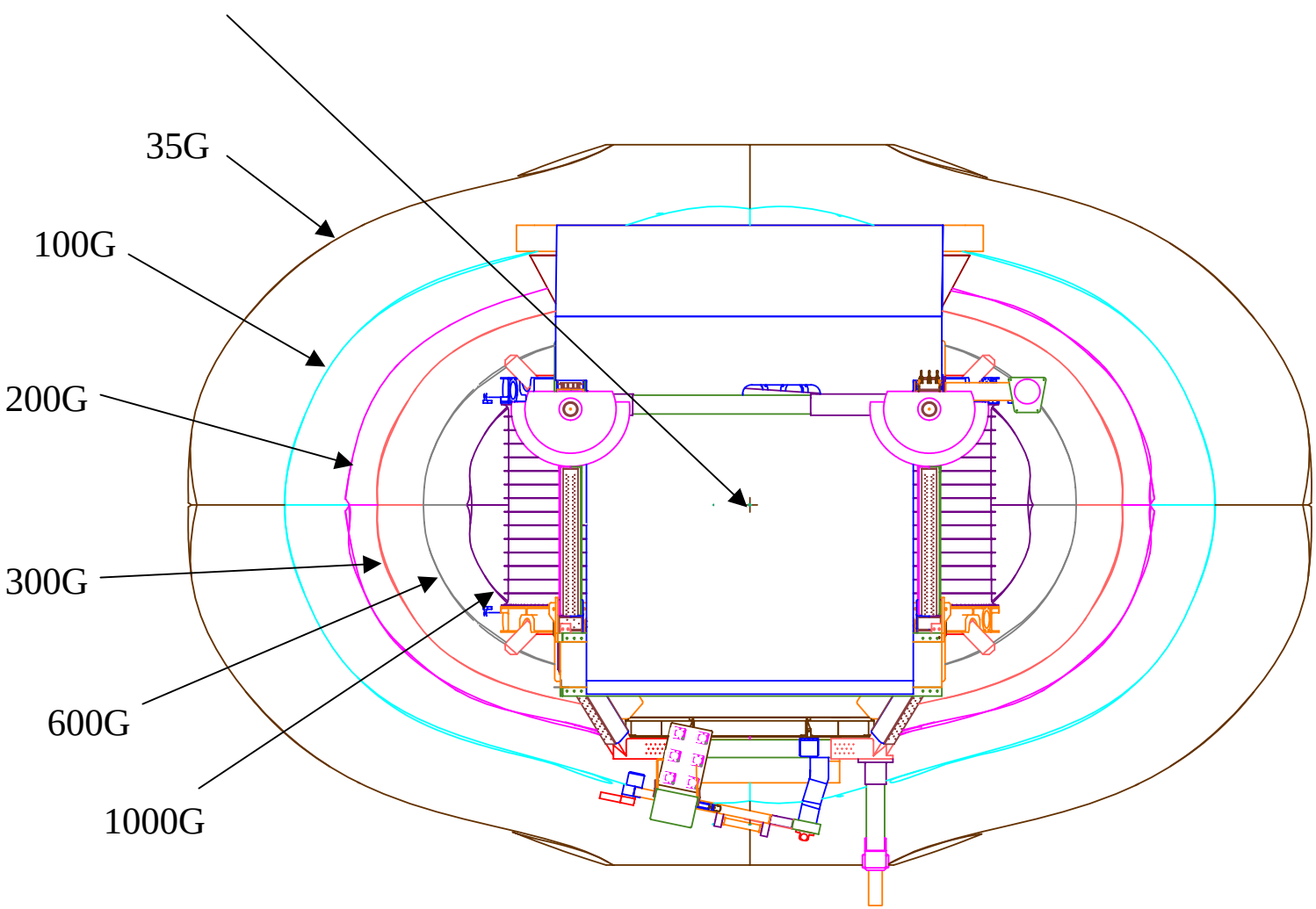
- Certification Testing, Cont.
  - Weld certification testing on VCs, SFHe tanks, and Cryosystem Plumbing
  - Magnet Coil Testing
    - Test coil to 5 kV
    - Individual Flight coils to 3 kV
    - Full magnet system to 1 kV
  - Quench Testing on Individual Coils & Magnet Assembly
  - CAB Testing
    - Vibration, Thermal Vacuum, EMI
  - Battery Testing
    - Abuse and Performance Testing
  - Dump Rectifiers Testing
    - Vibration & Thermal Vacuum

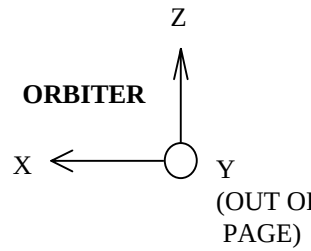
Cryomagnet, Cont.

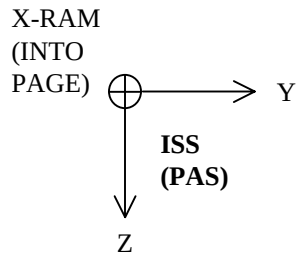
- Certification Testing, Cont.
  - Cryocooler
    - Magnetic Field, Vibration, Thermal Vacuum, Leak Testing, Pressure Testing, Life Testing
  - Warm Helium Tank
    - Pressure, Vibration, Leak


CONICAL FLANGE
2X
INNER CYLINDER
Z
X
Y
X (RAM)
ORBITER
Y
Z
ISS
LAUNCH DIRECTION
UPPER SUPPORT RING
CLEVIS PLATE
2X
UPPER INTERFACE PLATE
4X
OUTER CYLINDER
LOWER INTERFACE PLATE
4X
CRYOCOOLER
4X
ELECTRICAL/PLUMBING PORT & CLOSEOUT COVER
25X
STRAP PORT CLOSEOUT CAP
16X
LOWER SUPPORT RING

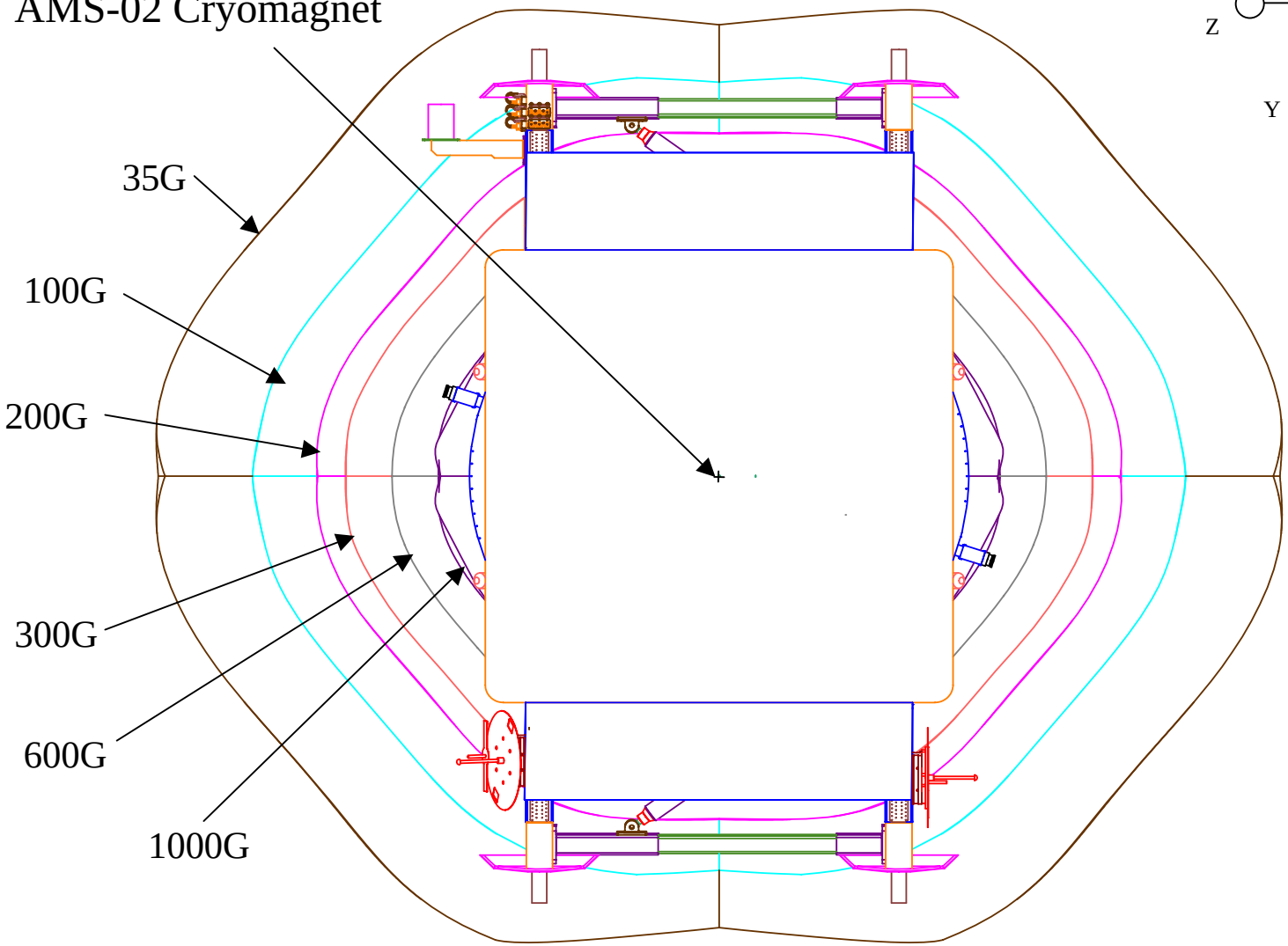
Geometric center of AMS-02 Cryomagnet

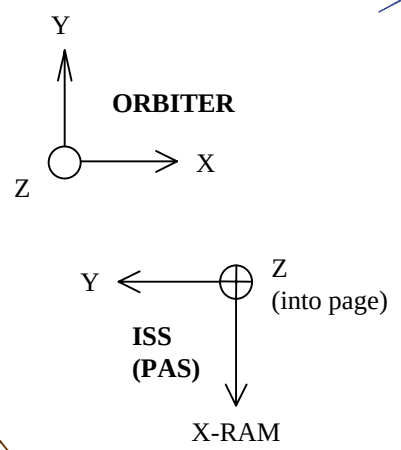


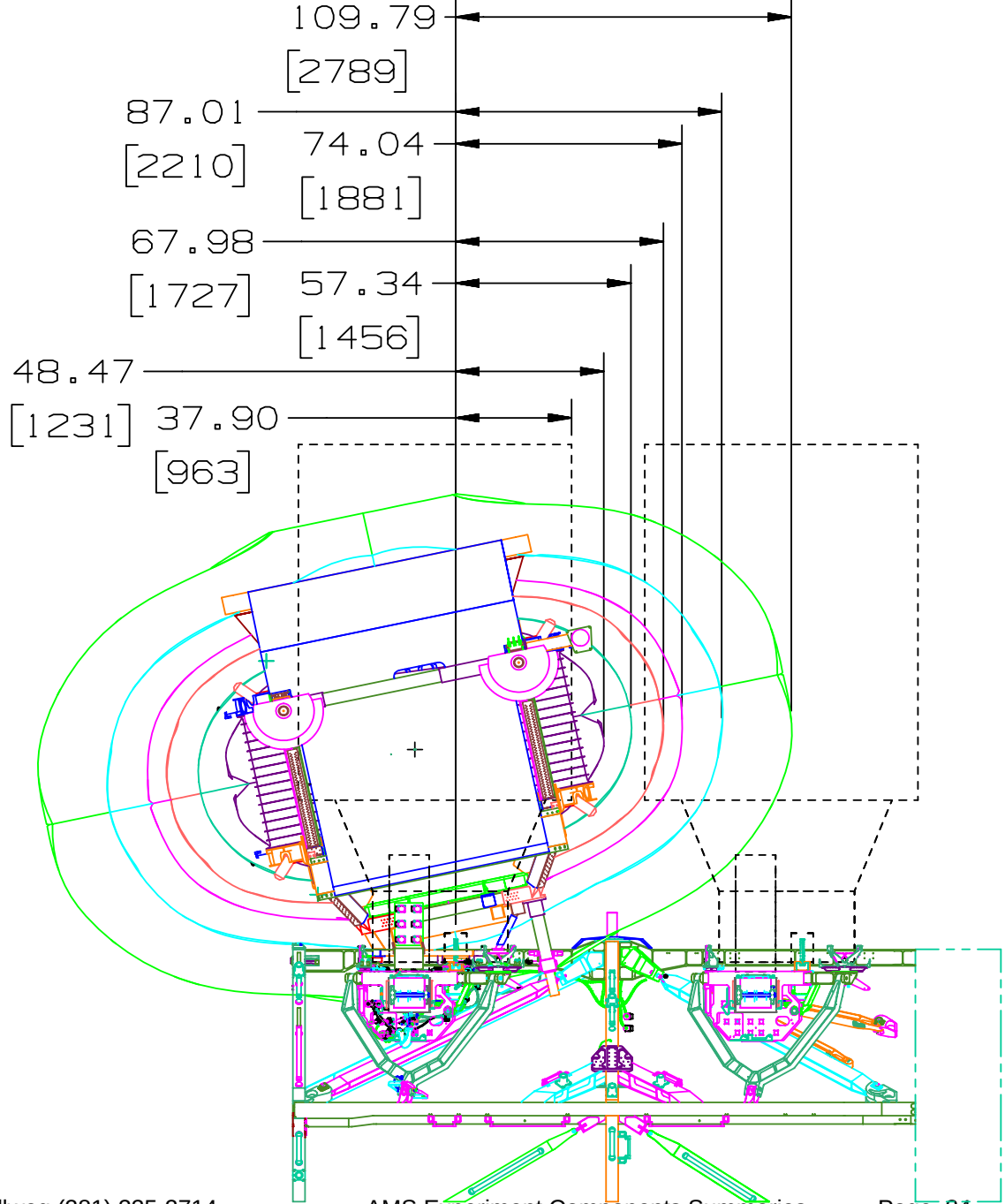




Geometric center of
AMS-02 Cryomagnet





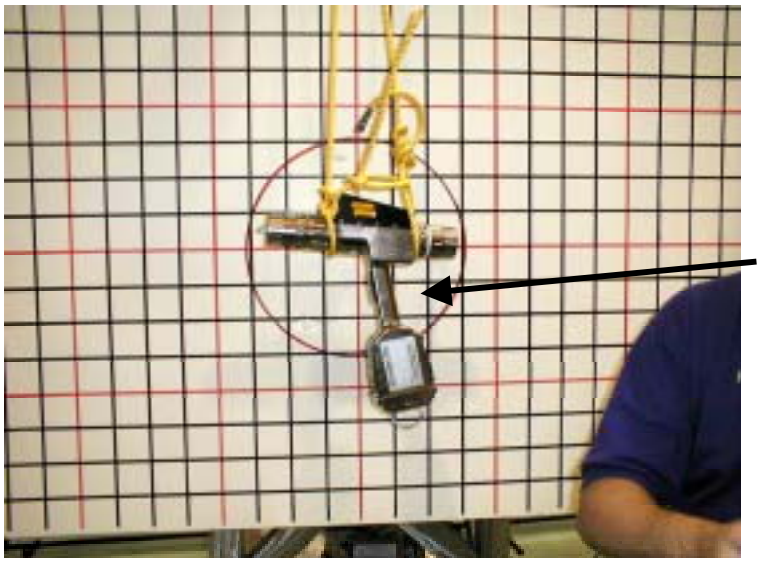

109.79
[2789]
87.01
[2210]
74.04
[1881]
67.98
[1727]
57.34
[1456]
48.47
[1231]
37.90
[963]

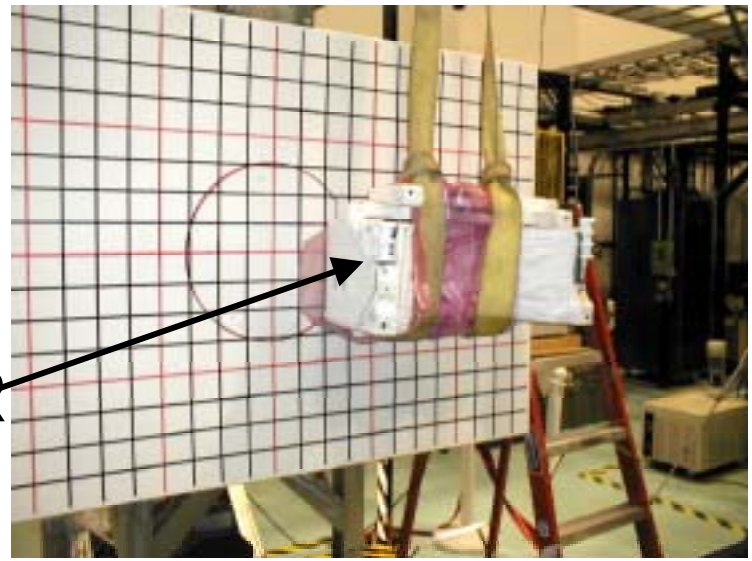
Magnetic Susceptibility Testing

EMU

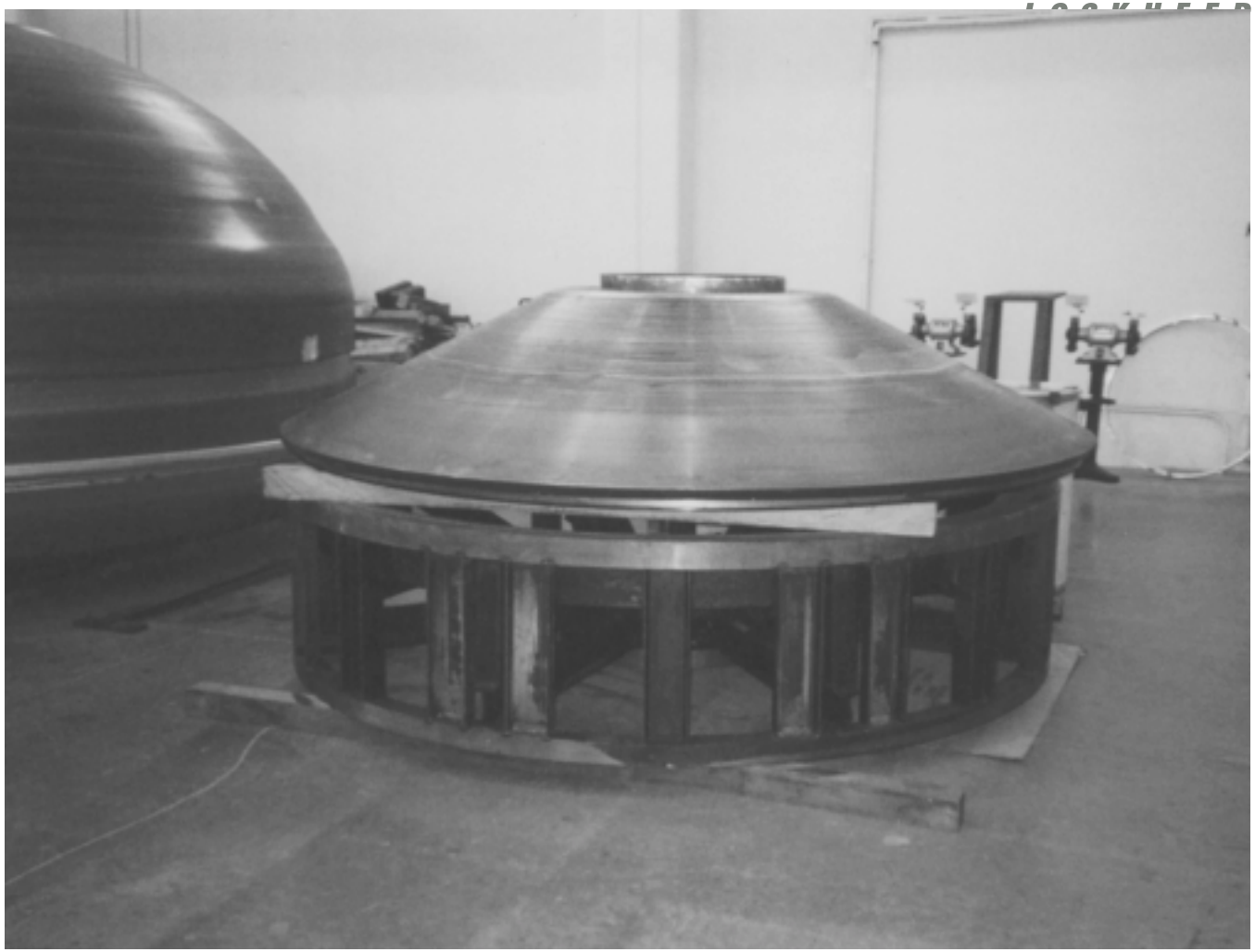
PGT

SAFER





Forgings



Conical Flange Spin Form Tooling

O-Ring Test Fixture

AMS-02 Cryocoolers Engineering Units 1&2

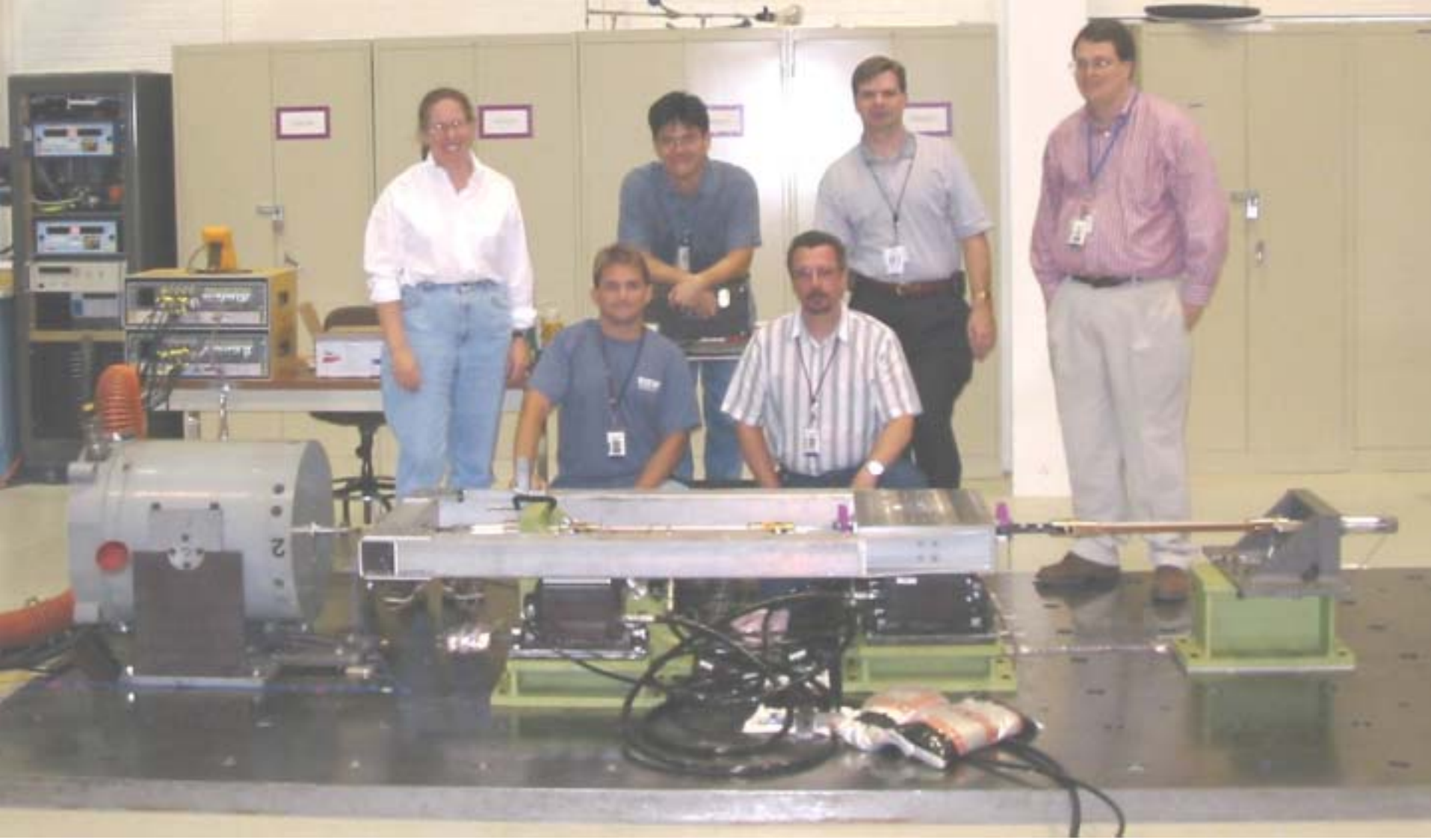
Goddard Space Flight Center **Cryogenics and Fluids Branch**

Space Cryomagnetics

ETH

Portions of Cryomagnet Support Strap Undergoing Static Testing

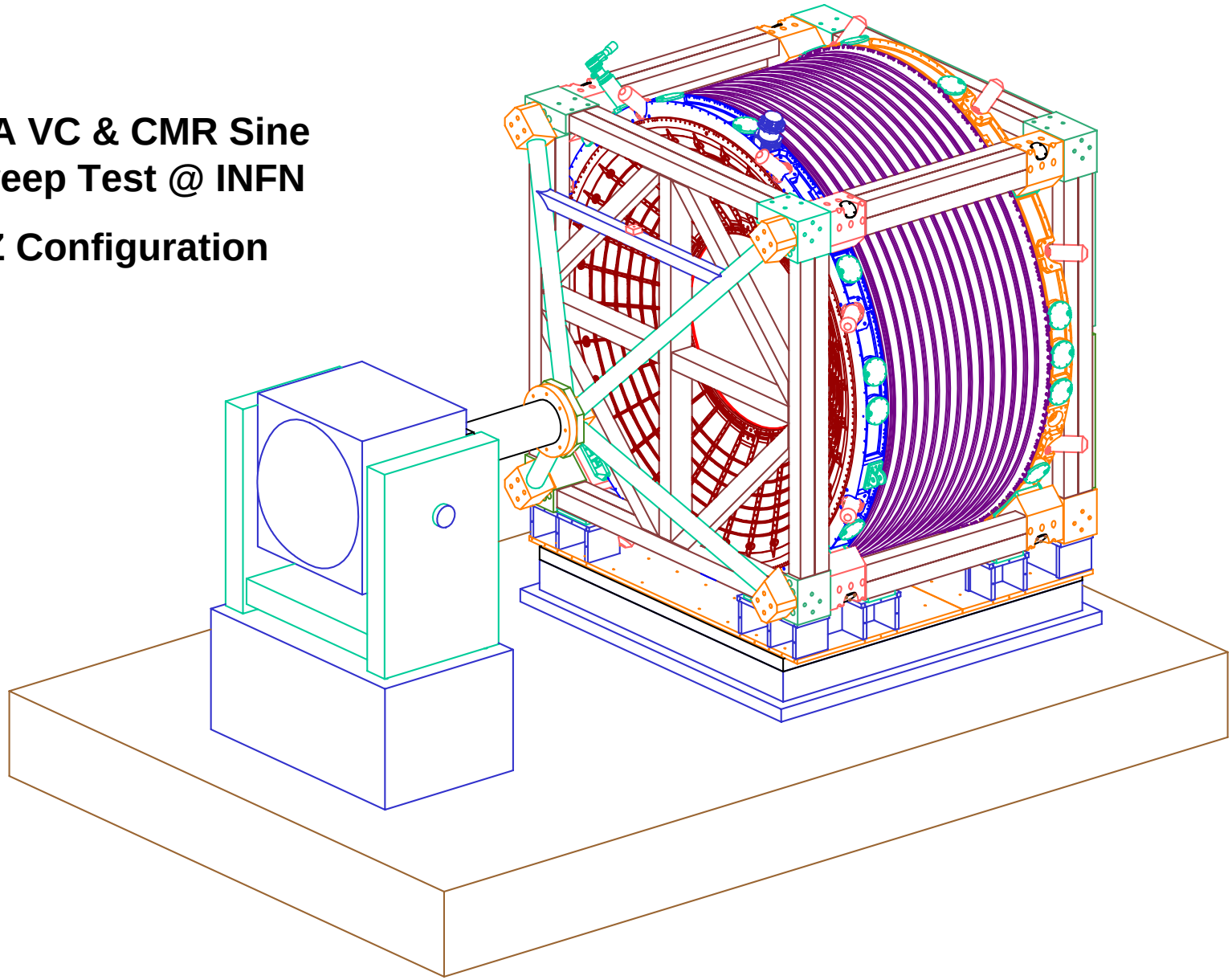
Fatigue Test Rig for Strap System: Allows fatigue testing to be performed with one end at 77K and the other at 300K.

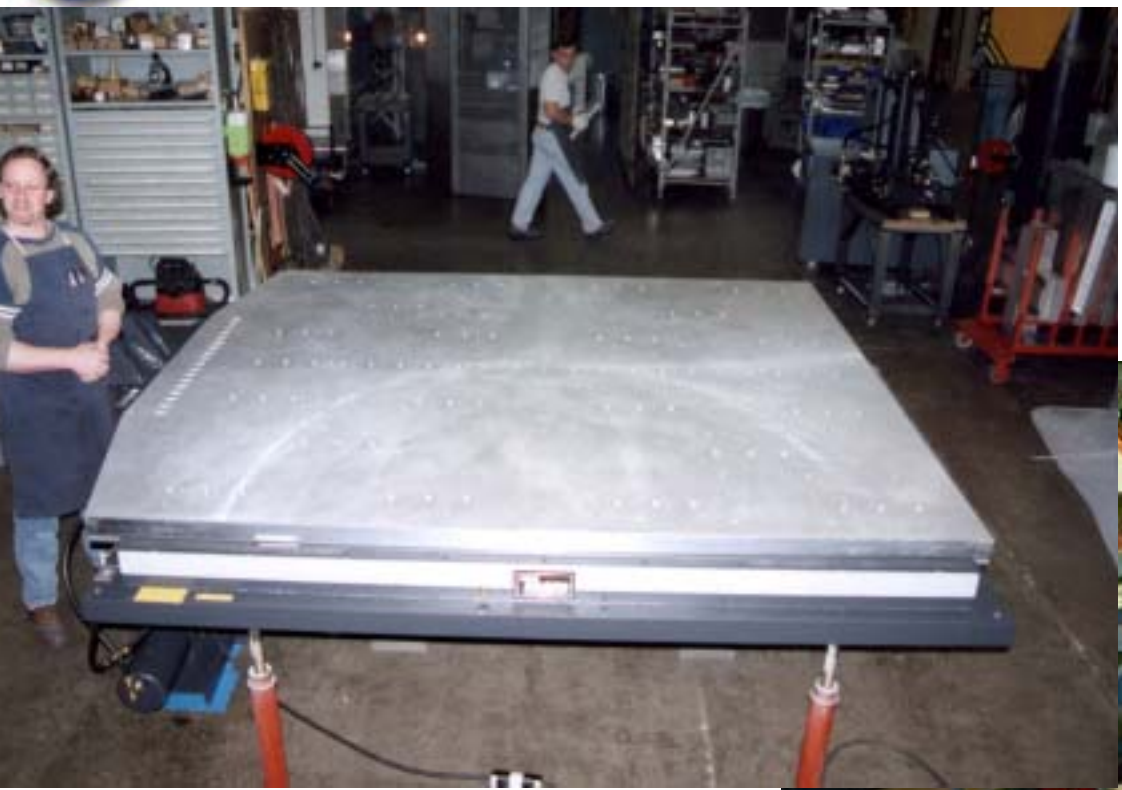


LMSO Team at SCL Non-linear Dynamic Strap Test – June 2002

STA VC & CMR Sine Sweep Test @ INFN

Z Configuration

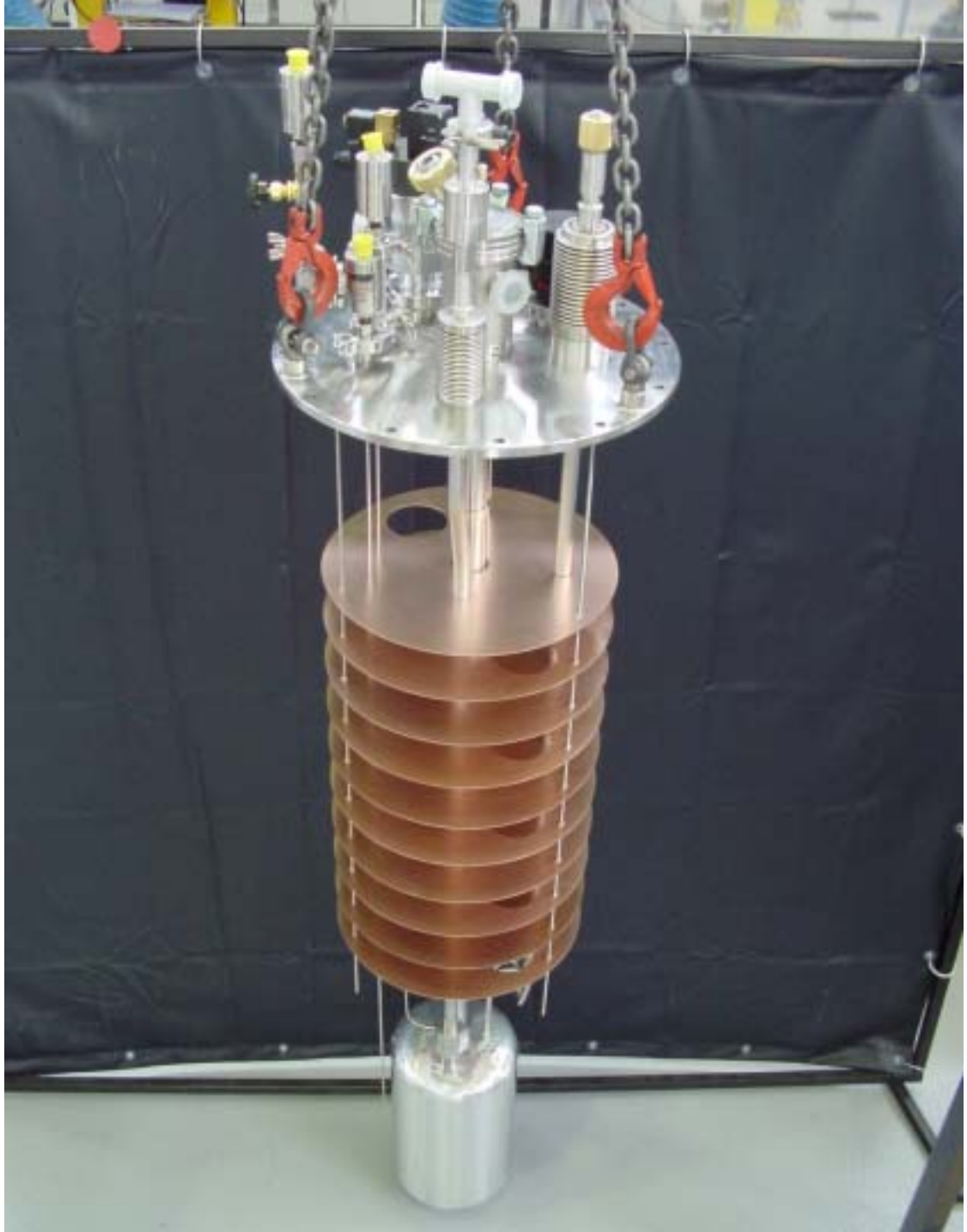




INFN 35K
Force-Pound
Actuator

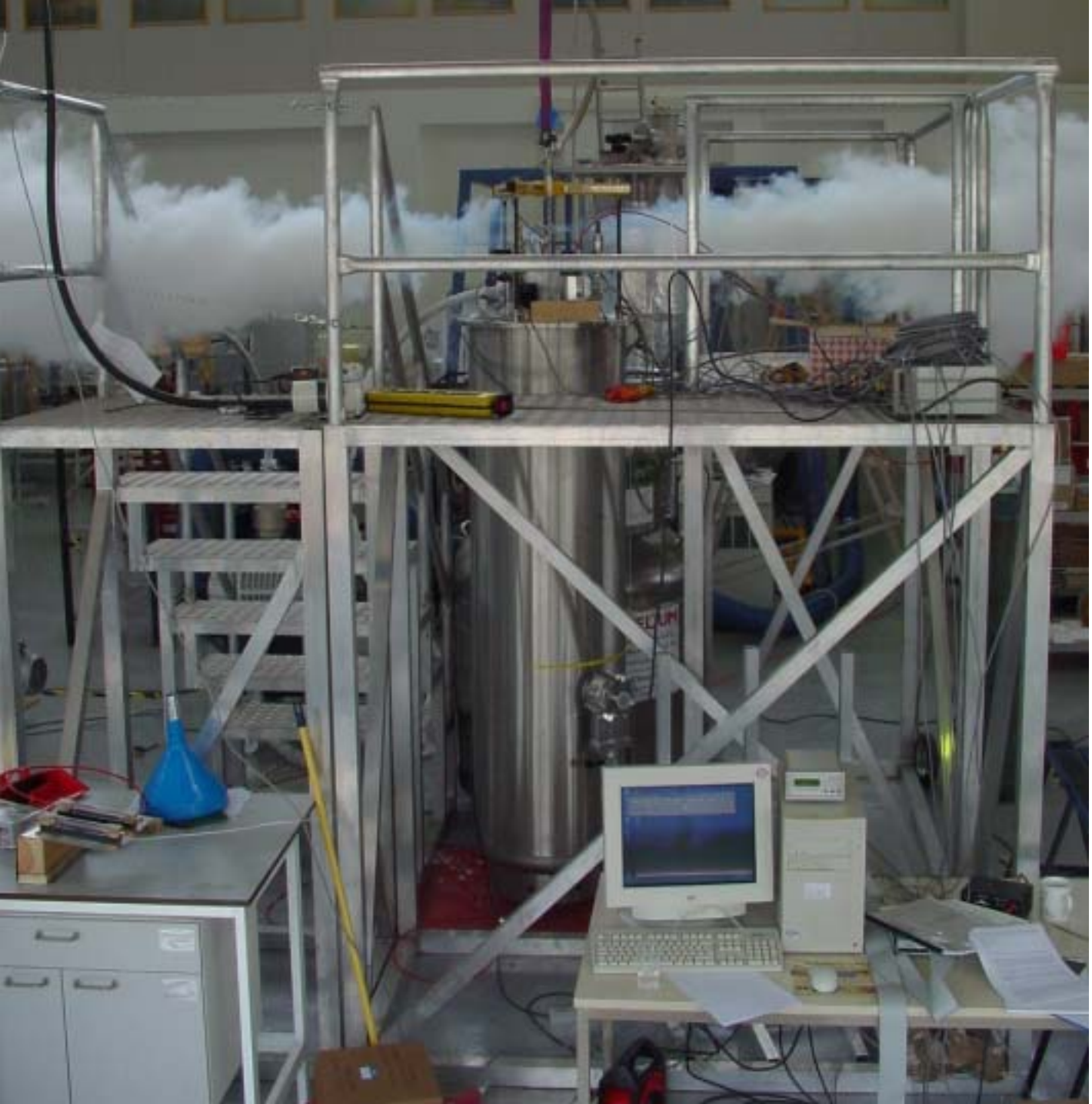
INFN 7’ x 7’
Slip Table

Space Cryomagnetics



ETH

Small Dewar Vent Test Rig

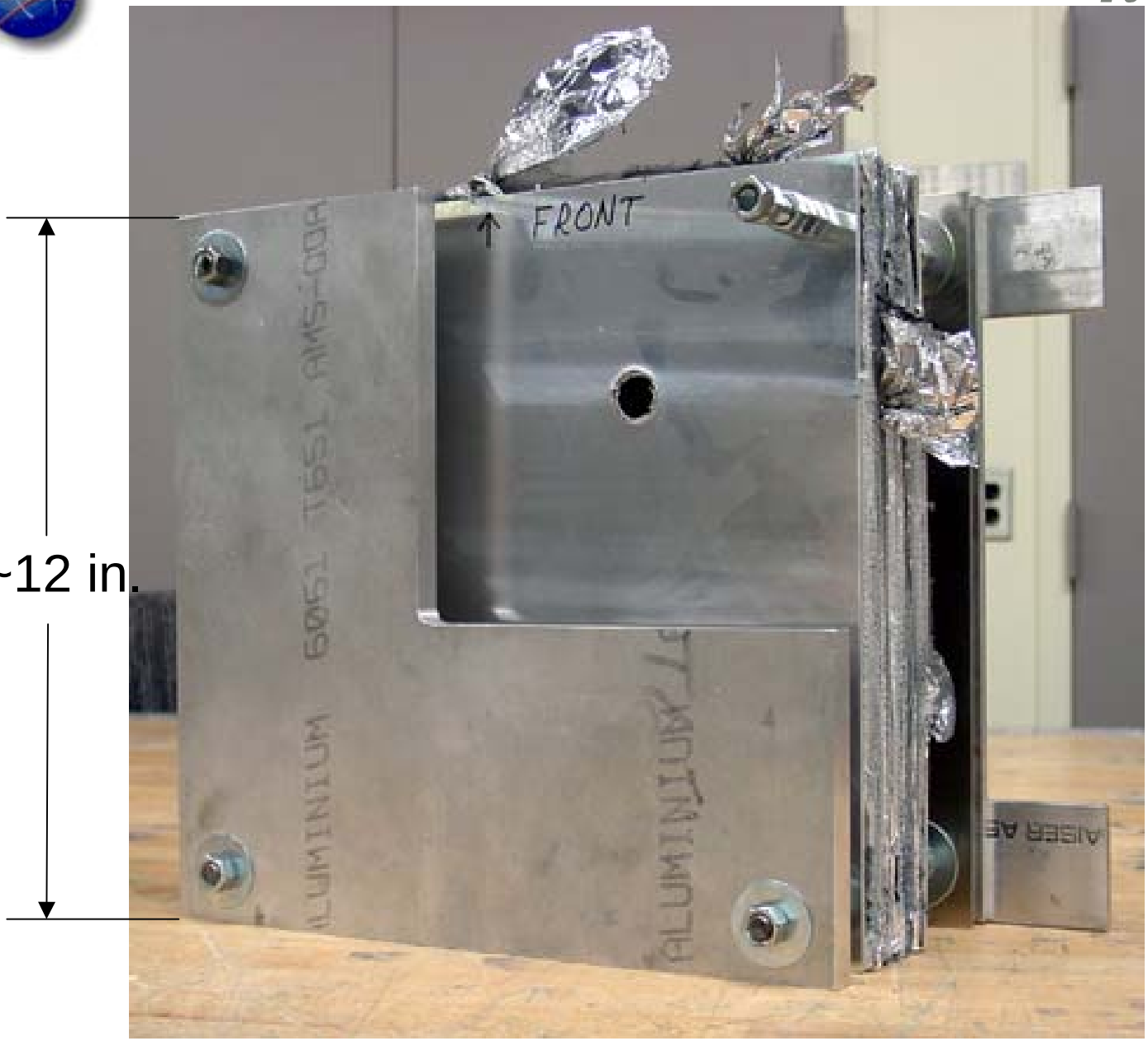


ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

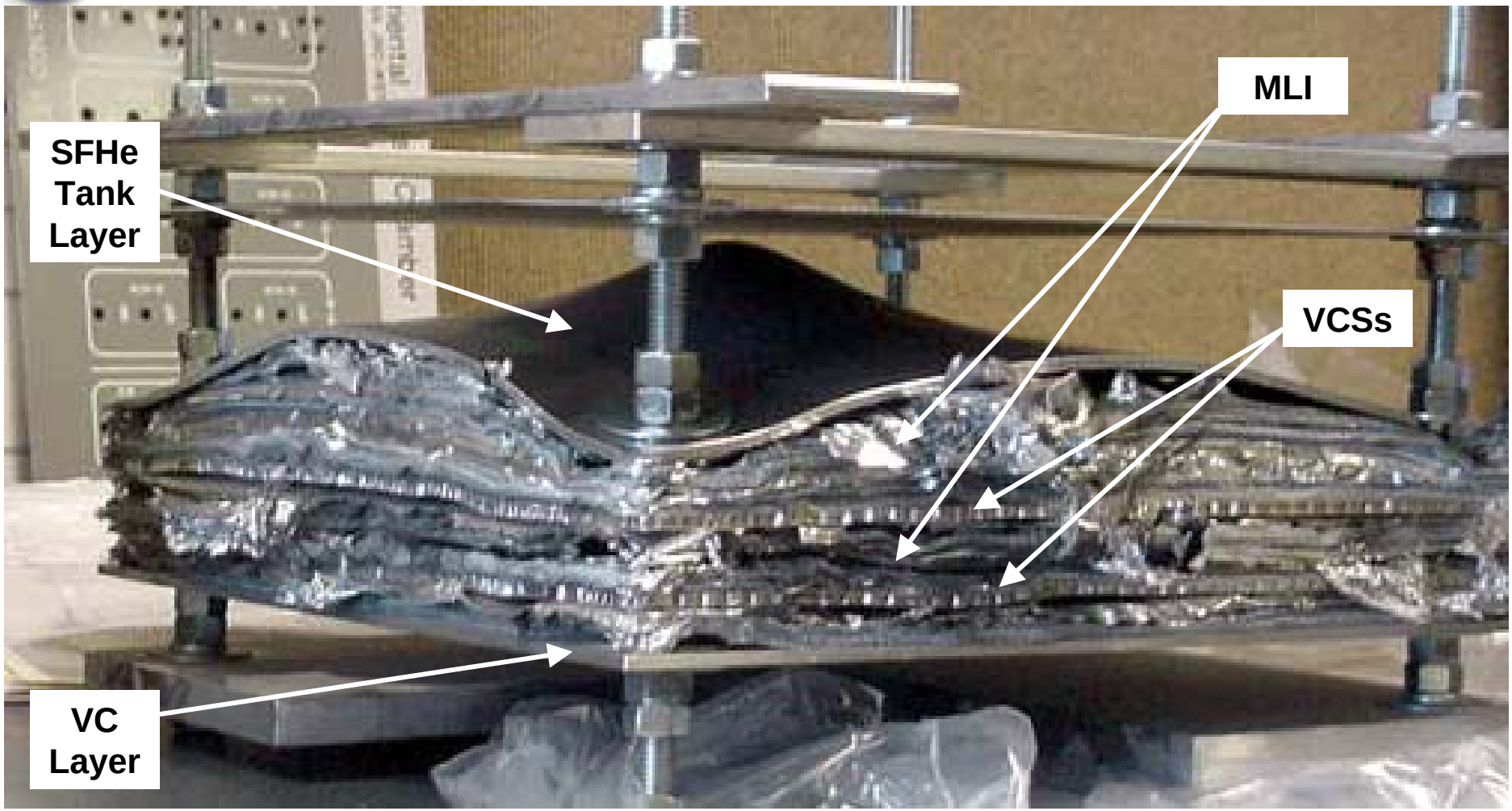
Space Cryomagnetics

Small Dewar Vent Test in Progress

Micro-meteoroid and Orbital Debris Testing of AMS Cryomagnet System



Shows hole made in Vacuum Case Layer from 5 mm Aluminum Orbital Debris Particle shot at ~15,000 mph



Test #3 – 7 mm diameter aluminum sphere shot at 6.92 km/sec (15,480 mph)

Cryogenic Super-Conducting Magnet

- Major Unique Safety Items
  - Venting of Helium
    - Nominal Vent Rate is 5 mg/sec has already been approved by PSRP and STS Integration
    - Emergency Vent Rate has been approved by PSRP and STS Integration
      No overboard Orbiter vent or full scale vent test is required
    - Cryogenic Temperatures
    - Zero Thrust
  - Dewar Certification
    - O-ring leakage
    - Weld Certification
    - Cryosystem Certification
  - Non-linear Support System Certification and Overall Structural Certification
  - Magnetic Field
  - High Voltage in Cryomagnet Self-protection System

Transition Radiation Detector (TRD)

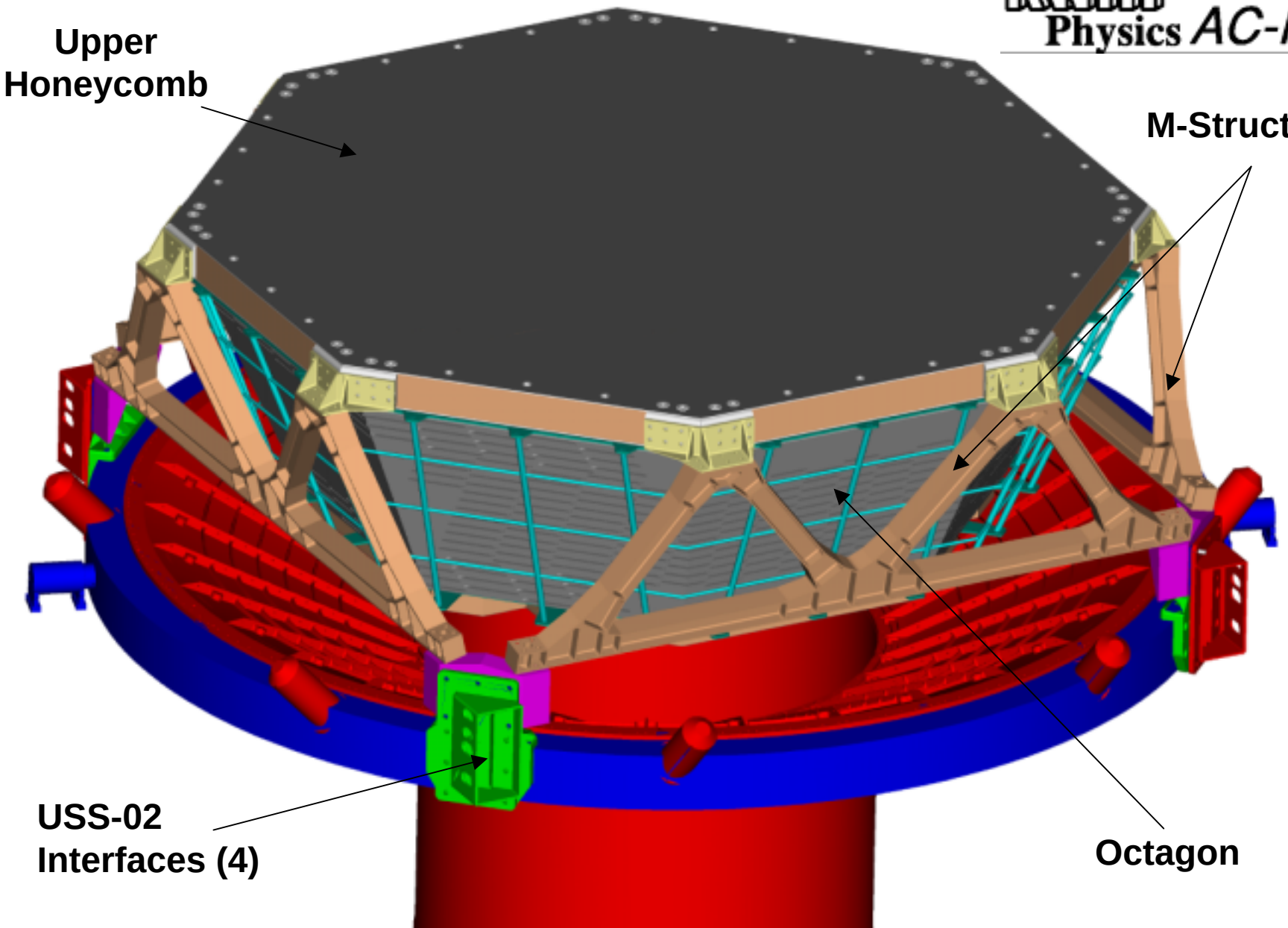
Transition Radiation Detector (TRD)

- Notes
  - TRD uses a gas system with Xe:CO_2 (80:20)
- Size, Location, and Description
  - TRD above the +Z TOF on the experiment stack
  - Octagonal shape max. size 2.31 m x 0.62 m (90.9 in. x 24.4 in.)
  - Mounts to USS-02 at four locations via the Aluminum M-Structure
  - Weight estimate = 328 kg (723 lbs)

TRD (Cont.)

- Components
  - Octagonal Support Structure and Bulkheads
  - 5248 proportional tubes
    - Multi-layer wound composite structure (outer diameter of 6 mm (0.24 in), wall thickness = 70 μ (.003 inches)
    - Gold plated tungsten wire (30 μ (.001 in) diameter) runs thru the center of the tube
    - 16 tubes are connected to make a Module
    - 4 Stacked Modules make a Tower
    - 2 Towers make a Group
    - 41 Groups are connected thru gas manifolds
    - Total of 20 tube layers high with a radiator material gap between each layer
      - Upper 4 and lower 4 layers oriented in Orbiter/AMS X direction
      - Middle 12 layers oriented in Orbiter/AMS Y direction
  - Gas Supply System (Details Covered in Another Presentation)

TRD Structure



TRD, Cont.

- Structural Verification
  - Verification by analysis with Fs_{ult}=2.0 and Fs_{yld}=1.25
    - Liftoff – Applied about CG of entire payload
      - Nx= ±5.7g, Ny= ±1.6g, Nz= ±5.9g
      - Rx=±10 rad/sec^2, Ry= ±25 rad/sec^2, Rz= ±18 rad/sec^2
    - Landing – Applied about CG of entire payload
      - Nx= ±4.5g, Ny= ±2.0g, Nz= ±6.5g
      - Rx=±20 rad/sec^2, Ry= ±35 rad/sec^2, Rz= ±15 rad/sec^2
  - A separate acoustic analysis has been performed to validate these load factors
    - Acoustic energy had significantly reduced by the time it reached the TRD providing an insignificant increase in load

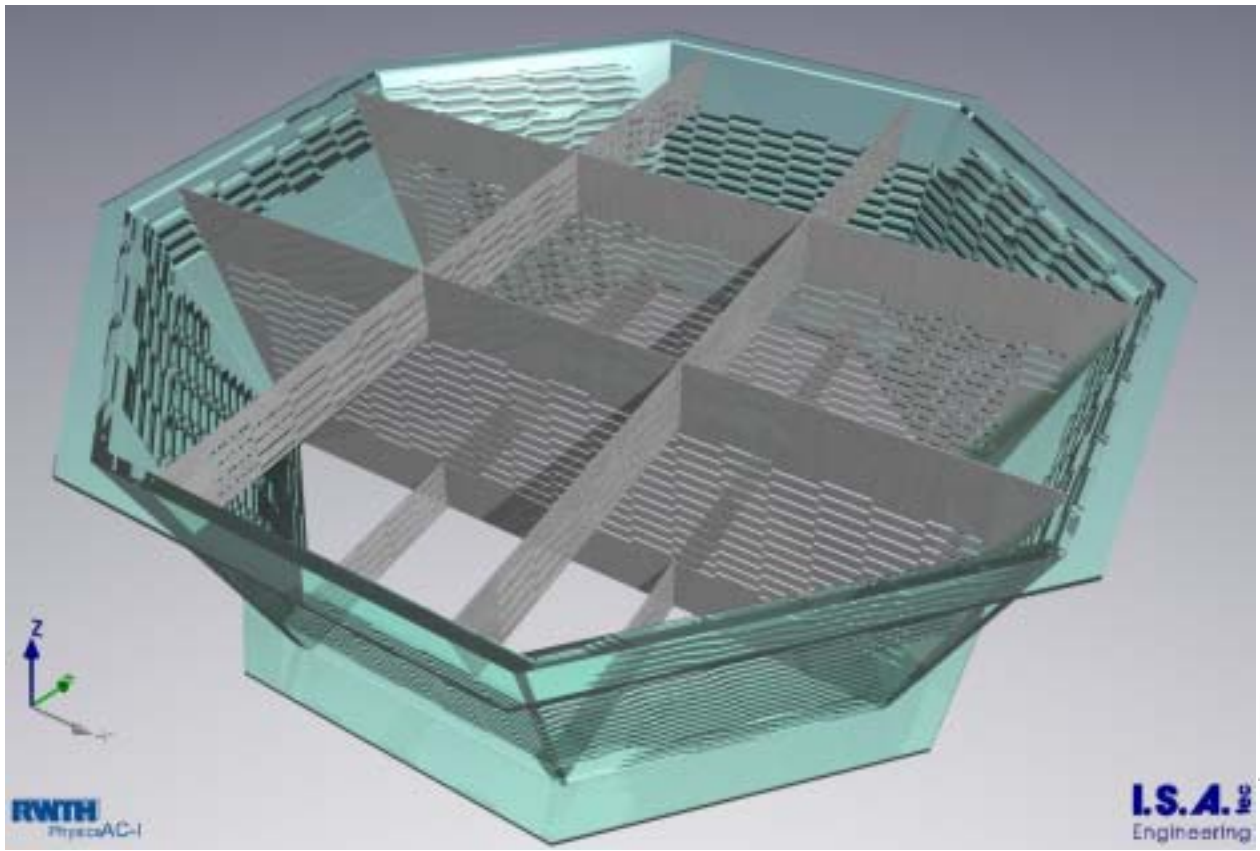
TRD, Cont.

- Components Minimum Margin of Safety:
  - Octagonal Bulkheads = 1.17
  - M Structure = 0.125 for buckling
  - Upper Honeycomb Panel = 2.4
  - Lower Honeycomb Panel = >2.4
  - Gas Supply System = in separate presentation
- Components First Dynamic Frequency:
  - Overall System = 51 Hz
  - Modules > 100 Hz (tested)
  - Gas Supply System = 70 Hz (tested)

TRD Mechanics

Octagon Production:
- 8 panels produced at FVT Aachen
- machined at IPT, RWTH Aachen
- glued together at Physics AC-I

Bulkhead Production:
- 6 panels produced at FVT Aachen
- machined at IPT, RWTH Aachen
- integrated at Physics AC-I



RWTH Physics AC-I

- **Mechanical accuracy (100 μm) of the octagon structure will be verified with a 3D coordinate measuring machine in Aachen.**
- **TRD assembly in a clean room with temperature (+/- 1°) and humidity control**
- **Test of the full TRD in Aachen on a cosmic stand.**

TRD Mockup

Used for plumbing and cable routing

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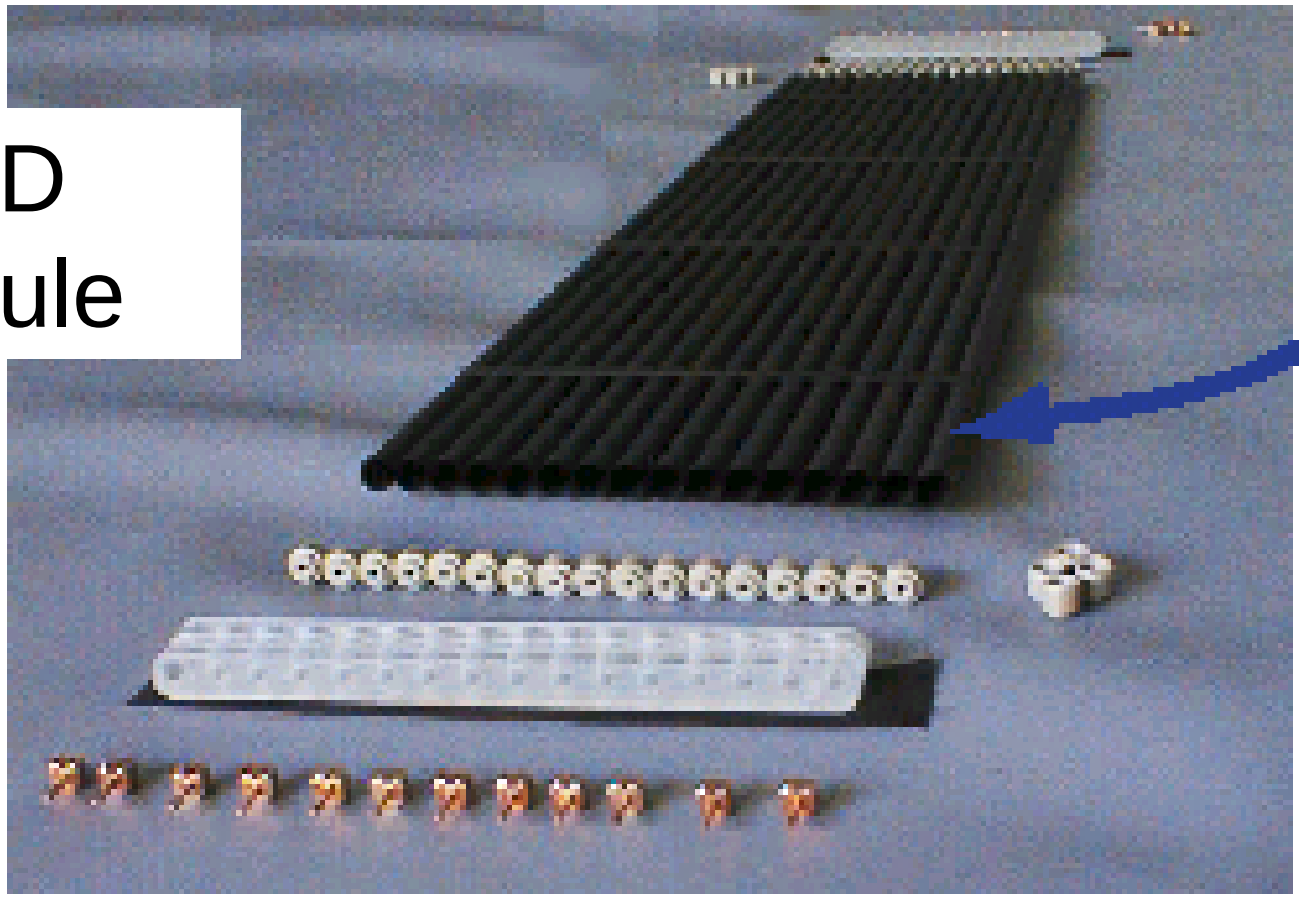
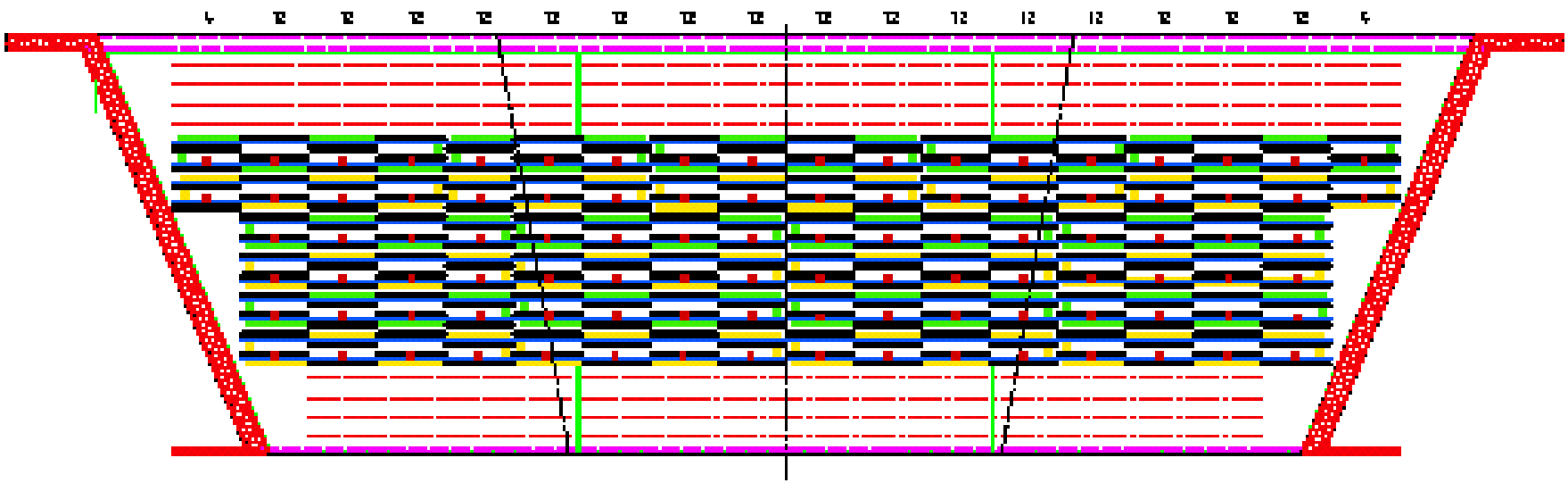
Multilayer Kapton Tubes

TRD Module





Readout boards Y+ side

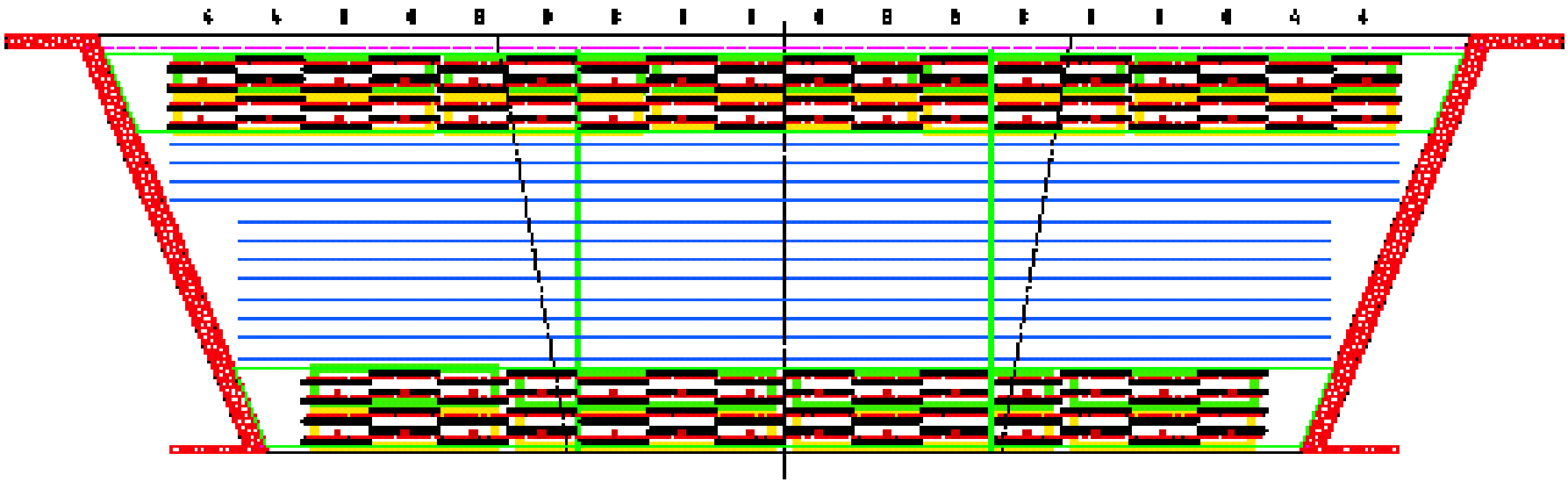
Heat source ~130 mW

Readout boards Y - side

Karpinski 22.02.00

DRAWING No.: AMS_ROYP_10

TRD X-Z Cross Section



Readout boards X + side

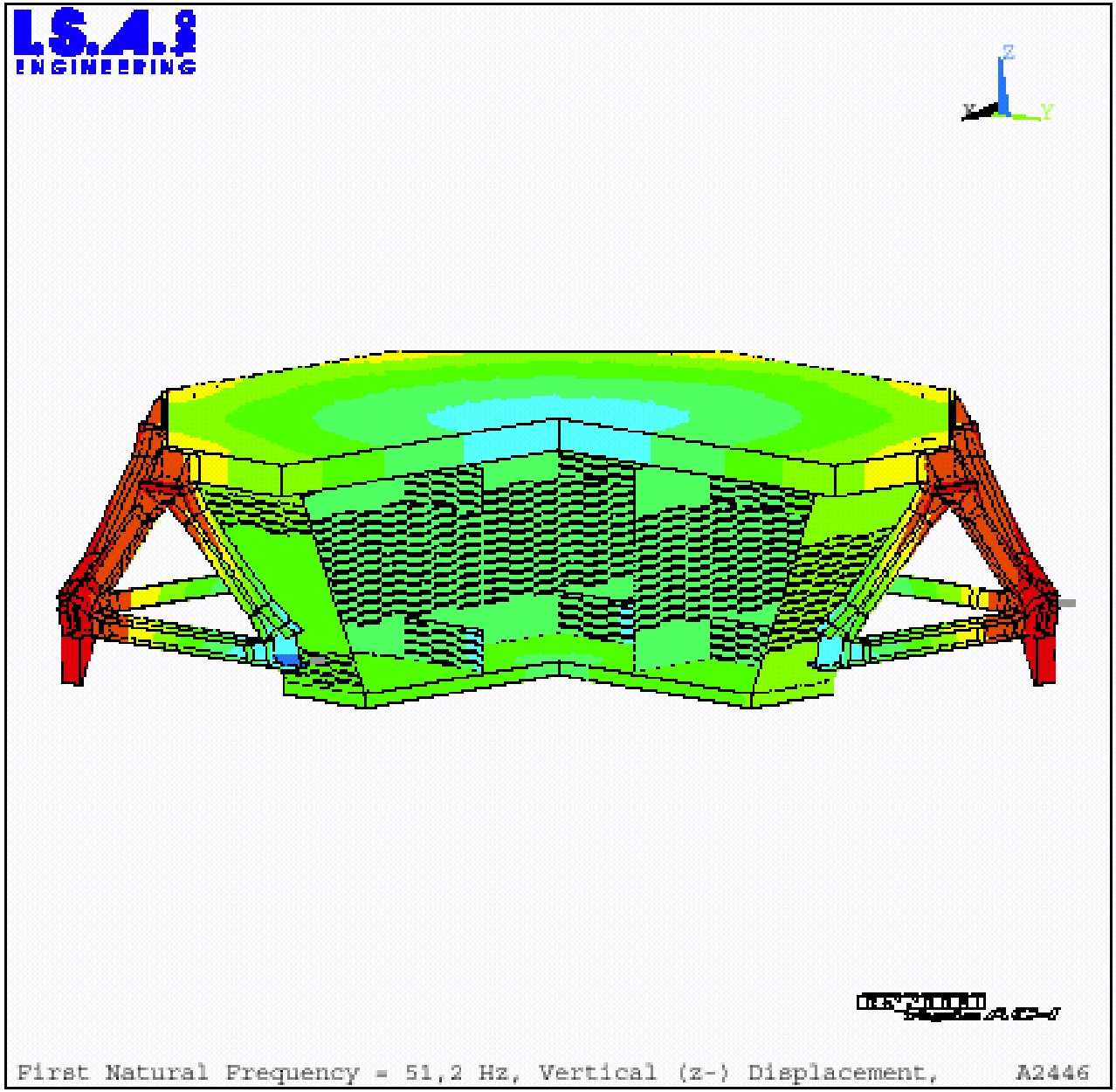
Readout boards- X - side

Heat source ~130mW

Karpinski 22.02.00

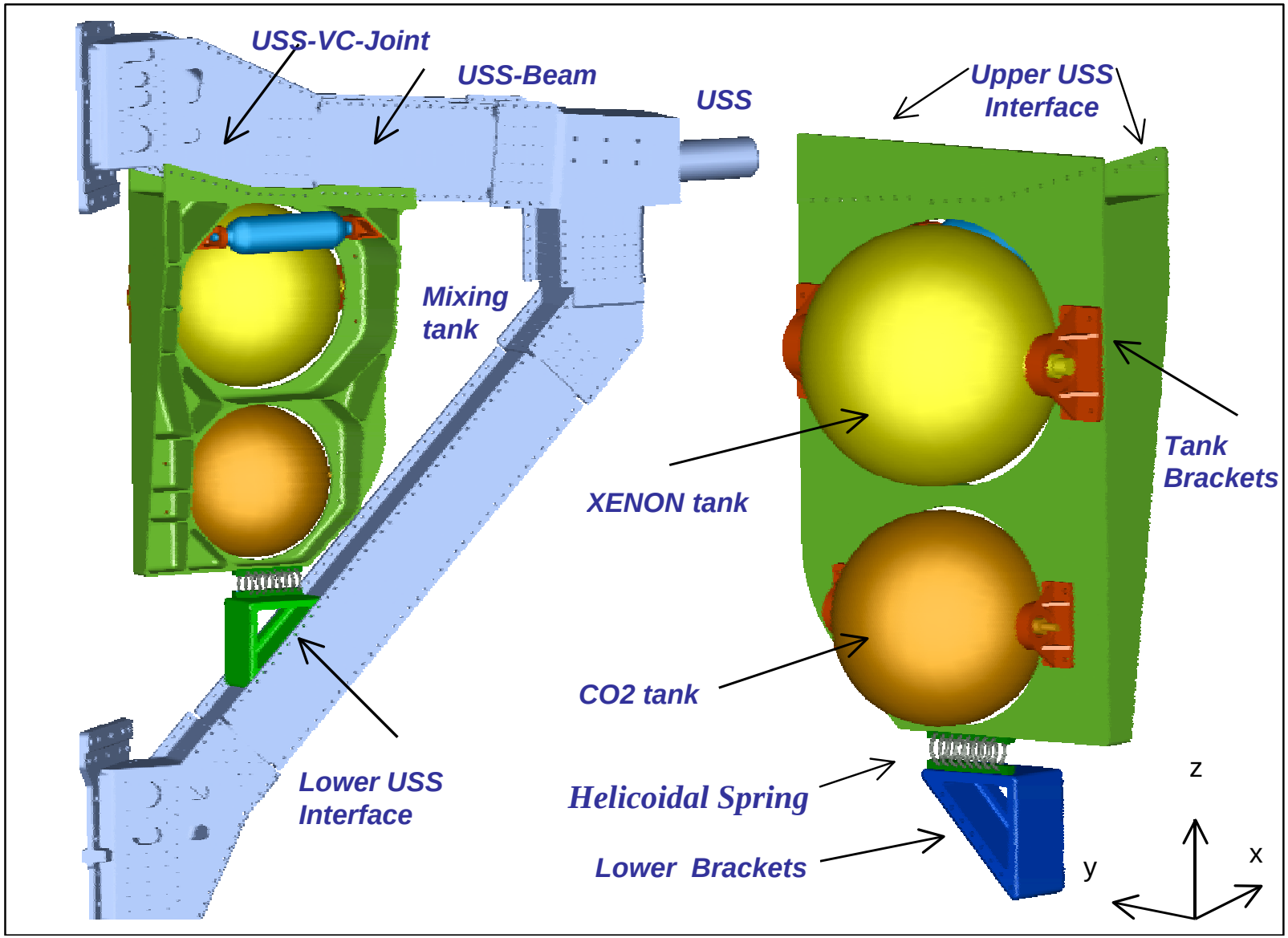
Drawing No. AMS_ROXP_10

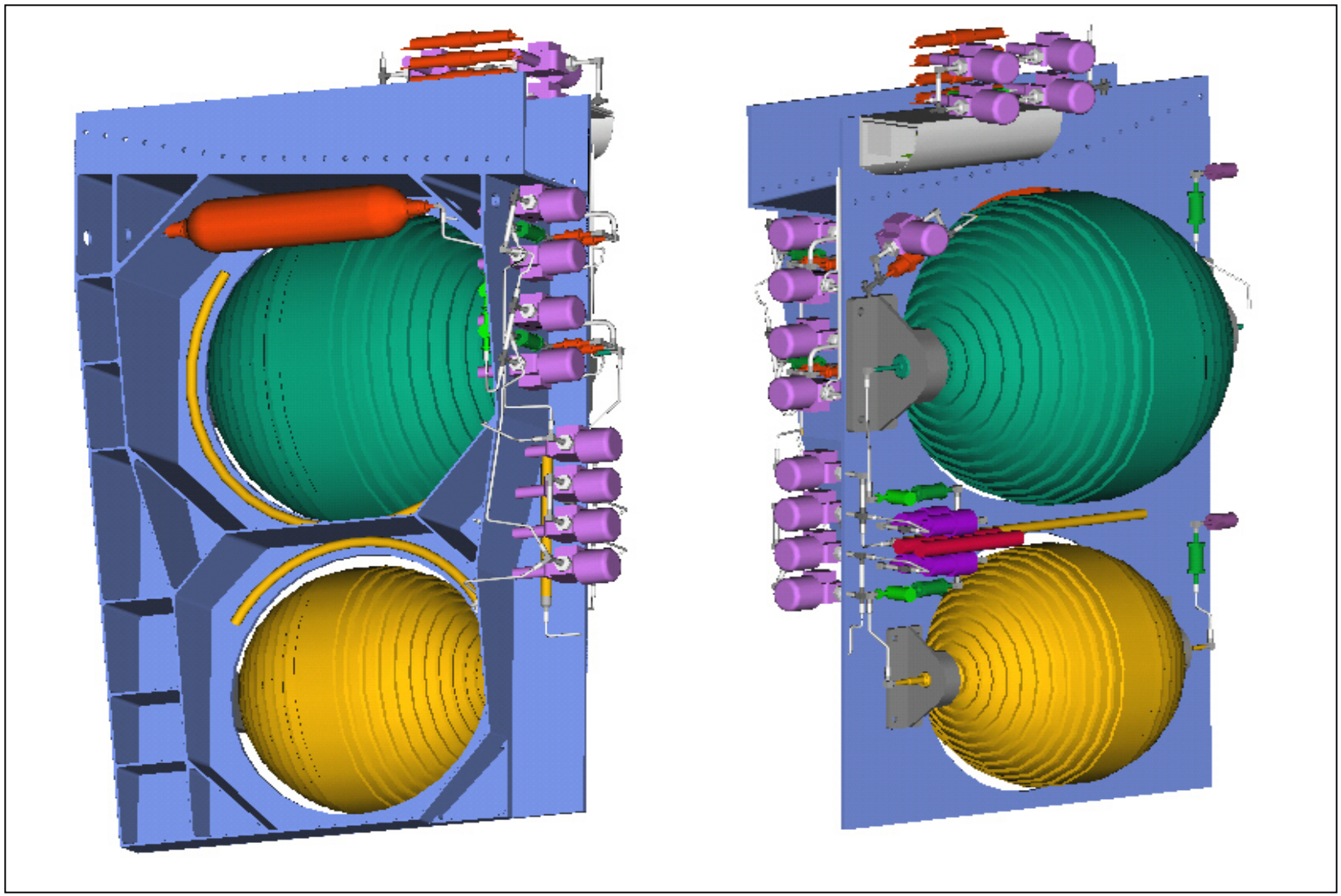
TRD Y-Z Cross Section



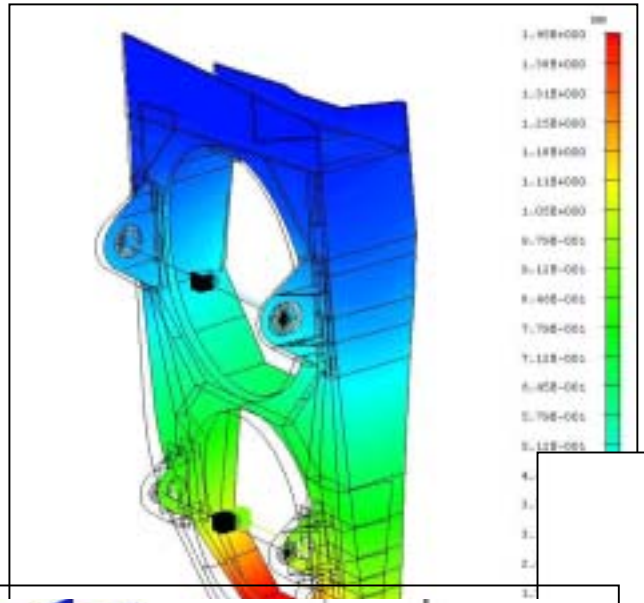
TRD Structural Analysis Finite Element Model

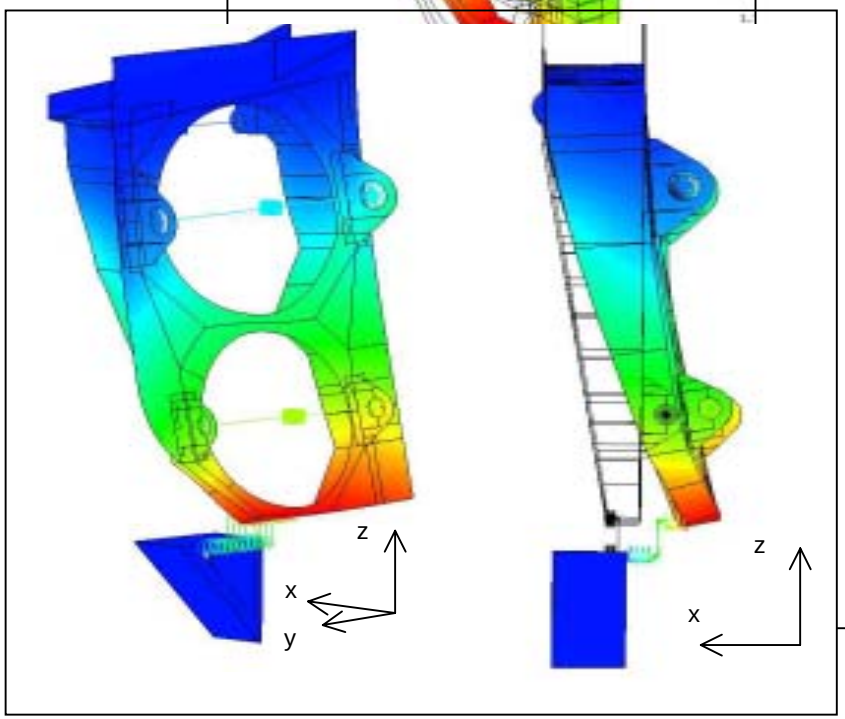
TRD Gas Supply System

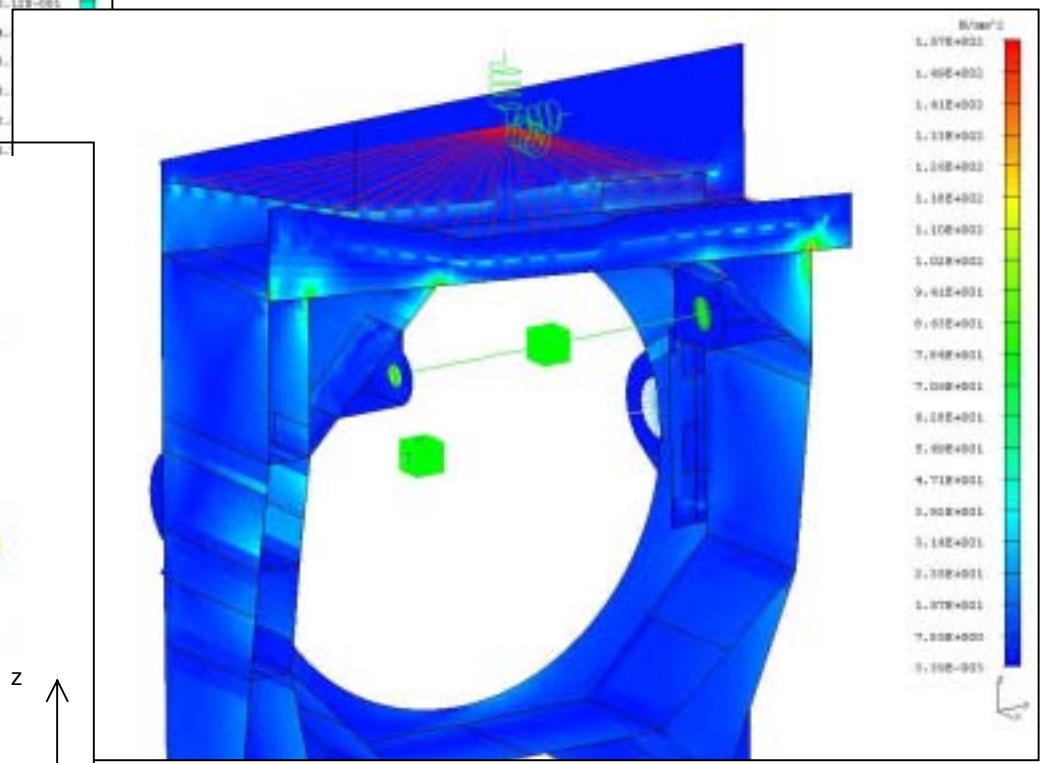


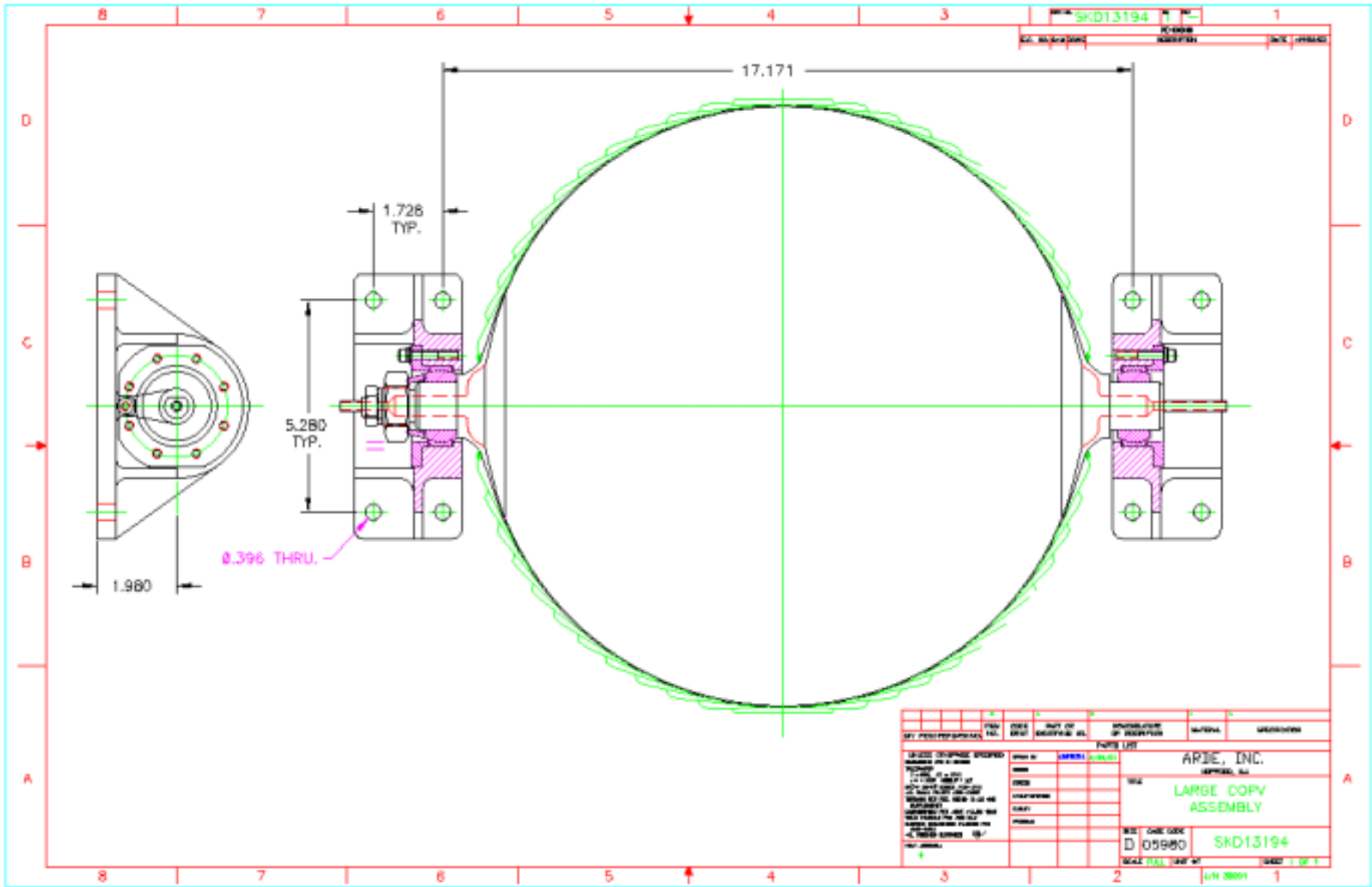


TRD Gas Supply Box Structural Analysis





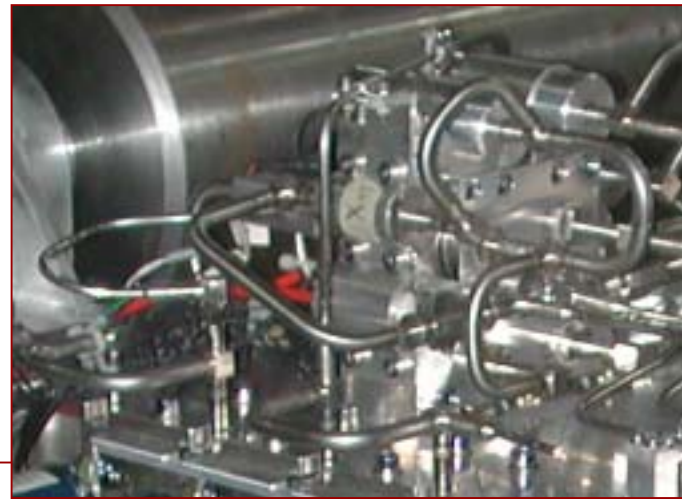



SKD13194
17.171
1.728
TYP.
5.280
TYP.
1.980
Ø.396 THRU.
ARDE, INC.
LARGE COPV
ASSEMBLY
D 05980
SKD13194

"Box S" Assembly & Test

CO_2 tank
Tank weight 1,85 kg filled with 4.5kg Isopropyl alcohol

MV197 valves assembly
weight 2,5kg



Two Marotta valves assemblies
weight 0,75 kg each

Four Marotta valves assembly
weight 2.95 kg

TRD (Cont.)

- Primary Materials
  - Aluminum 7075 – M-Structure
  - Polypropylene fibers for Radiators
  - M40J & T300 Carbon Fiber / Epoxy Face Plates with Aluminum Honeycomb Core for External Octagonal structure
  - See Materials Presentation for complete list

TRD (Cont.)

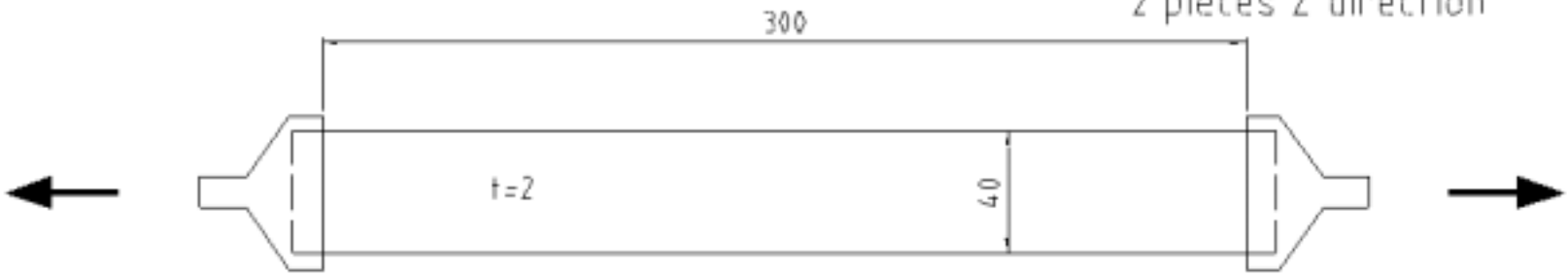
- Certification Testing
  - Component vibration testing of sample TRD tubes 1238 mm (49 in) long has been performed
  - 1 Tower of TRD including full unsupported tube length between bulkheads and outside wall was vibration & thermal vacuum tested
  - Modal test on M-structure if analysis shows entire TRD modes <50 Hz
  - Octagon honeycomb (carbon fiber) panel tests have been performed
    - Side panel skin tests - Completed
    - Side panel tests - Completed
    - Side panel corner junction tests - Completed
    - Test of full-size panel with slits - To be done
  - Straw modules
    - Random vibration - Complete
    - Thermo-vacuum test - Complete
    - Electro-magnetic interference test - Complete
    - Carbon fiber composite (CFC) stiffener tension test - Complete

TRD, Cont.

- Certification Testing, Cont.
  - Gas Supply System
    - Vibration & Sine Sweep on STA
    - Vibration & Sine Sweep on STA with new valves & mass sims
    - Vibration & Sine Sweep on flight tanks by similarity
    - Proof Pressure Testing on Tanks – Complete
    - Leak test on system
    - Thermal Vacuum test on system

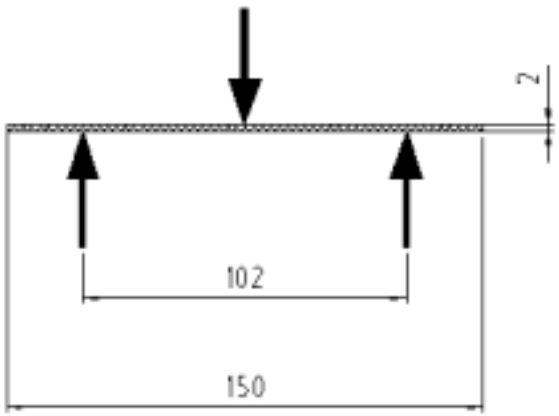
Side Panel Skin Tension Test.

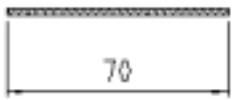
2 pieces X (Y) direction
2 pieces Z direction



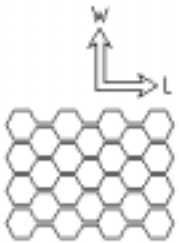
Side Panel Skin Bending Test.

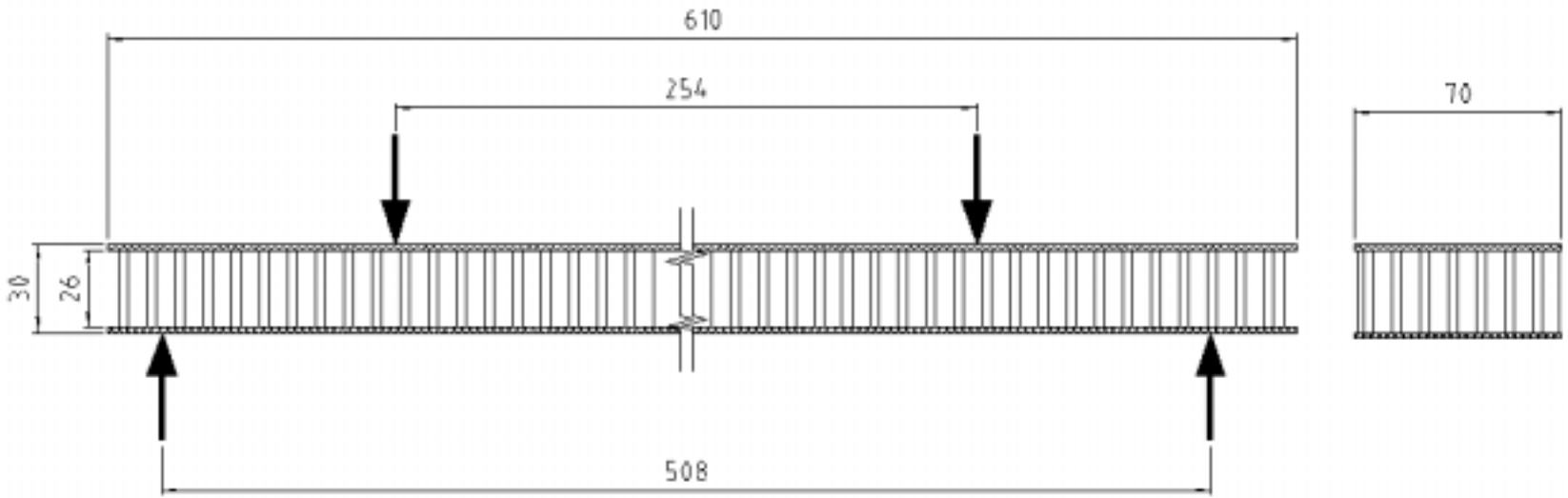
2 pieces X (Y) direction
2 pieces Z direction





Side Panel Bending Test



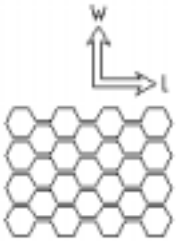


Upper skin marked

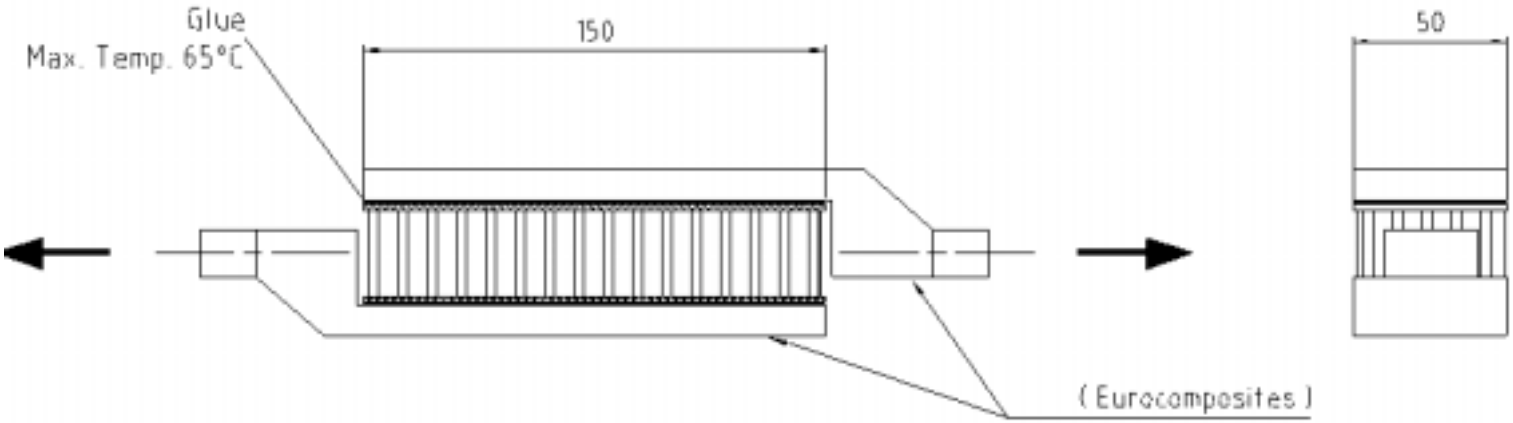
1 piece L direction

1 piece W direction

AMS II			TRD Octagon Test
		RWTH Physics AC-I	sma2001a



Side Panel Shear Test.

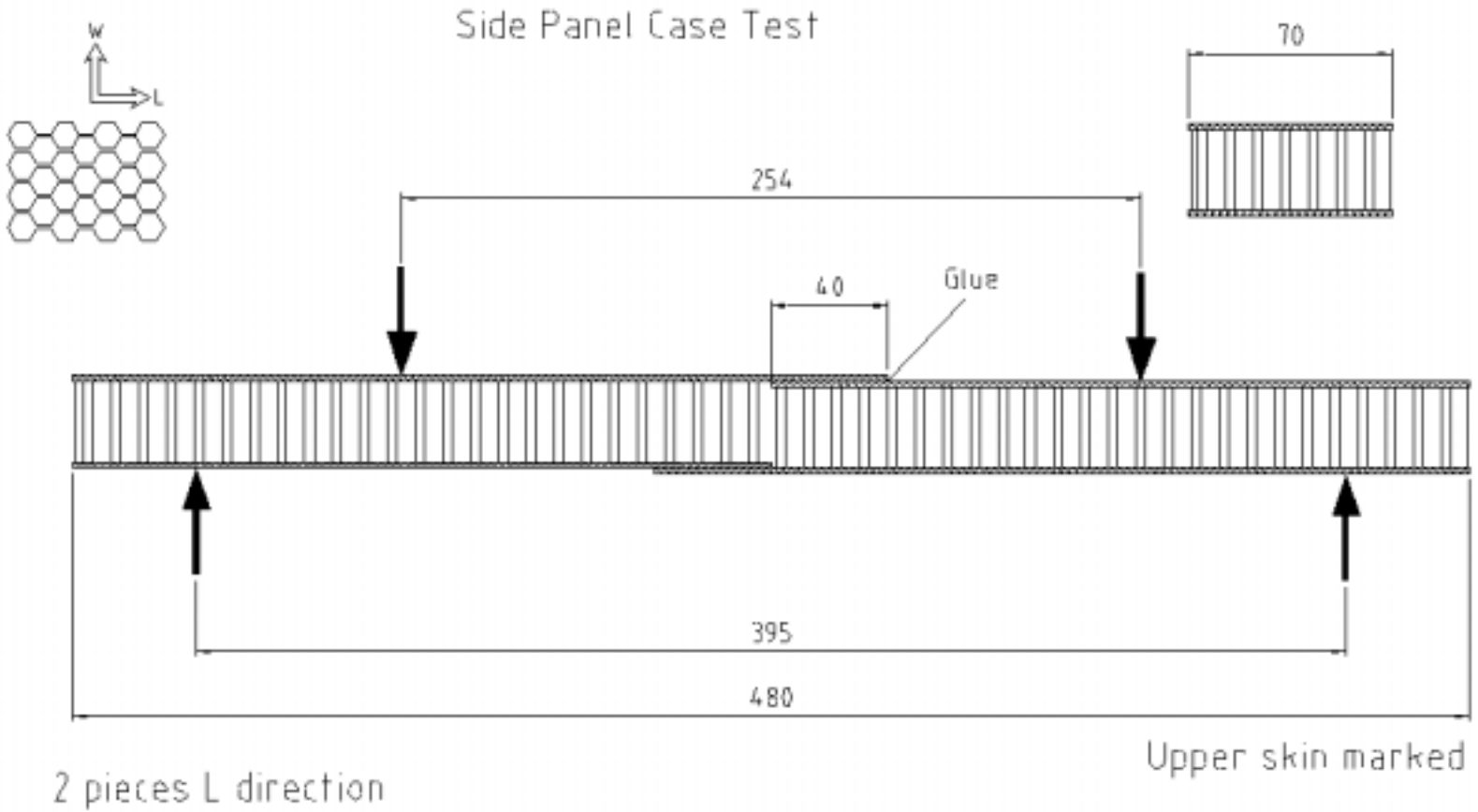


Upper skin marked

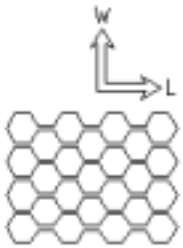
2 pieces L direction

2 pieces W direction

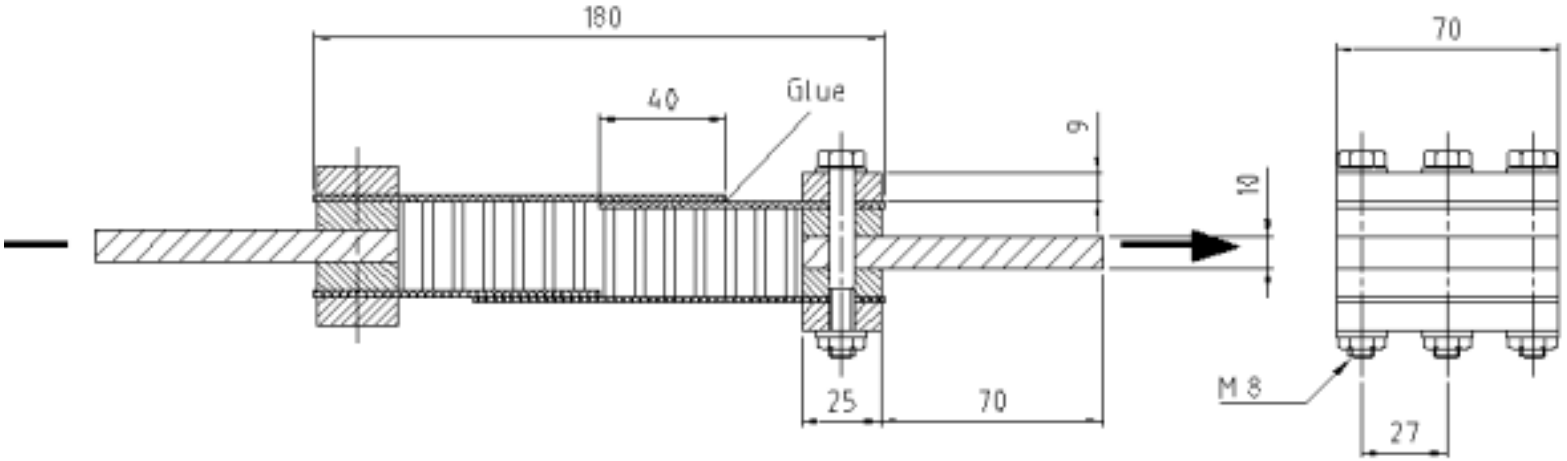
AMS II		DIN ISO 2768	1:2
			TRD Octagon Test
	RWTH Physics AC-I		ams2002a



AMS II		Zul. Abw. DIN ISO 2768 mittel		Maßstab 1:2	Gewicht
				Benennung	
				TRD Octagon Test	
		RWTH Physics AC-I		Zeichnungsnummer ams2003_1a	Blatt
Name	Änderung	Datum	Name	Ers. f.	Ers. d.



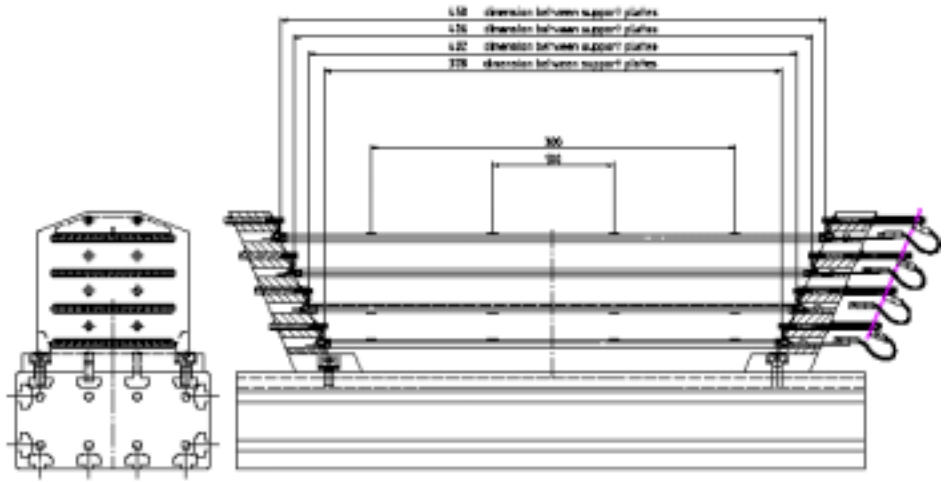
Side Panel Corner Junction Test.



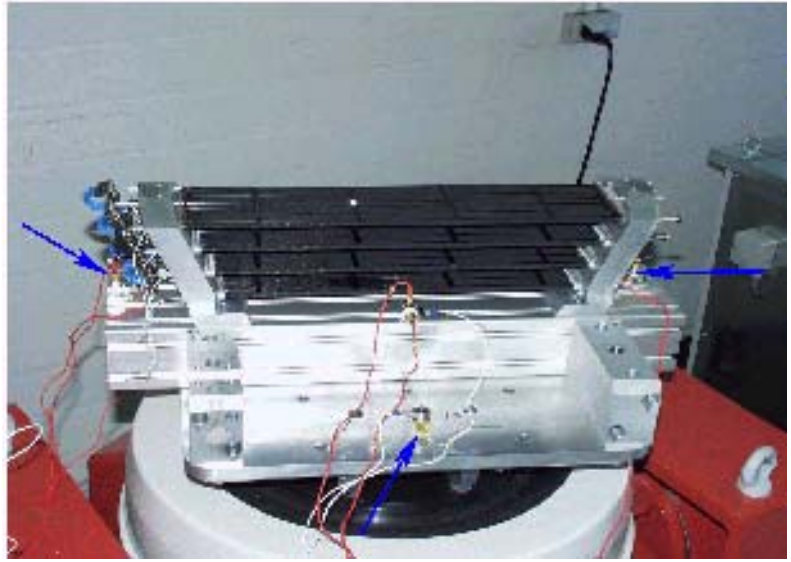
2 pieces L direction

Upper skin marked

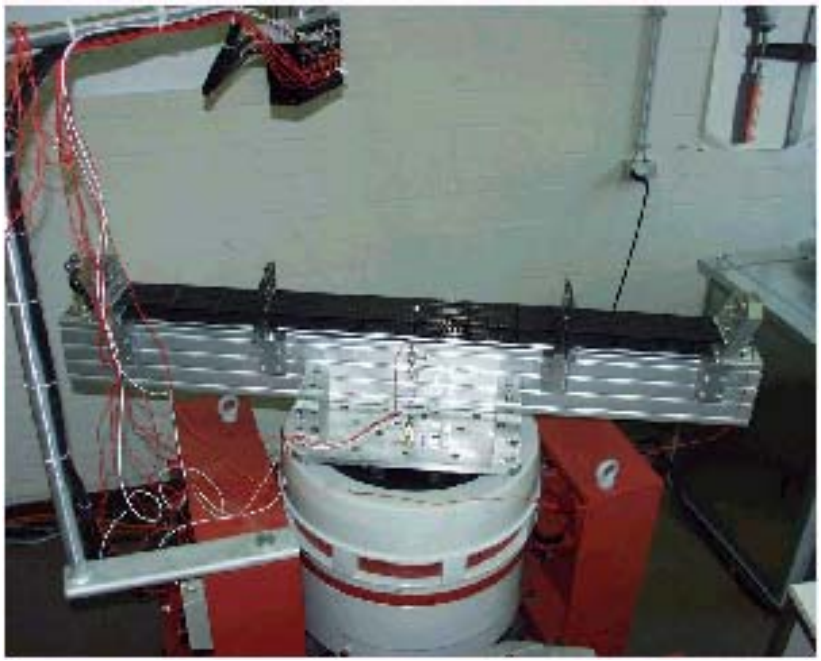
AMS II				1:2	
				TRD Octagon Test	
			RWTH Physics AC-I	ams2003_2a	



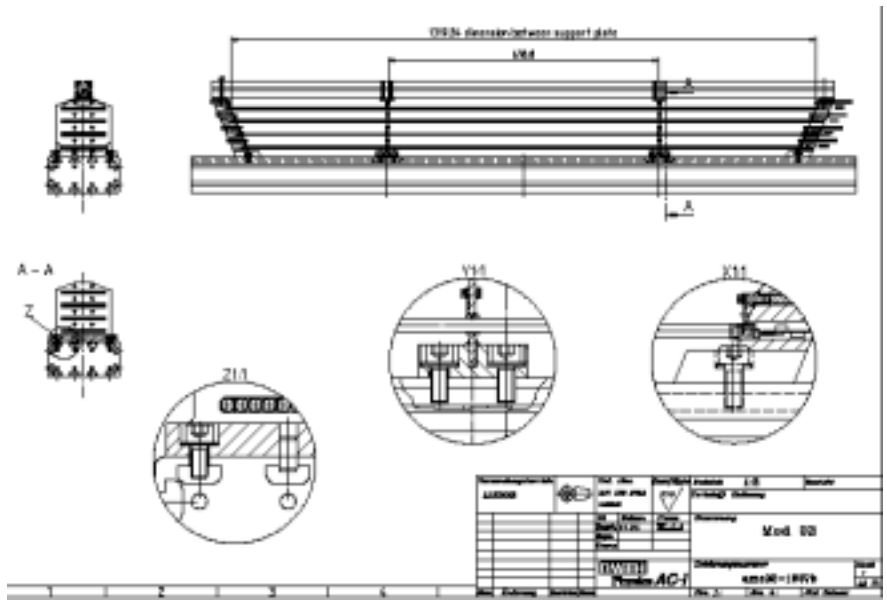
18” Module Vibration Test Setup



18” Module Vib Test No Radiator Material

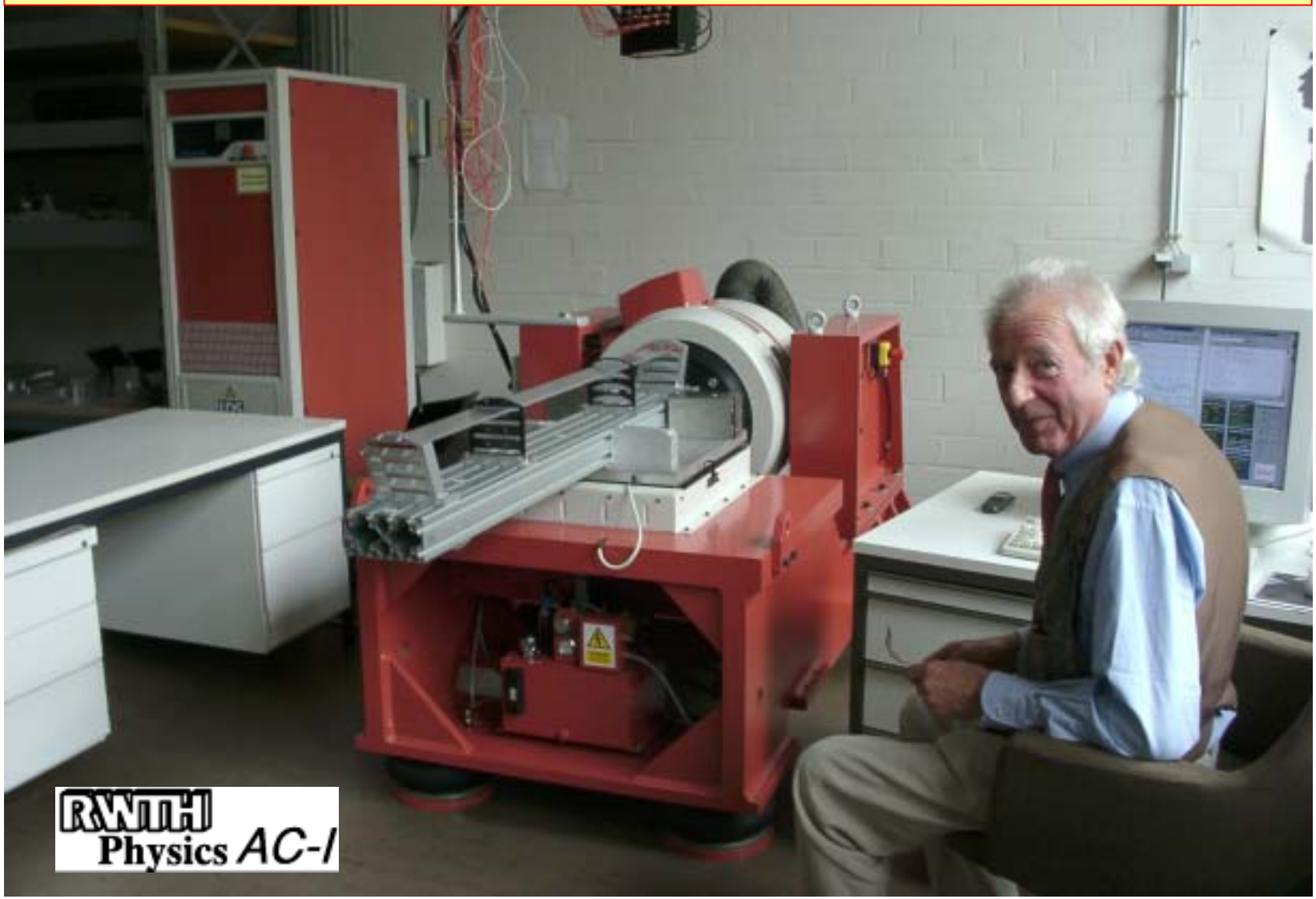


49” Module Vib Test No Radiator Material



49” Module Vibration Test Setup

TRD Module Vibration Test



Time of Flight (TOF)

Time of Flight (TOF)

- Notes:
  - TOF systems are very similar to those flown on STS-91
  - TOF systems are being developed by the same groups that developed the STS-91 TOFs
- Size, Location, and Description
  - Two ~1.5 m (59 in.) diameter circular honeycomb structures
  - Support scintillator detectors and photomultipliers
  - Located above and below the outer most planes of the Tracker

TOF, Cont.

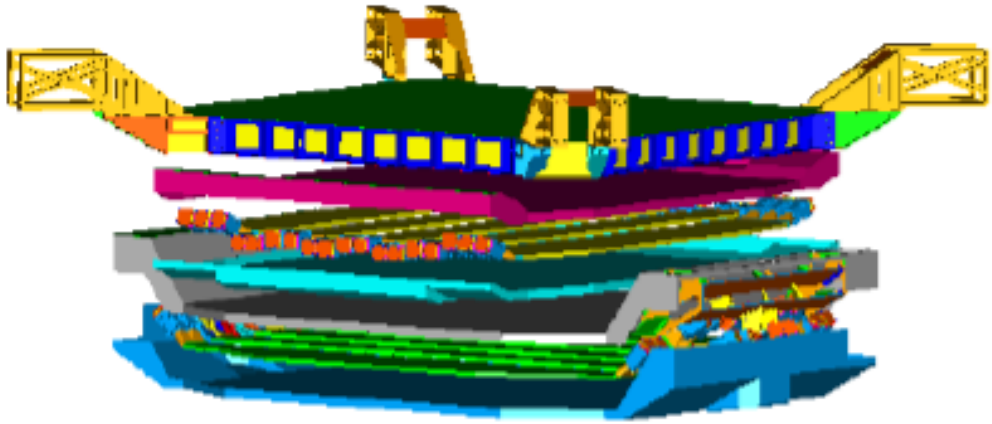
- Structural Verification
  - Upper and Lower TOF Verification by analysis with Fs_{ult}=2.0 and Fs_{yld}=1.25
    - Liftoff – Applied about CG of entire payload
      - Nx= ±5.7g, Ny= ±1.6g, Nz= ±5.9g
      - Rx=±10 rad/sec^2, Ry= ±25 rad/sec^2, Rz= ±18 rad/sec^2
    - Landing – Applied about CG of entire payload
      - Nx= ±4.5g, Ny= ±2.0g, Nz= ±6.5g
      - Rx=±20 rad/sec^2, Ry= ±35 rad/sec^2, Rz= ±15 rad/sec^2

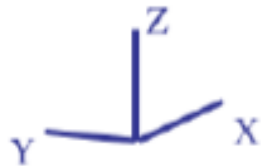
TOF, Cont.

- Components Minimum Margin of Safety:
  - Upper TOF = 0.61
  - Lower TOF = .16 Ring Bracket
- Components First Dynamic Frequency:
  - Upper TOF = 49.2 Hz
  - Lower TOF = 53 Hz

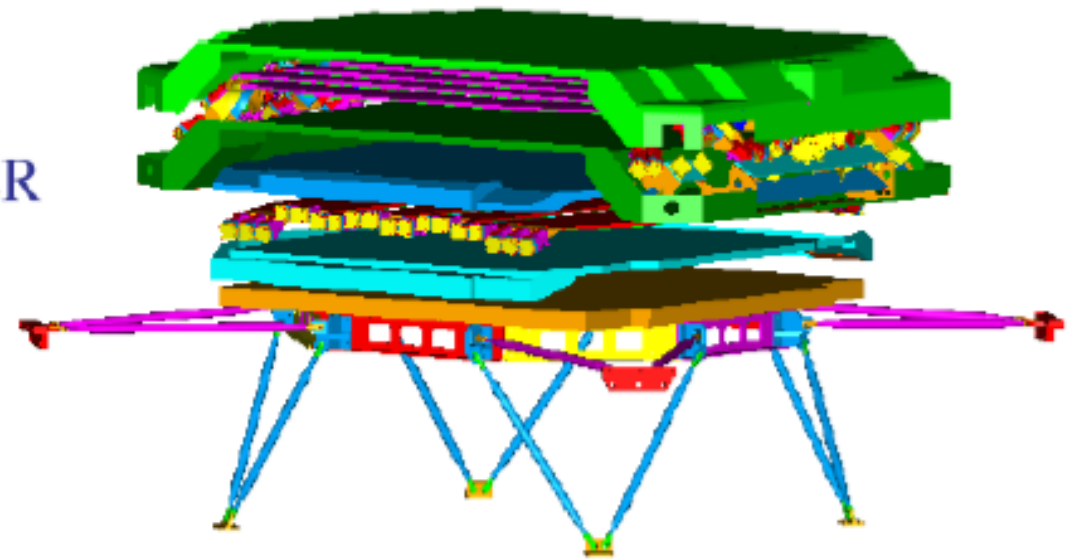
AMS II ToF

UPPER

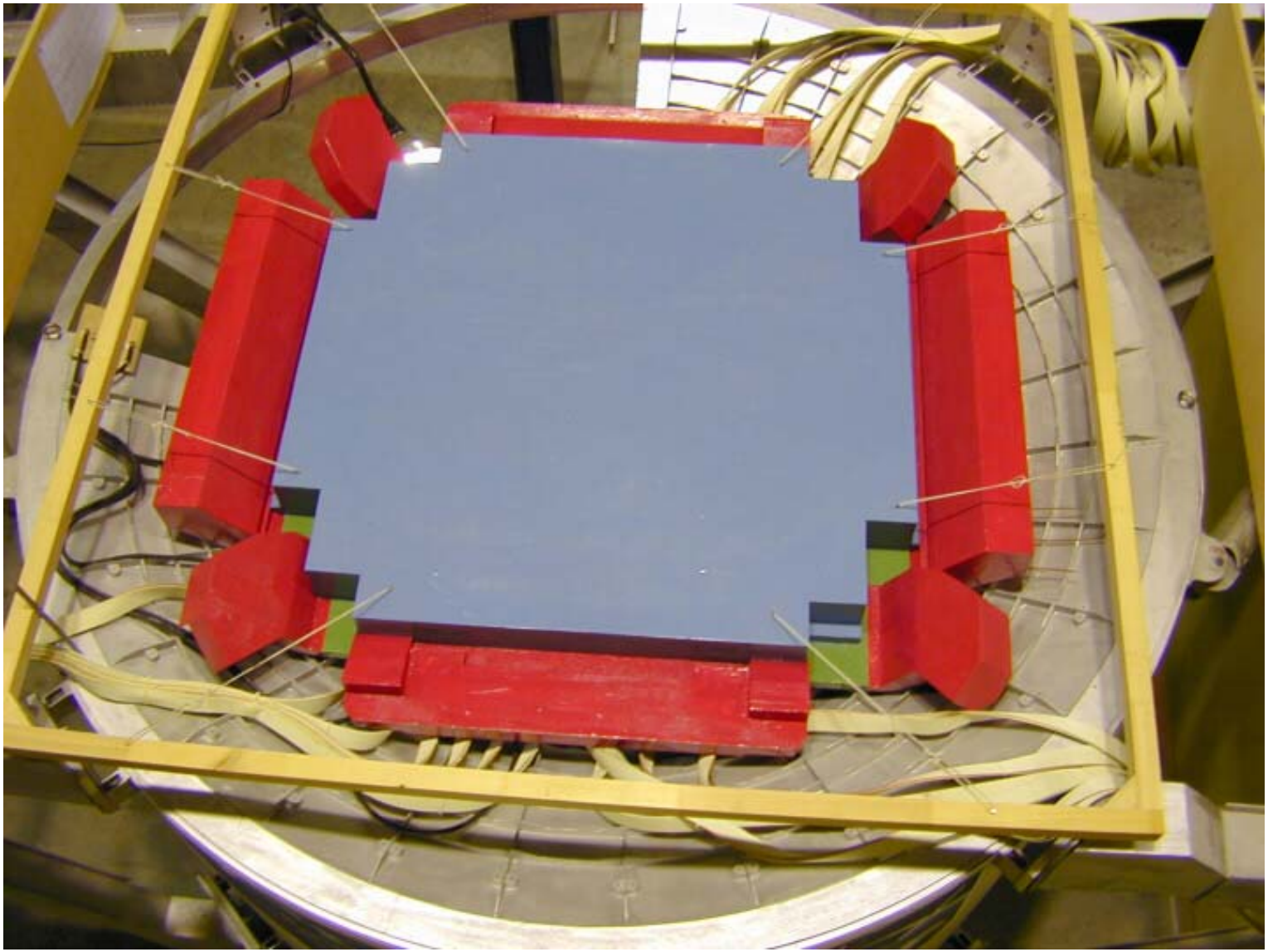




LOWER



Carlo Gavazzi Space SpA

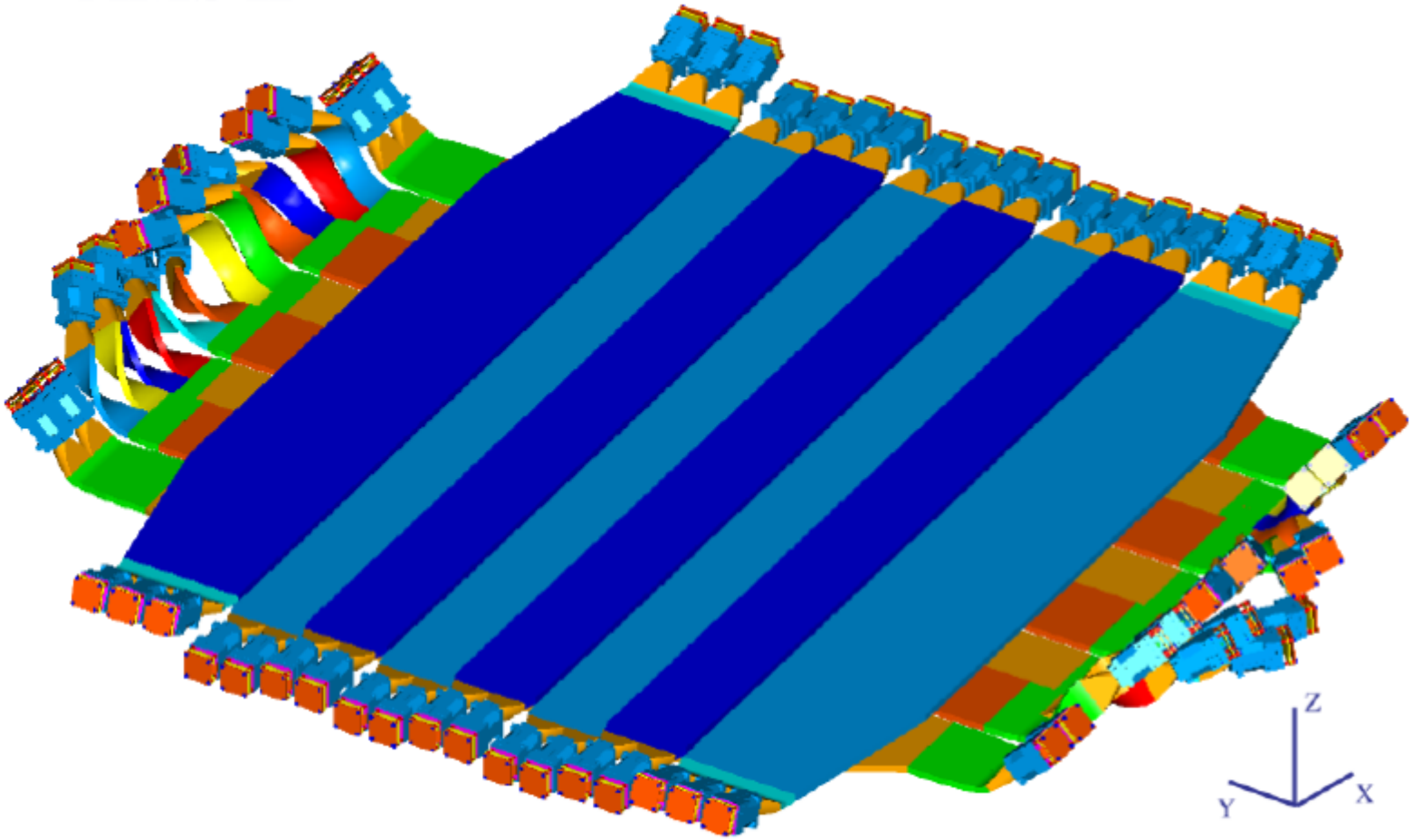


TOF Mockup with Tracker and TOF Cabling

Carlo Gavazzi Space SpA

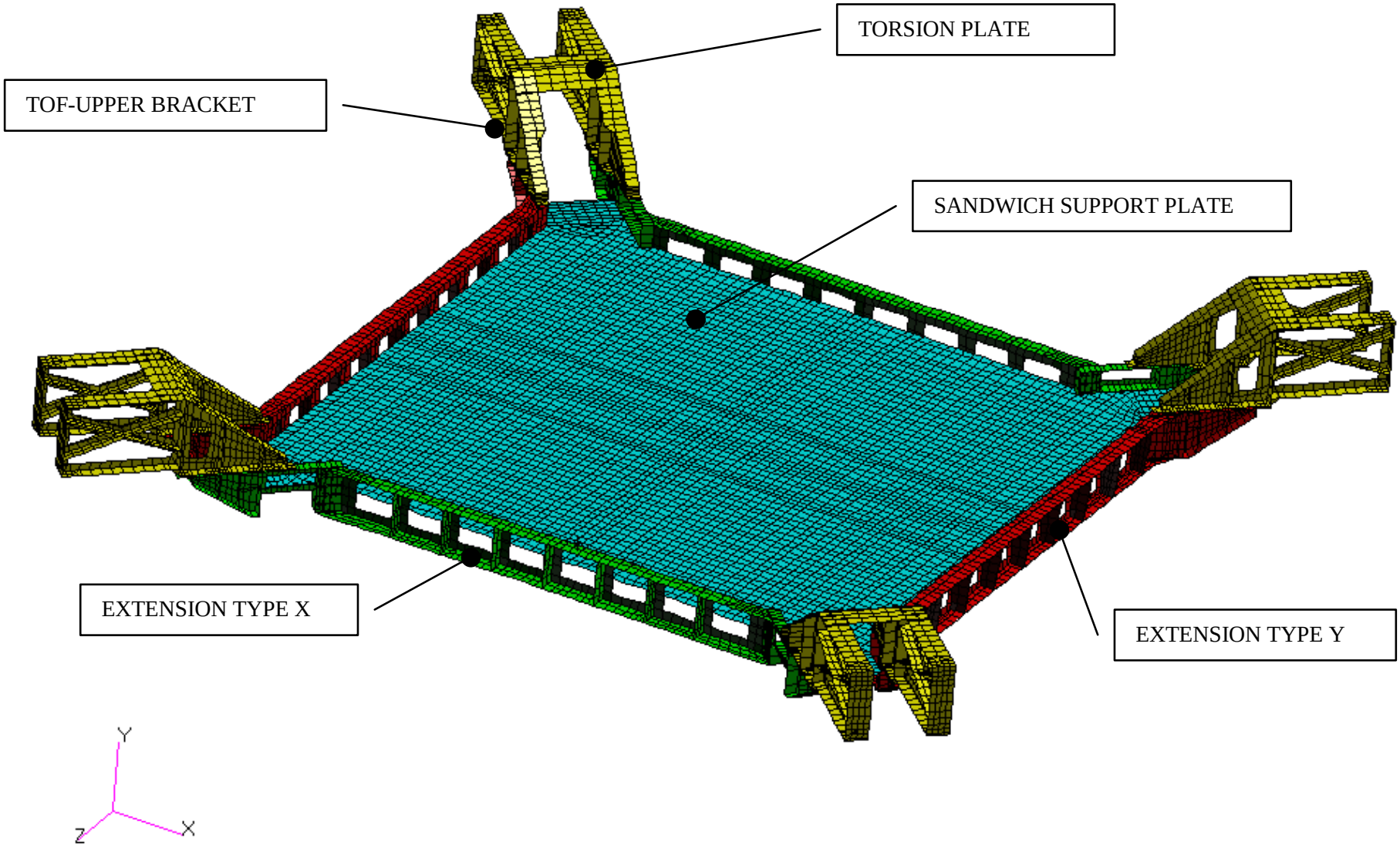
AMS II

PLANE X-Y UPPER TOF



Carlo Gavazzi Space SpA

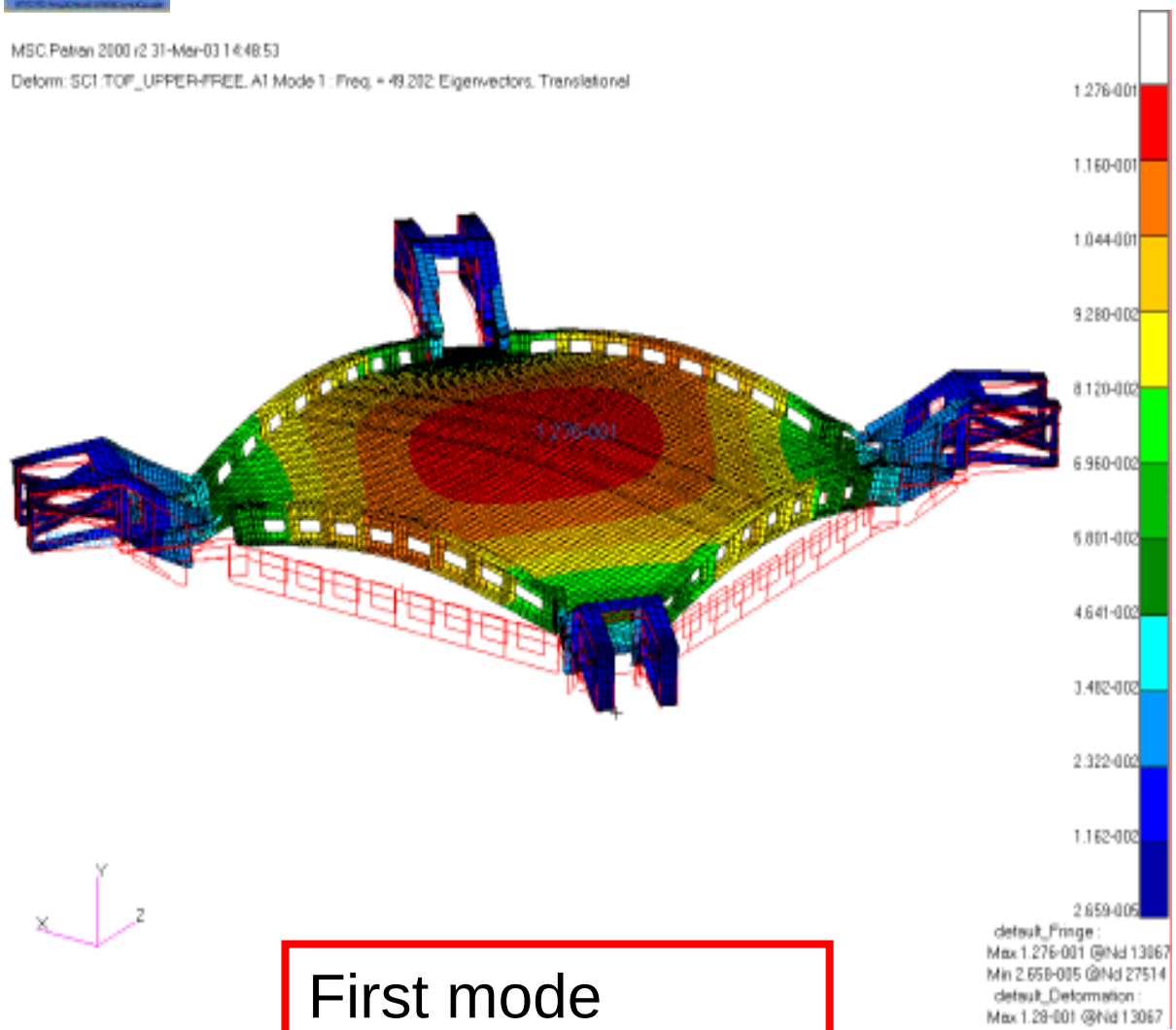
Upper TOF FEM



Carlo Gavazzi Space SpA

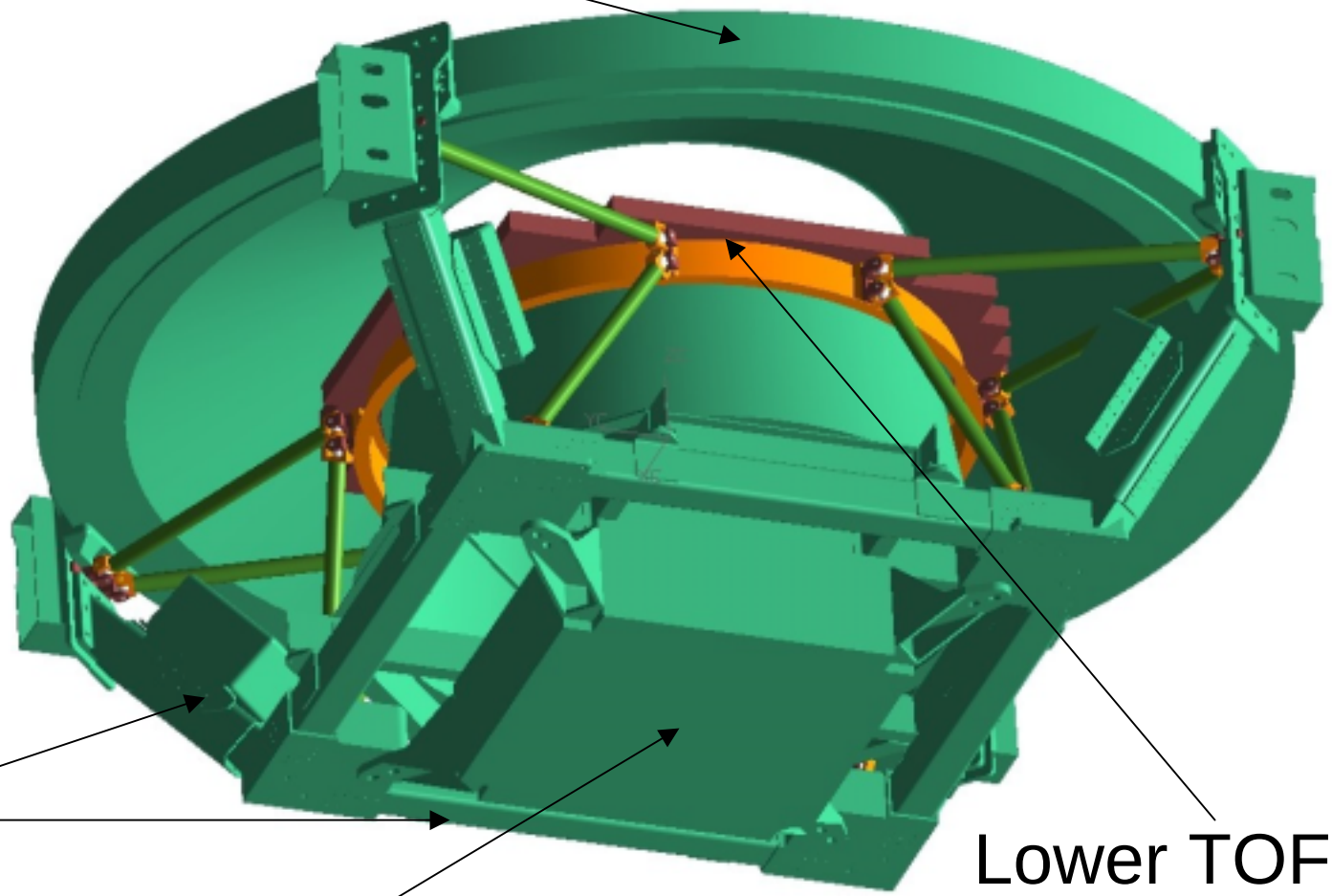
Eigenfrequencies

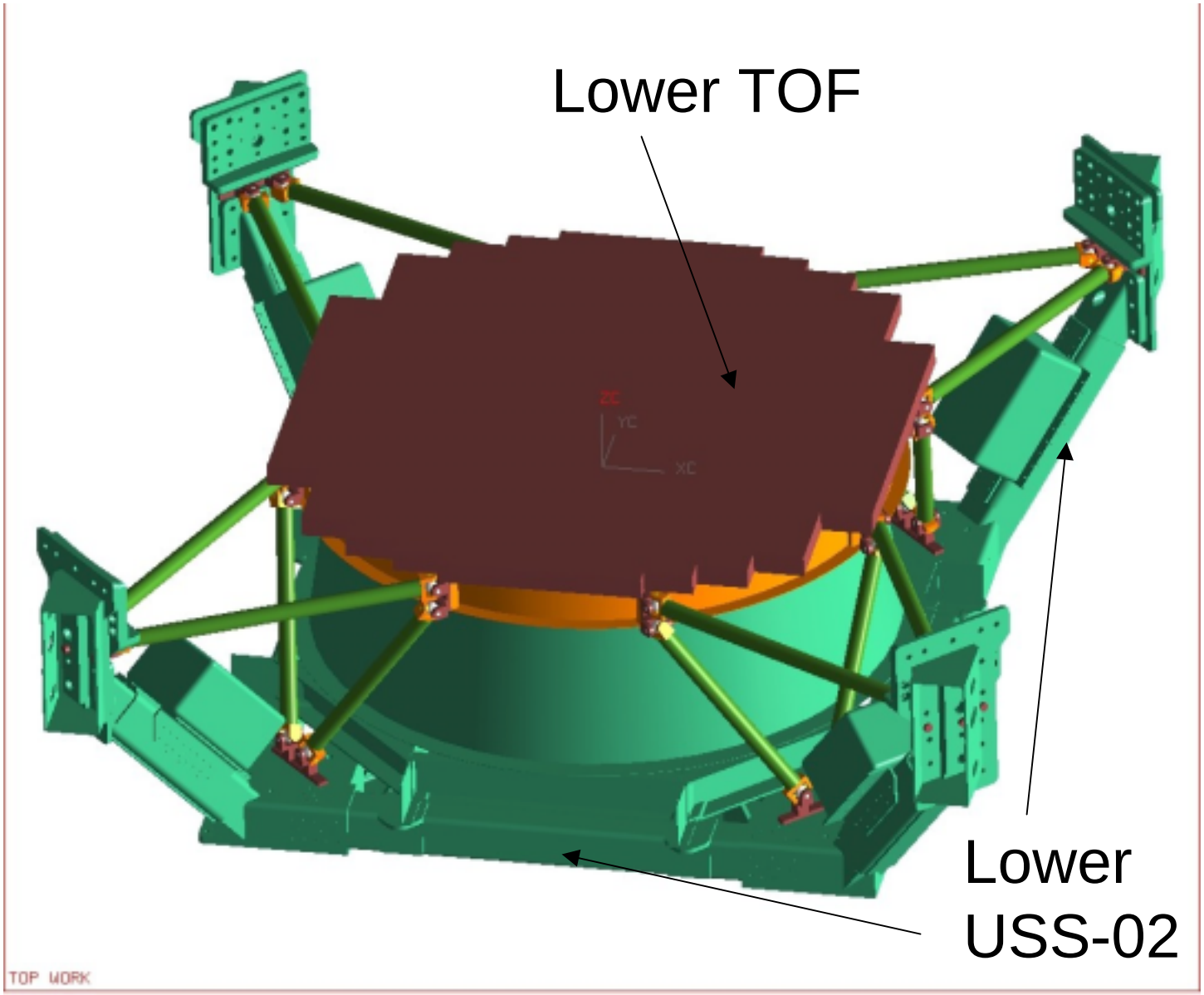
MODE	FREQUENCY [Hz]
1	**49.20**
2	53.85
3	63.64
4	64.65
5	92.56
6	130.26
7	130.92
8	142.25
9	173.12
10	189.16

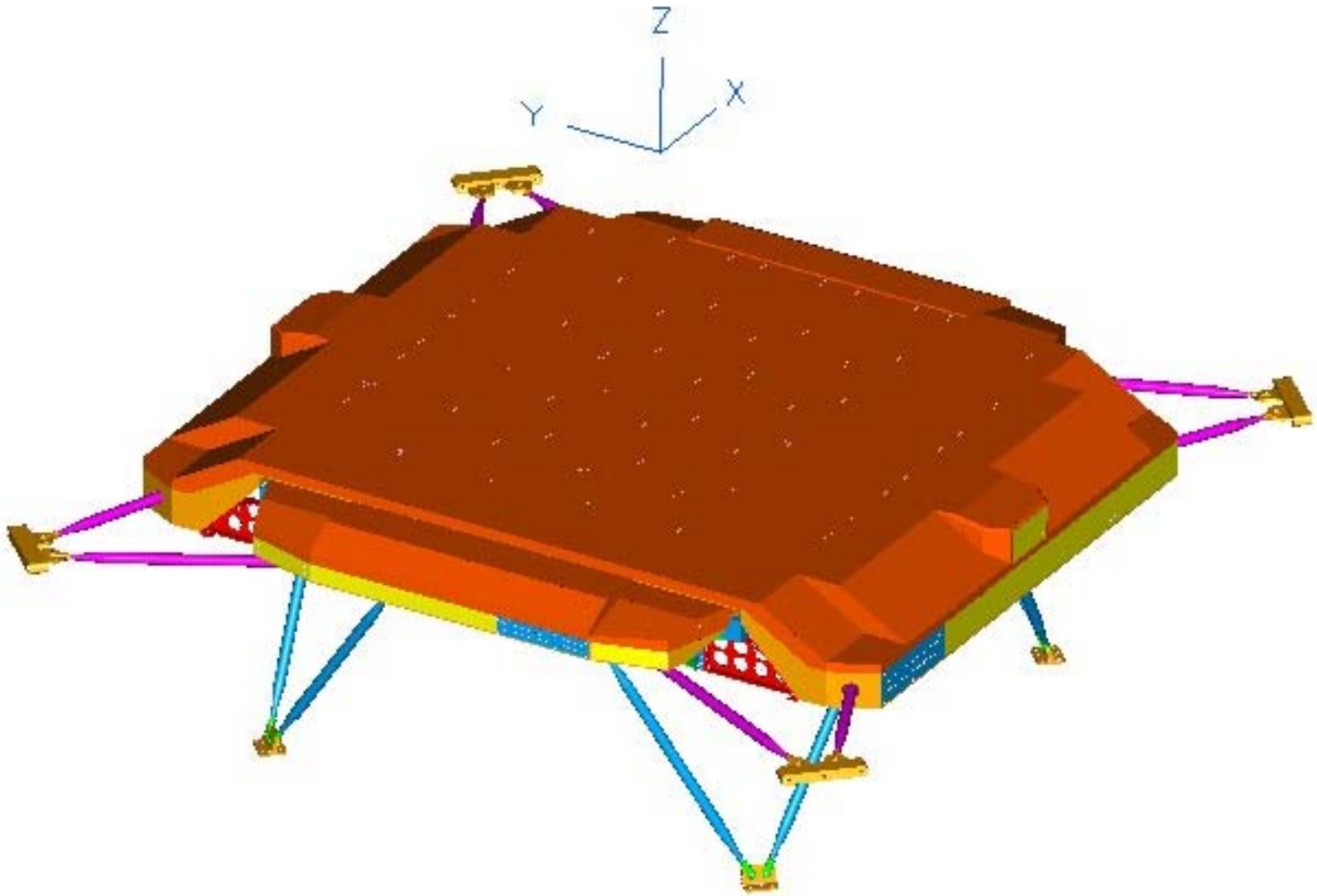


First mode (axial/drum) near 50 Hz limit.

Lower Support Ring of Magnet VC

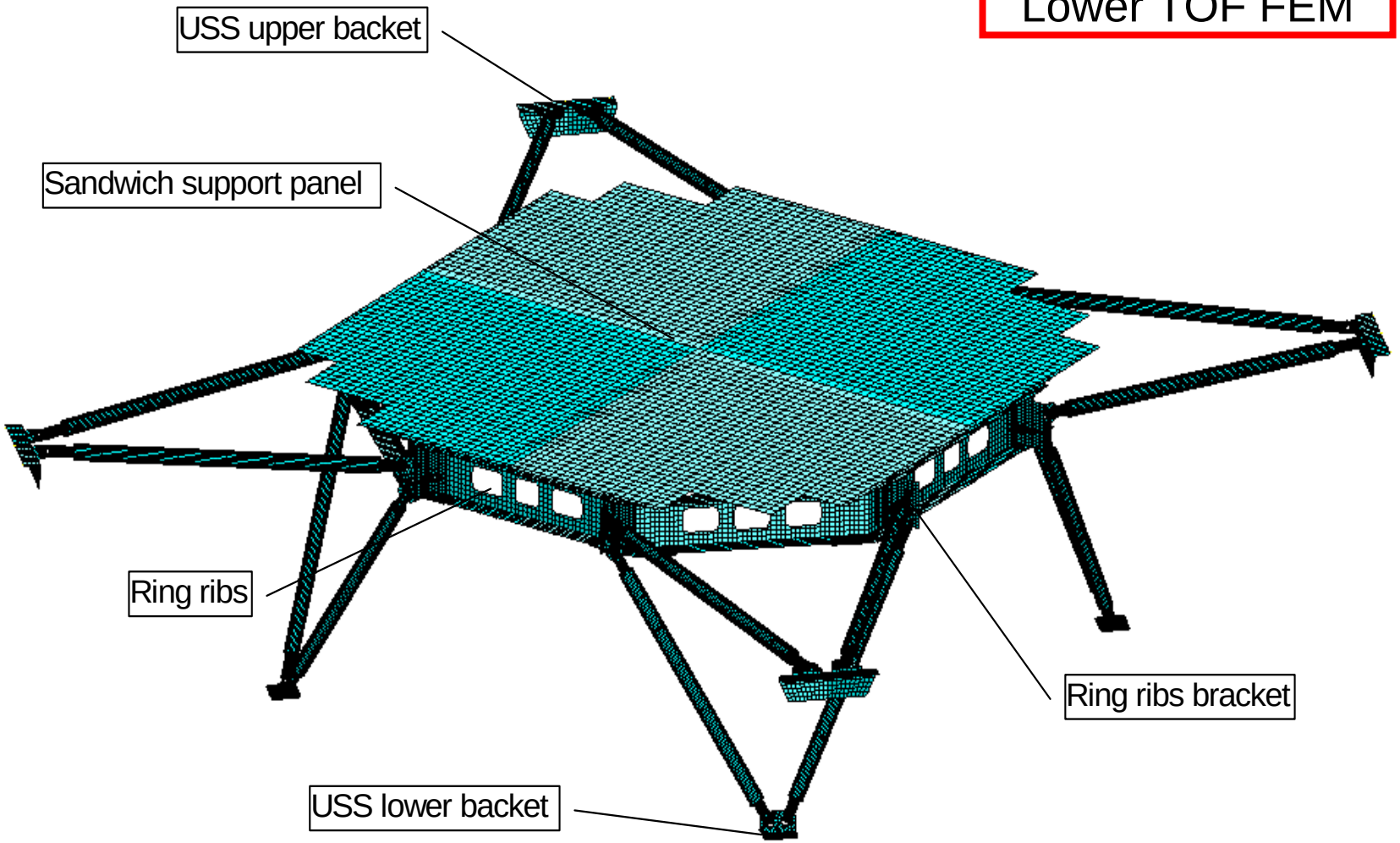



Lower TOF
Lower
USS-02
TOP WORK


Z
Y
X

Carlo Gavazzi Space SpA

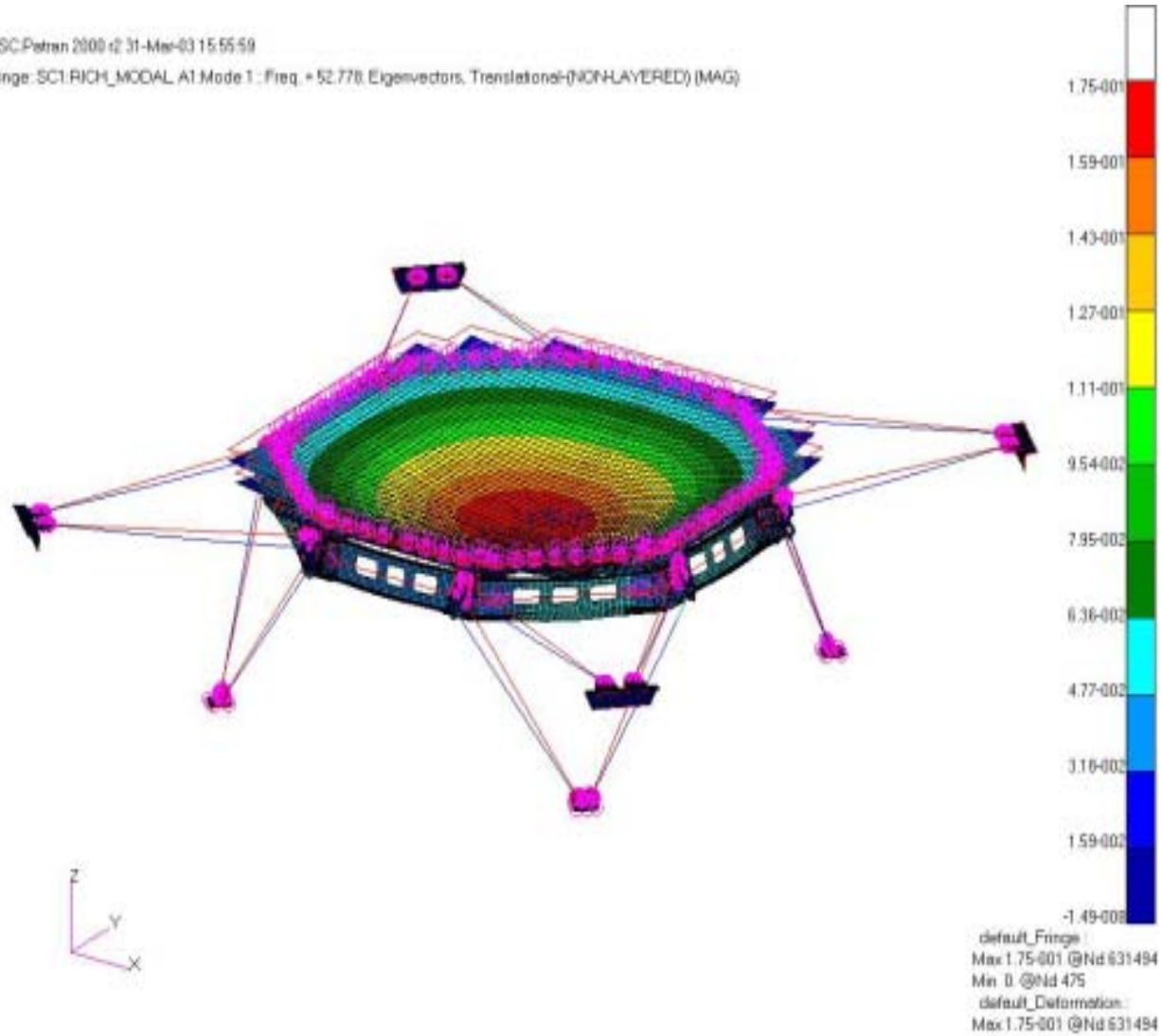
Lower TOF FEM

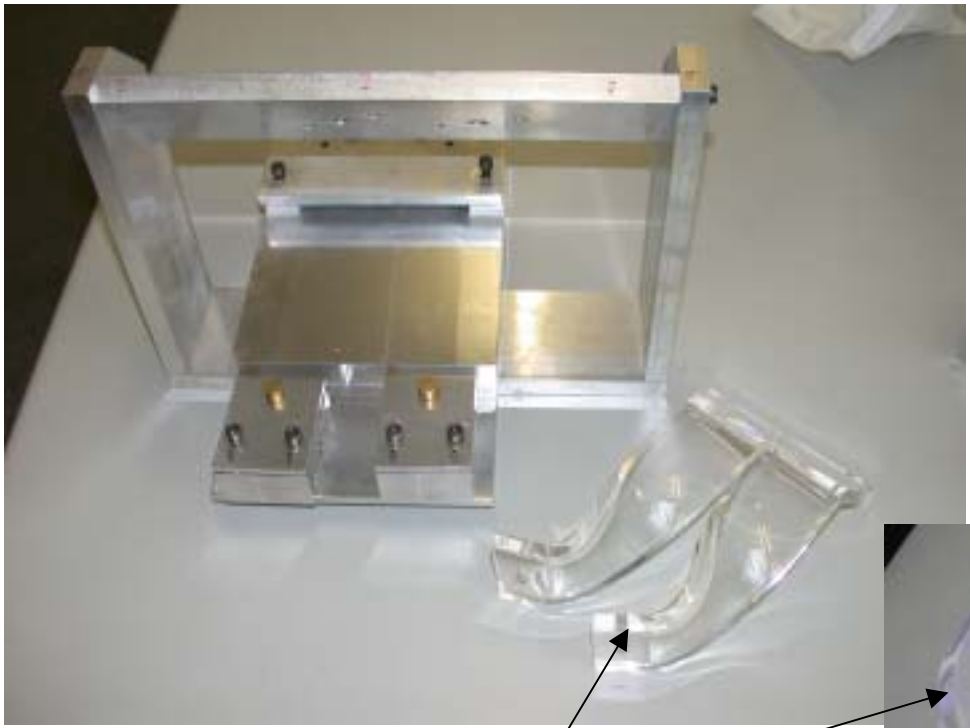


Carlo Gavazzi Space SpA

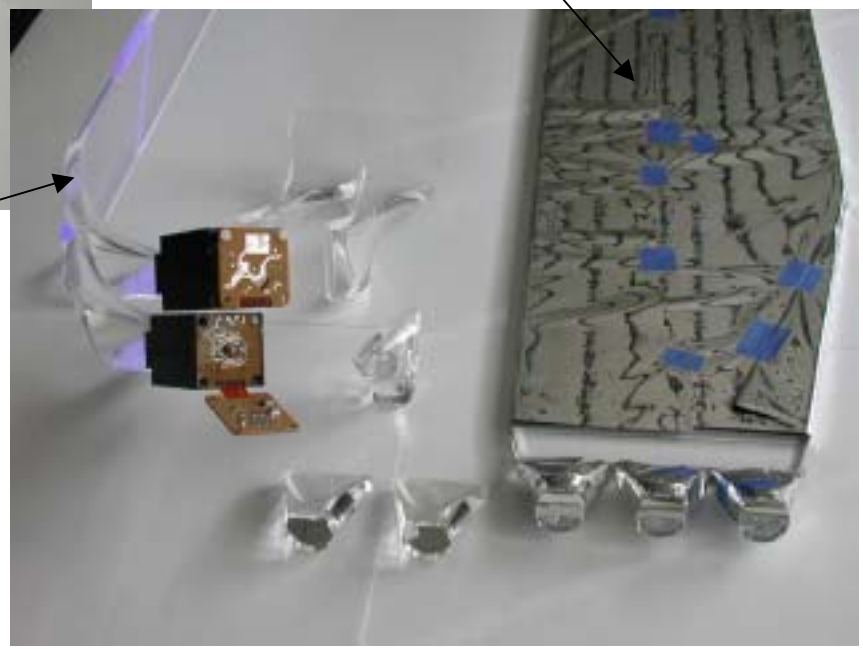
Eigenfrequencies

MODE	FREQUENCY [Hz]
1	**52.78**
2	64.01
3	64.50
4	69.60
5	70.69
6	74.54
7	78.02
8	82.85
9	123.00
10	123.47





Scintillator Panel



Light Guides

TOF, Cont.

- Weight Estimate
  - –Total Weight of Upper & Lower TOF = 238 Kg (525 lbs)
- Primary Materials
  - Polyvinyl Toluene material for Scintillators
  - Plexiglass (Acrylic) for Light Guides
  - Vicotex 1454 Carbon / Epoxy Composite for structural supports for Lower TOF.
  - Al 7075 Faceplates with Aluminum Honeycomb core for Upper TOF (Same as STS-91)
  - See Materials Presentation for Complete List

TOF, Cont.

- Certification Testing
  - If the first mode on the Upper TOF stays below 50 Hz, a sine sweep or smart-hammer test will be performed to verify the first natural frequency
  - Random vibration test to MEFL or MWL will be done for mission success
  - Thermal Vacuum testing on PMT assembly samples with electronics will be performed
  - Component vibration tests - Complete

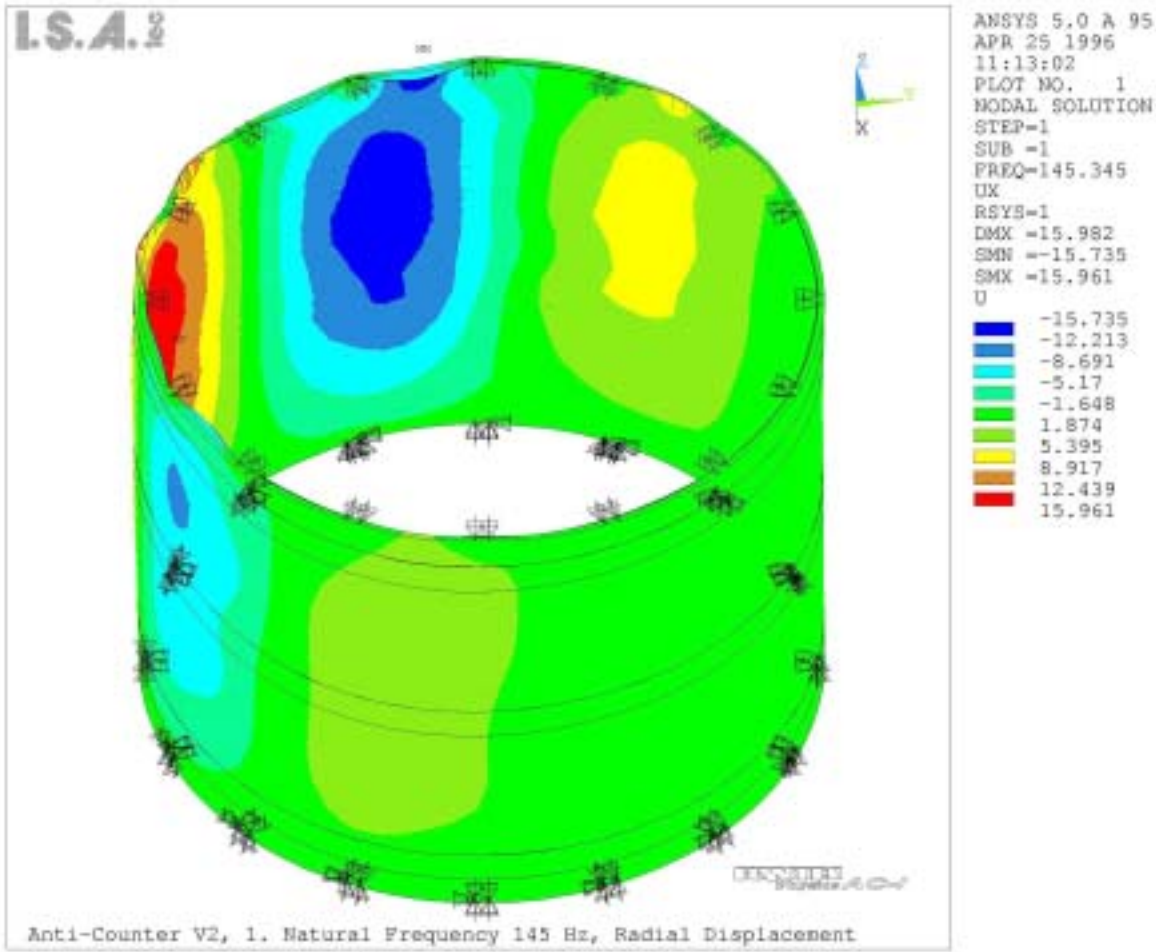
Anti-Coincidence Counter (ACC)

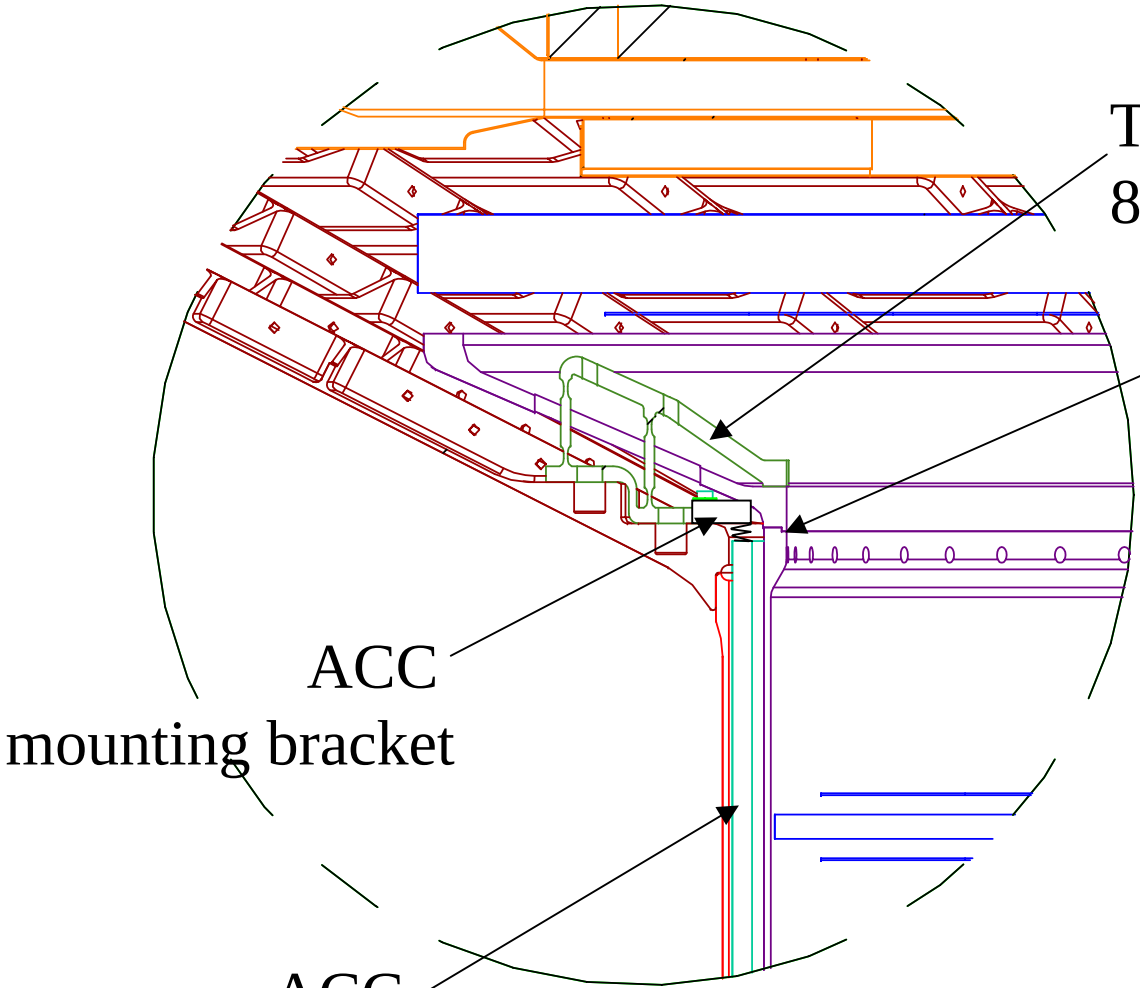
Anti-Coincident Counter (ACC)

- Notes:
  - Identical carbon fiber cylindrical structure to the ACC that was flown successfully on STS-91
- Size, Location, and Description
  - Mounts to inside diameter of VC Conical Flange
  - Made of single piece composite cylinder which fits tightly into magnet bore
- Weight Estimate
  - 53 kg (117 lbs)

ACC, Cont.

- Structural Verification
  - ACC Verification by analysis with Fs_{ult}=2.0 and Fs_{yld}=1.25
    - LF=17 g in worst direction with 4.25 g in remaining 2 orthogonal directions
- Components Minimum Margin of Safety:
  - Mounting Brackets/Bolts = 1.0
  - PMT Mounting Brackets = TBD (expected to be high)
- Components First Dynamic Frequency:
  - Overall System = 145 Hz

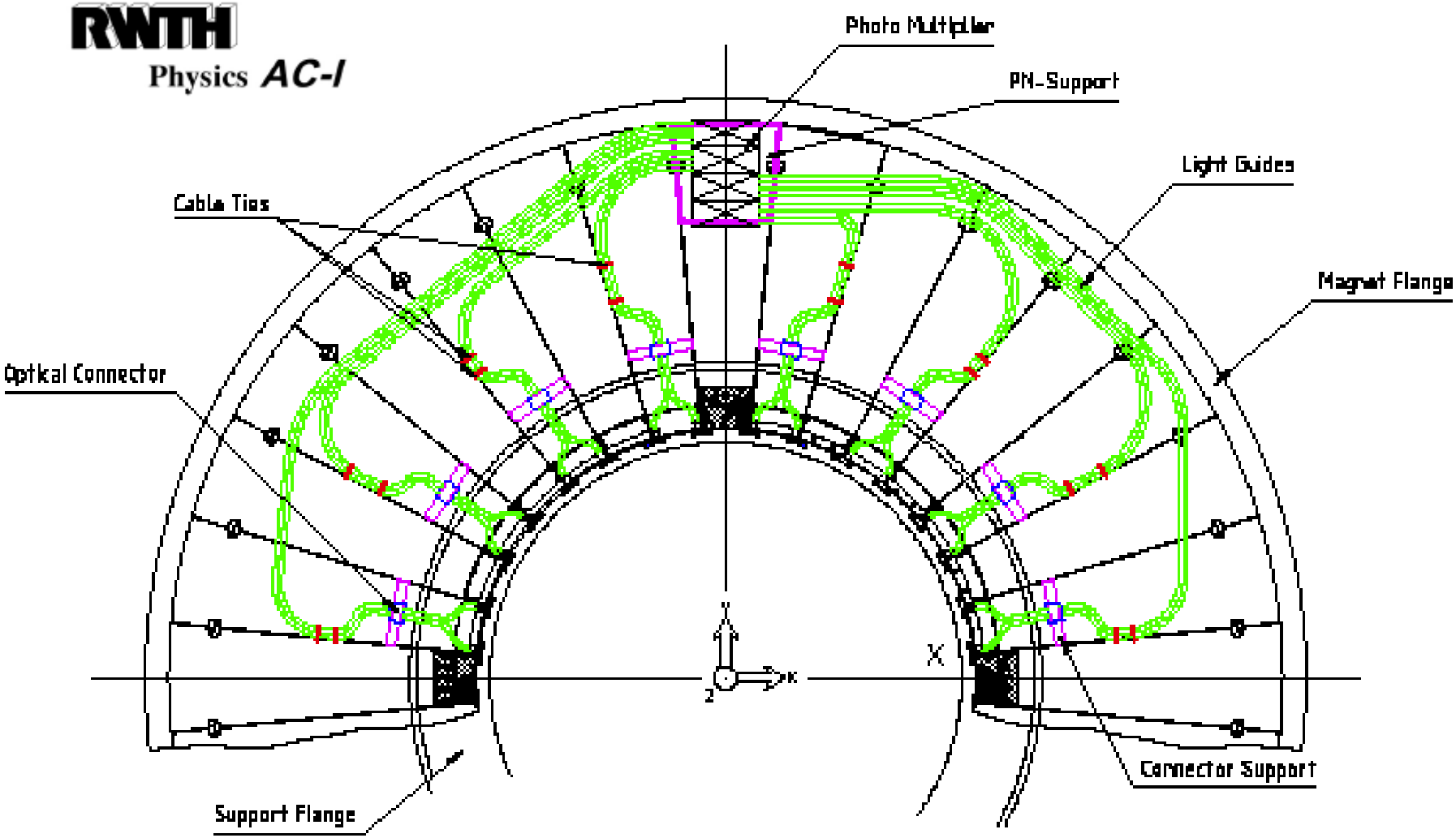

I.S.A.
ANSYS 5.0 A 95
APR 25 1996
11:13:02
PLOT NO. 1
NODAL SOLUTION
STEP=1
SUB =1
FREQ=145.345
UX
RSYS=1
DMX =15.982
SMN =-15.735
SMX =15.961
U
-15.735
-12.213
-8.691
-5.17
-1.648
1.874
5.395
8.917
12.439
15.961
Anti-Counter V2, 1. Natural Frequency 145 Hz, Radial Displacement

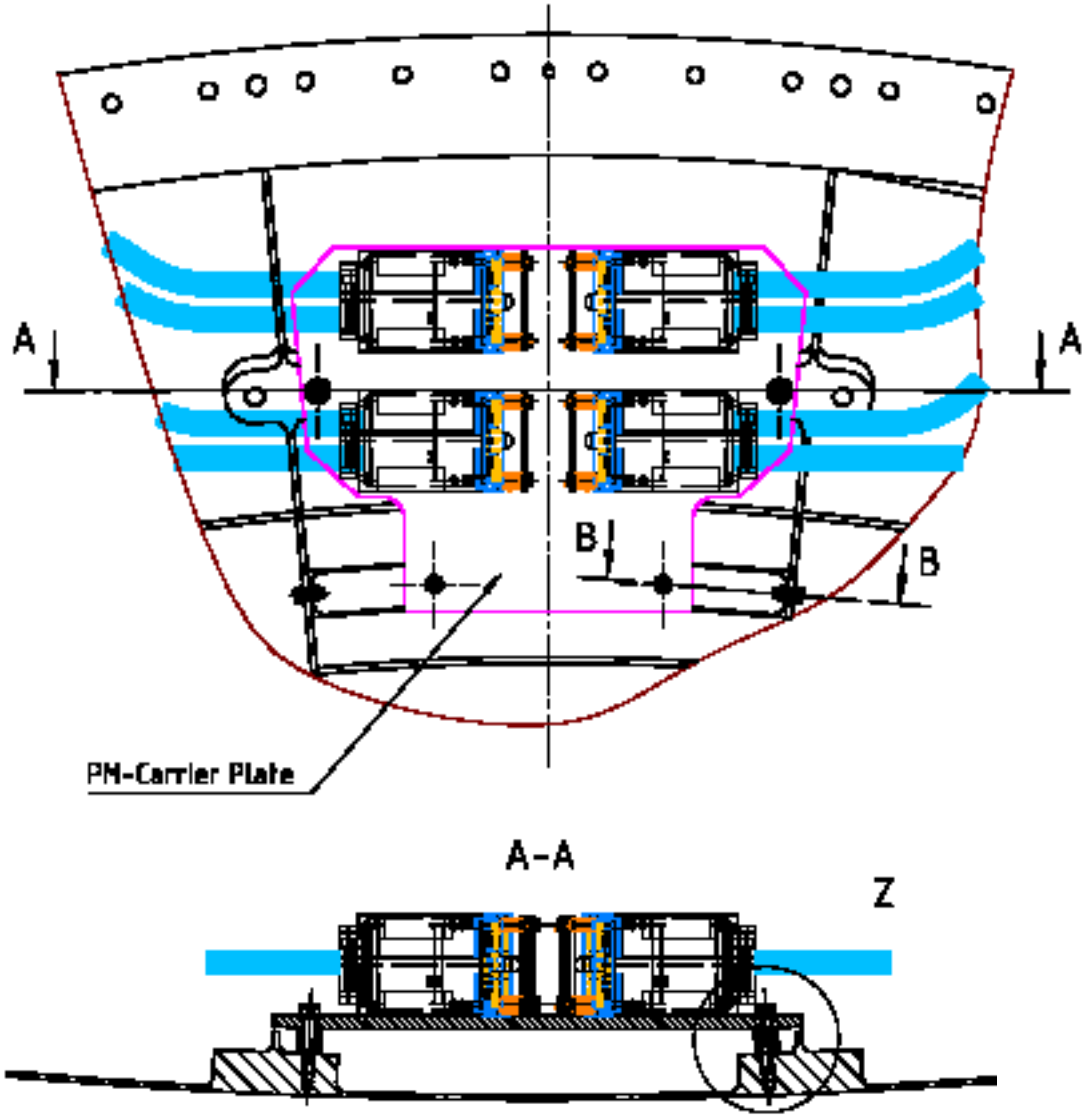


Tracker and ACC Mounting Interface Detail

ACC-PM Arrangement

RWTH Physics AC-I





RWTH Physics AC-I

ACC, Cont.

- Primary Materials
  - Carbon Fiber (Tenax) / Epoxy Resin (Araldite LY556) Composite System for Support Tubes
  - BCF-92 (Polystyrene core with acrylic cladding) as fiber material
  - See Materials Presentation for Complete List
- Testing
  - Strength vibration tests performed for STS-91
  - Sine Sweep Test for STS-91
  - Thermal Vacuum testing has been done on new PMTs
  - Vibration testing has been done on all new parts

Tracker

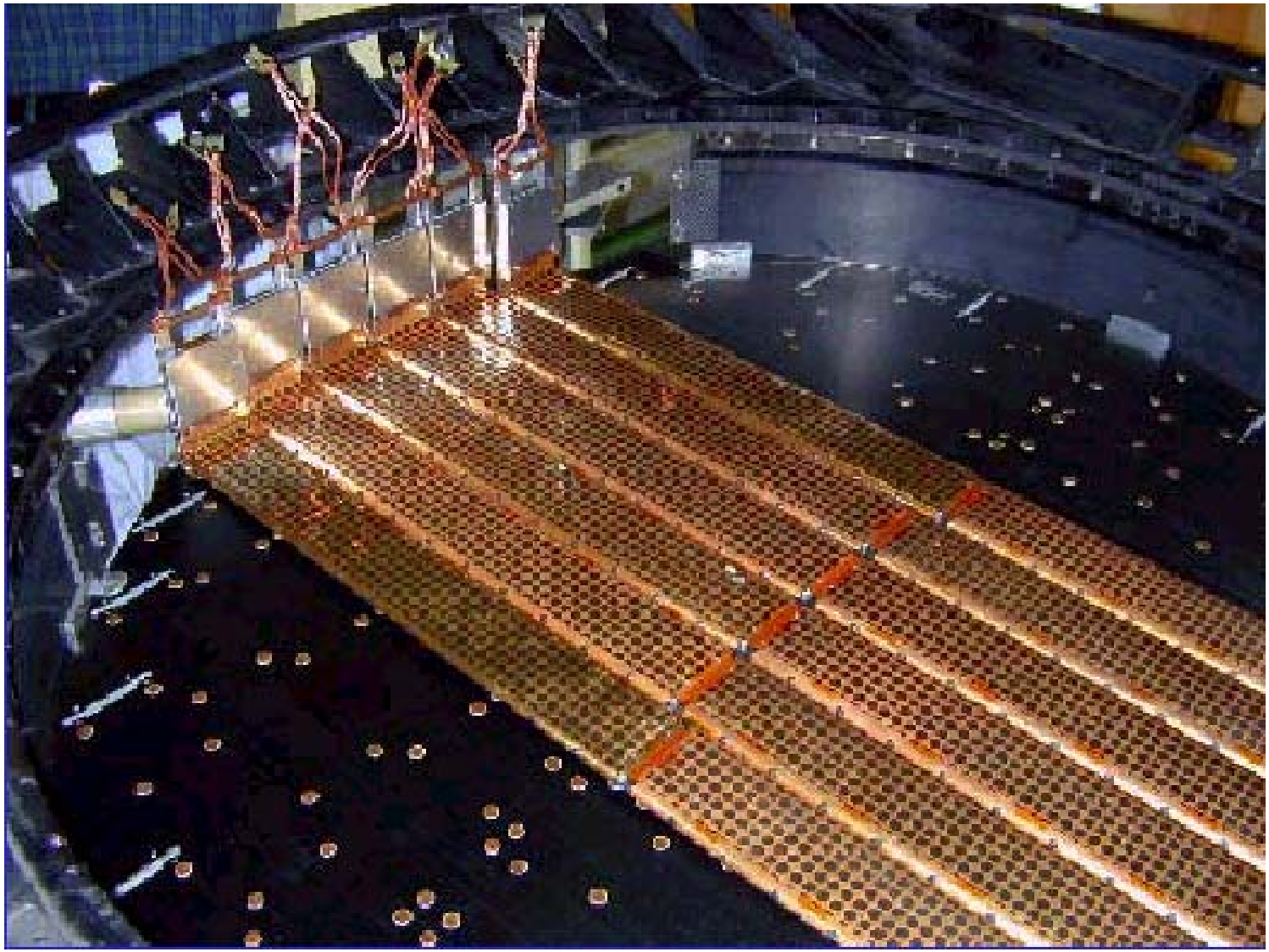
Tracker

- Notes:
  - Tracker flew on STS-91
  - Same Honeycomb panels will be re-flown
  - 3 inner planes have silicon ladders on both sides (ladders on one side only for STS-91)
  - Data from accelerometers flown on STS-91 has been used to lower the load factors for AMS-02
- Location and Size
  - Tracker is located inside the inner cylinder of the vacuum case
  - Mounts at 8 attach locations to the vacuum case flanges (changes made to Tracker Feet for AMS-02)
  - 3 Inner planes approximately 1.1 meters in diameter (were 4 on STS-91)
  - 2 Outer planes approximately 1.5 meters in diameter
- Weight Estimate
  - 198.5 kg (438 lbs) including cables

AMS-01
Tracker CFC
Cylinder

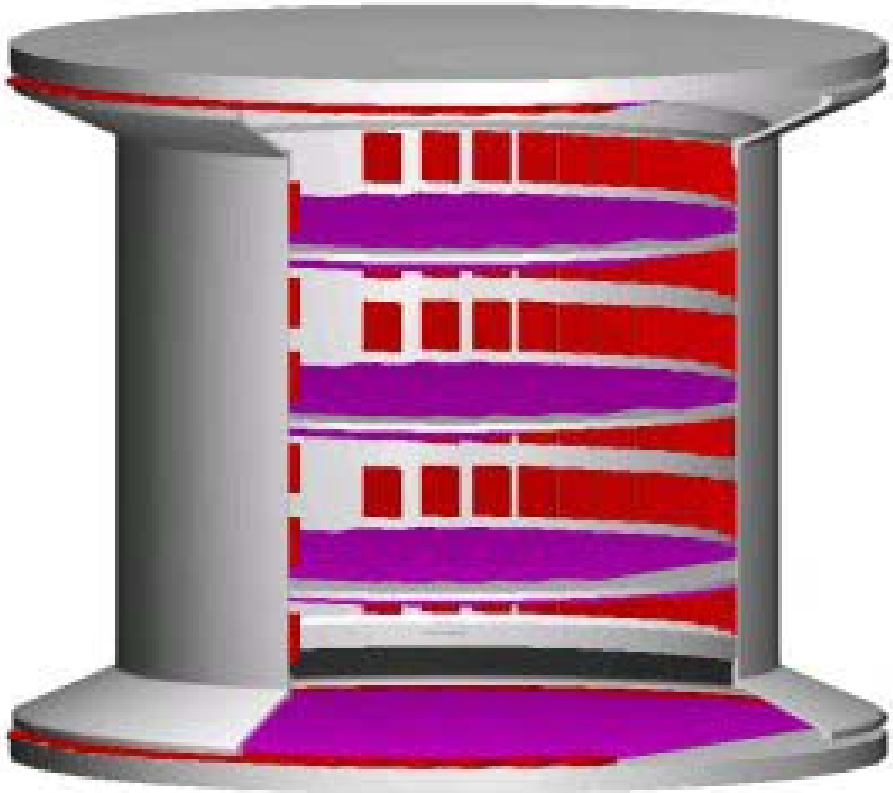
AMS-01 Tracker Planes

AMS-01 Tracker Planes with Silicon Ladders Installed



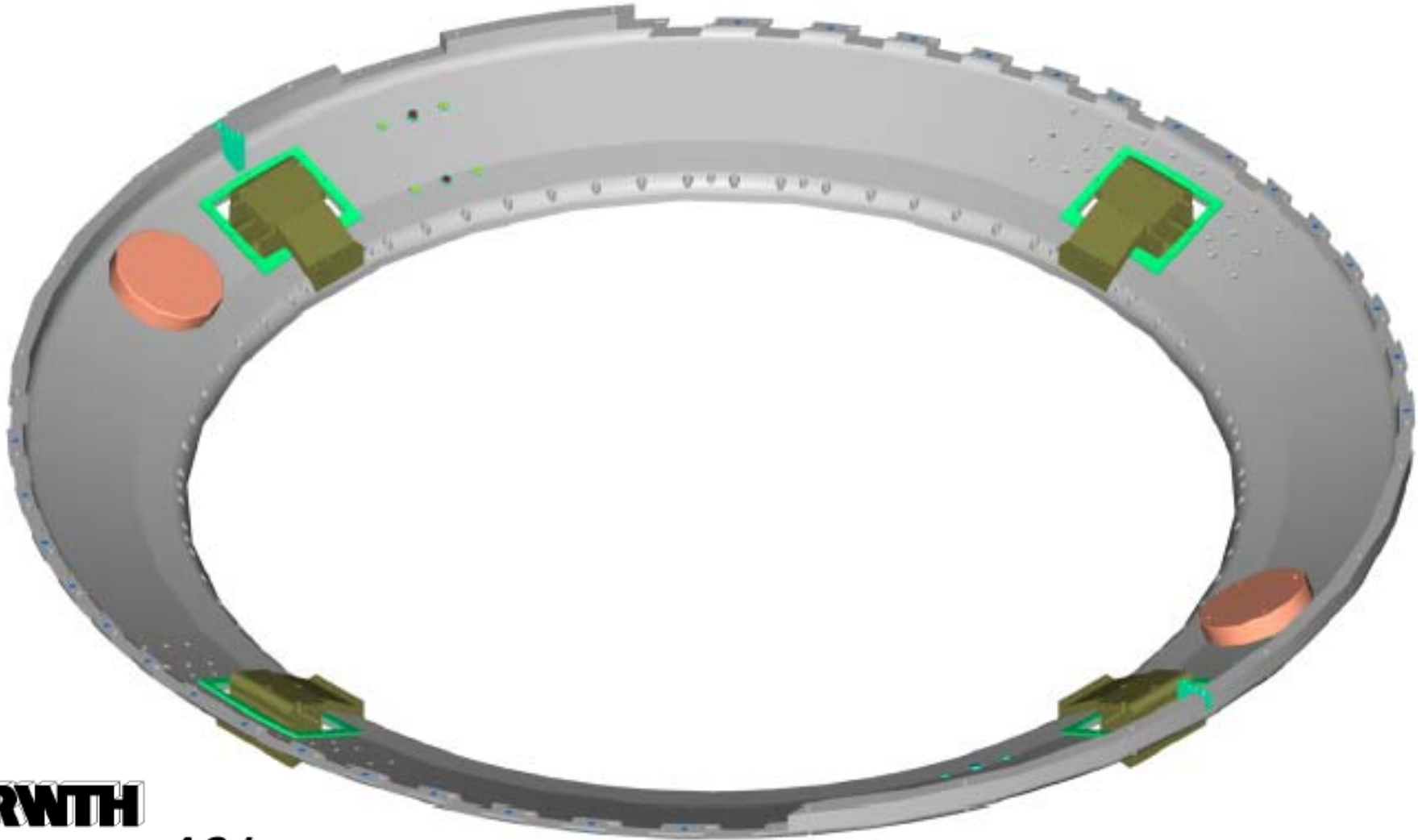
Tracker, Cont.

- Structural Verification
  - Tracker Verification by analysis with Fs_{ult}=2.0 and Fs_{yld}=1.25
    - Assembly - LF=13 g in worst direction with 3.25 g in remaining 2 orthogonal directions
    - Small Diameter Planes – Nx= ±7.2g, Ny= ±4.7g, Nz= ±7.9g
    - Large Diameter Planes - Nx= ±6.1g, Ny= ±2.7g, Nz= ±6.9g
    - Ladders & Thermal Bars – LF=40 g in worst direction with 10 g in remaining 2 orthogonal directions
- Components Minimum Margin of Safety:
  - Large Diameter Planes = 3.3 on Bolts
  - Small Diameter Planes = 0.12 on core shear
  - Support Feet = 0.25
  - Support Cylinder = 3.1
  - Ladders & Thermal Bars = 0.25
- Components First Dynamic Frequency:
  - Overall System > 50 Hz

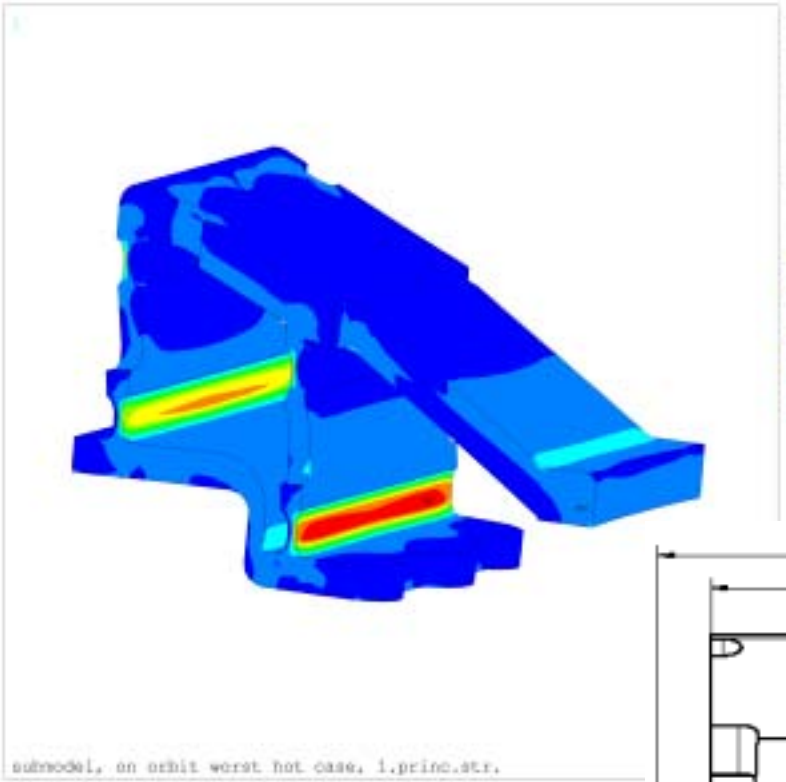


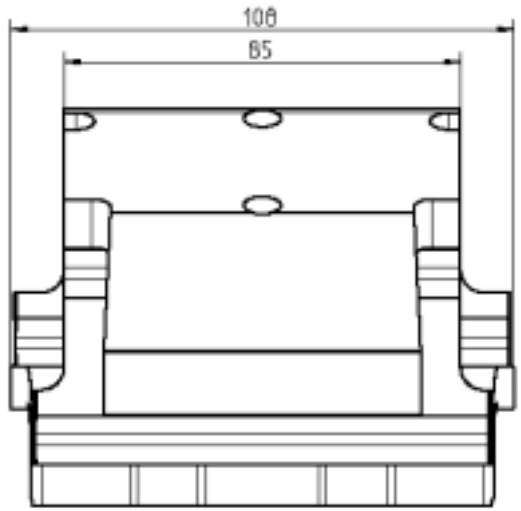
Tracker Silicon
& Hybrids

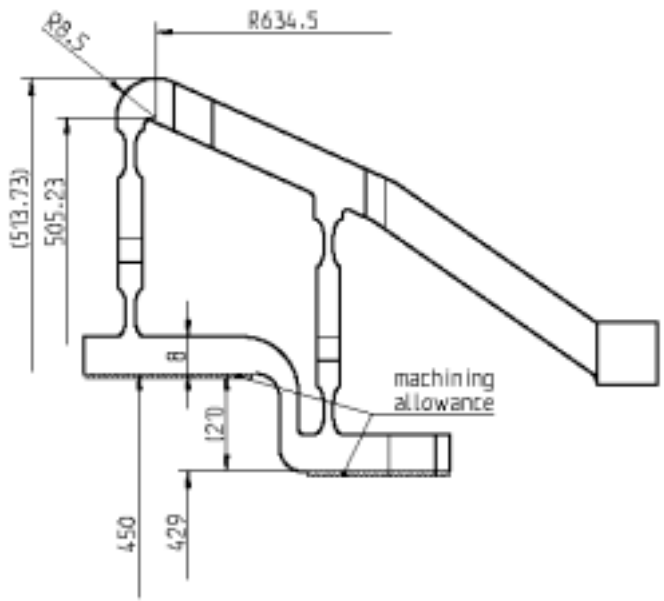
Tracker Support
Structure



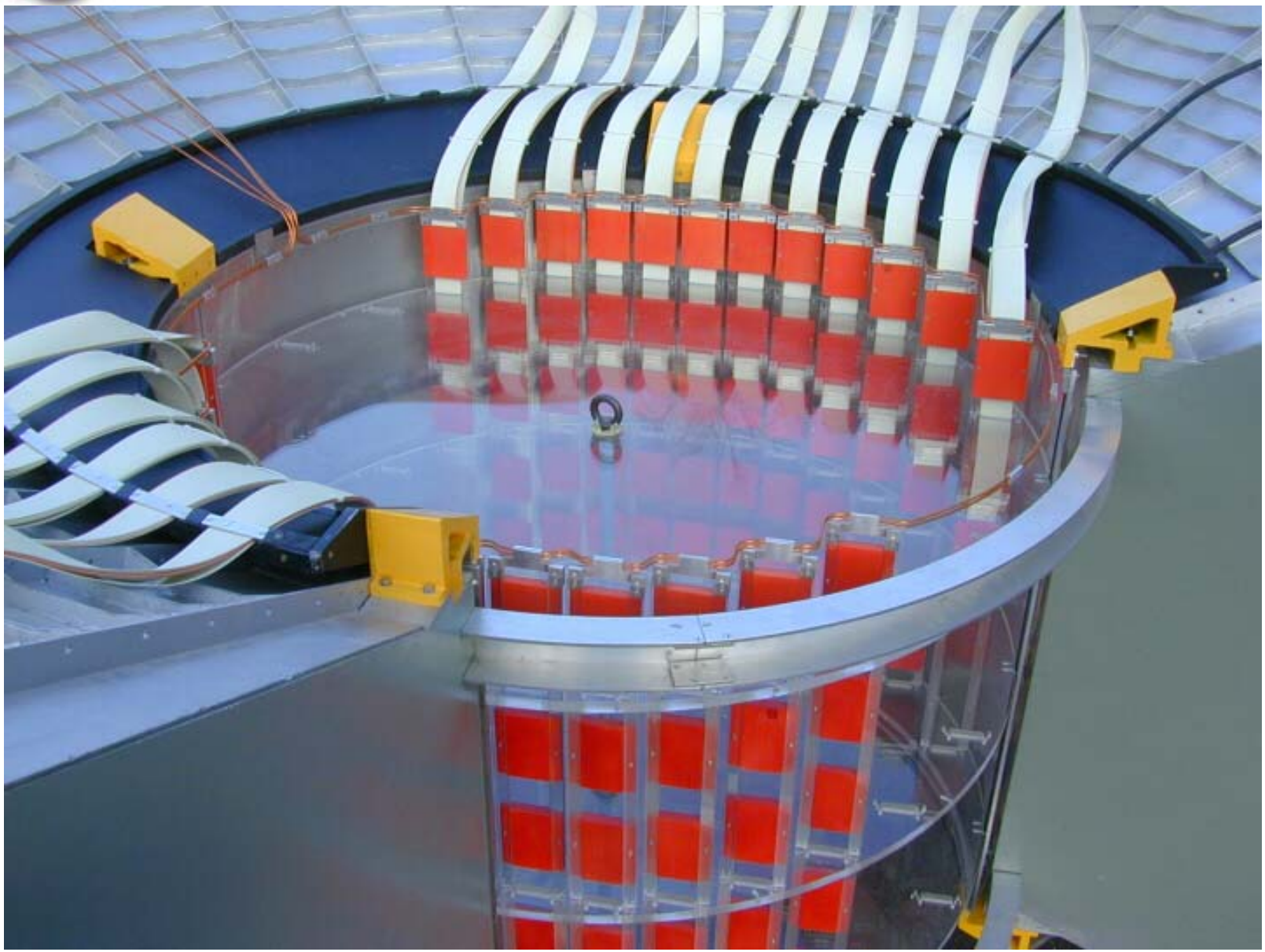
RWTH Physics AC-I


ANSYS 5.7.1
MAR 30 2003
13:33:37
PLOT NO. 1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
S1 (AVG)
DMX =.452146
SMN =-35.927
SMNB=-108.097
SMX =358.321
SMXB=375.032
-35.927
7.879
51.684
95.489
139.295
183.1
226.905
270.711
314.516
358.321
submodel, on orbit worst hot case, 1.princ.str.


108
85


R8.5
R634.5
(513.73)
505.23
8
120
machining
allowance
450
429

AMS-02 Tracker Mockup



AMS-02 Tracker Mockup with Cable Routing

Tracker (Cont.)

- Primary Materials
  - Tracker Support Plates, Cylindrical Shell, & Conical Flange – M55J Fiber / Cyanate Ester Composite facesheet and Hexcell Composite Honeycomb Core
  - Tracker Ladders – Carbon Fiber / Cyanate Ester Composite for Ladder re-enforcement, 7075 Al. Legs, Airex Foam
  - Support Feet - Titanium Ti6AlV4
  - See Materials Presentation for Complete List
- Testing
  - By similarity to AMS-01

Ring Imaging Cherenkov Counter (RICH)

RICH

- Size and Location
  - RICH is located near the bottom of the experiment stack
  - Approximately 140 x 140 x 57 cm (55 x 55 x 22 in)
- Weight Estimate
  - 184 Kg (406 lbs)
- Primary Materials
  - Al. 6061 T651 for mechanical parts
  - Reflector
    - CFC K1352U/EX-1515
  - See Materials Presentation for Complete List

RICH, Cont.

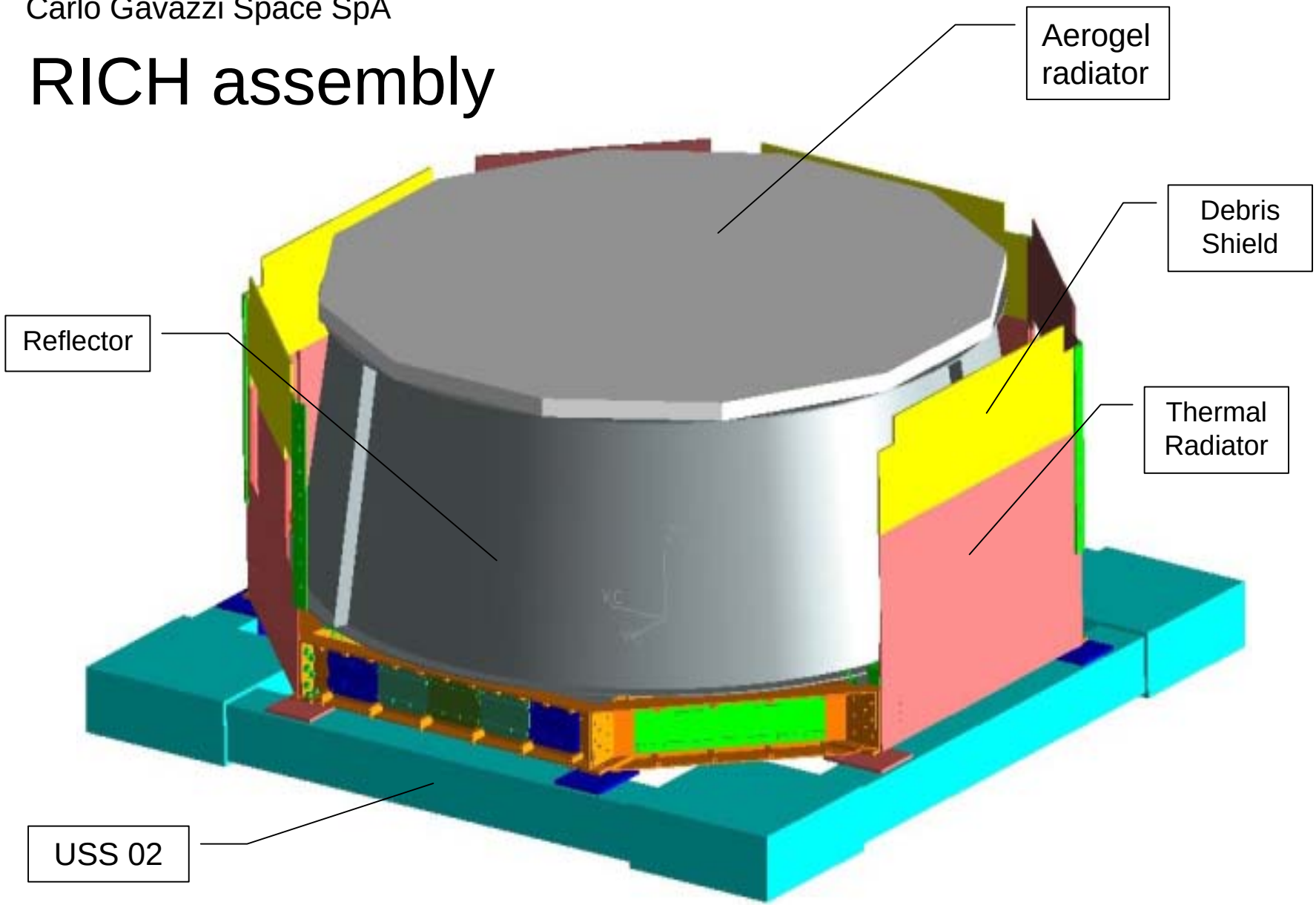
- Structural Verification
  - RICH Verification by analysis with Fs_{ult}=2.0 and Fs_{yld}=1.25
    - Liftoff – Applied about CG of entire payload
      - Nx= ±5.7g, Ny= ±1.6g, Nz= ±5.9g
      - Rx=±10 rad/sec^2, Ry= ±25 rad/sec^2, Rz= ±18 rad/sec^2
    - Landing – Applied about CG of entire payload
      - Nx= ±4.5g, Ny= ±2.0g, Nz= ±6.5g
      - Rx=±20 rad/sec^2, Ry= ±35 rad/sec^2, Rz= ±15 rad/sec^2
    - LF for reflector may be modified with acoustic analysis results.

RICH, Cont.

- Components Minimum Margin of Safety:
  - Reflector = 7.2
  - External Structure = -.16 (0.17 for buckling) (working with LMSO to eliminate this concern by modeling change or redesign)
  - Cell Aluminum support structure = 0.53
  - Radiator = 3.8 (2.99 for buckling)
- Components First Dynamic Frequency:
  - 1st local natural frequency at 31.1 Hz (Radiator/Debris Shield motion with effective mass < 1%)
  - 1st global natural frequency at 78.3 Hz (effective mass 5 %)

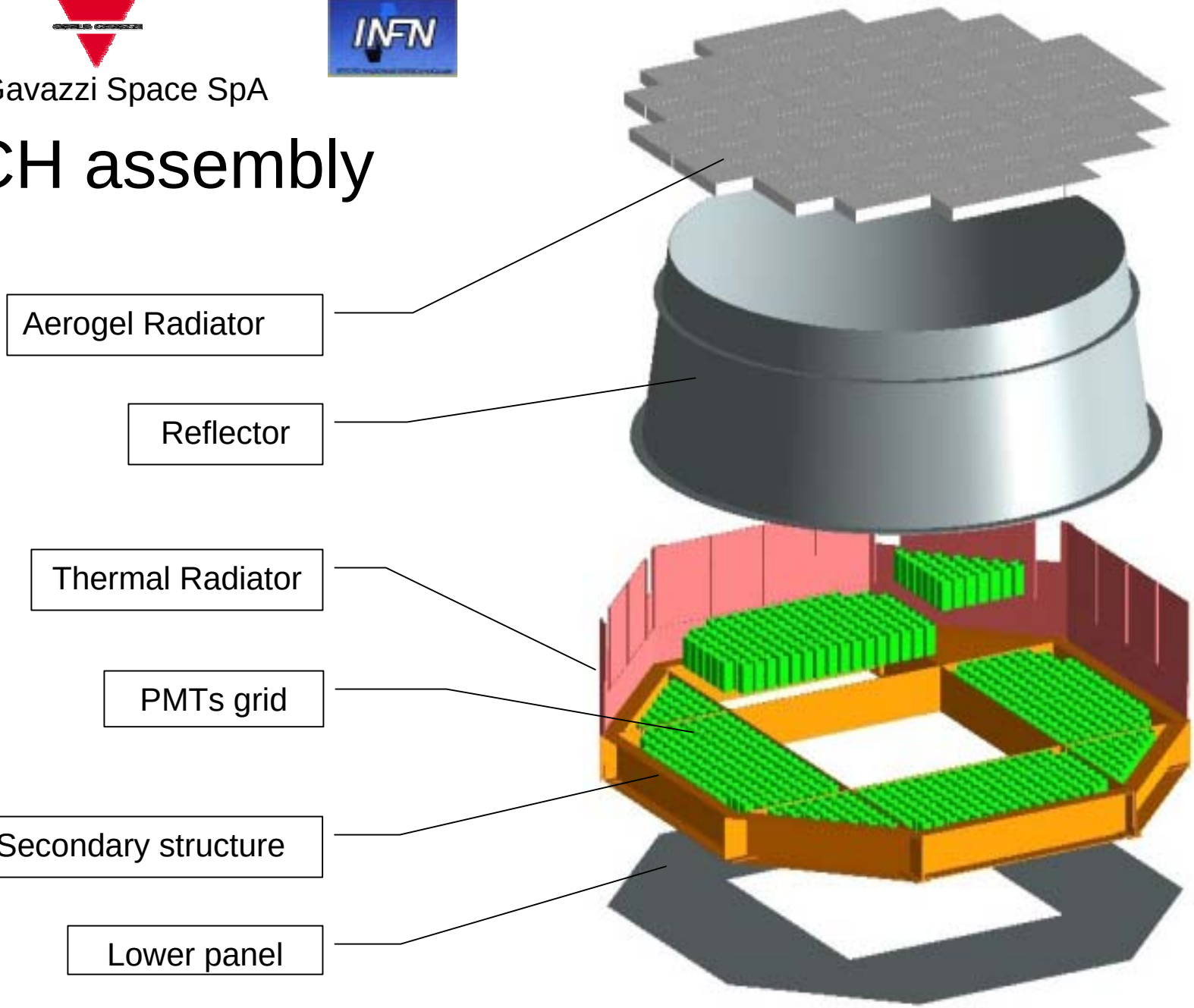
Carlo Gavazzi Space SpA

RICH assembly



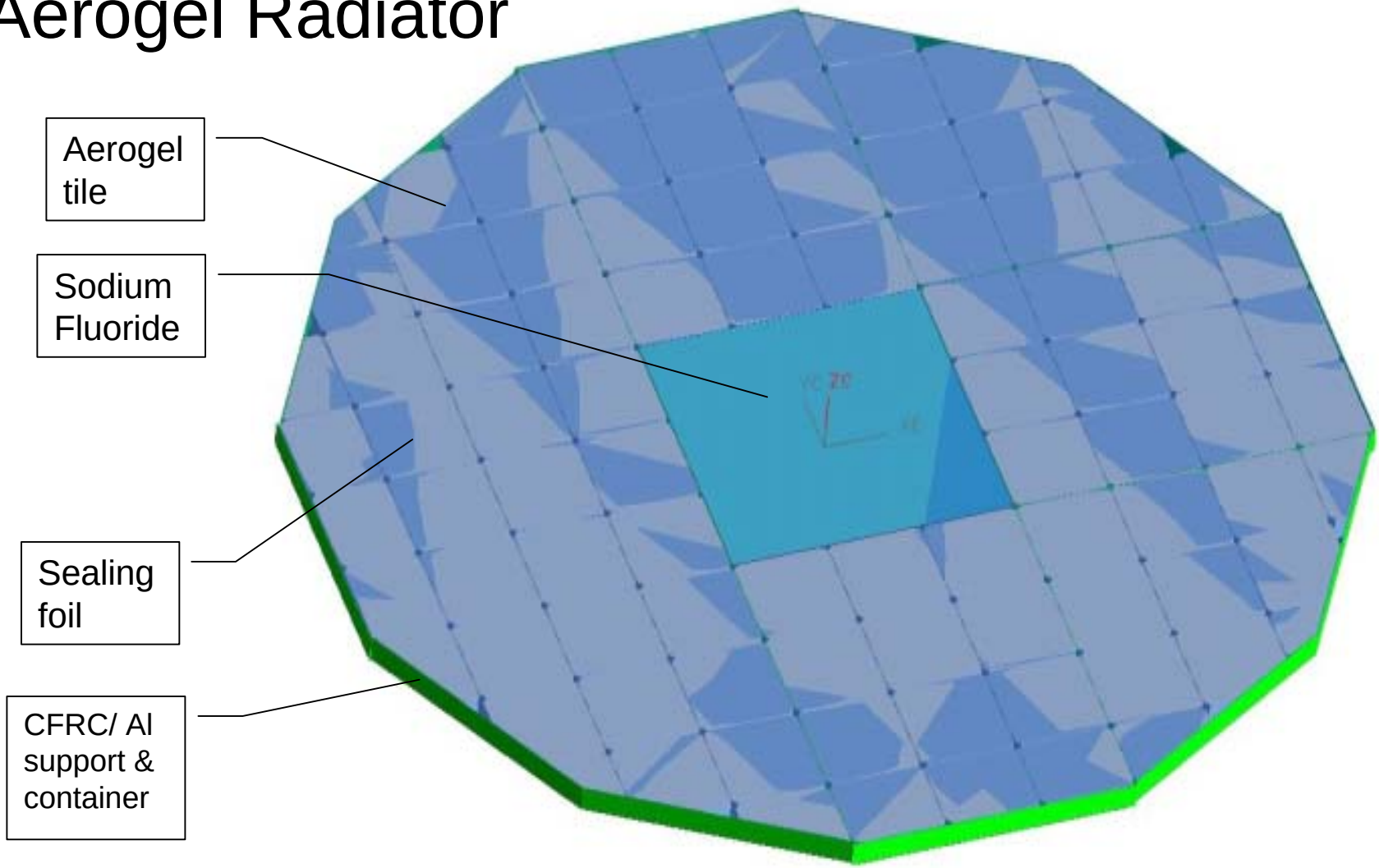
Carlo Gavazzi Space SpA

RICH assembly



Carlo Gavazzi Space SpA

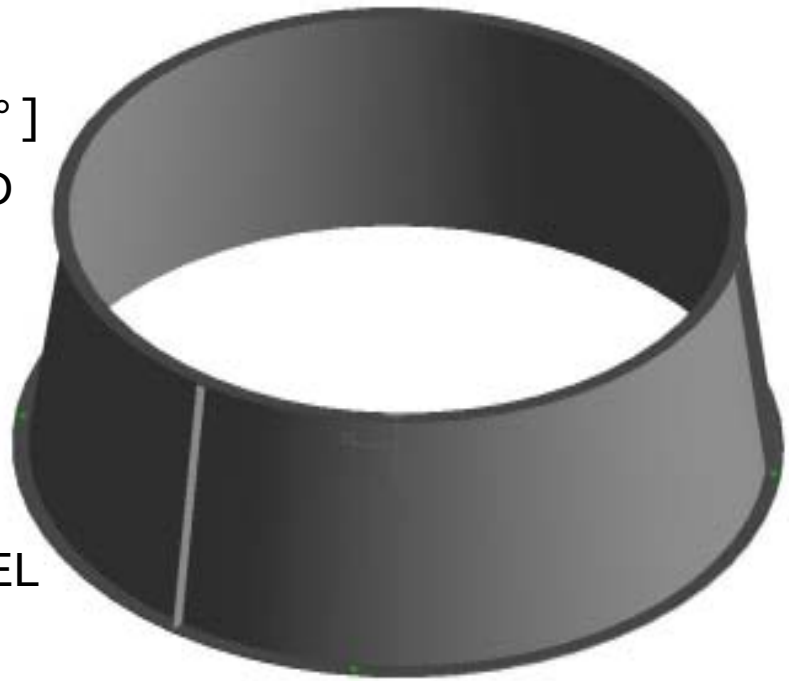
Aerogel Radiator



Carlo Gavazzi Space SpA

Reflector design

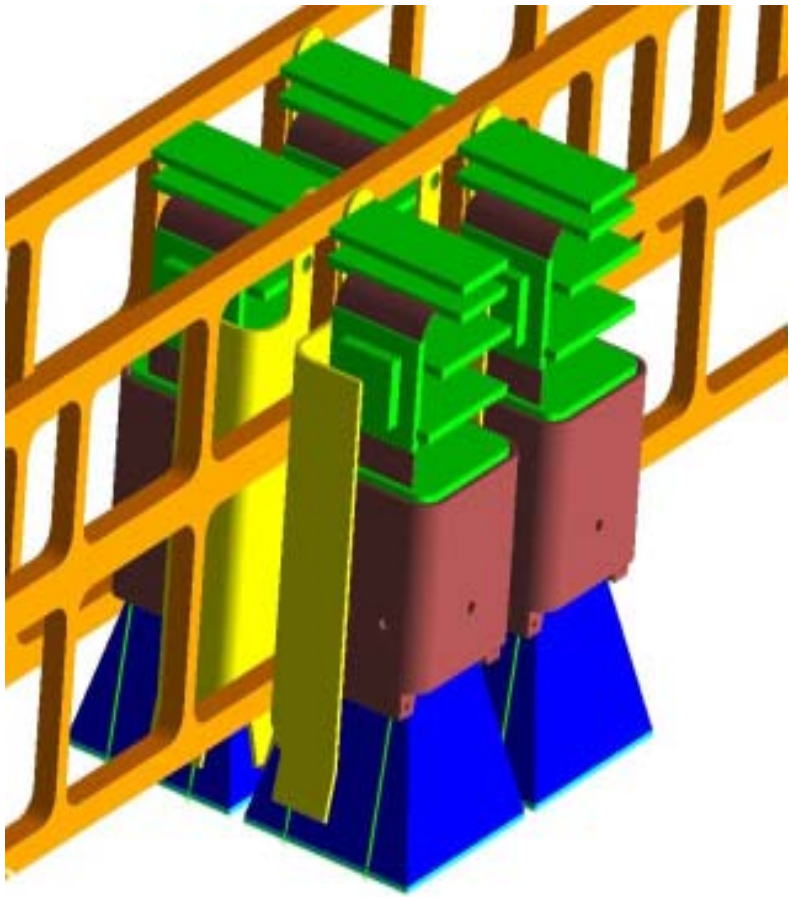
- **MATERIAL**: BRYTE EX-1515 (Cyanate Ester resin system)
- **LAMINATION**: 8 LAYERS:
  [0°/45°/-45°/90°/90°/-45°/45°/0°]
- **REFLECTING SURFACE**: ALUMINUM PLATED WITH MgF_2 PROTECTION
- **WEIGHT**: 3,5 Kg (CARRIER) + 1,5 Kg max (JOINTS)
- **STIFFENERS**: CARBON FIBER FLANGES ON BOTH BASE AND TOP
- **JOINTS TO SECONDARY STRUCTURE**: STEEL PLATES

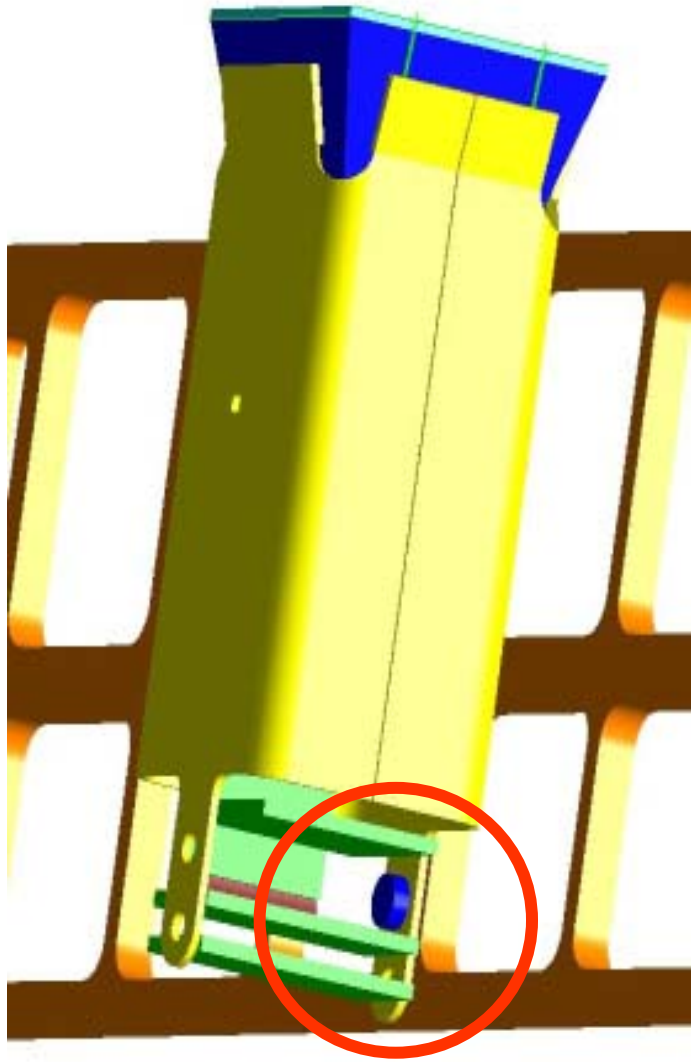


Carlo Gavazzi Space SpA

Mechanical layout

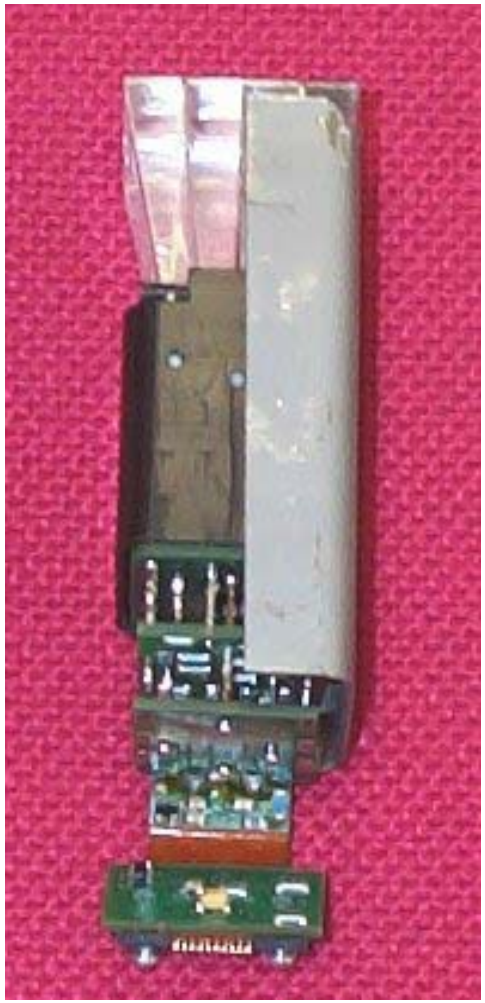
(PMT fixation) 1/2

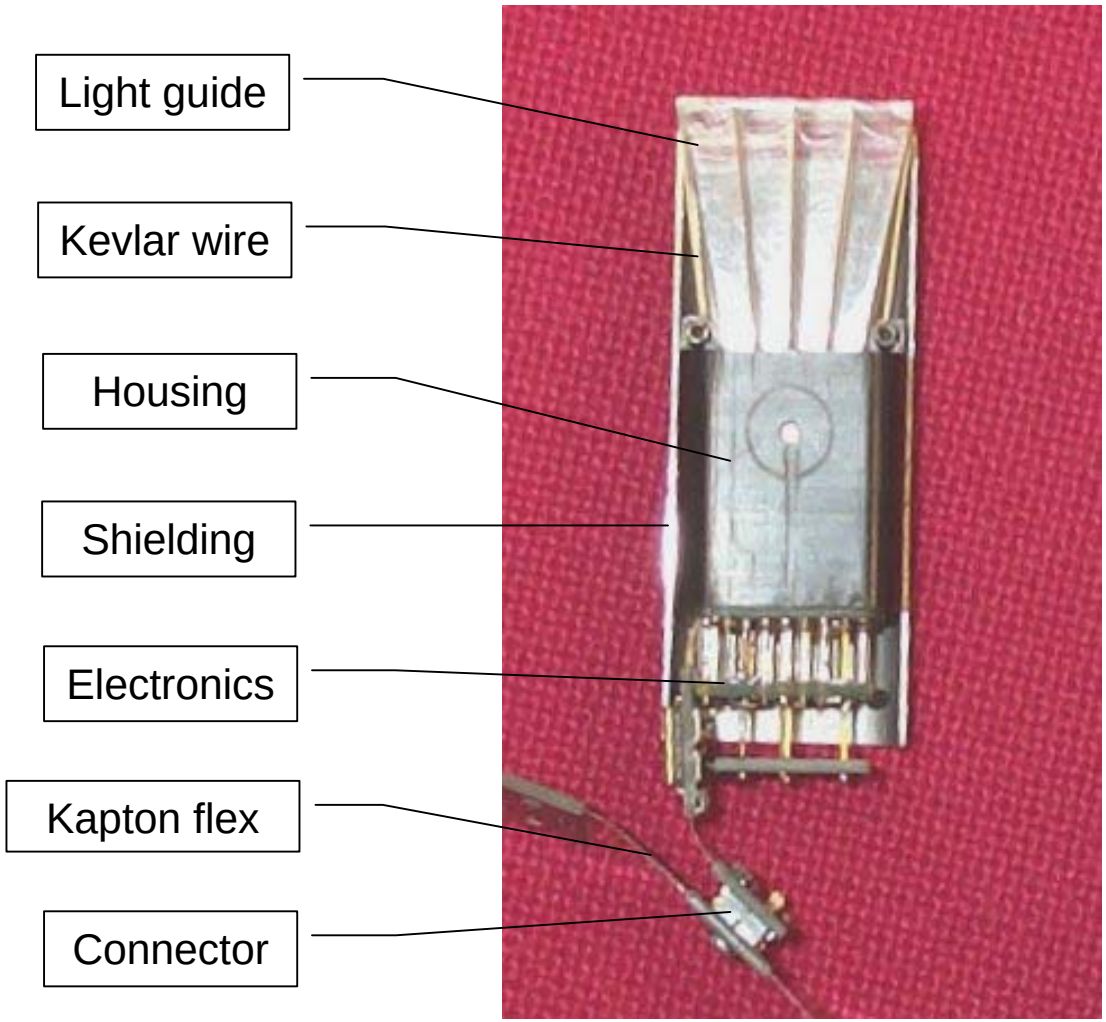




Carlo Gavazzi Space SpA

PMT assembly





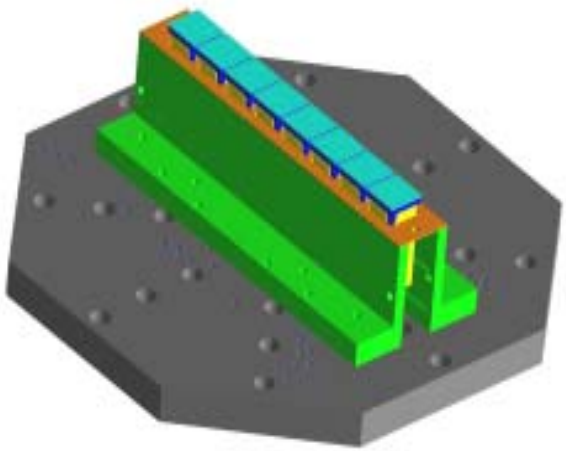
Carlo Gavazzi Space SpA

Vibration test

(Philosophy & Run sequence)

Maximum Expected Flight Levels = 3.2g RMS

Minimum Workmanship Levels = 6.8g RMS



1. Test on single-PMT assembly A: starting from MEFL up to breakage *(90 s @ MEFL+ 90 s @ MWL +30 @+3dB till breakage)*
2. Test on single-PMT assembly B: starting from MEFL up to breakage *(90 s @ MEFL+ 90 s @ MWL +30 @+3dB till breakage)*

PURPOSE:find out the mechanical limits

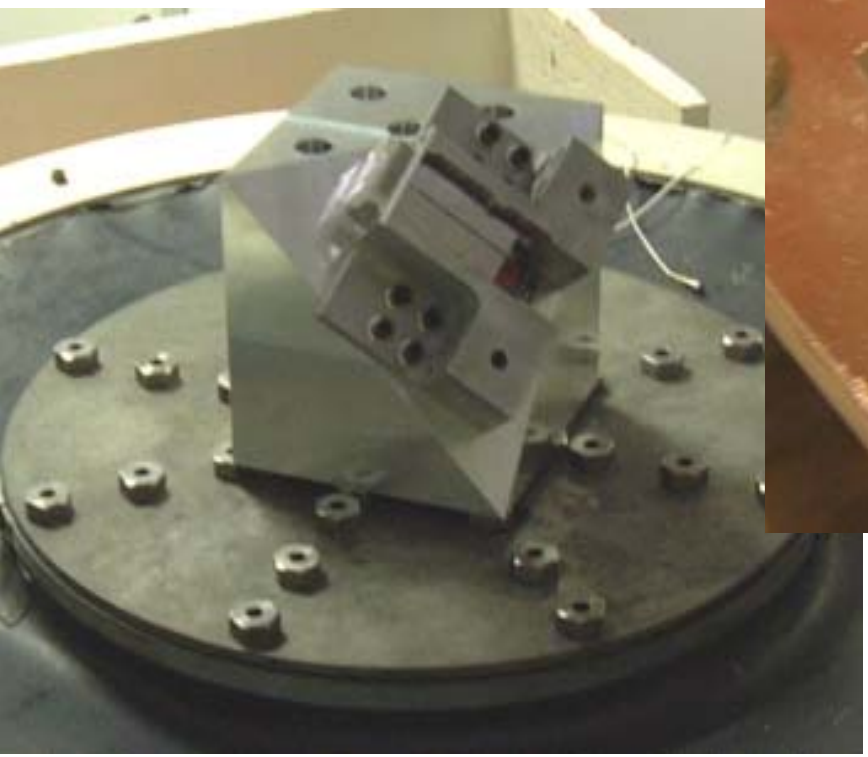
3. Test on 8-PMTs assembly at MWL *(90 seconds on each axis)*

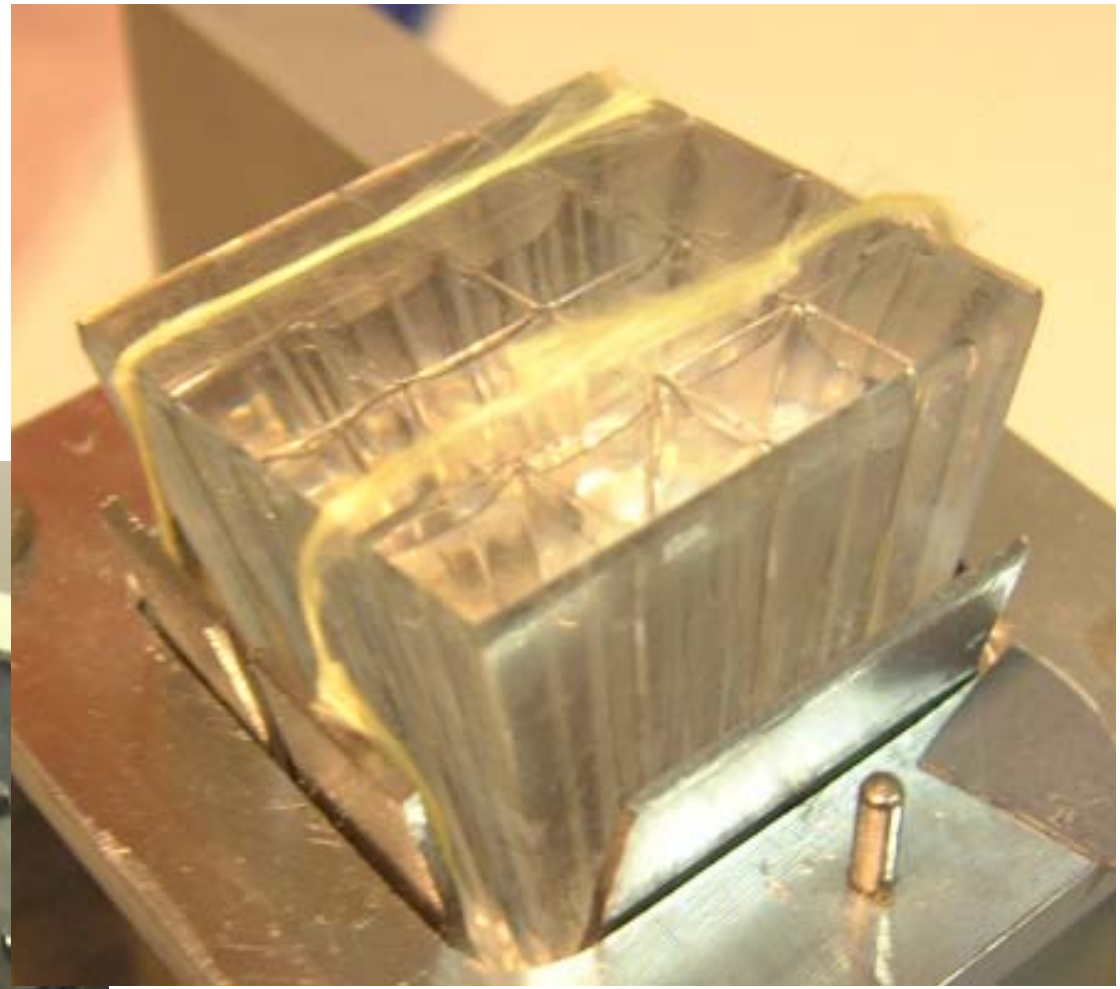
PURPOSE:qualify the mechanical assembly

Carlo Gavazzi Space SpA

Vibration test

(single PMT (B) test)



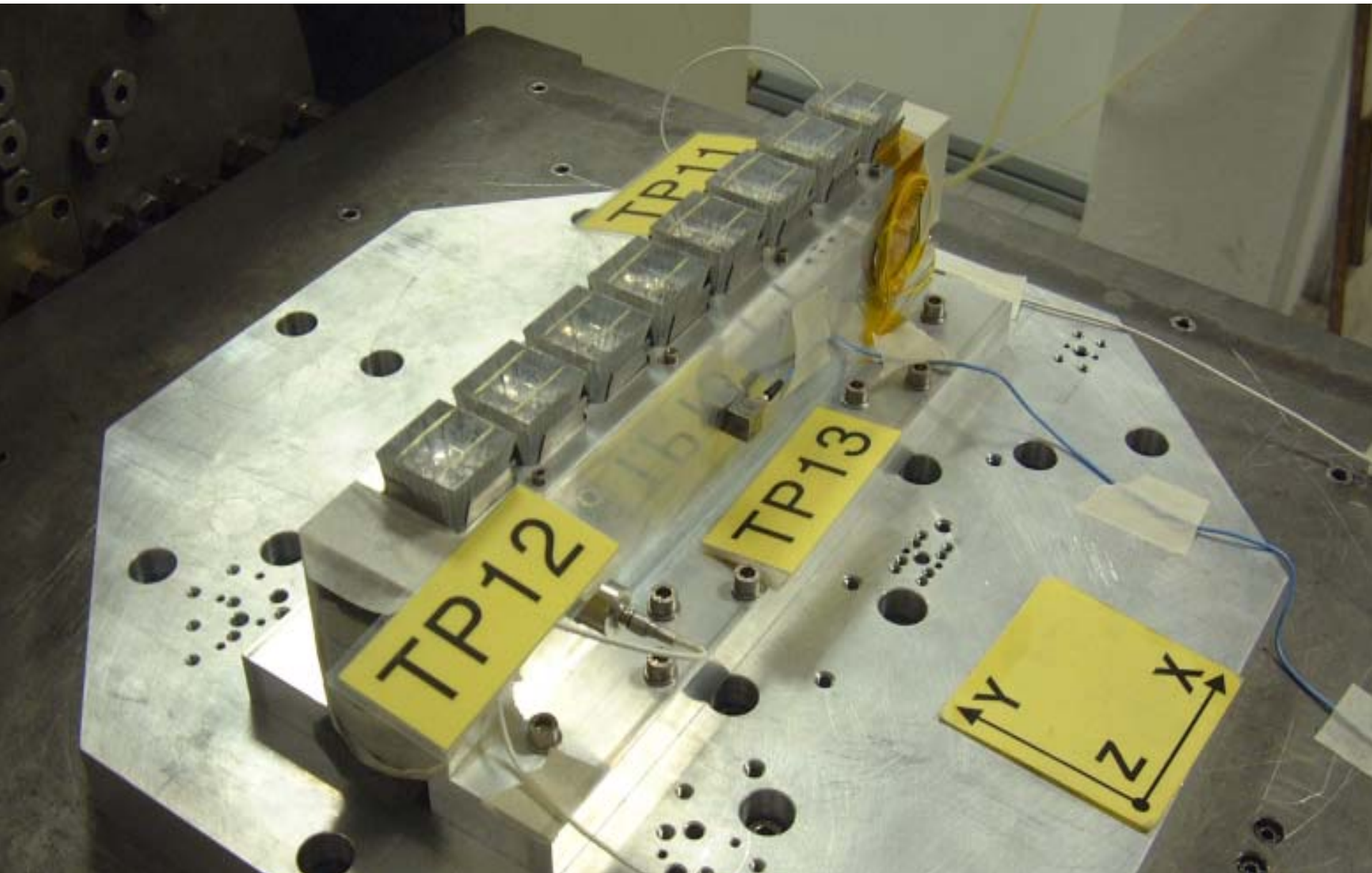


Breakage @ 19.1 g RMS

(total time under vibration >8 minutes)

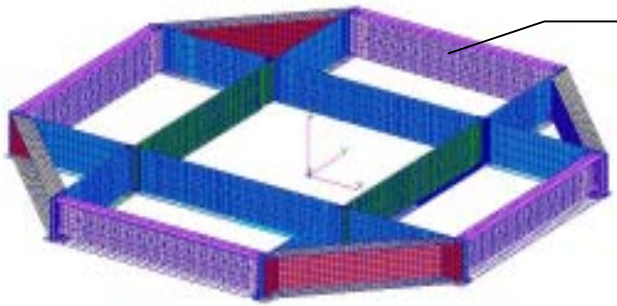
Carlo Gavazzi Space SpA

Vibration test on 8 PMTs



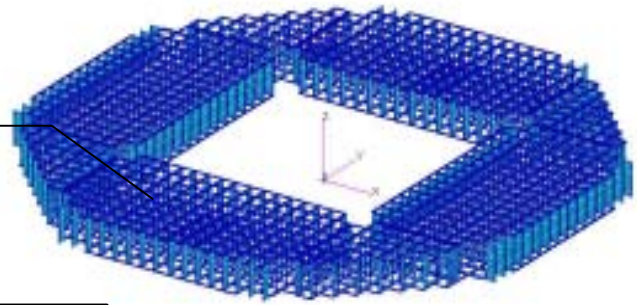
Carlo Gavazzi Space SpA

RICH FEM

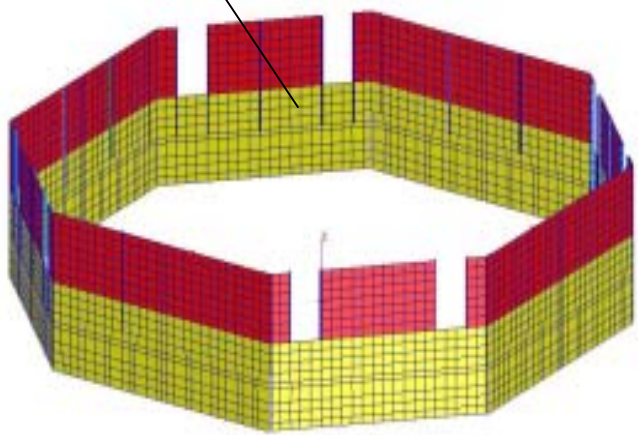


AL 6061External structure

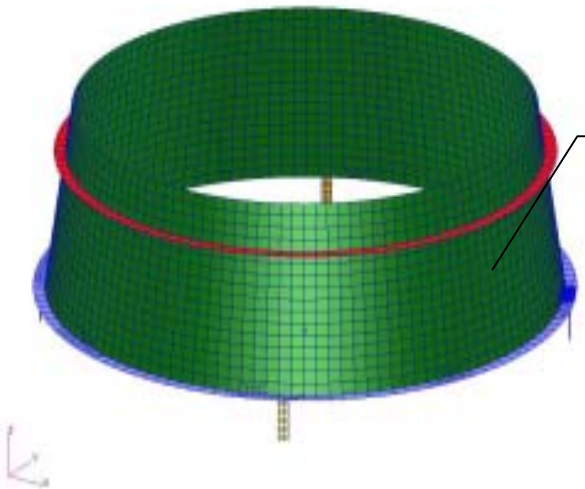
AL 6061 PMT support structure



AL 6061 PMT radiator

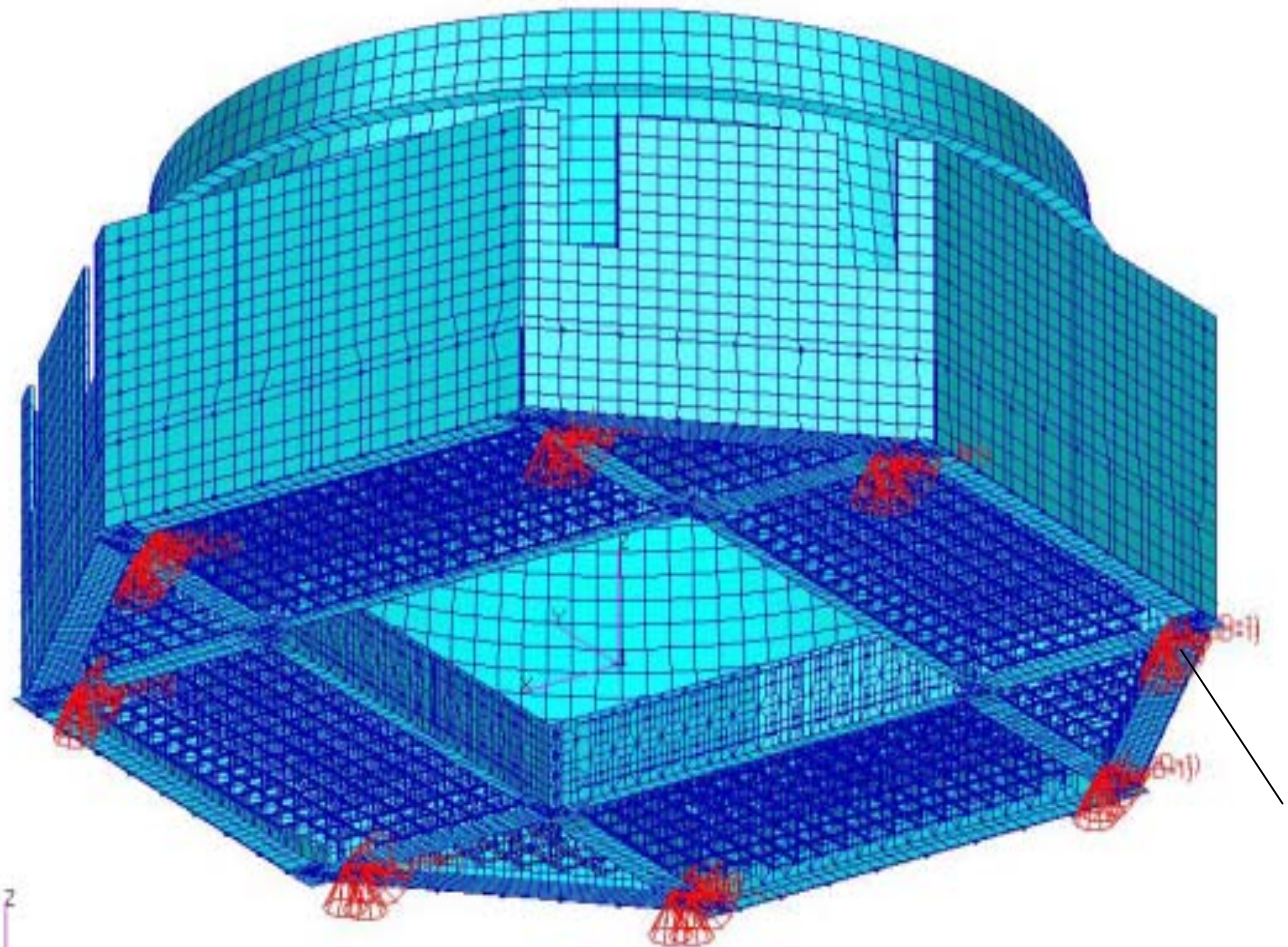


CFRP reflector



Carlo Gavazzi Space SpA

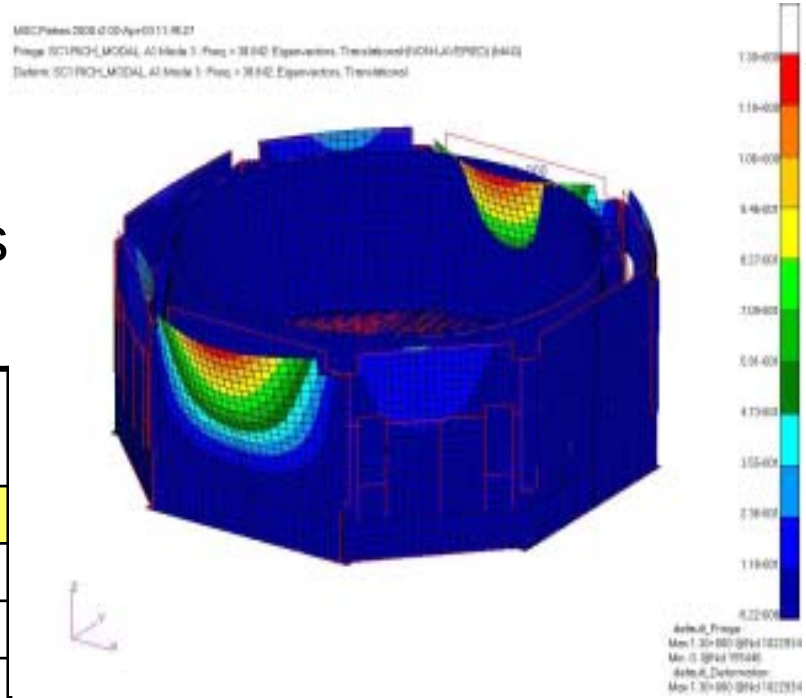
Boundary conditions



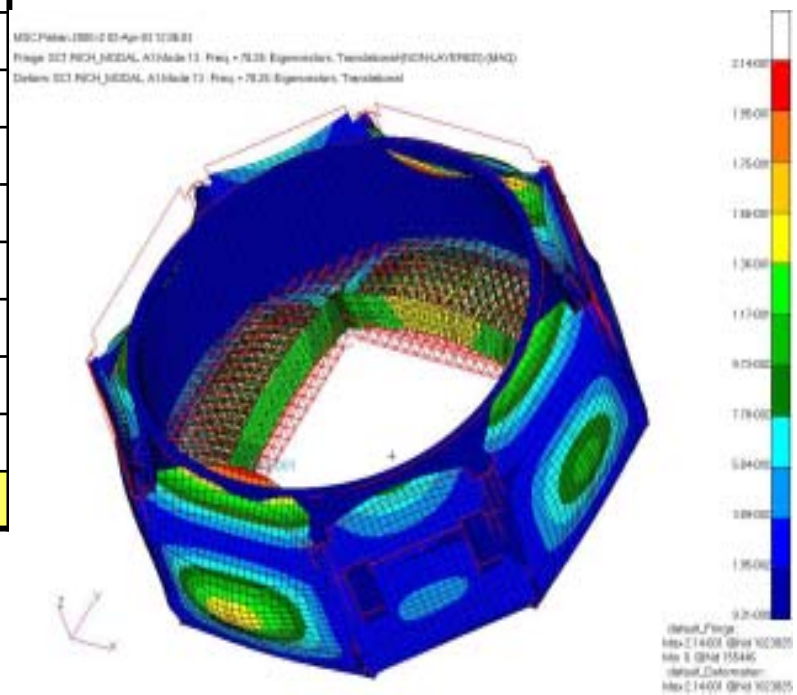
Axial and Radial constraint (bolts)

Eigenfrequencies

MODE	FREQUENCY [Hz]
1	**31.14**
2	38.43
3	38.84
4	39.36
5	41.56
6	50.17
7	51.39
8	52.07
9	57.59
10	59.97
11	72.82
12	75.55
13	**78.26**



MODE 1: LOCAL MODE WITH AN EFFECTIVE ASSOCIATED MASS UNDER 1% OF TOTAL MASS.



MODE 13: FIRST MODE WITH AN EFFECTIVE ASSOCIATED MASS OVER 5% OF TOTAL MASS.

Ken Bollweg (281) 335-2714
Trent Martin (281) 335-2139

RICH (Cont.)

- Testing
  - Since the first significant mode is above 50 Hz, a sine sweep, smart-hammer, or modal test will not be performed
  - Random Vibration test to MEFL or MWL will be done for mission success
  - Possible Acoustic Testing depending on acoustic analysis results
  - Thermal Vacuum testing of PMTs has been completed

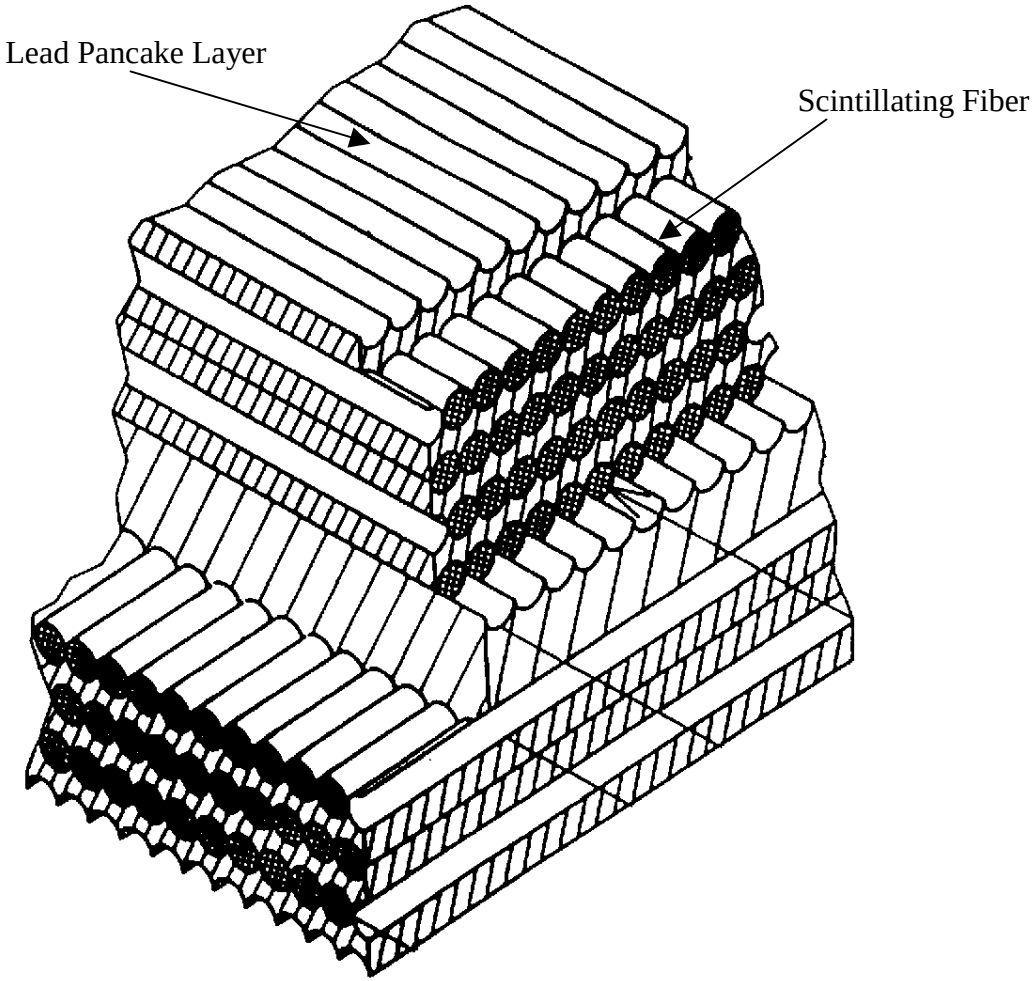
Electromagnetic Calorimeter (ECAL)

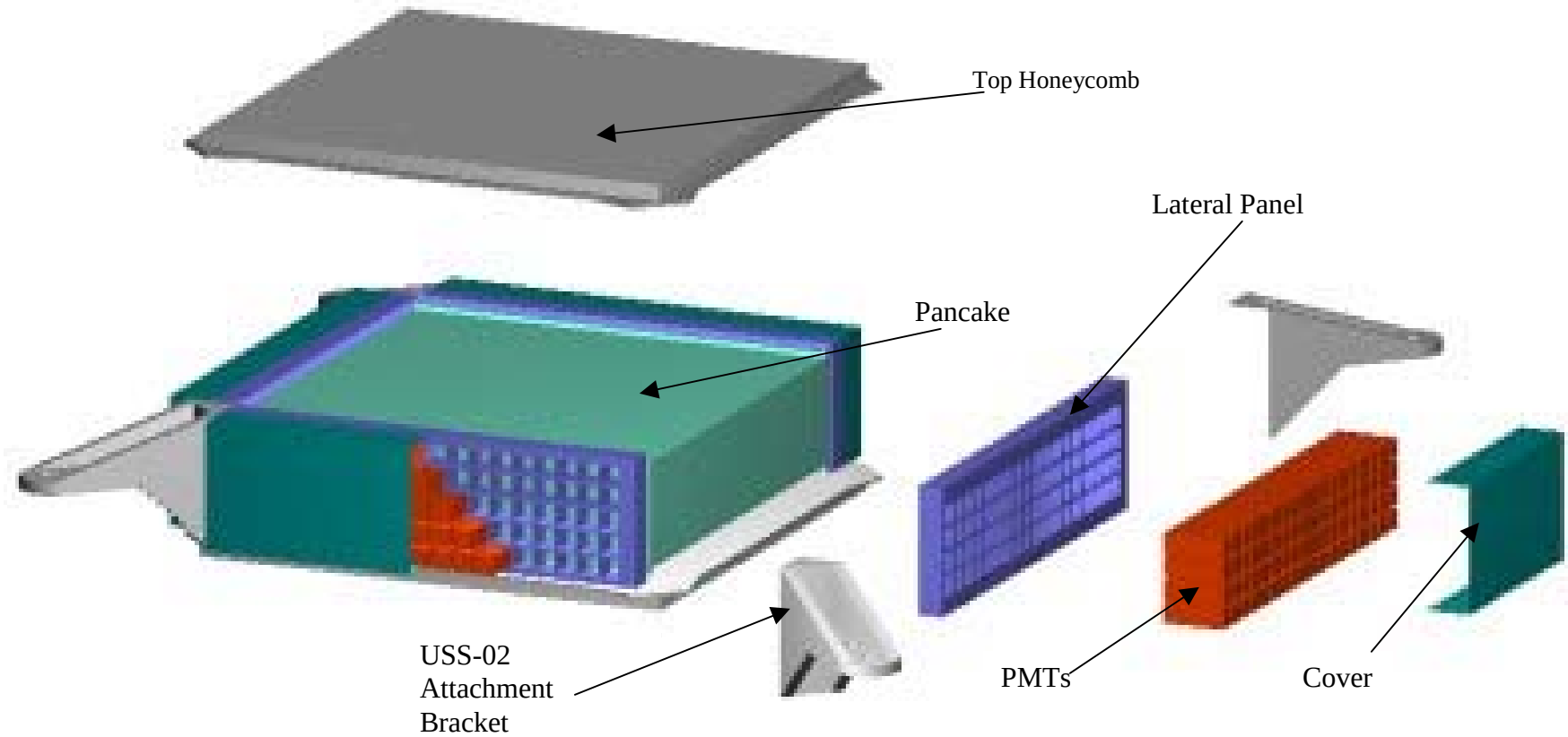
Electromagnetic Calorimeter (ECAL)

- Size, Location, and Description
  - ECAL is located at the bottom of the experiment stack
  - 658 X 658 X 250 mm (26 x 26 x 10 in.)
  - Mounts at 4 attach locations to USS-02 (radially slotted holes)
- Weight Estimate
  - 638 Kg (1407 lbs)

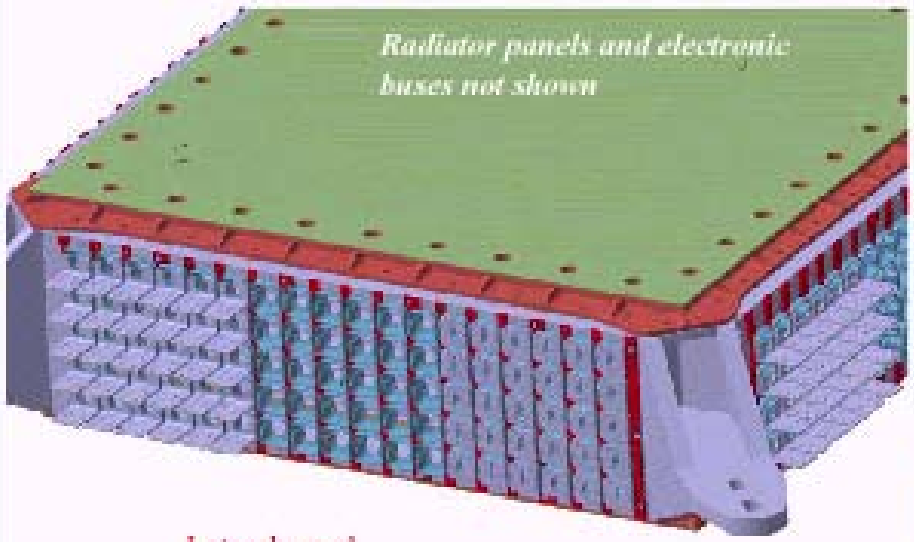
ECAL, Cont.

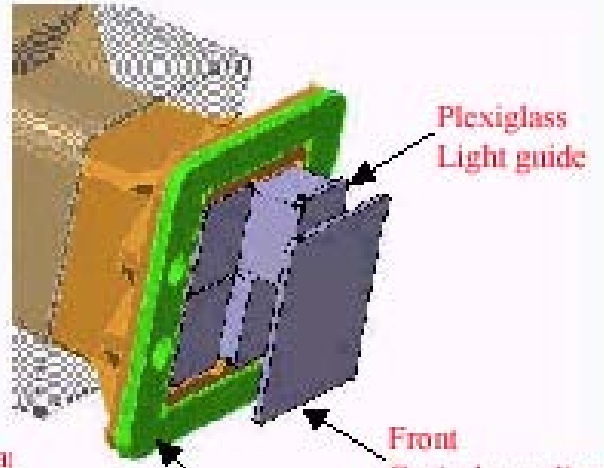
- Structural Verification
  - ECAL Verification by analysis & test with Fs_{ult}=1.4 and Fs_{yld}=1.2
    - Nx= ±7.8g, Ny= ±7.8g, Nz= ±11.1g
    - Rx=±146 rad/sec^2, Ry= ±123 rad/sec^2, Rz= ±51 rad/sec^2
  - For Sine Burst Testing, Equivalent Translation Only Load Factors are used:
    - Nx= ±9.8g, Ny= ±9.8g, Nz= ±13.9g
  - Random Vibration Flight Environment
    - X_{rms}=3.13g, Y_{rms}=3.54g, Z_{rms}=4.36g
- Components Minimum Margin of Safety:
  - Support Structure = 0.9
  - Detector = Non-Structural
- Components First Dynamic Frequency:
  - Overall System = 65 Hz (FEM Correlation still in work)

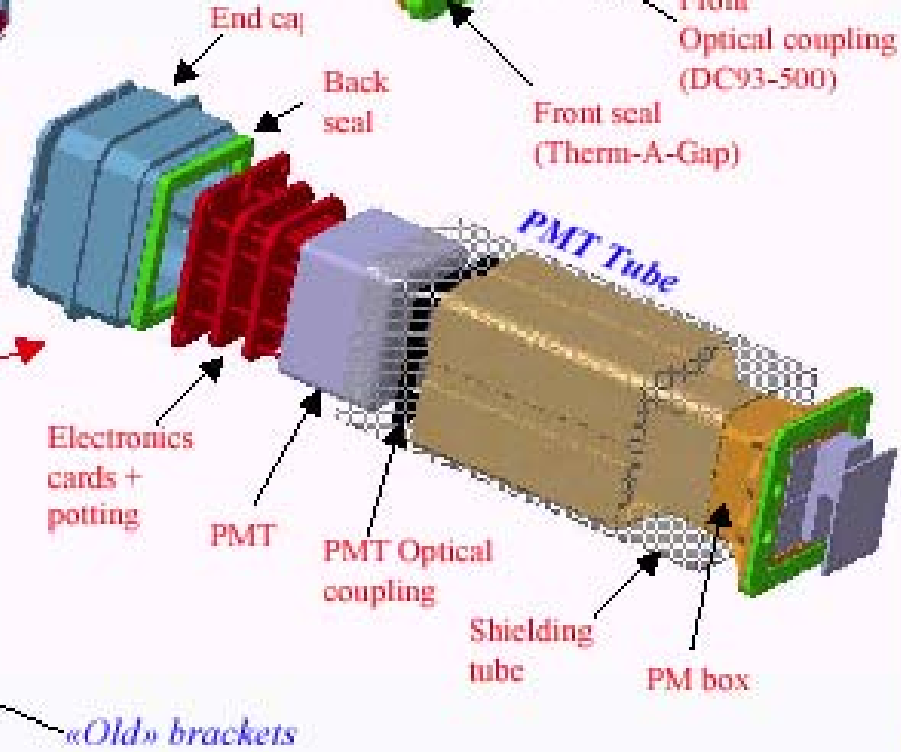

Lead Pancake Layer
Scintillating Fiber


Top Honeycomb
Lateral Panel
Pancake
USS-02
Attachment
Bracket
PMTs
Cover

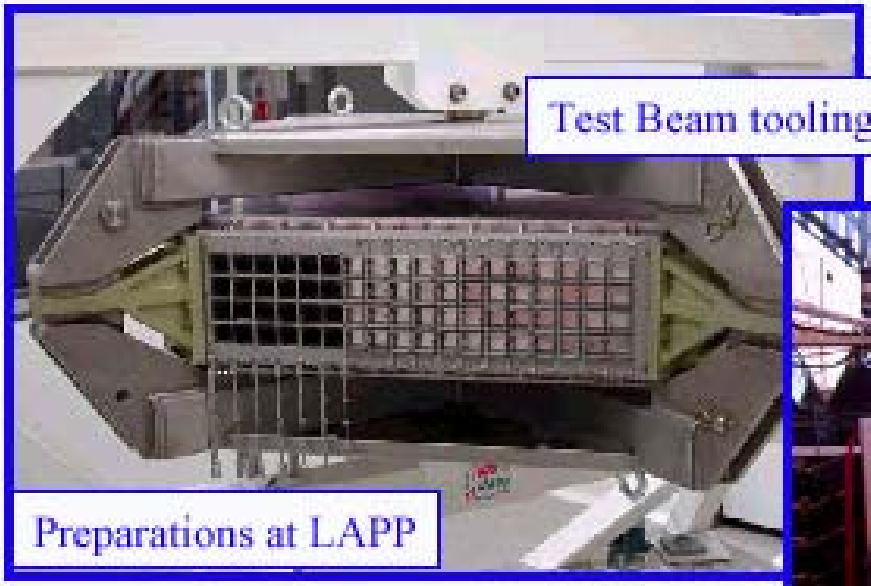
ECAL overview







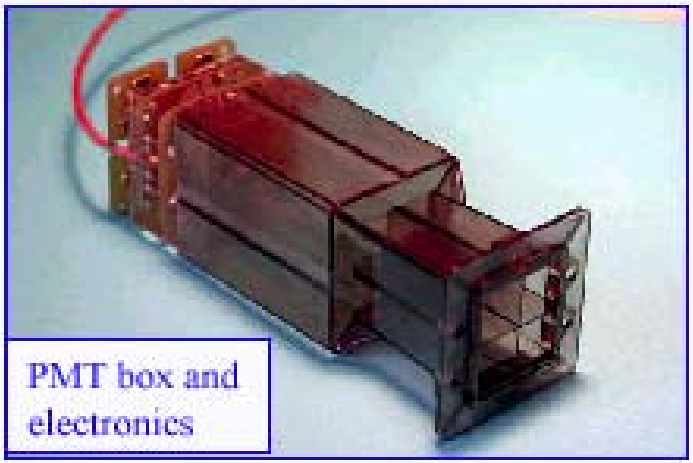
Photos of Ecal



Test Beam tooling and preparations

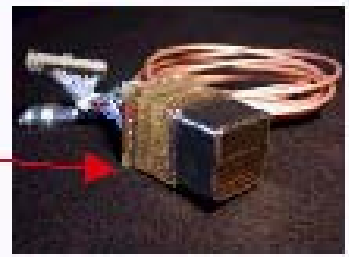
Preparations at LAPP

Preparations at CERN



PMT box and electronics

PMT with Electronics cards



ECAL Structural Testing

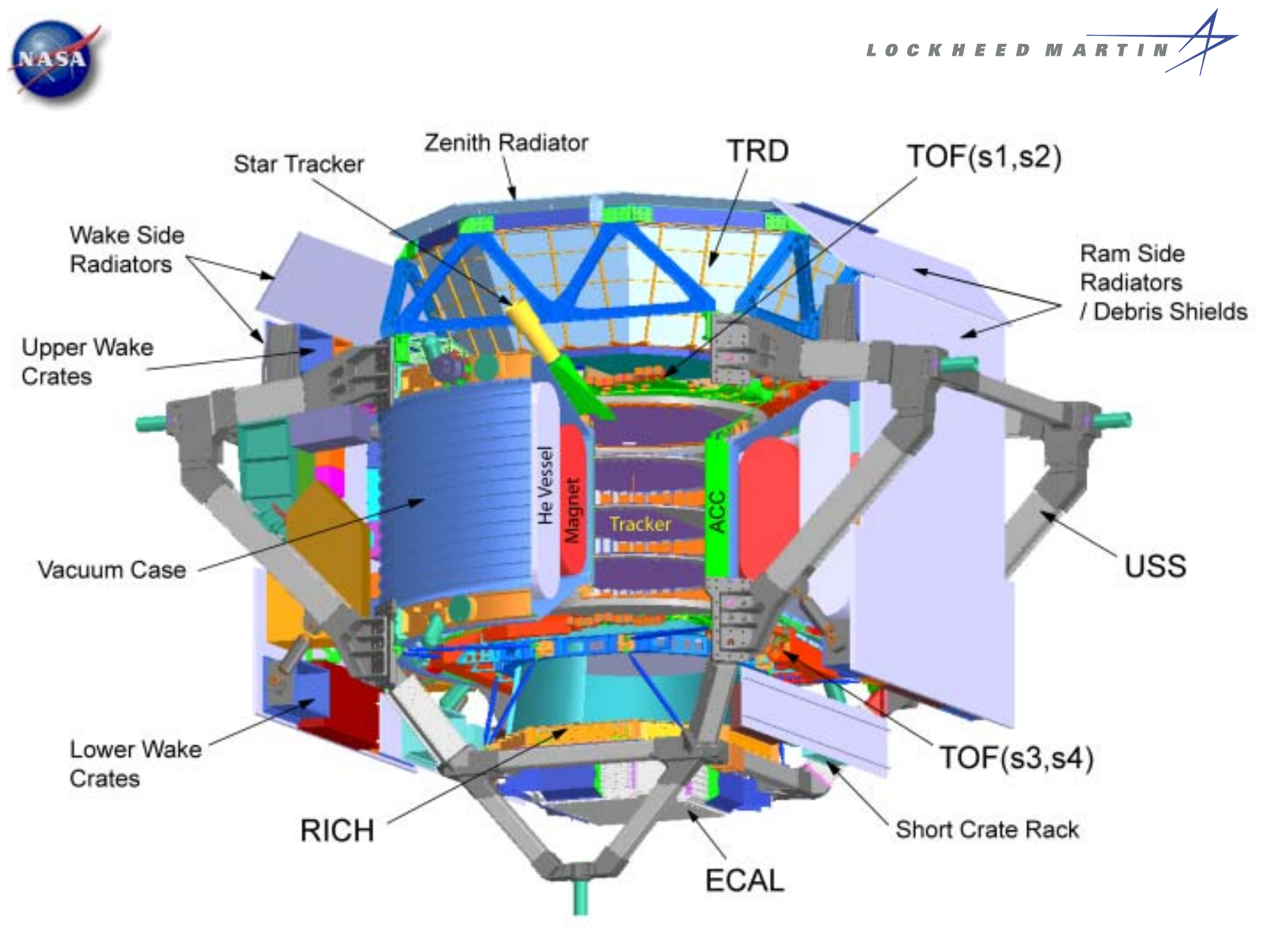
ECAL (Cont.)

- Primary Materials
  - Aluminum Housing & Brackets
  - Aluminum Honeycomb top and bottom plate
  - Lead Foil ‘pancake’ layers
  - Scintillating Fibers
  - BC 600 Epoxy
  - See Materials Presentation for Complete List
- Testing
  - Random Vibration of single PMT Tube (6.8 Grms) (Completed)
  - Thermal Vacuum Test of all PMT Tubes (In Progress)
  - Prototype Honeycomb Panels - static test to 1.4 x limit load (Completed)
  - Flight Honeycomb Panels – static test to 1.2 x limit load (Completed)
  - Prototype ECAL - Sine Sweep #1 (.25 g – 0-200 Hz) (Completed)
  - Prototype ECAL - random vibration (levels defined by LMSO) (Completed)
  - Prototype ECAL - Sine Sweep #2 (.25 g – 0-200 Hz) (Completed)
  - Prototype ECAL – Sine Burst Test to ~1.2 x limit load (Completed)
  - Prototype ECAL - Sine Sweep #3 (.25 g – 0-200 Hz) (Completed)
  - Flight ECAL – Sine Sweep (.25 g – 0-200 Hz)

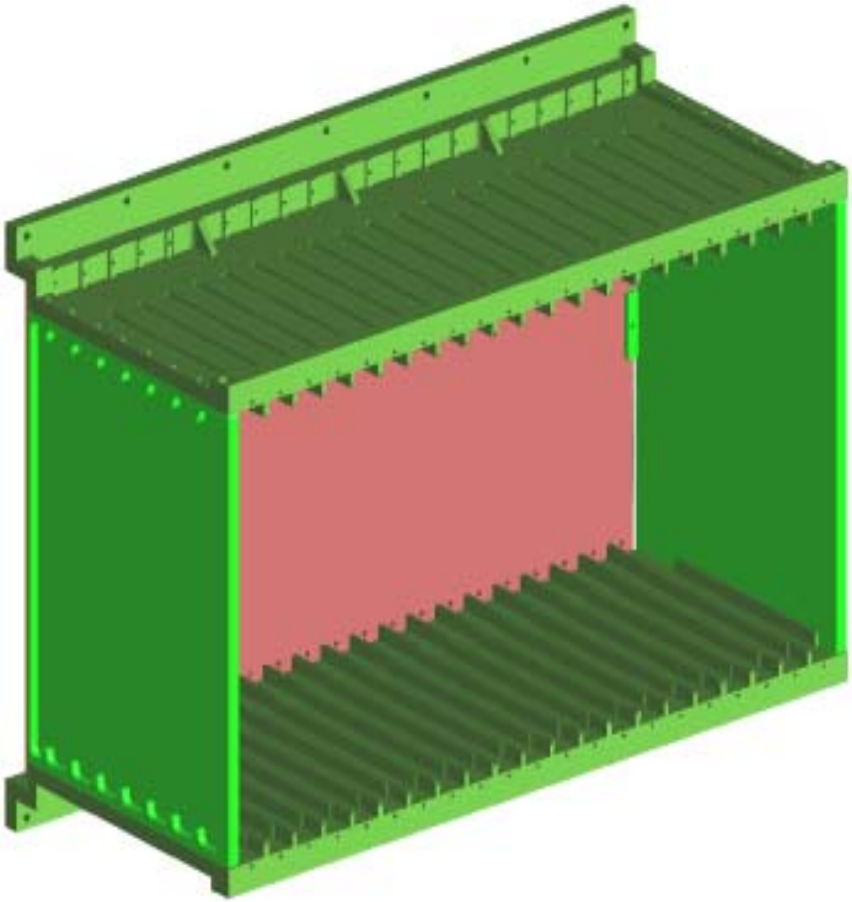
Electronic Crates

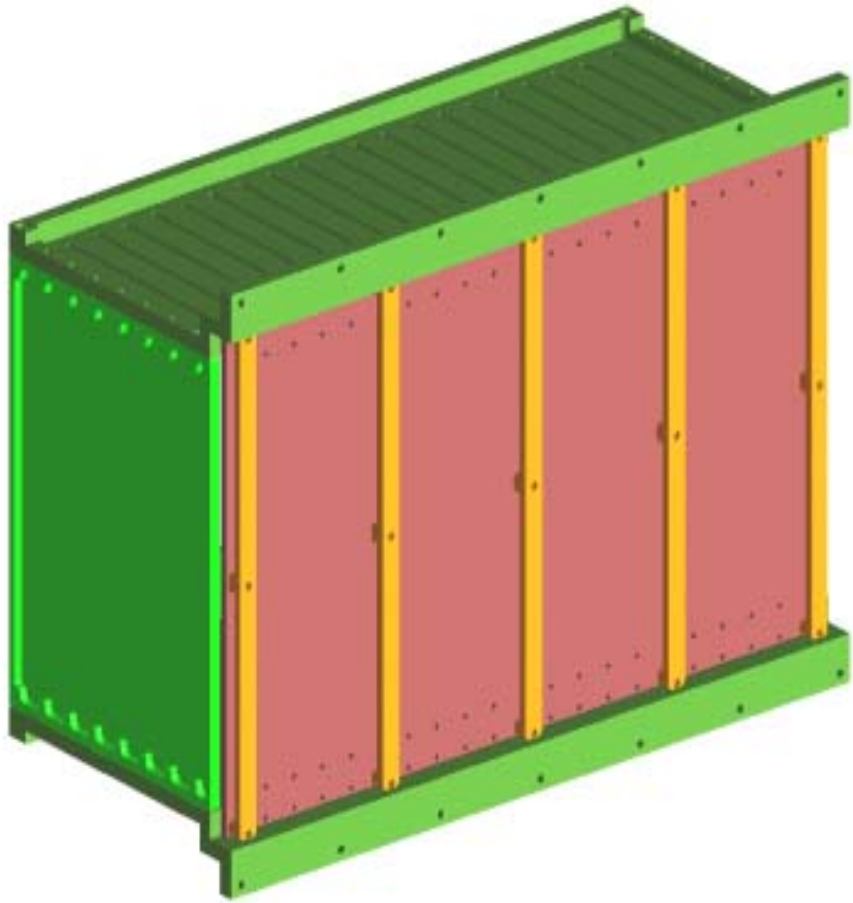
Electronics Crates

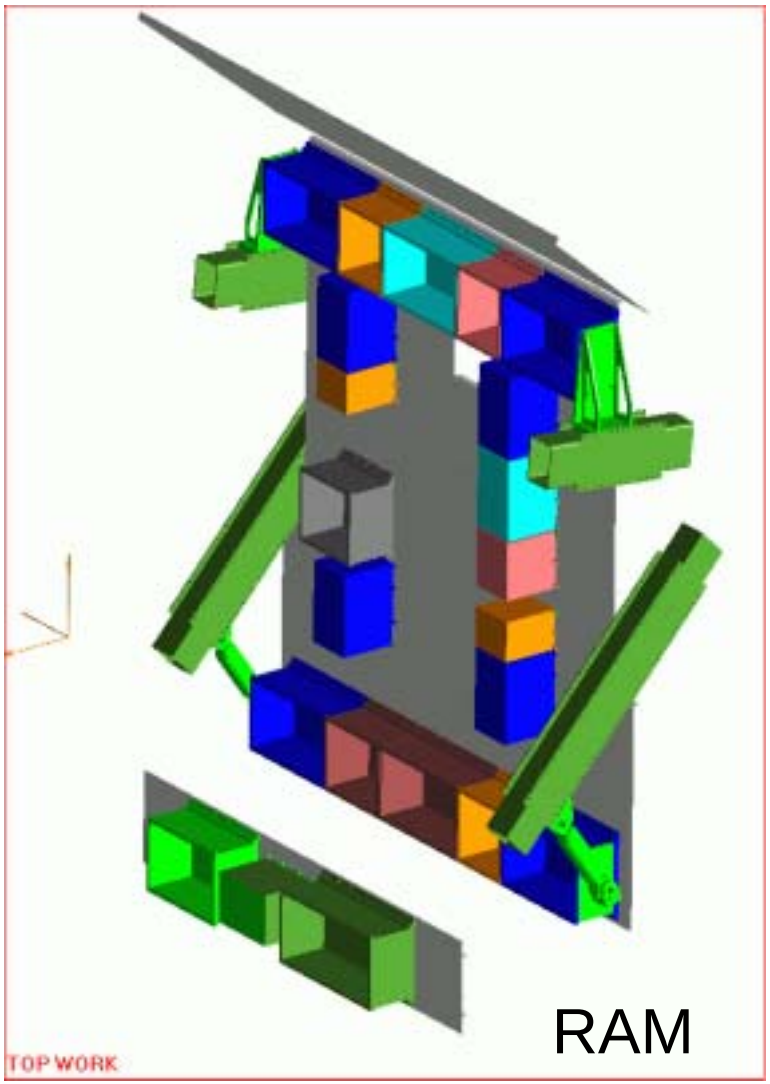
- Size, Location
  - 44 crates mounted at various points on the USS that form the support structure for the Ram & Wake Radiators
    - 24 crates are 195x293x(180-546) mm (8x12x(7-21) in)
    - 20 crates are 210x183x(145-295) mm (8x7x(6-12) in)
  - Altogether these crates contain ~600 printed circuit boards of 70 different designs
- Weight Estimate
  - Each Crate Varies, Most ~ 3.6-22 Kg (8-49 lbs)
  - Total Electronics Weight Budget (includes intercrate cables, cable clamps and other misc. items) = 460 Kg (1014 lbs)

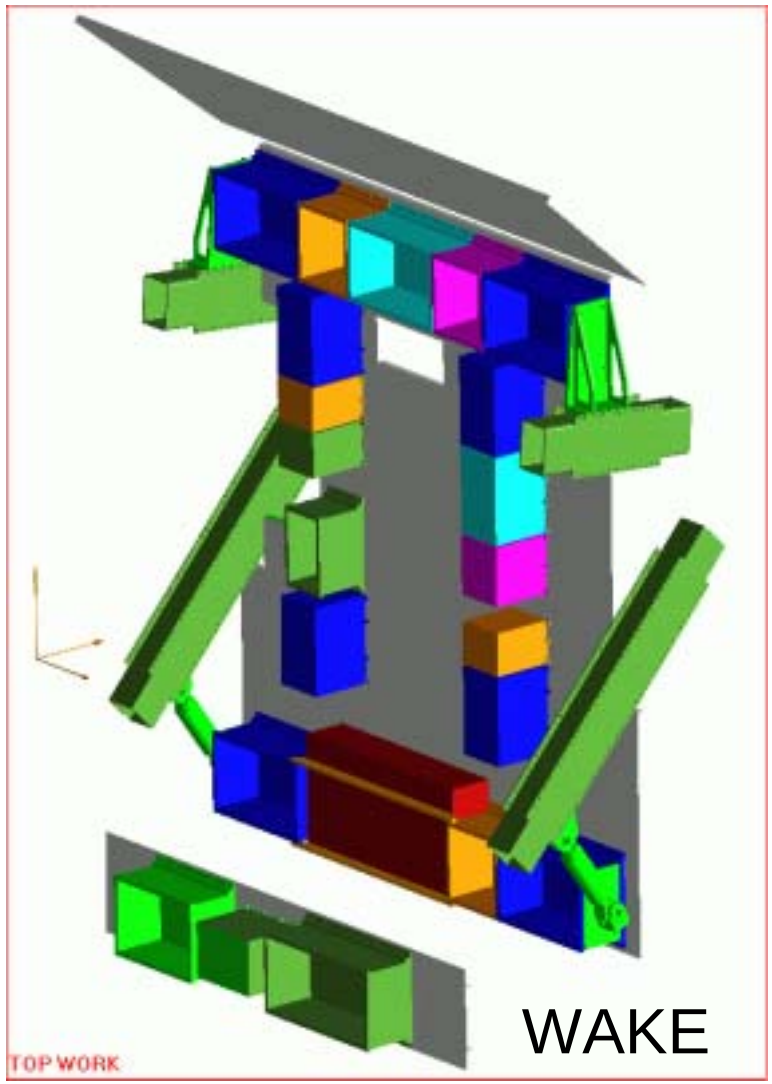

Star Tracker
Zenith Radiator
TRD
TOF(s1,s2)
Wake Side Radiators
Ram Side Radiators / Debris Shields
Upper Wake Crates
He Vessel
Magnet
Tracker
ACC
Vacuum Case
USS
Lower Wake Crates
TOF(s3,s4)
RICH
Short Crate Rack
ECAL

GARLO GAVAZZI






TOP WORK
RAM


TOP WORK
WAKE

Electronic Crates, Cont.

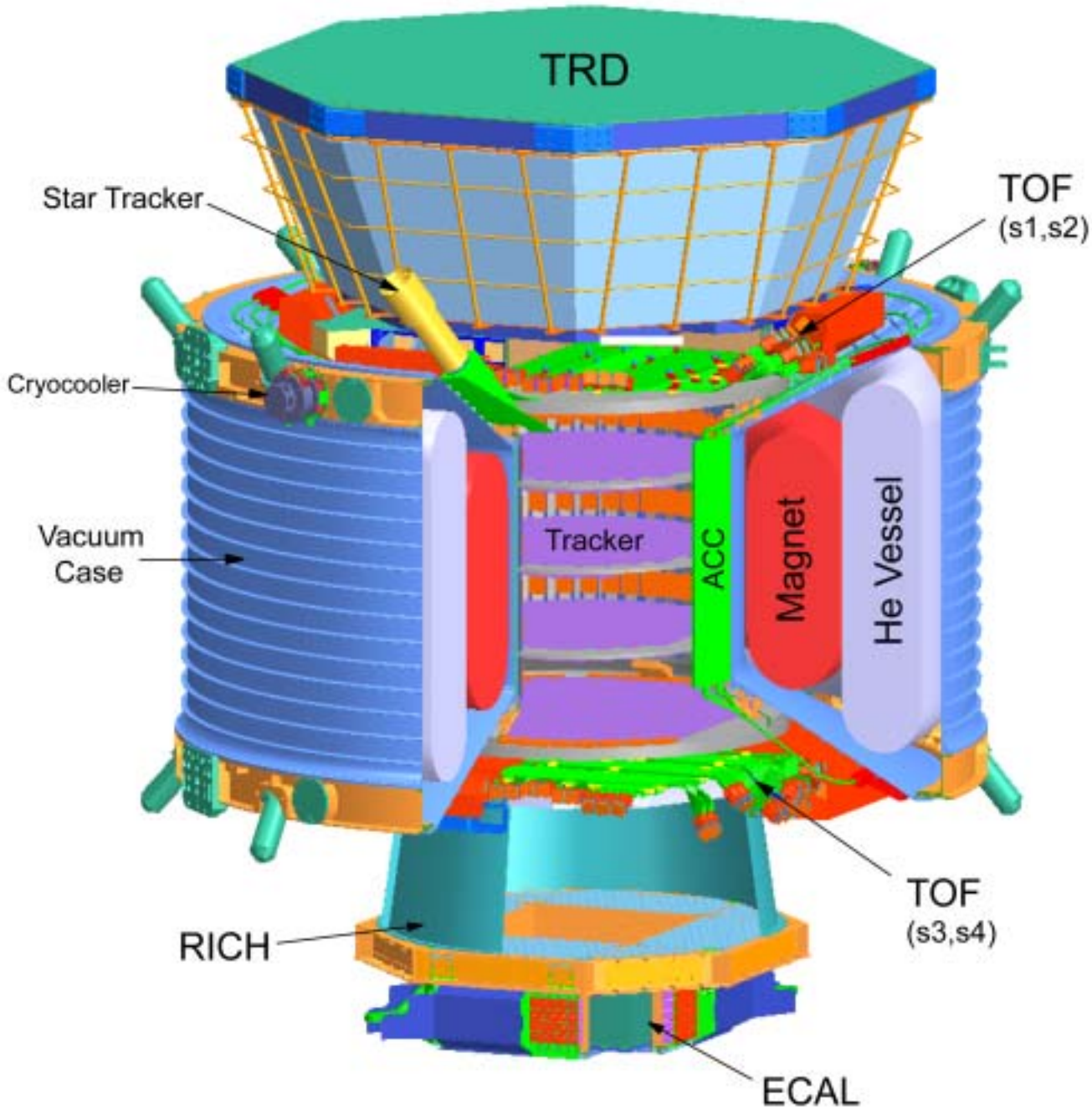
- Structural Verification
  - Electronic Crate Verification by analysis with Fs_{ult}=2.0 and Fs_{yld}=1.25
    - Secondary Structure Load Factors Dependent on Weight for crates not mounted to TCS
    - TCS load factors from inertial loads plus forced displacements used for all crates mounted to TCS radiators
- Components Minimum Margin of Safety:
  - Ram/Wake Radiator Mounted Electronic Crates = -.32 (working with LMSO to rectify this negative margin)
  - ECAL/RICH Radiator Mounted Electronic Crates = .44
- Components First Dynamic Frequency:
  - Overall Ram/Wake Radiator System = 34 Hz
  - Overall ECAL/RICH Radiator System = 103 Hz

Electronic Crates (Cont.)

- Structural Materials
  - 7075-T7351 Series Aluminum alloy for electronic crate structures
  - Solithane 113 for Conformal Coating
  - XL-ETFE insulated cables
  - See Materials Presentation for Complete List
- Testing
  - Ram/Wake Radiator Structural Test Article assembly with crate simulators will be tested during full payload modal test
  - Each crate will undergo
    - Random Vibration test to MWL will be performed for mission success reasons on the crates
    - Thermal vacuum tests on all crates
    - EMI/EMC & DC Magnetic Field testing for all crates

Star Tracker

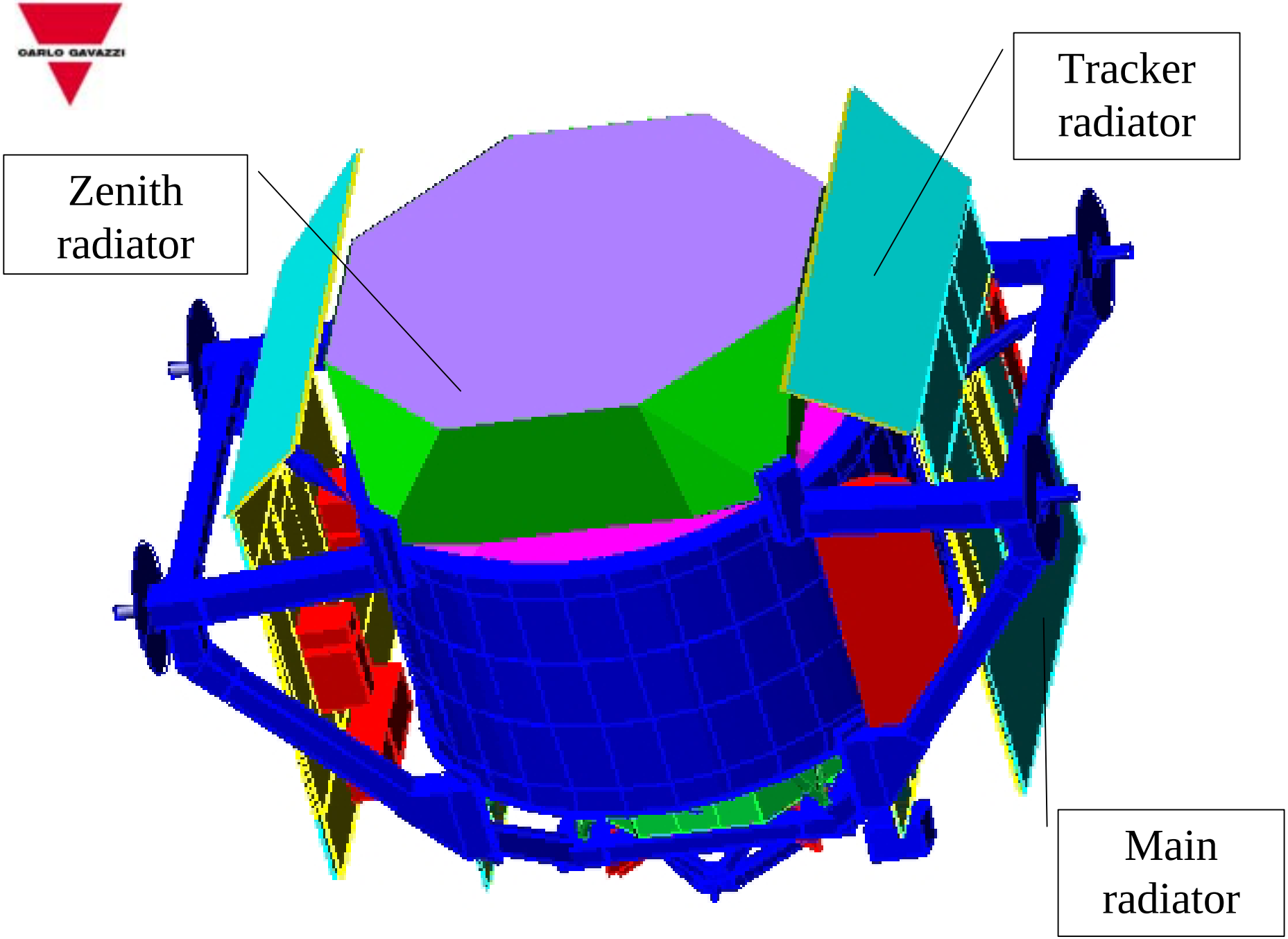
- 2 small subcomponents mounted to upper Tracker Plane and Conical Flange
- Total Weight = 3.3x2 Kg (15 lbs)
- Designed to 15 g Load Factor
- Margins of Safety = TBD
- Testing
  - Vibration to MWL
  - Thermal Vacuum
  - EMI/EMC


TRD
Star Tracker
TOF
(s1,s2)
Cryocooler
Vacuum
Case
Tracker
ACC
Magnet
He Vessel
TOF
(s3,s4)
RICH
ECAL

Thermal Control System

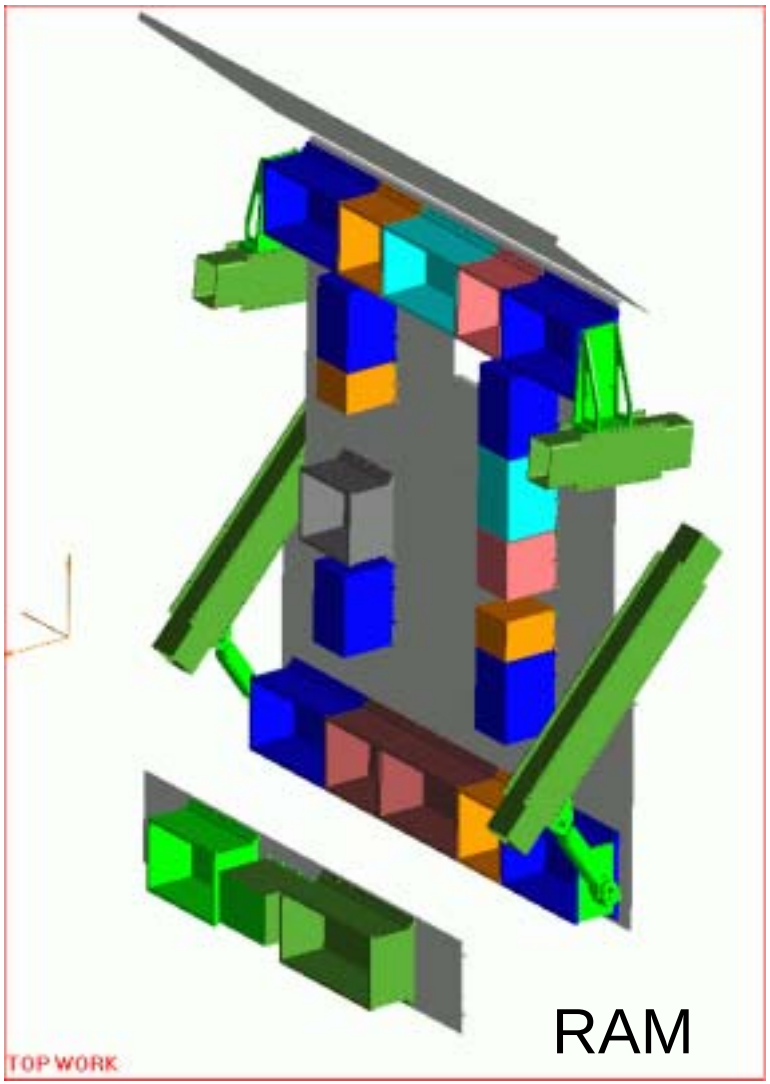
Thermal Control System

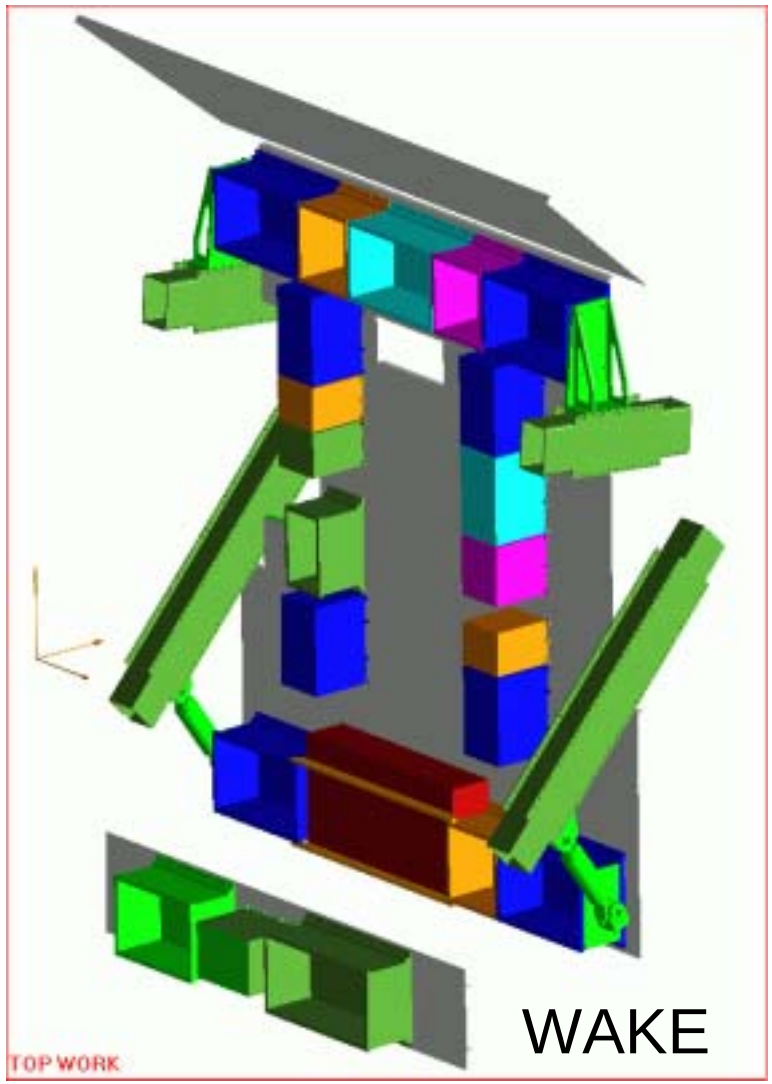
- Overall TCS discussed in another presentation
- Radiator Systems
  - Ram/Wake Radiators
  - ECAL/RICH Crates Radiators
  - Zenith (Cryocooler) Radiator
  - Tracker Ram/Wake Radiators
- Tracker Thermal Control System (TTCS) Overview (Details in another presentation)
- Total TCS weight w/o crate supports 311 Kg (686 lbs)


Zenith radiator
Tracker radiator
Main radiator

TCS (Cont.)

- Ram & Wake Radiator System
  - Aluminum Honeycomb
  - Electronic Crates provide stiffness to large flat plates
  - Aluminum Heat Pipes filled with Ammonia
    - Small amounts of Ammonia needed
    - Completely sealed system
  - Minimum Margins of Safety = TBD
  - First natural frequency: 34 Hz
  - Structural Test Article will be built and tested with full AMS payload during static and modal test

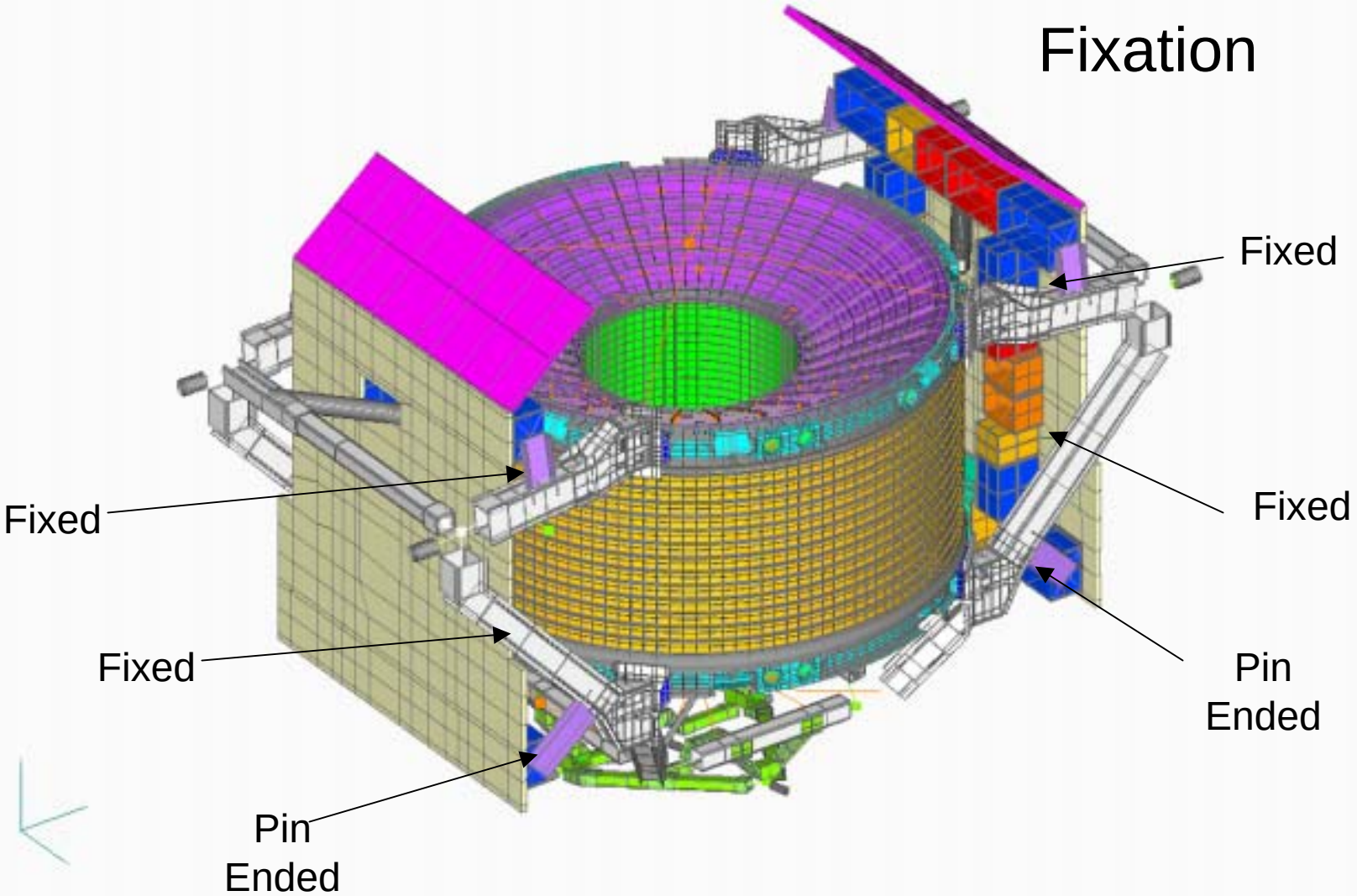

TOP WORK
RAM


TOP WORK
WAKE

Attachment and Loads

- Fixation to USS-02
  - Fixed at upper USS-02 via Electronic Crates
  - Fixed in center of Radiator via mounting bracket
  - Pin Ended Strut to bottom of radiator via Electronic Crates
- Design Loads
  - Liftoff – Applied about CG of entire payload
    - Nx= ±5.7g, Ny= ±1.6g, Nz= ±5.9g
    - Rx=±10 rad/sec^2, Ry= ±25 rad/sec^2, Rz= ±18 rad/sec^2
  - Landing – Applied about CG of entire payload
    - Nx= ±4.5g, Ny= ±2.0g, Nz= ±6.5g
    - Rx=±20 rad/sec^2, Ry= ±35 rad/sec^2, Rz= ±15 rad/sec^2
  - Inertia loads plus forced displacement

Fixation



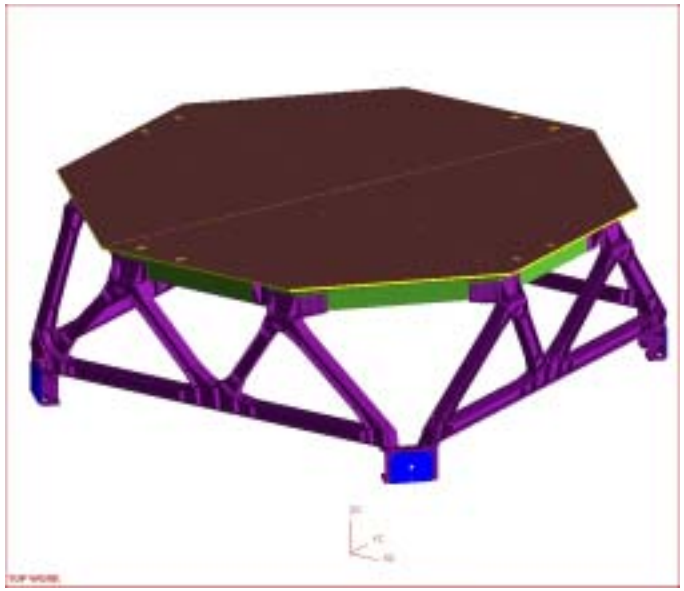
TCS, Cont.

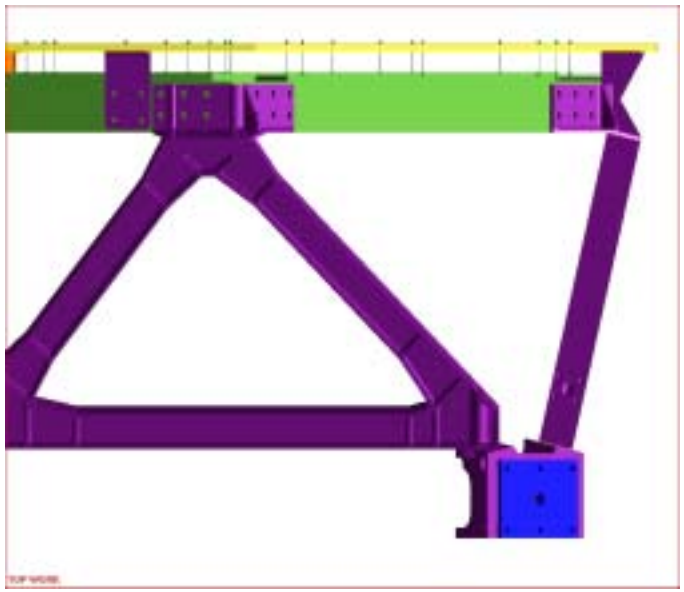
- ECAL/RICH Crates Radiators
  - Aluminum Plate Radiator
  - Electronic Crates Mounted directly to plate
  - Minimum Margins of Safety = TBD
  - First Natural Frequency = 103 Hz

TCS (Cont.)

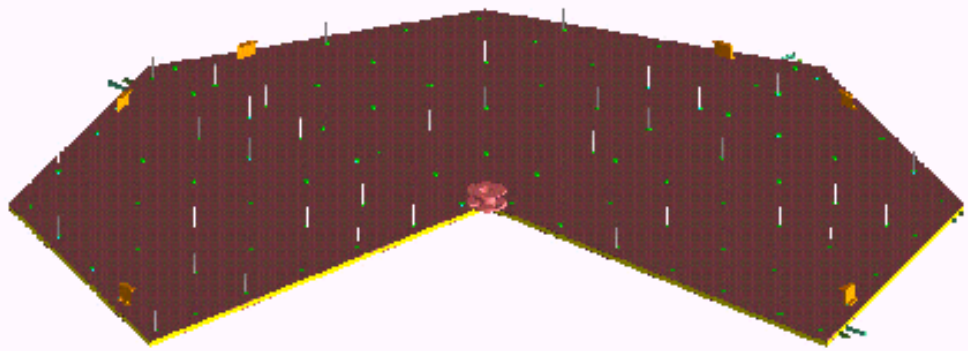
- Zenith Radiator
  - 1.6 mm aluminum upper face sheet
  - 0.3 mm aluminum lower face sheet
  - 10 mm Rohacell core
  - Aluminum tubes (3 mm OD, 2 mm ID)
  - Tubes soldered to upper face sheet
  - Bimetallic interface where aluminum tubes transition to stainless steel tubes before running down the structure and attaching to the Cryocoolers
  - Supported in the Z direction by 10 thermally isolating spokes on each quadrant that are 3 mm diameter and 35 mm long
  - Also supported by 2 aluminum brackets – 1 fixed in all directions & located at edge – 1 in center fixed in tangential direction (relative to outer support) & flexible in radial direction
  - Acoustically susceptible – 12 G Acoustic Load (3-sigma)
  - Minimum Margin of Safety = 0.14 on isolating spokes
  - First Natural Frequency = 63 Hz

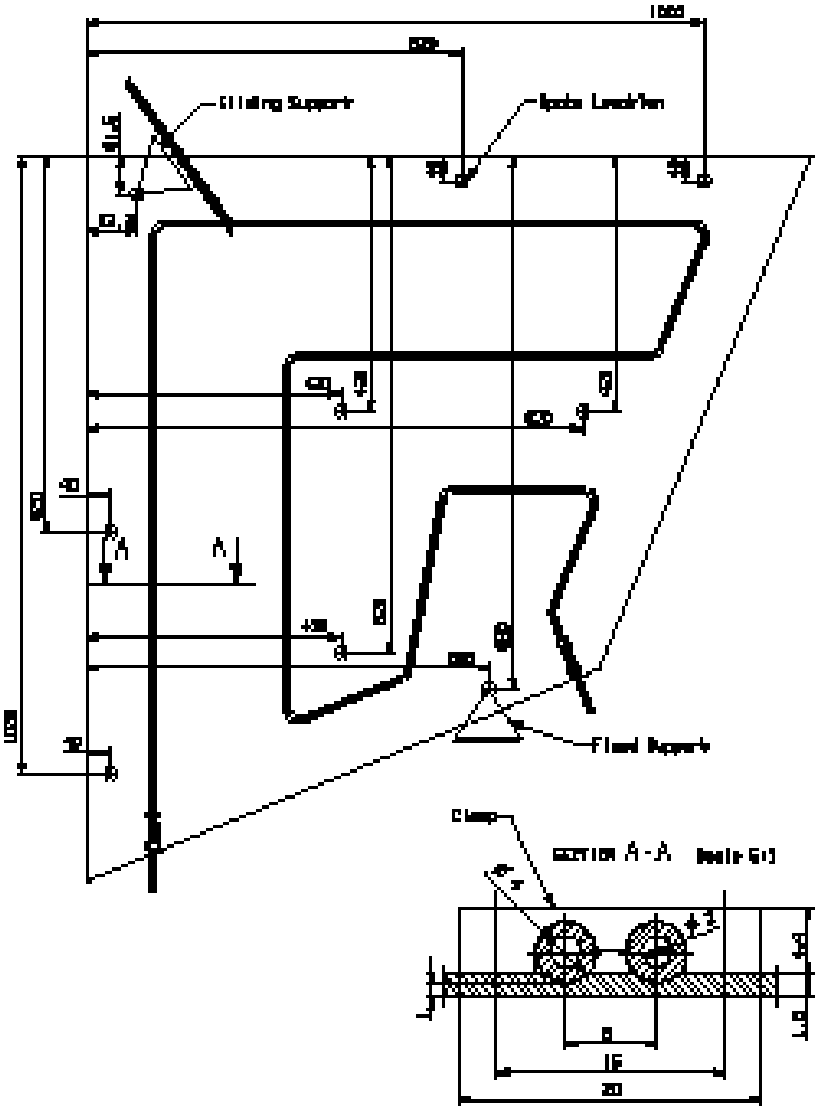
Zenith Radiator for Cryocoolers

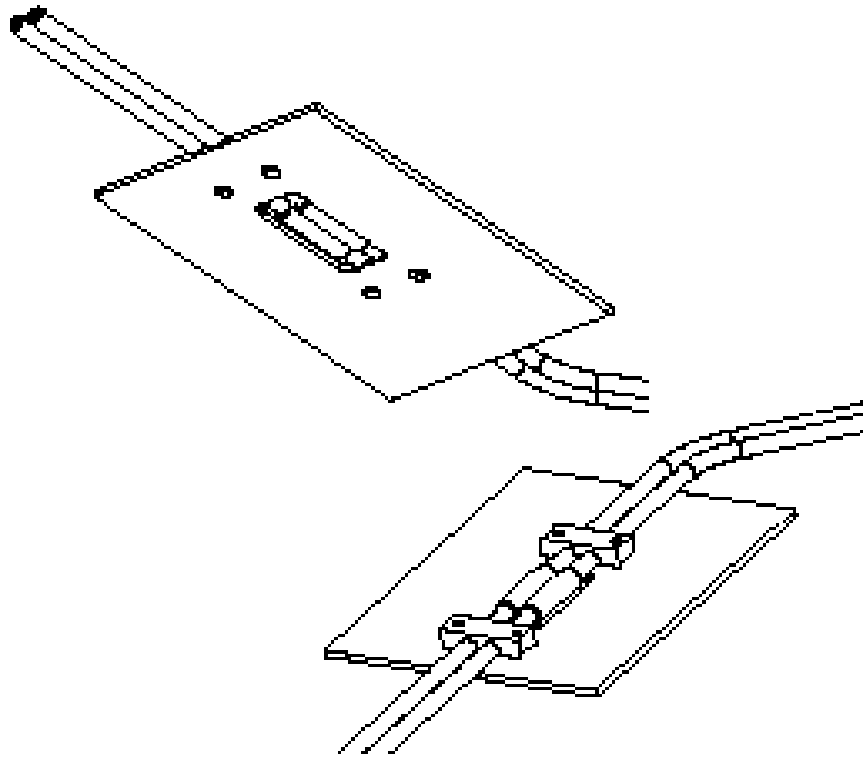




Radiator with one section removed

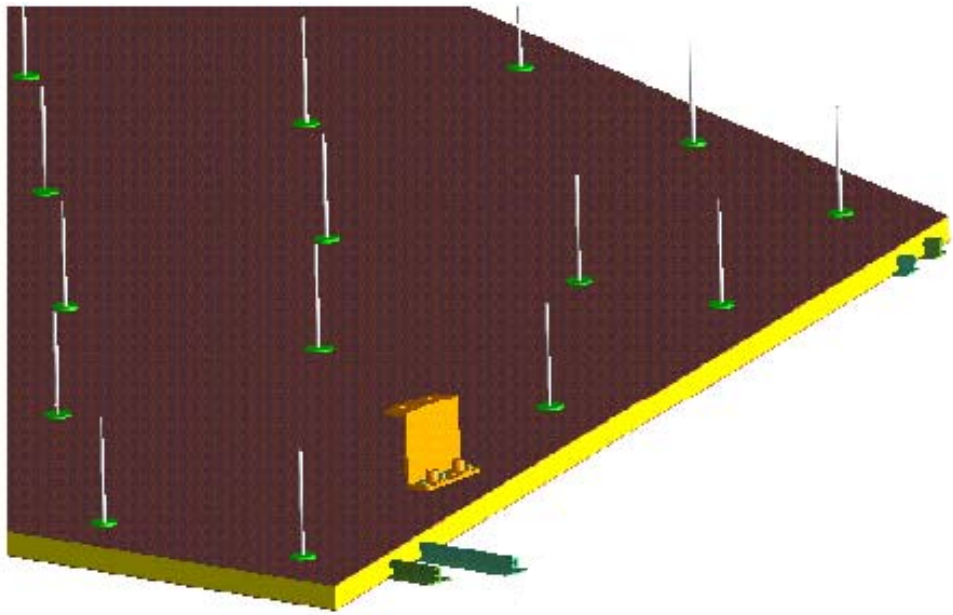


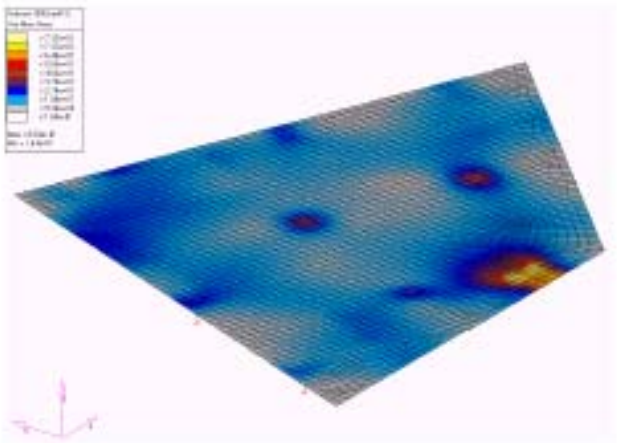


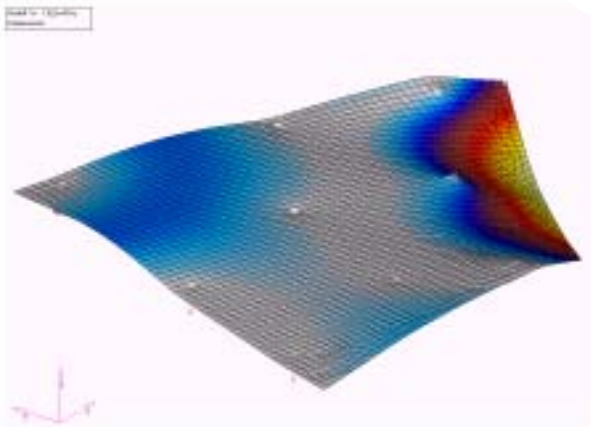


Zenith Radiator Condenser Layout and attachment to upper plane of honeycomb

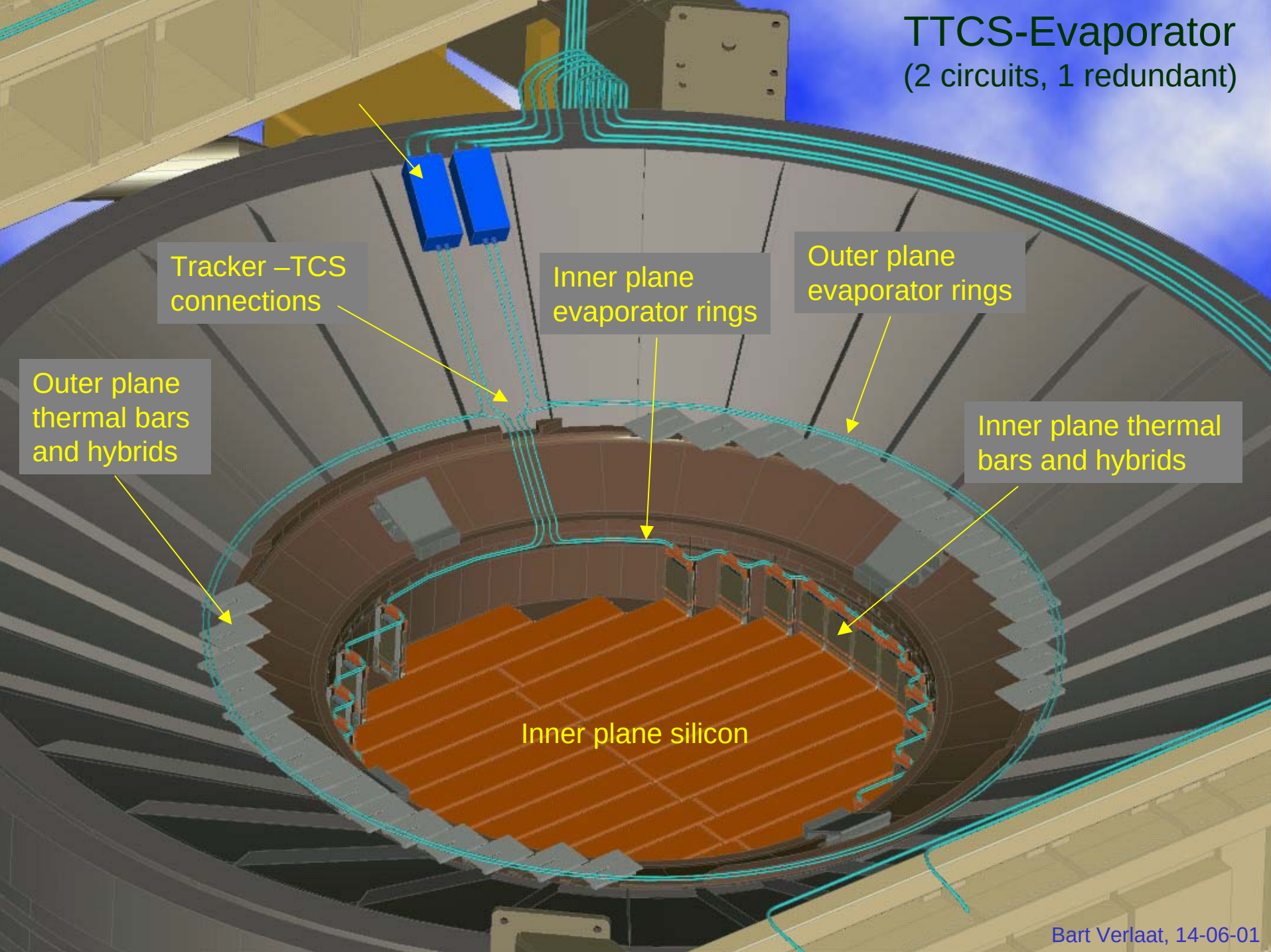
Zenith Radiator Layout and FEM

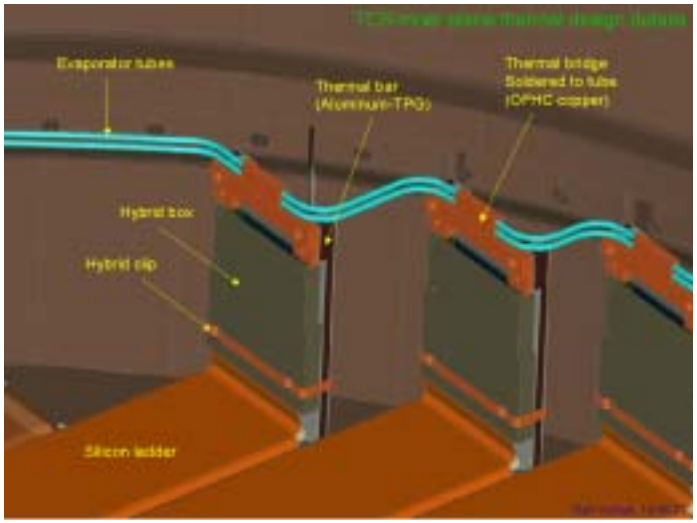




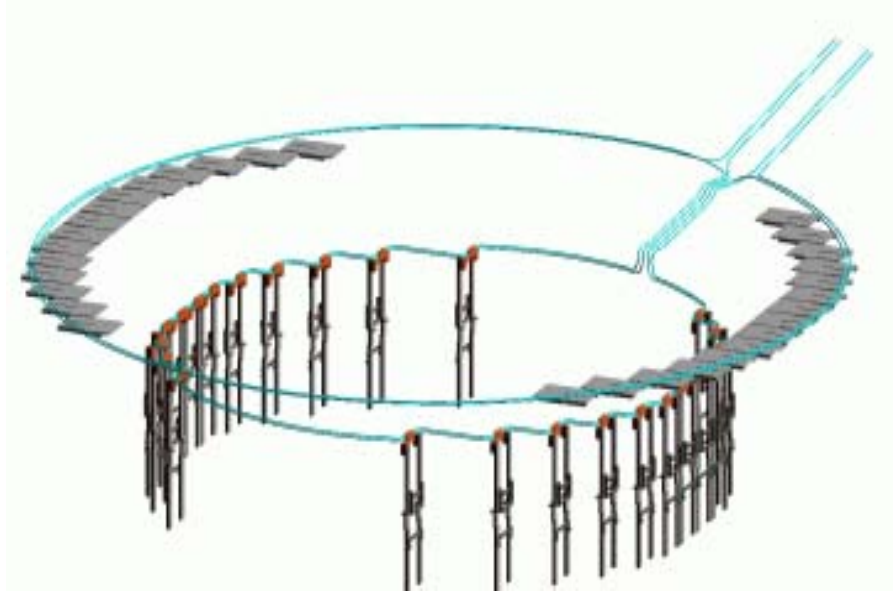


TTCS-Evaporator
(2 circuits, 1 redundant)

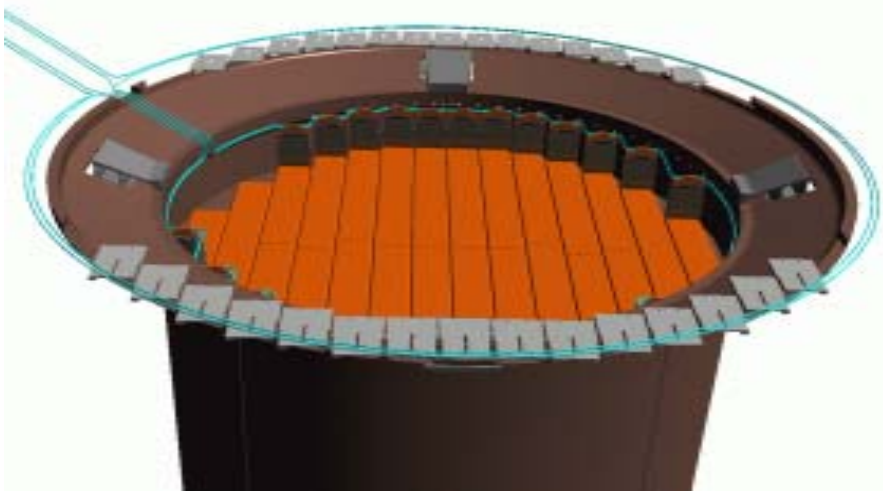




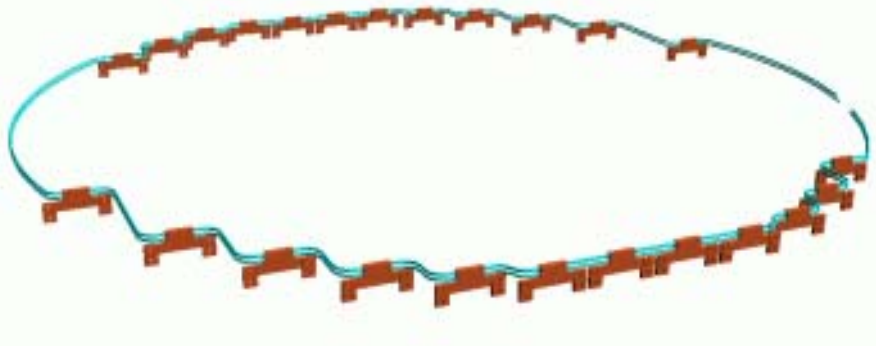
TTCS evaporator connection to inner thermal bars



Complete thermal system in side the tracker (Thermal bars+ evaporators)

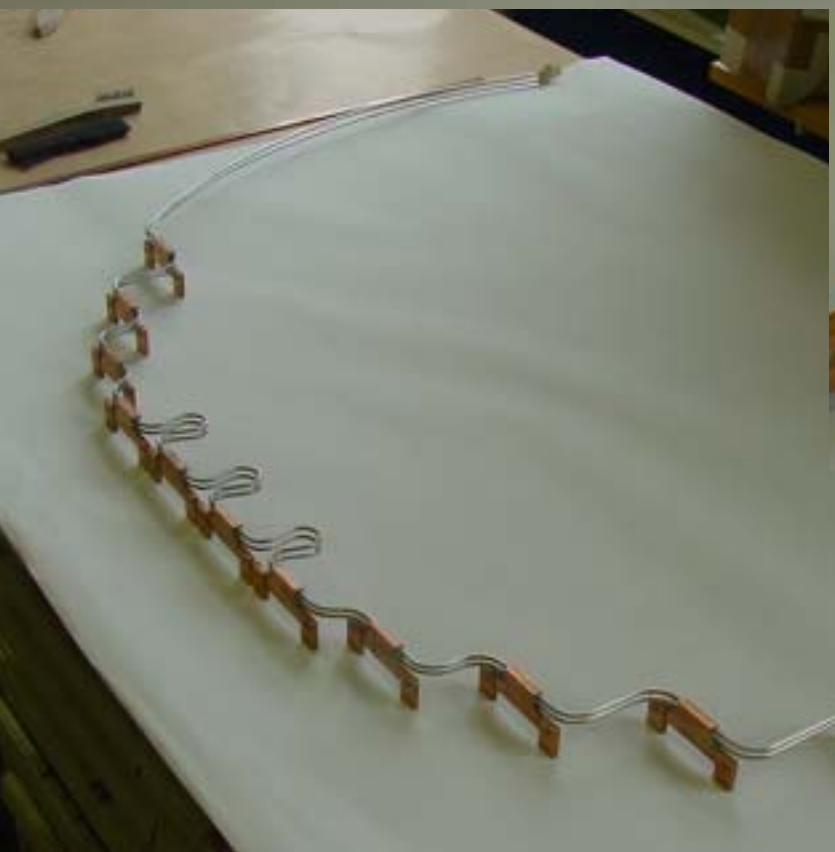


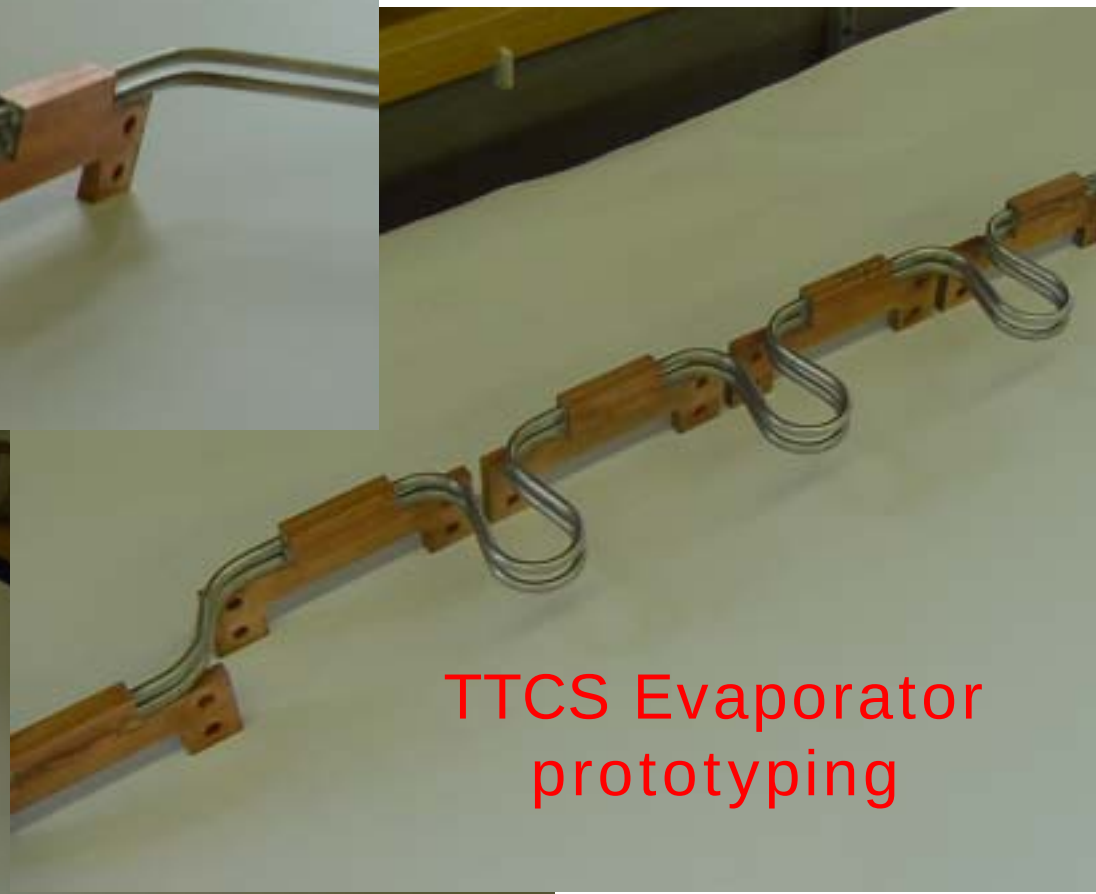
Complete overview of one evaporator in the Tracker



Inner planes evaporator

TTCS Evaporator design overview





TTCS Evaporator prototyping

NIKHEF

Weight Summary

AMS-02 WEIGHT

LOCKHEED MARTIN

(IN ORBITER PAYLOAD BAY AND ON ISS TRUSS ONLY)

	AMS EXPERIMENT HARDWARE	CDR May, 2003 (LBS)	CDR May, 2003 (KG)
1	ANTICOINCIDENCE COUNTER (ACC) (w/ STRUCTURE TO VC)	117	53
2	TRACKER (w/ STRUCTURE TO VC, TTCS EVAPORATOR, & LASER ALIGNMENT SYSTEM)	438	198.5
3	TIME OF FLIGHT (TOF) (w / BOTH UPPER & LOWER SUPPORT STRUCTURES)	525	238
4	TRANSITION RADIATION DETECTOR (TRD) (WITH SUPPORT STRUCTURE)	723	328
5	TRD GAS SUPPLY SYSTEM (WITH HOUSING, 3 TANKS, PLUMBING, VALVES, CONTROLLER, AND INTERNAL & EXTERNAL MOUNTING BRACKETS)	258	117
6	RING IMAGING CHERENKOV COUNTER (RICH) (W/MOUNTING BRACKETS TO LOWER USS-02)	406	184
7	ELECTROMAGNETIC CALORIMETER (ECAL) (W/ MOUNTING BRACKETS TO LOWER USS-02)	1407	638
8	ALL AVIONICS CRATES (WITH STAR TRACKER, CABLES BETWEEN CRATES, CONNECTORS, CLAMPS, MISC. MOUNTING BRACKETS, CRATE SUPPORT STRUCTURES NOT INCLUDED WITH TCS, ETC. CAB & CCEB ARE INCLUDED WITH THE CRYOMAGNET WEIGHT; ALL EXPERIMENT COMPONENT CABLE WEIGHT INC	1014	460
9	CRYOMAGNET SYSTEM (INCLUDES MAGNET & STRUCTURE, SFHe TANK, CRYOSYSTEM, SUSPENSION, ALL VC PORT CONNECTIONS/COVERS, VENT PUMP, ALL INTERNAL & EXTERNAL PLUMBING, CRYOCOOLERS WITH MOUNTING BRACKETS, RELIEF DEVICES, "HELIOMATIC"/PNEUMATIC VALVE SUPPLY TANK, C	5196	2357
10	THERMAL CONTROL SYSTEM (TCS) (INCLUDES HEAT PIPES, LOOP HEAT PIPES, PUMPS, RADIATORS, SUPPORT STRUCTURES, CONDENSERS, PRE-HEATERS, CO2 RESERVOIR, VALVES, ETC. ALSO INCLUDES SOME SUPPORT STRUCTURE THAT WILL CARRY ELECTRONICS CRATES.)	686	311
11	CONTINGENCY	213	96.5
12	**AMS EXPERIMENT HARDWARE TOTAL:**	**10981**	**4981**

AMS-02 WEIGHT

LOCKHEED MARTIN

(IN ORBITER PAYLOAD BAY AND ON ISS TRUSS ONLY)

	SPACE SHUTTLE INTEGRATION HARDWARE	CDR May, 2003 (LBS)	CDR May, 2003 (KG)
13	UNIQUE SUPPORT STRUCTURE - 02 (CARRIES 14,809 lbs on STS)	1592	722
14	CRYOMAGNET VACUUM CASE (CARRIES 14,809 lbs on STS)	1587	720
15	BRACKETS, MISC. FASTENERS & HARDWARE, SAFETY WIRE	23	10
16	THERMAL BLANKETS (TRD SIDES, ECAL BOTTOM, RICH SIDES, & +/-Y SIDES ON VACUUM CASE - NO OTHER BLANKETS ARE INCLUDED IN THIS WEIGHT)	35	16
17	SHUTTLE INTEGRATION HARDWARE CONTINGENCY	0	0
19	**SHUTTLE INTEGRATION HARDWARE TOTAL:**	**3238**	**1469**

	ISS INTEGRATION HARDWARE	(LBS)	(KG)
20	ISS PAS/UMA INTERFACE HARDWARE WITH CABLES (CARRIES 14,809 lbs on ISS)	225	102
21	GRAPPLE FIXTURES (1 FRGF & 1 PVGF), BRACKETS, & CABLE TO EBCS	131	59
22	MICROMETEORITE/ORBITAL DEBRIS (M/OD) SHIELDS & SUPPORTS	102	46
23	EVA CONNECTOR PANEL, SCUFF PLATES & BRACKETS	55	25
24	PAYLOAD DISCONNECT ASSEMBLY (PDA) FOR THE REMOTELY OPERATED ELECTRICAL UMBILICAL (ROEU) WITH MOUNTING BRACKETS, CABLES & CONNECTORS	36	16
25	EVA HANDRAILS & PORTABLE FOOT RESTRAINT (PFR) INTERFACE	16	7
26	EXTERNAL BERTHING CAMERA SYSTEM (EBCS), MOUNTING BRACKETS & HEATER CABLES	25	11
27	ISS INTEGRATION HARDWARE CONTINGENCY	0	0
28	**ISS INTEGRATION HARDWARE TOTAL:**	**590**	**268**

AMS-02 WEIGHT

(IN ORBITER PAYLOAD BAY AND ON ISS TRUSS ONLY)

	TOTAL WEIGHT SUMMARY	CDR May, 2003 (LBS)	CDR May, 2003 (KG)
29	AMS EXPERIMENT HARDWARE TOTAL:	10981	4981
30	SHUTTLE INTEGRATION HARDWARE TOTAL:	3238	1469
31	**TOTAL EXPERIMENT & SHUTTLE INTEGRATION HARDWARE WEIGHT:**	14219	6450
32	ISS INTEGRATION HARDWARE TOTAL:	590	268
33	**TOTAL PAYLOAD WEIGHT:**	14809	6717
34	**TOTAL CONTROL WEIGHT:**	14809	6717
35	TOTAL OVER/UNDER CONTROL WEIGHT:	0	0