

***NASA/Goddard Thermal Technology
Overview 2012***

***Dan Butler and Ted Swanson
NASA/GSFC***

***Aerospace Spacecraft Thermal Control Workshop
March 20-22, 2012***

So What's NASA's Future Budget Look Like Now??



- President's Proposal for FY13 – \$17.71B, a slight decrease from the enacted FY12 budget, but a 5.4% drop from FY10
 - Seems to be less controversial than last year...stay tuned
- Major Goals:
 - Nearly \$3B for the congressionally mandated Space Launch System (SLS) heavy-lift rocket and the Orion deep-space exploration. No mission yet defined for these vehicles.
 - Nearly \$830M for the Commercial Crew Program
 - *Significant increase* for the Space Technology program, \$699M (from \$575M in FY12).
 - JWST survives...about \$630M in FY13. Now still on track for 2018 launch.
 - Big hit to Planetary Program...\$1.2B (from \$1.5B)
 - 40% cut to Mar's Program (no 2016 or 2018 missions with ESA)
 - No guaranteed new starts for some time.
 - Lunar science program gone.
- SOMD and ESMD combined into one directorate, Human Exploration and Operations Mission Directorate (HEOMD)
- Reductions in SBIR Program; Thermal Control may be rotated out for one year

NASA's OCT is Up and Operating

Space Technology Status



- Space Technology included in NASA Authorization Act of 2010
- FY 2011 Operating Plan funded Space Technology at approximately \$350M
- Space Technology Program account (SPTX) created and appropriated in FY 2012 at \$575M
- Three months into execution, Space Technology Program has taken the “first step”
 - formulated a “Portfolio” with 10 programs
 - combination of new programs and existing programs
 - combination of directed and new, competitively selected content transitioned from ~400 FTE in FY 2011 to ~900 FTE in FY 2012
- Portfolio Commitment Agreement (PCA) signed August 2011
- Established processes – OCT PMC (equivalent to DPMC)
- Program execution
 - Selected and initiated new projects
 - Executing over 1000 projects

Recent OCT Program AOs for FY13



- **Edison Small Satellite Demonstration Missions**
 - AO for; close proximity operations for small S/C, propulsion for CubeSats, or novel communication for SmallSats
 - Multiple awards, \$10M for 2 years or \$15M for three years, from TRL 5/6 to TRL 7, proposals due May 20th
- **Technology Demonstration Missions**
 - AO for “Green Propulsion” as a replacement for hydrazine
 - \$50M plus 25% contribution from non-OCT, from TRL 5/6 to TRL 7, proposals due April 30th
- **Suborbital Technology Development – SIGNIFICANT THERMAL OPPORTUNITIES**
 - To go from TRL 3 to 5, proposals due March 26th
 - Payloads to Develop Space Technologies – up to 15 awards, \$50K to \$500K each...including **two-phase devices, variable heat rejection technology, etc.**
 - Vehicle Capability Enhancements and Onboard Research Facilities for Payload Accommodation – up to 5 awards, to \$500K

NASA Space Technology Roadmap (STR); the 14 Technology Areas (TAs) identified by OCT



TA01		• LAUNCH PROPULSION SYSTEMS	*	TA08		• SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS
TA02		• IN-SPACE PROPULSION TECHNOLOGIES		TA09		• ENTRY, DESCENT & LANDING SYSTEMS
TA03		• SPACE POWER & ENERGY STORAGE	*	TA10		• NANOTECHNOLOGY
* TA04		• ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS	*	TA11		• MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING
* TA05		• COMMUNICATION & NAVIGATION	*	TA12		• MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING
TA06		• HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS	*	TA13		• GROUND & LAUNCH SYSTEMS PROCESSING
TA07		• HUMAN EXPLORATION DESTINATION SYSTEMS	*	TA14		• THERMAL MANAGEMENT SYSTEMS

* = Technology Areas with GSFC team member

Quick Summary of OCT Technology Roadmap Status



- **Summer of 2010 - OCT directed the development of 14 Technology Assessment Roadmaps (TAs) to assess NASA's technology and future needs.**
 - Matching needed technologies to planned missions was hampered by lack of clarity for human missions
 - Roadmaps were intended to be *Agency* technology Roadmaps, not OCT Roadmaps
- **The National Academies was contracted to assess these Technology Roadmaps**
 - *largely viewed as an NRC "Decadal Study" for technology; significant visibility – puts technology on the radar for now*
- **February 1, 2012 - the NRC released its final report; 463 pages, numerous observations, findings and recommendations**
 - The 320 NASA identified technologies were narrowed down *16 top priority technologies* by NRC.
 - NRC selections reflect near term opportunities (5 year horizon)
 - Press response to NRC report generally quite positive; many stress NASA's depleted technology inventory, as recognized by the NRC report
- **Given the numerous recommendations and, for some technologies, very high costs/long lead time to develop, it is unclear how the NRC report will drive future OCT funding decisions. Assumed to act as a guideline.**
 - OCT prioritization will be an ongoing effort; TA teams to take first cut
- **Next steps – TA teams respond to NRC then release final TA document this summer**



TA14 – Technology Recommendations. Future missions require high heat rejection, high heat flux levels, cryogenic propulsion stages, operation/survival in extreme environments, and high energy atmospheric reentry trajectories. Based on these criteria, the Thermal Management TA has prioritized the following top 10 technical challenges:

- **Mid-density ablator materials and systems for exo-LEO missions (near term)**
 - enabling technology needed for dual heat pulse reentries & >11 km/s entries
- **Innovative thermal components and loop architecture (near term)**
 - enabling technology offering significant mass/power savings and increased reliability while maintaining crew safety
- **20K Cryocoolers & propellant tank integration (near term)**
 - minimize boil off & decrease required propellant mass for long duration space missions
- **Low Conductivity Structures/supports (near term)**
 - reduce structure-derived heat leaks & minimize active cooling power requirements
- **Inflatable/Flexible/Deployable heat shields (far term)**
 - enable the consideration of an entirely new class of missions to the Martian surface



- **Two-phase Heat Transfer Loops (near term)**
 - demonstration of fundamental thermophysical properties in partial & μ gravity environments
 - flight demonstration of LHP's with multiple evaporators & condensers
- **Obsolescence-driven TPS materials and processes (near term)**
 - development of replacement cryoinsulation, primer, adhesive, & ablator TPS materials
- **Supplemental Heat Rejection Devices (SHReDs) (near term)**
 - development of heat rejection hardware for transient, cyclical applications
 - evaporative heat sink development efforts focused on efficient use of consumable fluids
 - phase change material (PCM) heat exchanger development focused on improving specific energy storage density
- **Hot structures (mid-term)**
 - high-temperature materials, environmental coatings, material characterization, structural design and manufacturing processes, life & damage assessment methods
- **Low temperature/power cryocoolers for science applications (mid-term)**
 - enable operation of detectors for scientific observation of the universe
 - advances in size, efficiency & reduced vibration/interference are needed



The NRC's Report on NASA's Roadmaps

Full 463 page report available at: http://www.nap.edu/catalog.php?record_id=13354



DISCLAIMER: The following slides are taken from the NRC briefing to NASA; they should not be interpreted as our Agency's position, priorities or plans.

NRC Observations on NASA's Space Technology

(from NRC Interim Report)



- Success in executing future NASA space missions *will depend on advanced technology developments that should already be underway*
- **NASA's technology base is largely depleted**
- *Currently available technology is insufficient to accomplish many intended space missions in Earth orbit and to the Moon, Mars, and beyond*
- Future U.S. leadership in space **requires a foundation of sustained technology advances**
- Importance of a foundational technology base cited in 2010 NASA Authorization Act
- Technologies prioritized in this study represent a foundation upon which to build the strategic goals outlined in the 2011 NASA Strategic Plan

NASA Technology Roadmaps will help provide direction and stability

Three technology objectives were defined by steering committee

- *Technology Objective A: **Extend and sustain human activities beyond low Earth orbit.** Technologies to enable humans to survive long voyages throughout the solar system, get to their chosen destination, work effectively, and return safely*
- *Technology Objective B: **Explore the evolution of the solar system and the potential for life elsewhere.** Technologies for in-situ measurements on Earth (astrobiology) and on other planetary bodies*
- *Technology Objective C: **Expand our understanding of Earth and the universe in which we live.** Technologies for remote measurements of Earth and other planetary bodies, and from other in-space and ground-based observatories*

Comment: NRC assumed that NASA would have a “balanced” program amongst all three objectives

The 16 Highest Priority Technologies



Objective A Extend and sustain human activities beyond low Earth orbit	Objective B Explore the evolution of the solar system and the potential for life elsewhere	Objective C Expand understanding of Earth and the universe
Radiation Mitigation for Human Spaceflight	Guidance, Navigation, and Control	Optical Systems (Instruments and Sensors)
Long-Duration Crew Health	Solar Power Generation (Photovoltaic and Thermal)	High-Contrast Imaging and Spectroscopy Technologies
Environmental Control and Life Support Systems	Electric Propulsion	Detectors and Focal Planes
Guidance, Navigation, and Control	Fission Power Generation	Lightweight and Multifunctional Materials and Structures
(Nuclear) Thermal Propulsion	Entry, Descent and Landing Thermal Protection Systems	Active Thermal Control of Cryogenic Systems
Lightweight and Multifunctional Materials and Structures	In-Situ Instruments and Sensors	Electric Propulsion
Fission Power Generation	Lightweight and Multifunctional Materials and Structures	Solar Power Generation (Photovoltaic and Thermal)
Entry, Descent, and Landing Thermal Protection Systems	Extreme Terrain Mobility	

Yellow = thermal or thermal related technologies



- Breadth of country's space mission has expanded
- Necessary technological developments less clear than in the past
- Recommendations would enhance effectiveness of OCT technology development in the face of scarce resources
- NRC recommendations focus on the highest-priority challenges and technologies in the first 5 years of the 30 year assessment window

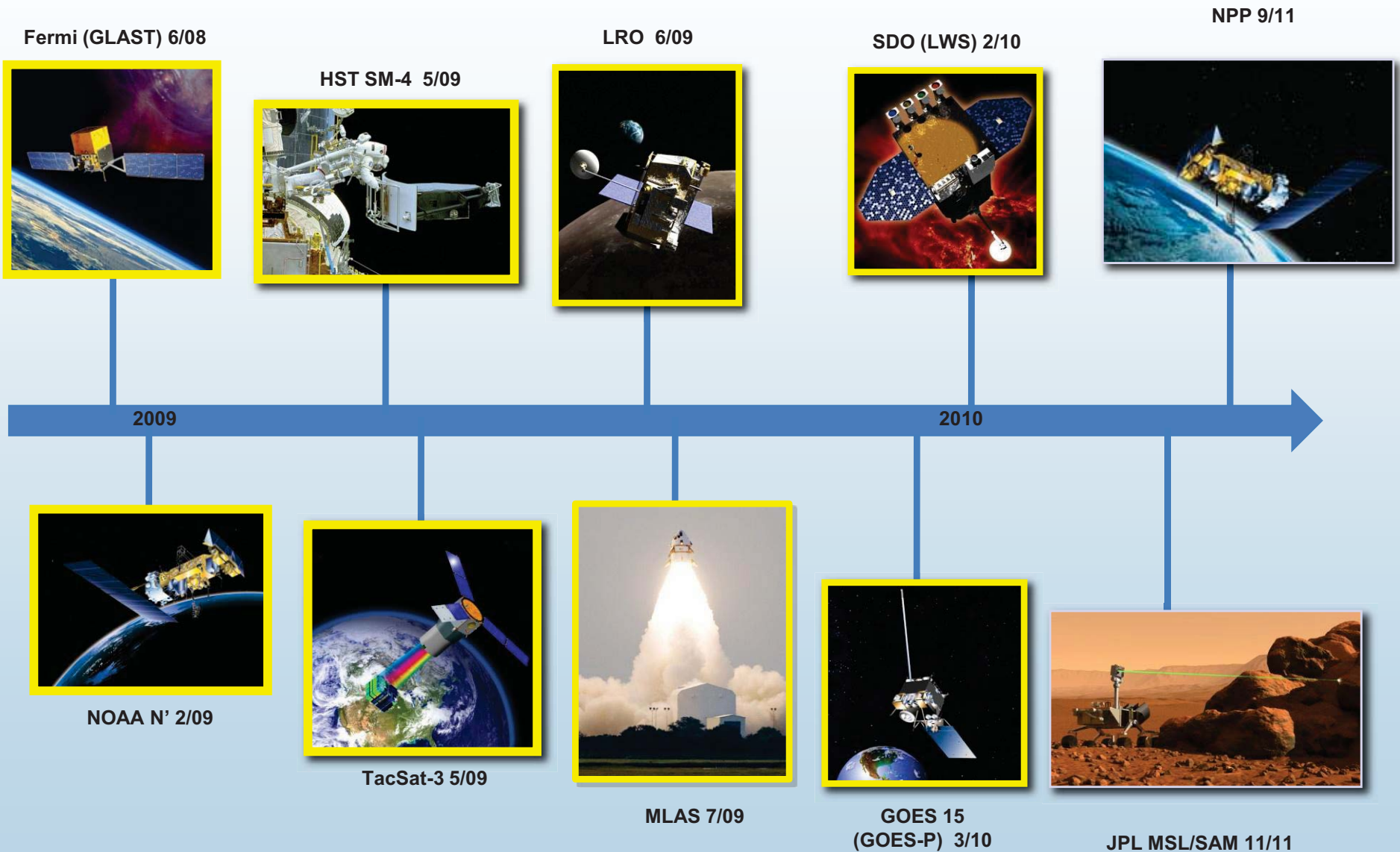


Goddard's NASA Mission

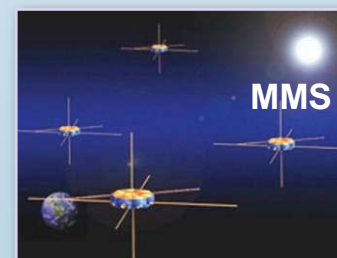
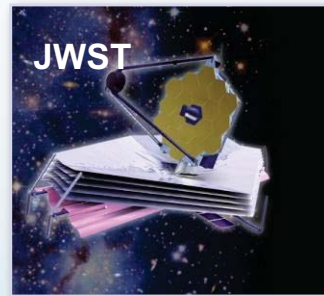
- ***Science, Exploration, and the Technology to support these Missions***
 - **Goddard Space Flight Center (GSFC) and the Jet Propulsion Lab are the prime science satellite development centers for the agency, both Earth Science and Space Science**
 - **Relatively modest impact due to changes in the Exploration Program**
- ***Goddard Core Focus Areas***
 - **Cradle to Grave Effort on Science Satellite Projects**
 - **Mission Design, Development and Operations**
 - **Sensors and Instruments**
 - **Weather satellites for NOAA**
 - **Space Communication and Navigation**
- ***Thermal Control applies to all areas!***



NASA GSFC Recent and Near Term Missions



NASA GSFC Future Missions





Current Events at Goddard

➤ Missions recently launched;

- **Lunar Robotic Orbiter (LRO)** – now taking pictures of the moon, 40th anniversary of Apollo 11
- **Final Hubble Servicing Mission** – Upgrades to instruments plus repairs, telescope now fully operational
- **GOES Weather Satellites**
- **Solar Dynamics Observatory** – observes solar “weather”
- **NPP** – Next generation of weather satellites, launched in 9/11. Unusual contamination event observed on VIRS cooler, otherwise healthy.
- **SAM instrument on Mars Science Laboratory (MSL)**, launched in 11/11.

➤ Missions in Work

- **GOES-R** - next generation of Geosynchronous weather satellites
- **Landsat Data Continuity Mission** – launch in 2012, or early 2013
- **Global Precipitation Mission (GPM)** to provide data for Weather forecasting, launch in 2013
- **MMS** – 4 satellites - Explore Earth’s Magnetic Field, launch in 2014





Current Events at Goddard (cont.)

➤ **Missions in Work (cont.)**

- **JWST – Large Telescope Mission scheduled for launch in 2018 – Very challenging thermally.**
 - **ICESat-II (2015) – Uses lasers to measure polar ice sheet thickness (or lack there-of)**
 - **GEMS – small satellite to study x-rays (2015)**
 - **Mars Atmosphere and Volatile Evolution (MAVEN) to orbit Mars (2015)**
 - **DSCOVR – Triana missions revived, launch in 2014, funded by NOAA/AF**
 - **TDRS – continuation mission, TV testing underway, launch 2012/13**
 - **LCRD – Laser Communication Relay Demo – to be flown on a Comsat**
- **Technology funding extremely lean – Renewed push for Technology funding is encouraging, but SBIR Thermal Subtopics have been cycled out for CY 12.**



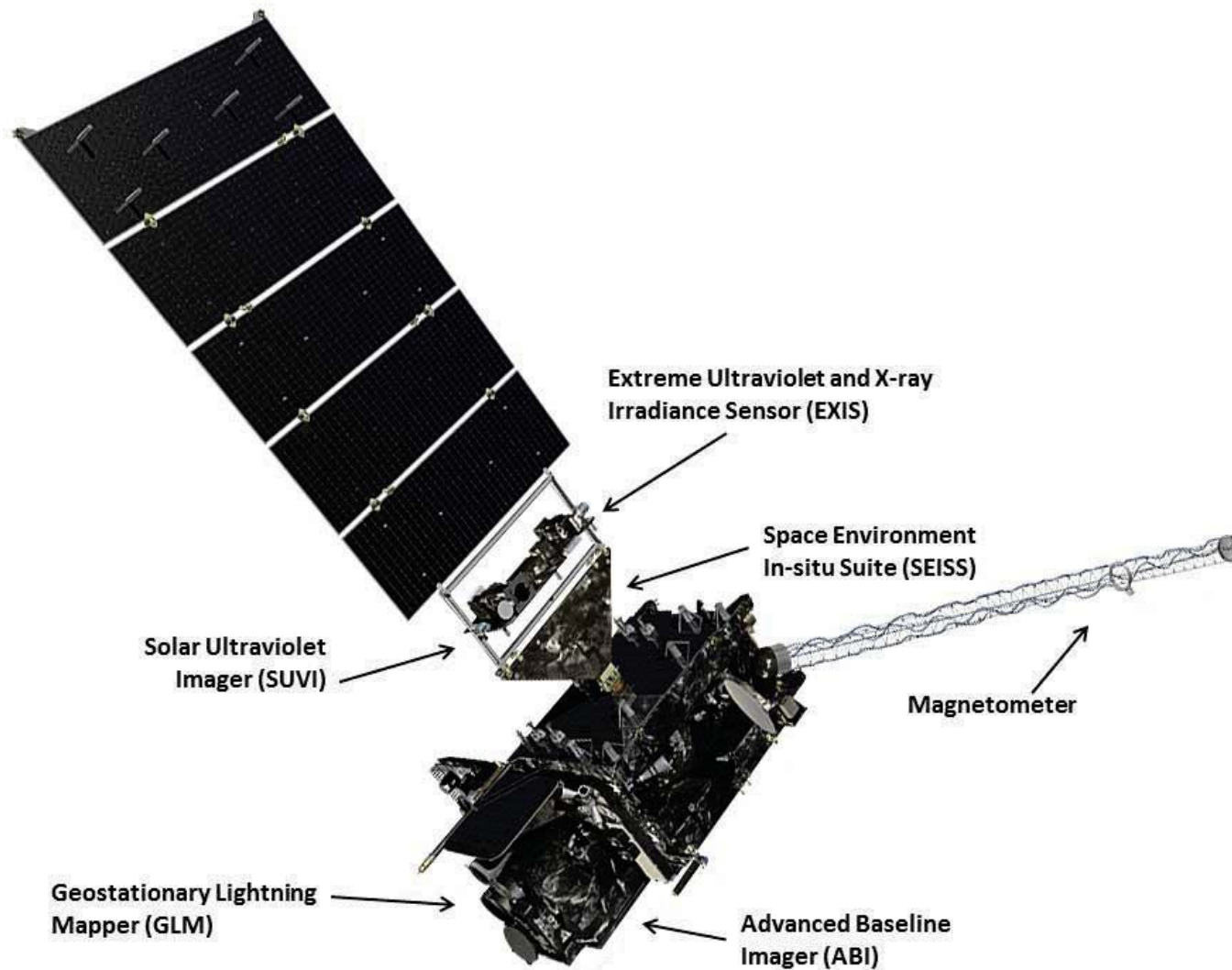


Thermal Challenges within Current Missions



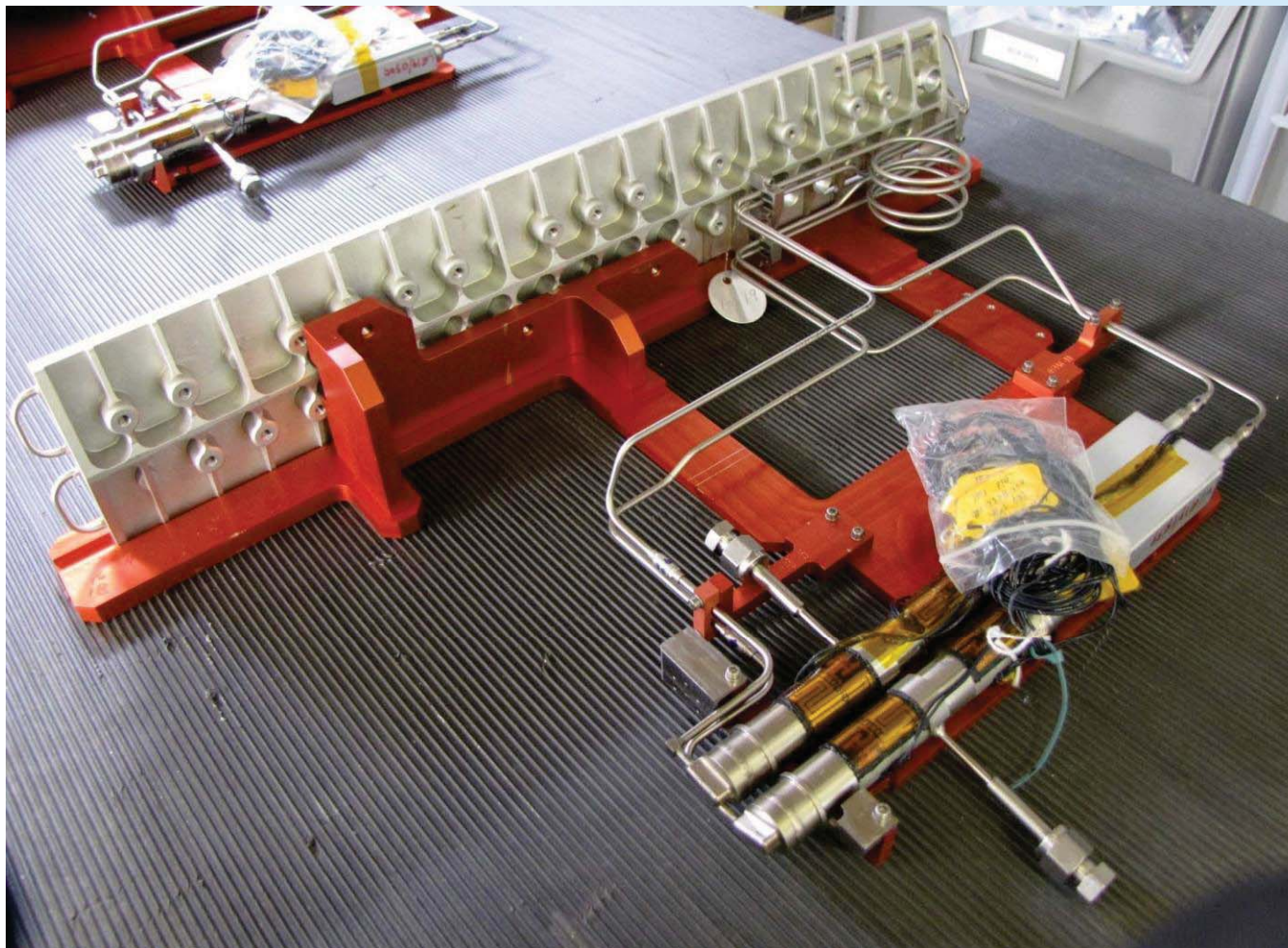


GOES-R Spacecraft



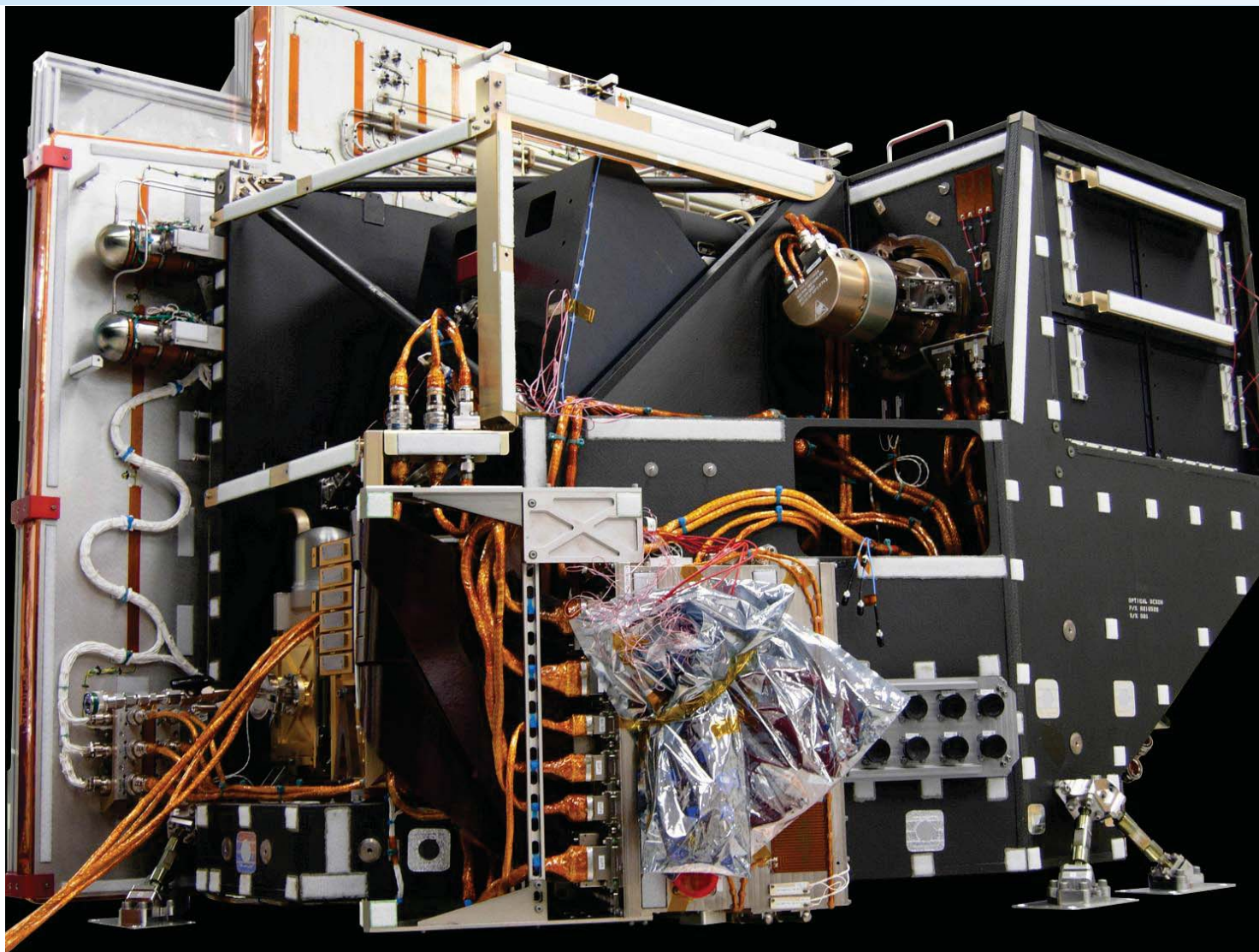


GOES-R GLM Loop Heat Pipe Flight



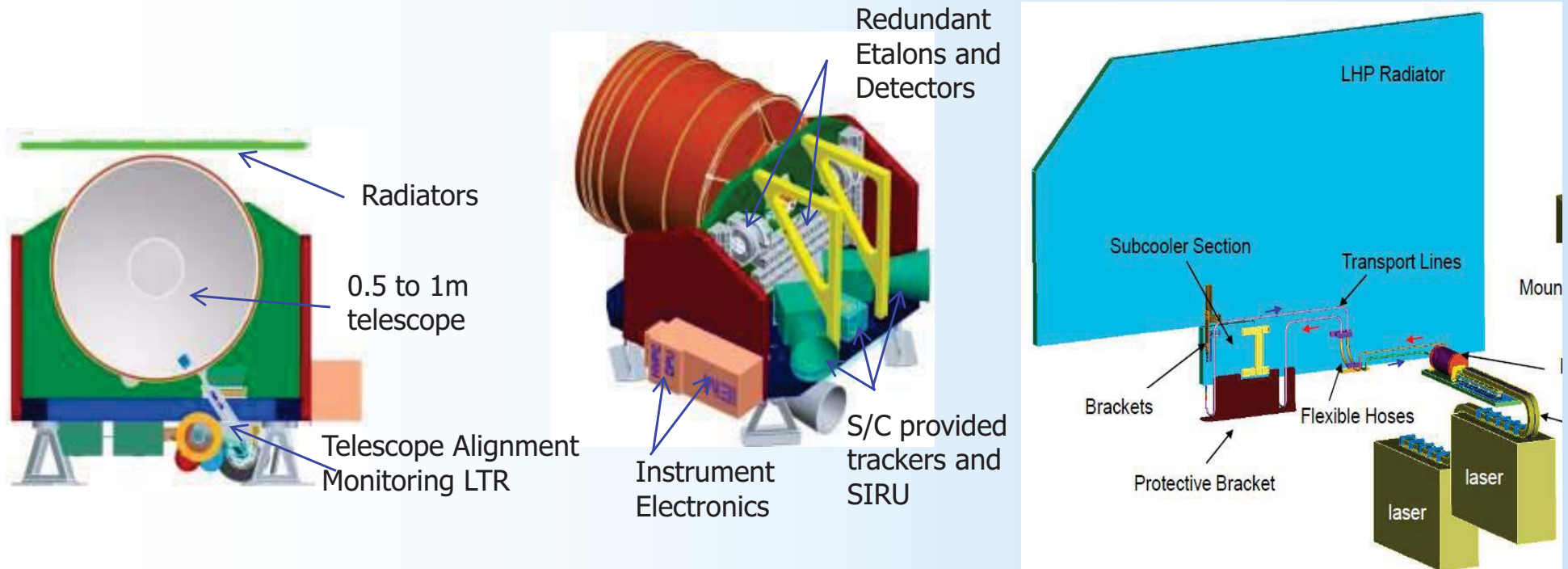


GOES-R ABI Instrument



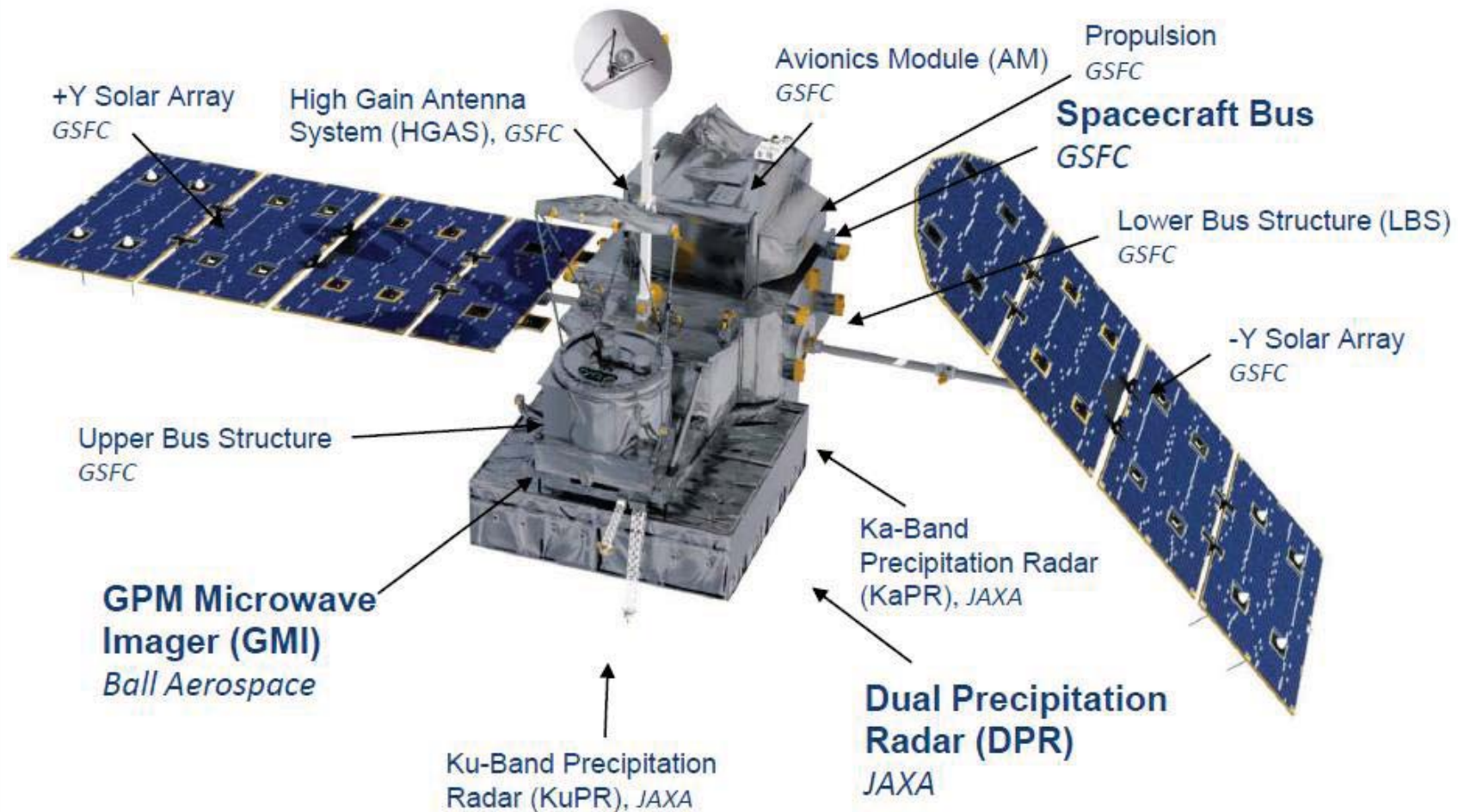


ICESAT-2/ATLAS Instrument LHP Cooling





Global Precipitation Mission – Open Architecture complicates Thermal Design



Launch Date:
Early 2014

Launch Vehicle:
Mitsubishi Heavy
Industries H-IIA
(provided by JAXA)





GPM Avionics HP Design

Internal SAM Pipes mounted using Nusil in channel cut through ribs



2" Channel

Embedded L Shaped Spreaders to improve Radiator Efficiency

C Shaped PSE-BME Header**

BME

PSE

MACE

S Shaped PSE-BME Header

CDH

MACE

CDH

** Expected to work in Reflux for Launch

Embedded Dual-Bore Straight Spreader for Failed Header

Embedded L Shaped Spreader (1/2")

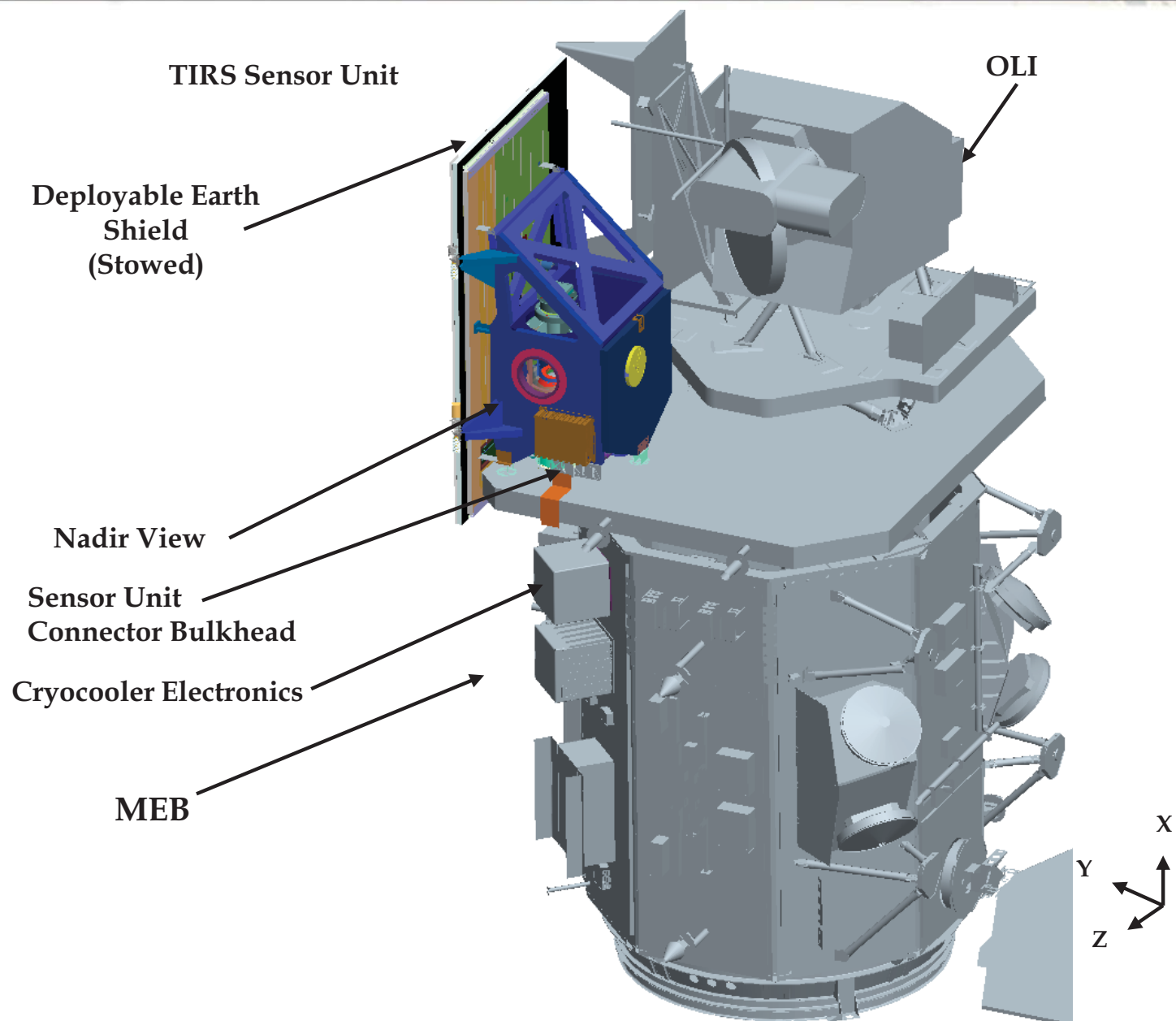
Embedded Dual-Bore Spreader (1/2")

PSE Header Saddle

PSE Header (3/4")

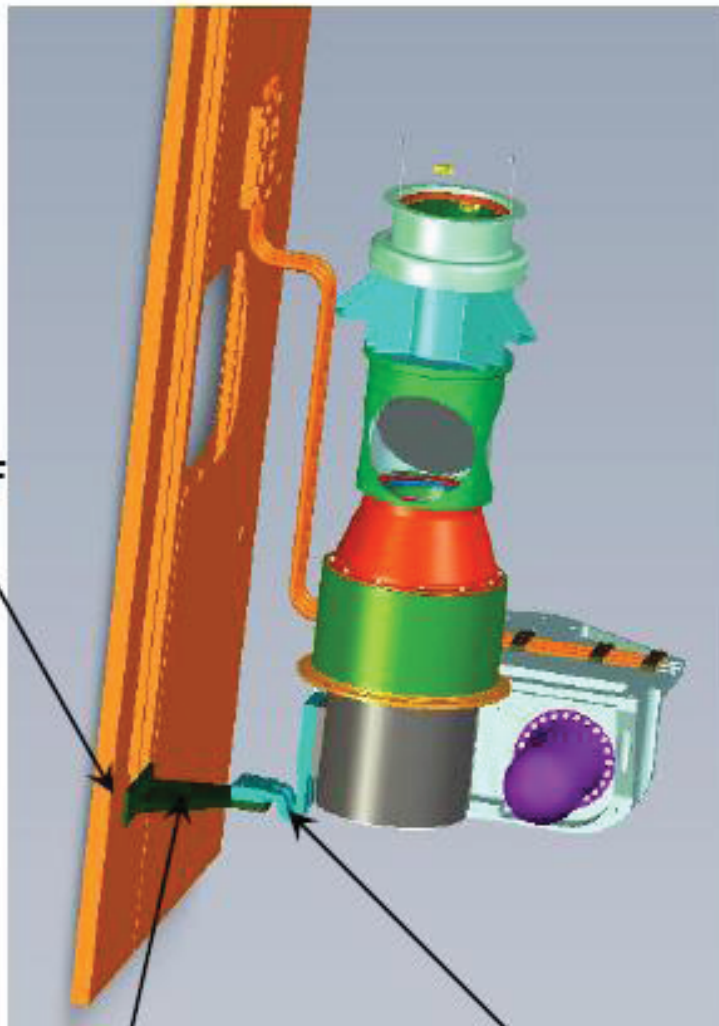
Welded Capture Nut

Thermal Infrared Sensor (TIRS) on Landsat (LDCM)



+Y Radiators Configuration

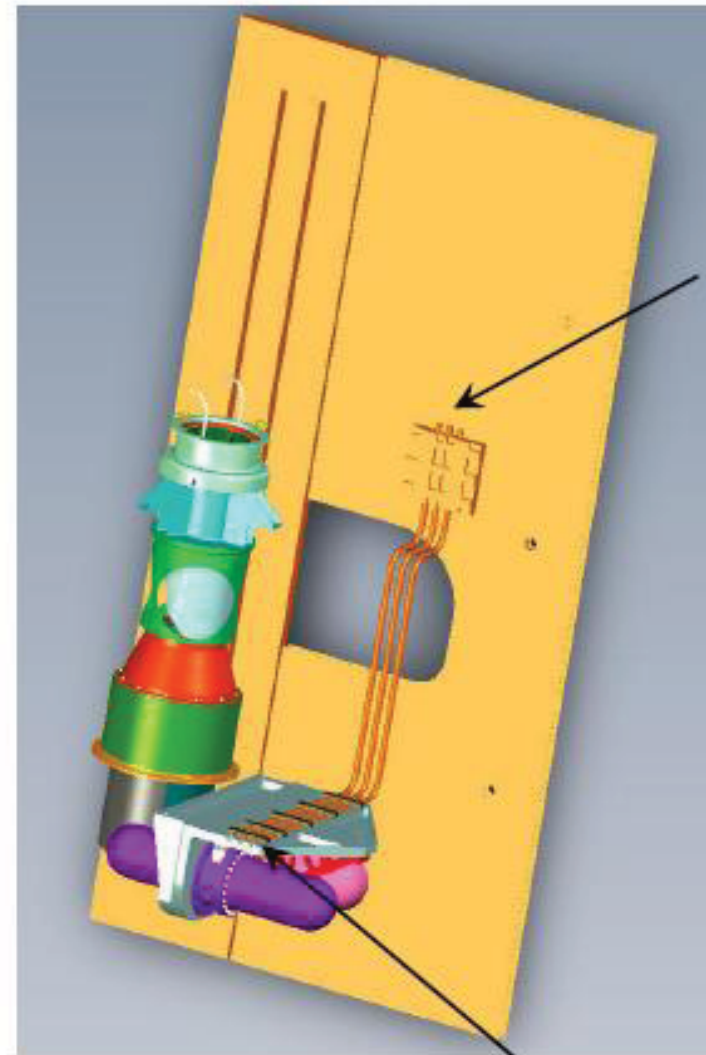
TIRS
LDCM



Telescope
Radiator I/F

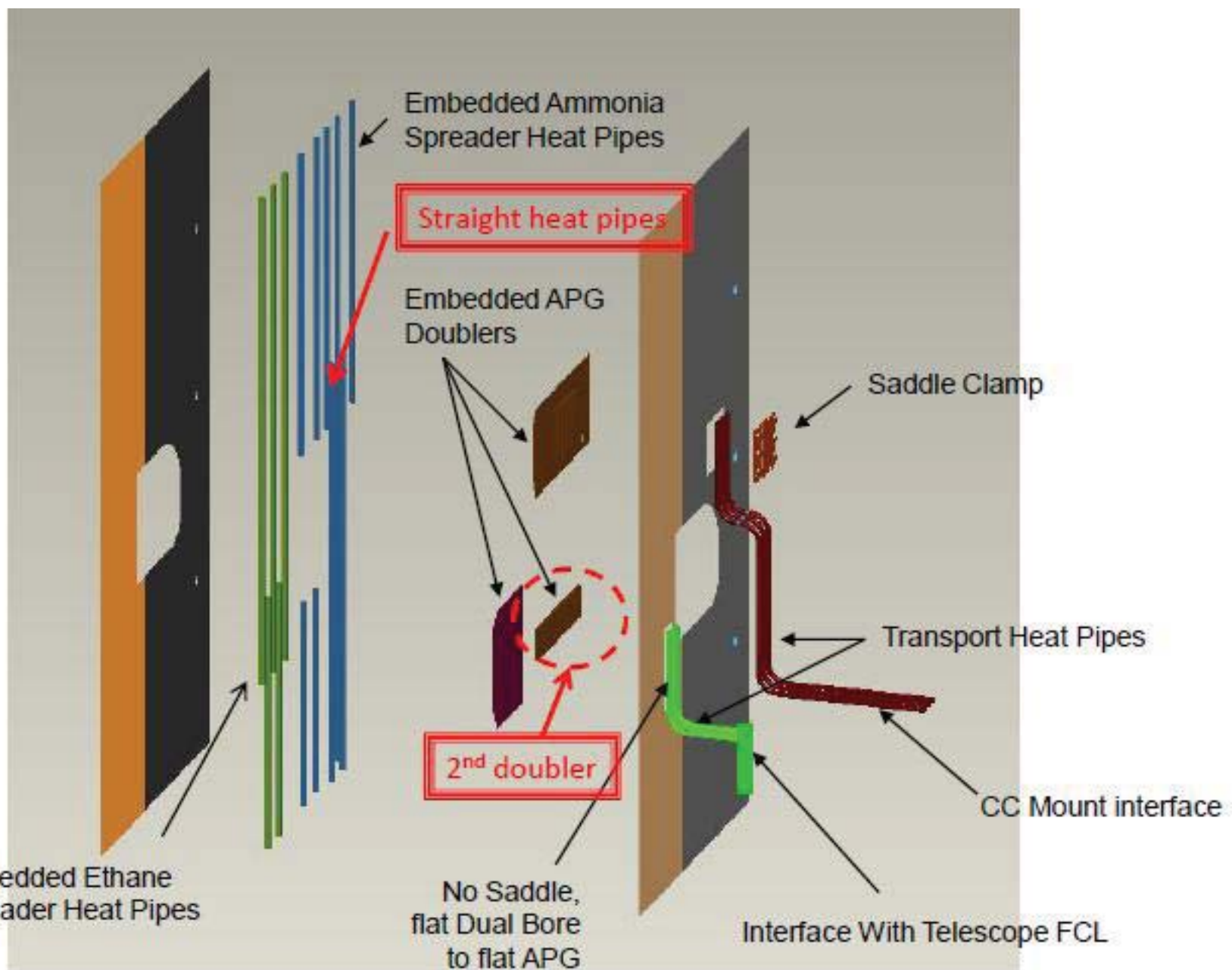
Telescope APG bar

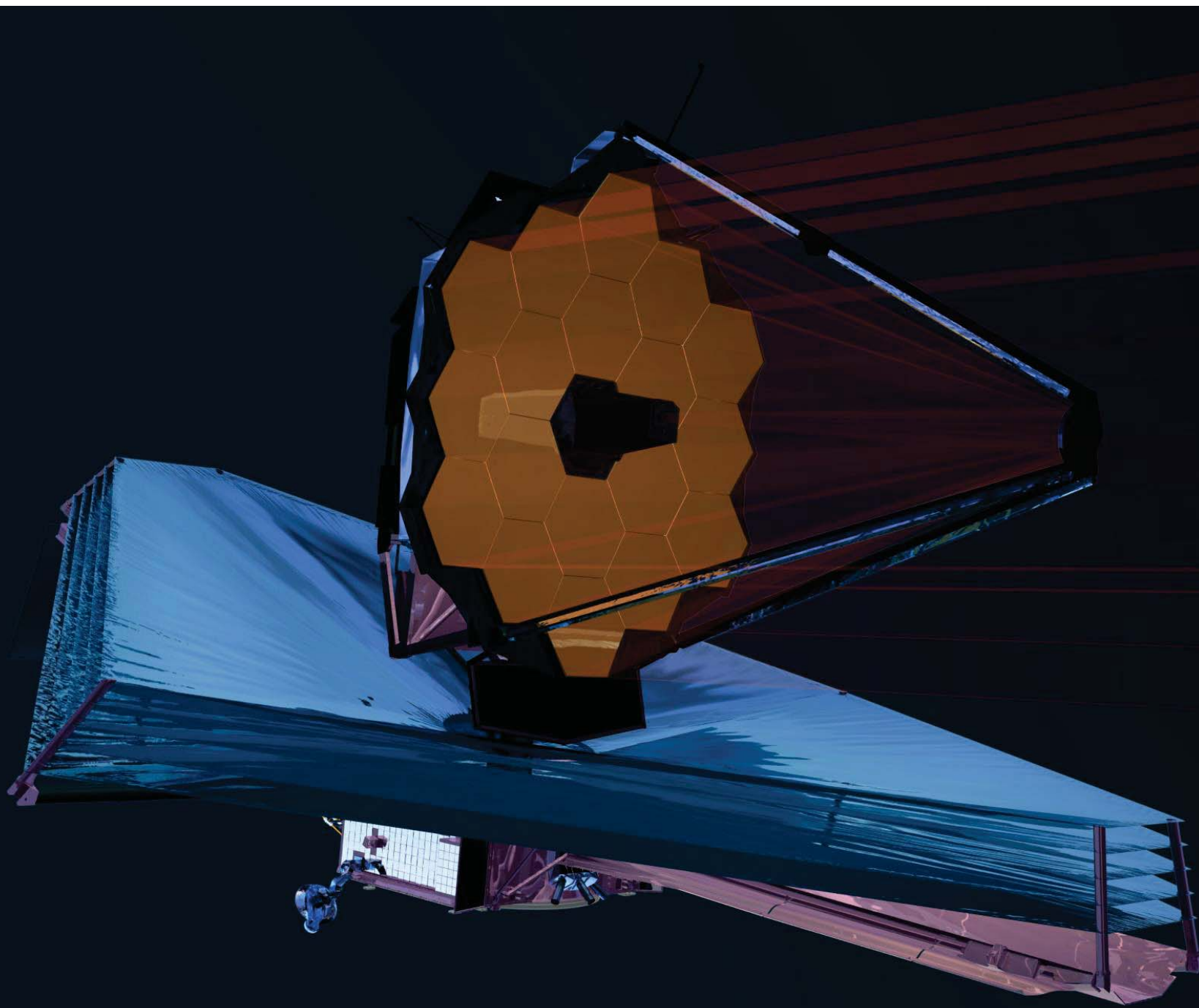
Telescope Heat Strap



Cryocooler
Radiator I/F

Three Ammonia Heat Pipes
Cryocooler Keel-to-Radiator
(53" long end-to-end)

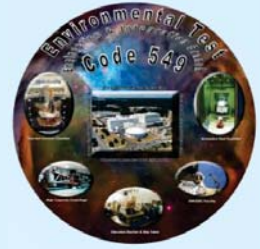




Artist's image of Deployed JWST



JWST Helium Shroud



- 25.5'D x 28'H payload volume
- +75°C to -255°C (18K)
- $\pm 3K$ uniformity at 20K with 700W load
- Cooled with 1000W helium refrigerator
- Chamber shroud flooded with LN₂



Helium Refrigerator

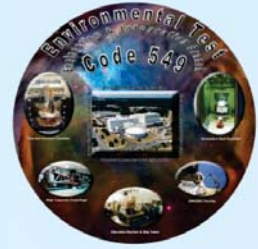


Valve Box





GSFC's Successes Have Been Based On Thorough Testing



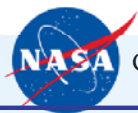
- Strong component and box-level test polices
 - Comprehensive system level testing
 - **HOWEVER** - Recent pressure to cut back on TV test programs to save costs – reduce number of cycles
- *General Environmental Verification Specification (GEVS) for STS & ELV Payloads, Subsystems, and Components*

<http://standards.gsfc.nasa.gov/gsfc-std/gsfc-std-7000.pdf>

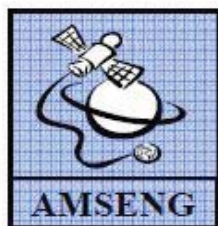




Emerging Thermal Control Technologies



GODDARD SPACE FLIGHT CENTER



NASA SBIR/STTR Technologies

S3.02- 9946- The Conductive Thermal Control Material Systems for Space Applications

PI: M.S.Deshpande
AMSENG - Schaumburg, Illinois, IL 60194



Identification and Significance of Innovation

Future Spacecraft and Instruments for NASA's Science Mission Directorate needs increasingly sophisticated thermal control technology. This innovative proposal is submitted to fulfill the needs identified in this solicitation for the following area: More sensitive instruments are resulting in increased requirements for high electrical conductivity on spacecraft instruments and surfaces. This has increased the need for advanced thermal control coatings, particularly with low absorptance, high emittance, and good electrical conductivity. This Proposal is submitted to fulfill this need to provide Space Stable, Reliable, High conductivity Thermal Control Material System (TCMS). The technology feasibility assessment will be provided in the phase I and the efforts to mature the technology and validating the same can be planned in phase II, so that by the end of phase II the technology Demonstration activity can be undertaken as phase III.

Expected TRL Range at the end of Phase II Contract: (7-8)

Technical Objectives and Work Plan

The overall technical goals of the proposed efforts are to produce solid state chemistries for BNNT-BNNM and Zinco-Indates type highly conductive compounds to tailor the diffuse TCMS that have the following performance characteristics:

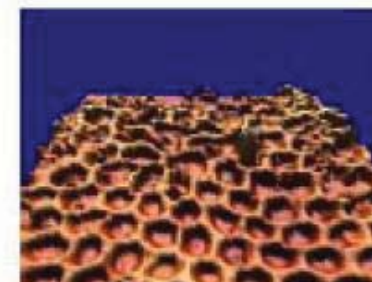
- Total Solar Absorbance: BOL - $\alpha_s < 0.10$ (0.07 to 0.09 typical)
EOL - $\alpha_s \cong 0.02$ to 0.04 (LEO)
 $\alpha_s \cong 0.06$ to 0.10 (GEO)
- Total Normal Thermal Emittance:
BOL - $\epsilon_N \cong 0.90 \pm 0.05$
EOL - $\epsilon_N \cong 0.90 \pm 0.05$
- Surface Resistance: $R_s = 1.0 \times 10^2 \Omega/\text{sq}$ to $1.0 \times 10^7 \Omega/\text{sq}$

These goals will be met by synthesizing Boron Nitride nano Tubes, Nano mesh (BNNM-BNNM™) and Zinco-Indates to tailor the TCMS for the high current carrying capabilities.

Firm Contacts: M.S.Deshpande. AMSENG - Schaumburg, Illinois



BNNTs
Boron Nitride Nano Tubes



BNNM
Boron Nitride 2D Nano Structures

NASA Applications

The concepts on the suggested nano-science inspired generic multifunctional high conductivity capable thermal control material system are suitable for the science and o exploration hardware needs and are geared towards delivering the reliable end products. These developments will contribute uniquely to the survivable material systems. The NASA missions that can benefit from its applications: Tether concepts. The missions that need white (low α_S/ϵ_T) conductive TCMS coatings are: JUNO, MAVEN, GOES-R, LADEE GRAIL, JPSS, & SAA.

Non NASA: DOD and Commercial Applications

Like NASA, the commercial industry has plans for several satellites for the broad band communication activities. The transportation authorities are also planning commercial space based radars for air traffic control. These planned candidate optimal fleet designs may call for putting assets in the mid-earth orbits (MEO) which require radiation stability along with the high conductivity for the higher leakage current carrying capability. Currently technology gap exists and no TCMS is available that is space stable and provides flexibility in leakage current. Success of this program spells fulfillment of this gap. Many commercial as well as the DOD platform hardware can also benefit from the fulfillment of this technology gap. Thus, the return on investments can be sizable and multifaceted

NON-PROPRIETARY DATA

Phase 2 Underway

NASA SBIR/STTR Technologies

Proposal No.S3.02-9111 – Integrated Composite Heat Pipe Radiator Panel

PI: Mark J. Montesano

k Technology Corporation – Langhorne, PA



Identification and Significance of Innovation

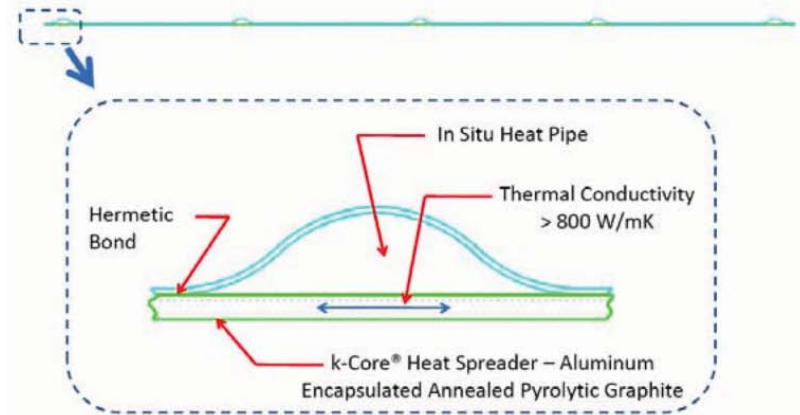
kTC proposes a general technology development that permits the design of a high performance thermal distribution panel (TDP) concept.

The panel will be fabricated with a high conductivity (>800 W/mK) macro composite skin and in situ heat pipes.

The processing technologies proposed to build such a panel can also be used to produce this panel with high structural stiffness, similar to aluminum honeycomb type structure currently in use.

Expected TRL Range at the end of Contract: 5

Proposed Integrated Heat Pipe and k-Core® Radiator or Thermal Distribution Panel



Technical Objectives

Demonstrate a robust, repeatable manufacturing technique to fabricate the k-Core® panels with in situ plenums.

Work Plan

	1	2	3	4	5	6
Layout Optimization, Analysis, and Design	■	■				
Process – Bonding and Forming		■	■	■	■	
Process -- Heat Pipes and Finishing			■	■	■	
Prototype Evaluation and Validation					■	■
Refinement and Design Updates					■	■
Reporting					■	■

NASA and Non-NASA Applications

Potential NASA application include Orion thermal distribution panels, lunar surface power radiators, several unmanned JPL missions such as the Mars Science Laboratory (MSL)

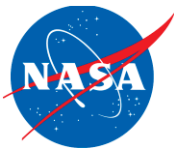
Potential non-NASA applications include DoD and commercial satellite structures, airborne rack-mounted electronics and radar systems. Additional potential applications include IGBT module cooling for solid state power conversion, and high power work station farms in need of more efficient cooling to reduce HVAC costs

Firm Contacts

Mark Montesano: 631-285-6580 ext 11

Phase 2 Underway

NON-PROPRIETARY DATA



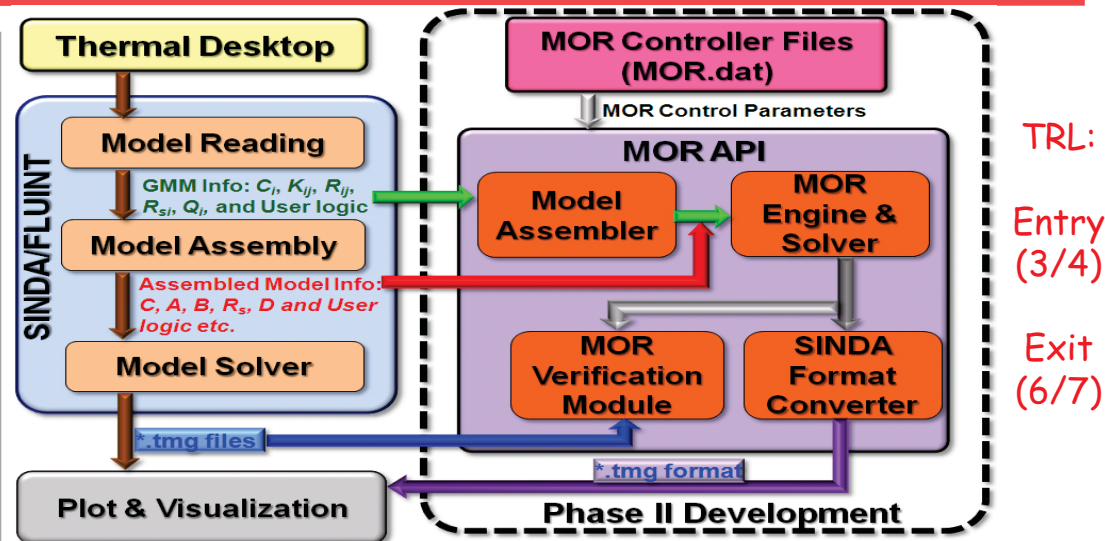
Title: Software for Automated Generation of Reduced Order Models for Spacecraft Thermal Control

Company Name: CFD Research Corporation

Proposal #: S3.02-9436 COTR: Jentung Ku

Technology Description and Objective:

- Further expansion of Model Order Reduction techniques developed in Phase I.
- Benefits in solution time are clearly demonstrated in Phase 1 (> 20x speedup).
- Limitations of time and temperature dependent terms necessitating more frequent generation of the projection matrix are clearly identified.
- Offeror proposes solutions to minimize the frequency of regeneration of the projection Matrix to maintain speed improvement for larger class of models.



Assessment of Proposal:

- Based on Phase 1, Phase II proposal is a logical progression to further develop the approach to handle a larger class of thermal models (e.g. temperature/time dependent conditions).
- Proposer has also teamed with C&R (primary thermal software vendor) to further embed technology in end user product..
- Proposer clearly has the experience and knowledge to execute their proposal based on past performance and publication history.
- Application Programming Interface (API) deliverable allows technology to be used in other disciplines (CFD, Structures, Controls, etc.)

Attributes

- NASA Applications:

James Webb Space Telescope, Laser Interferometer Space Antenna

- Primary SMD Division or Category:

!!! ANY NASA MISSIONS REQUIRING THERMAL ANALYSIS !!!

- Deliverables:

Application Programming Interface (e.g. DLL)

- PI: Dr. Yi Wang

- Consultants/Subcontractors: Brent Cullimore (C&R Technologies)



Thermal Coatings Technology Development

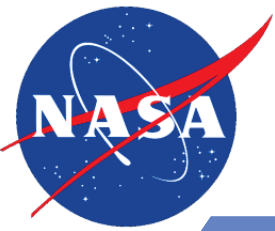


- **Qualifications completed in 2011**

- Z93C55 (Alion Science and Technology), white, ESD dissipative silicate for use at geosynchronous orbits
- MLP300 (AZ Technology) and ESD dissipative hybrid primers for bonding silicates to non-metallic substrates (e.g. carbon composite, polyimide films)
- MH55 ICP (Alion Science and Technology), black, ESD dissipative silicate

- **Current Development Activities**

- Flexible silicate coated tapes with ESD dissipative silicate coatings
- Low absorptance layered silicate coatings to reduce absorptance below 0.13 at thicknesses less than 5 mils
- Boron Nitride Nano-Mesh and Nanotube (BNNM) pigmented coatings (AMSENG) – Phase II SBIR and pigment post processing work for improved spray application
- STAMET coating (Astral Technologies) for replacement of vapor deposited germanium on polyimide film (exterior layer of MLI) for high electrical conductivity – partially funded by NESC



Atomic Layer Deposition to Enable the Production, Optimization and Protection of Valuable Spaceflight Hardware

PI: Dr. Vivek H. Dwivedi / Code 545



Goddard Space
Flight Center

Description and Objectives:

Demonstrate ALD and its benefit to GSFC in providing a manufacturing method to meet NASA's Nanotechnology Roadmap. The goal of this work is to demonstrate the flexibility of an ALD system to coat multiple materials on multiple substrates that will leave the newly developed technology in an ideal situation for immediate applications in X-ray detectors, thermal radiators and boxes that require radiation protection.

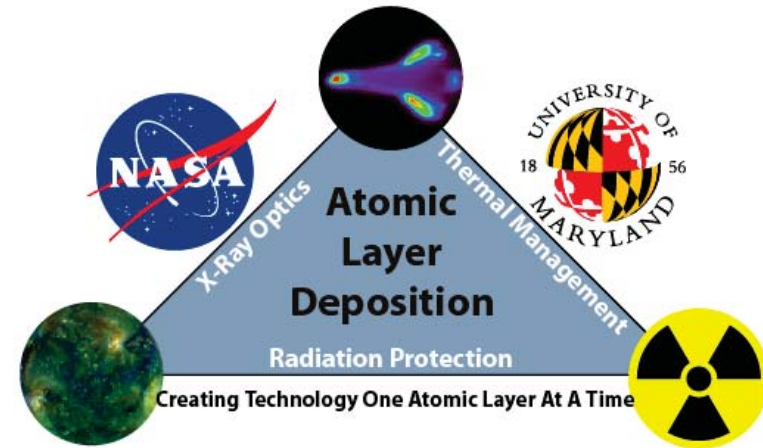
Key challenge(s)/Innovation: *Currently, high temperature processes are used to deposit metal/metal oxide films, processes that are difficult to control and are physically detrimental to the substrate onto which the films are deposited. The technique we propose will utilize benign temperature/pressure to coat multiple substrates.*

Approach:

The ALD processes will be carried out at the University of Maryland's NanoCenter in College Park. The work of this IRAD is meant to take this nascent technology to the point where it can be used to coat several thousand mirrors with iridium, tune a radiator with a passive thermal coating within an emissivity range and manufacture boron nitride nanotubes with a predefined tube hole diameter and length.

Collaborators:

- Professor Raymond A. Adomaitis (UMD)
- Dr. Catherine C. Fay (NASA LRC)



Milestones and Schedule:

- Passive Variable Emittance Film Prototype (April 2012)
- Iridium Coated X-Ray Optic (May 2012)
- Boron Nitride Film (Aug 2012)

Application / Mission:

- Funding opportunities as related to NASA's Nanotechnology Roadmap. -ROSES
- Next generation of X-ray missions such as the International X-Ray Observatory and Explorer missions in the coming decade.
- Next generation nano-sat missions.



Nanotechnology for Advanced Imaging and Detectors

PI: John Hagopian/551



Goddard Space Flight Center

Description and Objectives:

- Objective 1- Apply technology developed during FY11 IRAD to create 1x4 nanotube absorber infrared detector array
- Objective 2 – Refine carbon nanotube fabrication and characterization technology for use in the far infrared (FIR) for stray light suppression, detector absorbers and on-board instrument calibrators.
- Objective 3 – Model, fabricate and test 4th generation magnetic mirror with the goal of suppressing diffraction and investigating advanced applications in imaging and detection.
- Objective 4 – Model, fabricate and test nanostructured devices that have enhanced detector performance.

Key challenge(s)/Innovation: Challenge is to bring these technologies to rapid maturity for use on space flight hardware. Each objective can have a major impact on imaging and detector technologies.

Approach:

- Each objective requires an incremental advancement in the technologies we have developed during previous IRAD years. So we expect a high probability of success in each area while delivering something that is unique.

Collaborators:

Co-Investigators: G. Hidrobo, S. Getty/541, R. Shiri, M. Quijada/551, P. Roman/553, J. Tuttle/552
E. Wollack/665 J. Brasunas, S. Aslam/693

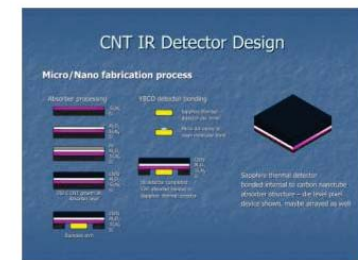
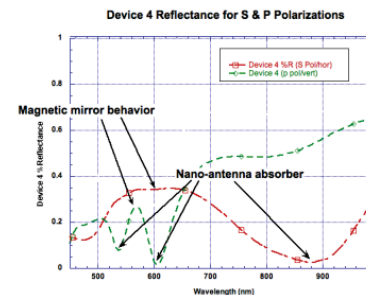
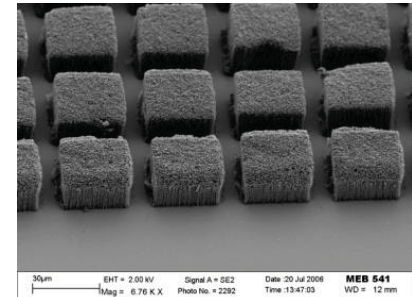
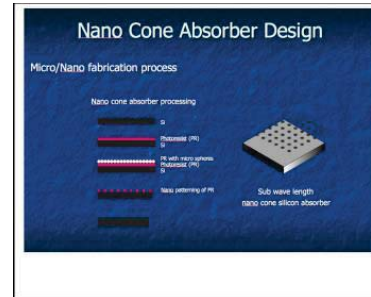


Fig2. Notional process for CNT Detector

Deliverable	Date (mm/dd/yyyy)
1 1x4 Detector Array with CNT Absorber Fabricated and Tested	04/30/2012
2 CNT optimized and characterized to 100 micron wavelength	03/01/2012
3 4th Generation Hybrid Magnetic Mirror Fabricated and Tested for	03/01/2012
4 5th Generation Hybrid Magnetic Mirror Fabricated and Tested for D	06/01/2012
5 Nano-antenna absorber fabricated tested from VIS-MIR	06/01/2012
6 Hybrid detector using Nanoantenna absorber fabricated and teste	08/15/2012
7 Emissivity of CNT samples measured	06/15/2012

Application / Mission:

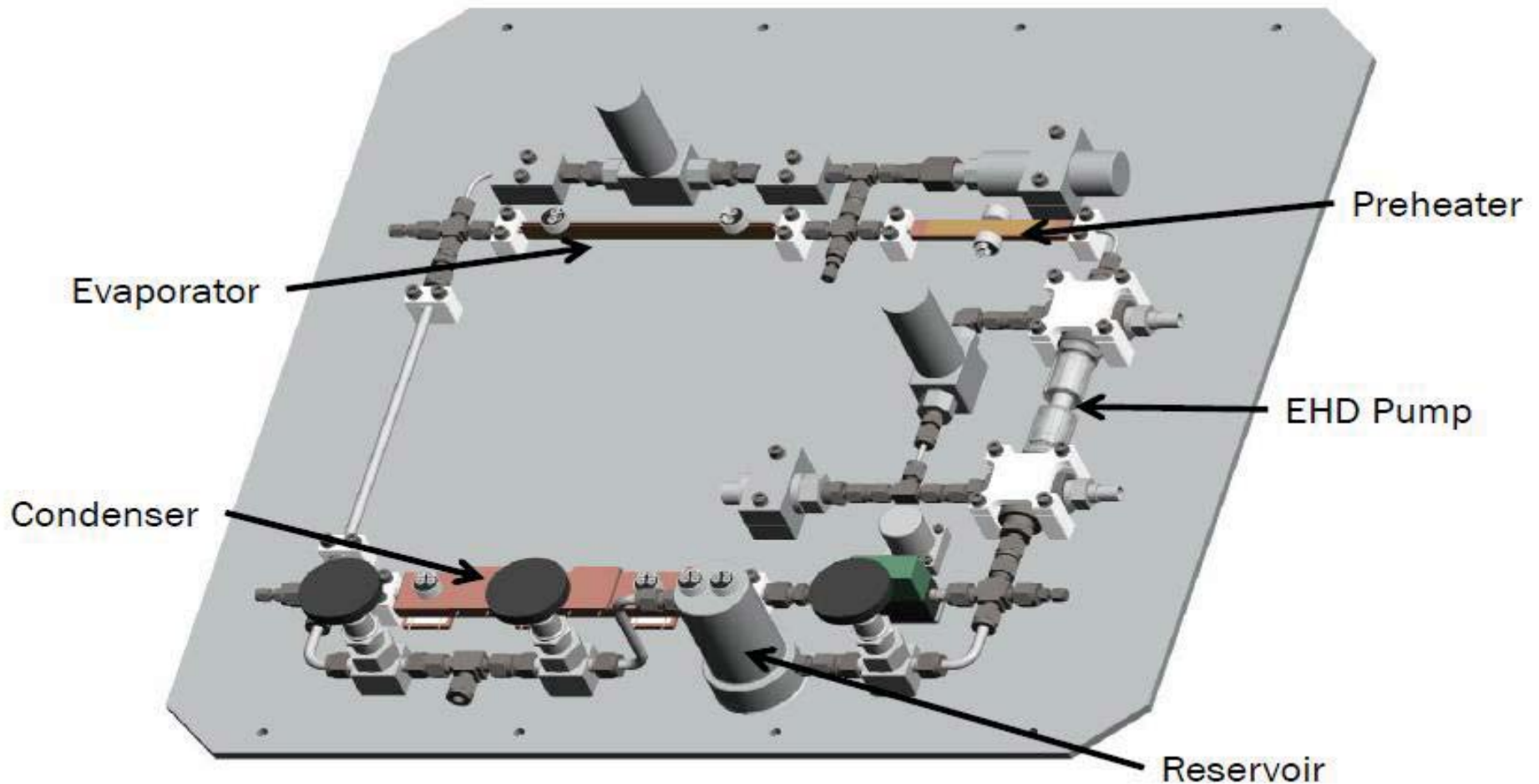
- CIRS-Lite (Instrument Incubator) will use our 1x4 array
- We will partner with Ramsey Smith to deliver a prototype calibrator for use on TIRS II
- Our broad band nanotube formulations are applicable to stray light control, calibrators and radiators. We will continue to scale up our capability in 6" furnace.
- Our nanostructure mirrors/antennas have the potential to be technologically disruptive in imaging, detectors, solar power 38



EHD Variable Gravity Flight Experiment



Experiment Configuration





EHD ISS Space-cube Experiment

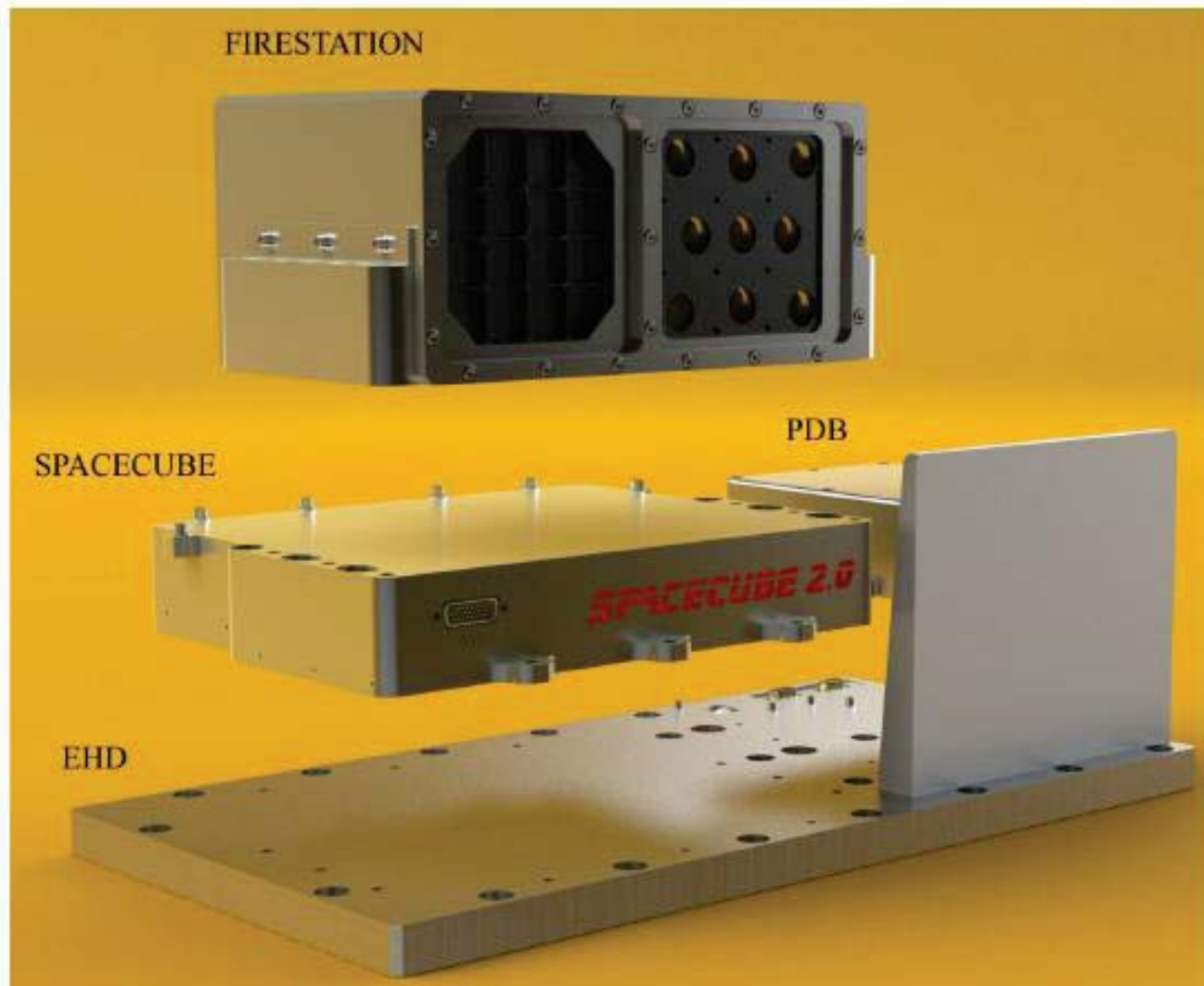


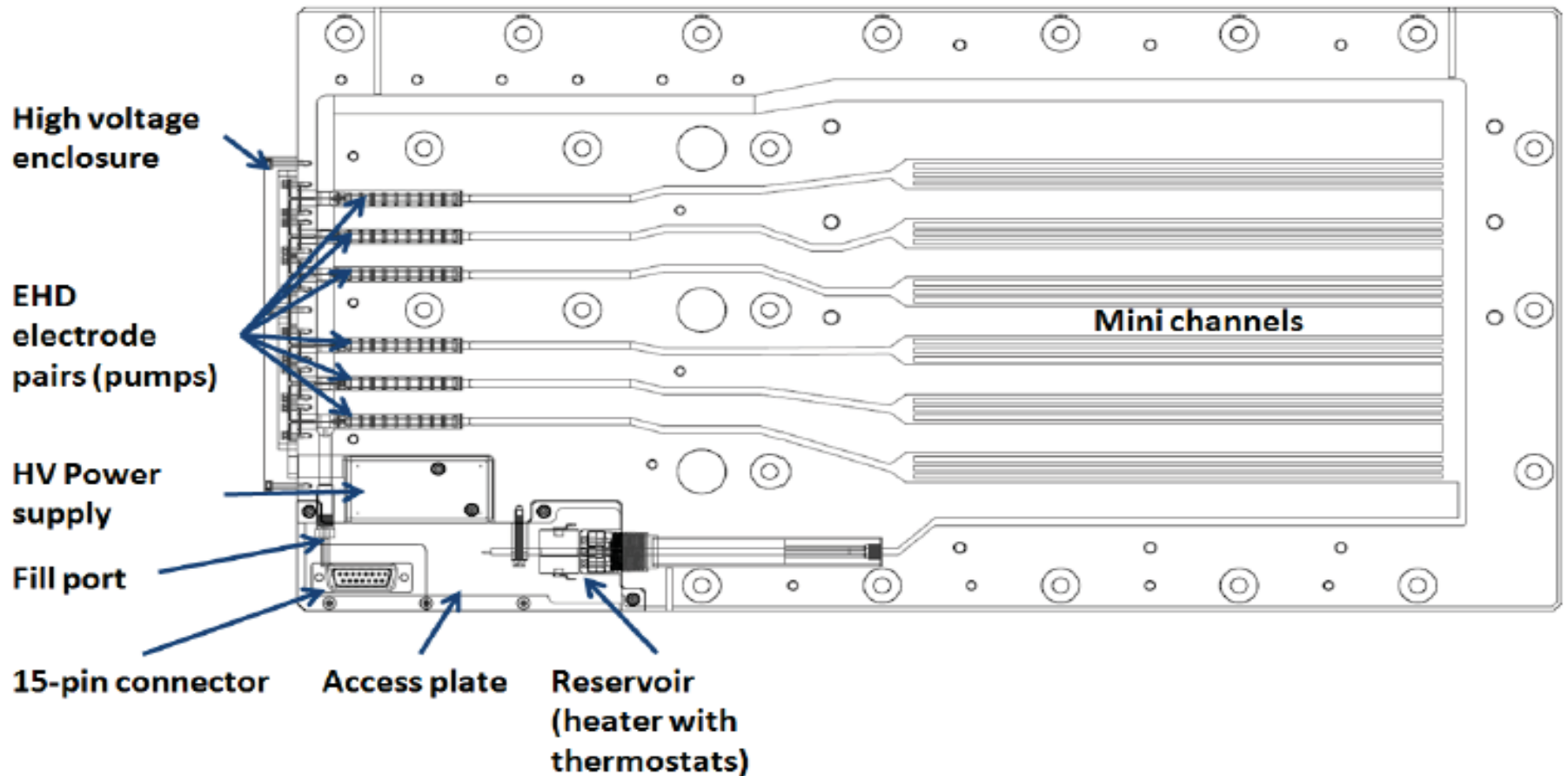
Image credit: Alberto Rosanova



EHD ISS Space-cube Experiment



EHD Plate Assembly





Summary

- **New Technology program underway at NASA**
- **NASA/GSFC's primary mission of science satellite development is healthy and vibrant, although new missions are scarce**
- **Future mission applications promise to be thermally challenging**
- **Direct technology funding is still very restricted**
 - **Projects are the best source for direct application of technology**
 - **SBIRs program continuing, good source of new ideas, but program reduction in Thermal planned for FY 12**
 - **Limited Technology development underway via IRAD and other sources**
 - **New administrator wants to revive technology and educational programs at NASA – encouraging signs**

