NASA Goddard Thermal Technology Overview 2018

Dan Butler, Ted Swanson, NASA Goddard

Spacecraft Thermal Control Workshop
Aerospace Corporation
El Segundo, CA 20 March, 2018

X-ray: NASA/CXO/Oxford University/J. Conlon et al.
Radio: NRAO/AUI/NSF/Univ. of Montreal/Gendron-Marsolais et al.
Optical: NASA/ESA/IoA/A. Fabian et al.; DSS

FY18: Where is the budget going?

- **The trend is positive! FY14** - $17.65B, **FY15** - $18.01B, **FY16 -** $19.28B, **FY17 - $19.653B, and FY18 - $19.519**

	FY17 *	FY18 **
Science	$ 5,762	$ 5,726
Space Technology	$ 826	$ 821
Aeronautics	$ 656	$ 655
Exploration	$ 4,184	$ 4,223
Space Operations	$ 4,492	$ 4,850
Safety, Security, Mission Services	$ 2,769	$ 2,750
Other	$ 514	$ 495

- **President's FY19 Request; $ 19.892B**

https://www.nasa.gov/sites/default/files/atoms/files/nasa_fy_2019_budget_overview.pdf

- * NASA FY17 Budget per funding amounts specified in Public Law 115-31, Consolidated Appropriations Act, 2017
- .** FY 2018 reflects Continuing Resolution funding as enacted under Public Law 115-56, as amended.

Presidential Policy Directive

The United States shall;

“Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations”

- Presidential Space Policy Directive 1

NASA is:

- Enabling U.S Global Leadership: Our scientific, technological, aeronautics and space exploration efforts are uniquely visible expressions of American leadership
- Extending Human Presence Deeper into Space Starting with the Moon for Long-term Exploration and Utilization
- Expanding Human Knowledge Through New Scientific Discoveries
- Addressing National Challenges that Catalyze Economic Growth
- Improving Capabilities and Operations NASA and American Leadership

Notes on Future Program and Budget

- Major emphasis on returning to the moon and focus on exploration
  - Proposed small- to medium-sized (up to 1,000 KG) lunar landers through 2023
  - Initial efforts on a human-rated lander in late 2023 or 2024.
  - Continued funding for “Gateway” concept, which is a small outpost in orbit near the Moon in the mid-2020s
- Proposed elimination of direct support for ISS in 2025
- Continued funding for the Space Launch System rocket and Orion spacecraft
- Science budget basically flat, with increased emphasis on planetary including Mars 2020 and Europa Clipper
- In FY19, the existing "Space Technology" directorate is proposed to be rolled into the "Deep Space Exploration Systems” account

What else is happening regarding technology?

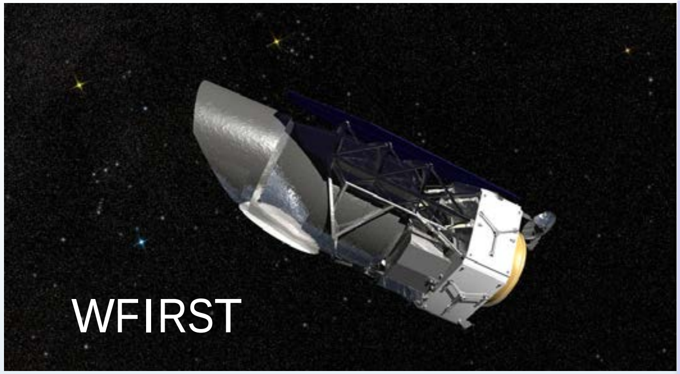
- **Technology Roadmaps** continue; referenced by many NASA solicitations.
  - Expect some taxonomy changes; elements of TA14.3, Thermal Protection Systems

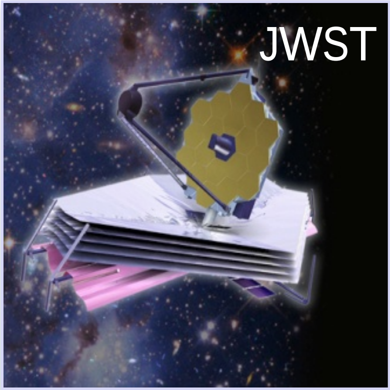
http://www.nasa.gov/offices/oct/home/roadmaps/index.html

- **TechPort** – continues to mature as a database for technology developments
  - Detailed information on over a thousand individual technology programs and projects
  - Allows extensive search capability and sharing of information

http://techport.nasa.gov

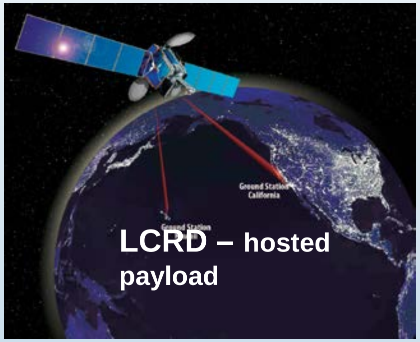
NASA GSFC Future Missions


WFIRST


JWST


NextGen TDRS


LUCY



LCRD – hosted payload

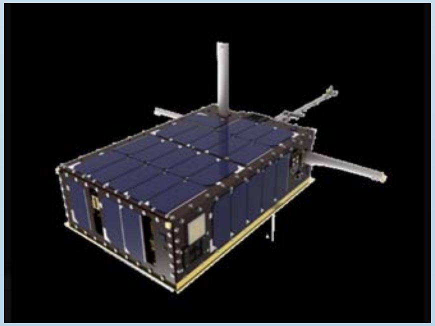

ICESAT-II

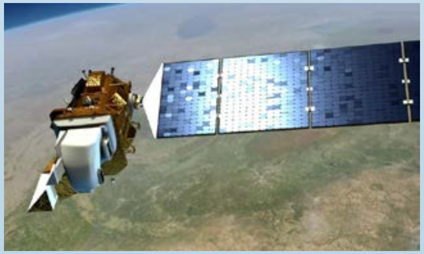

PACE


GOES-S

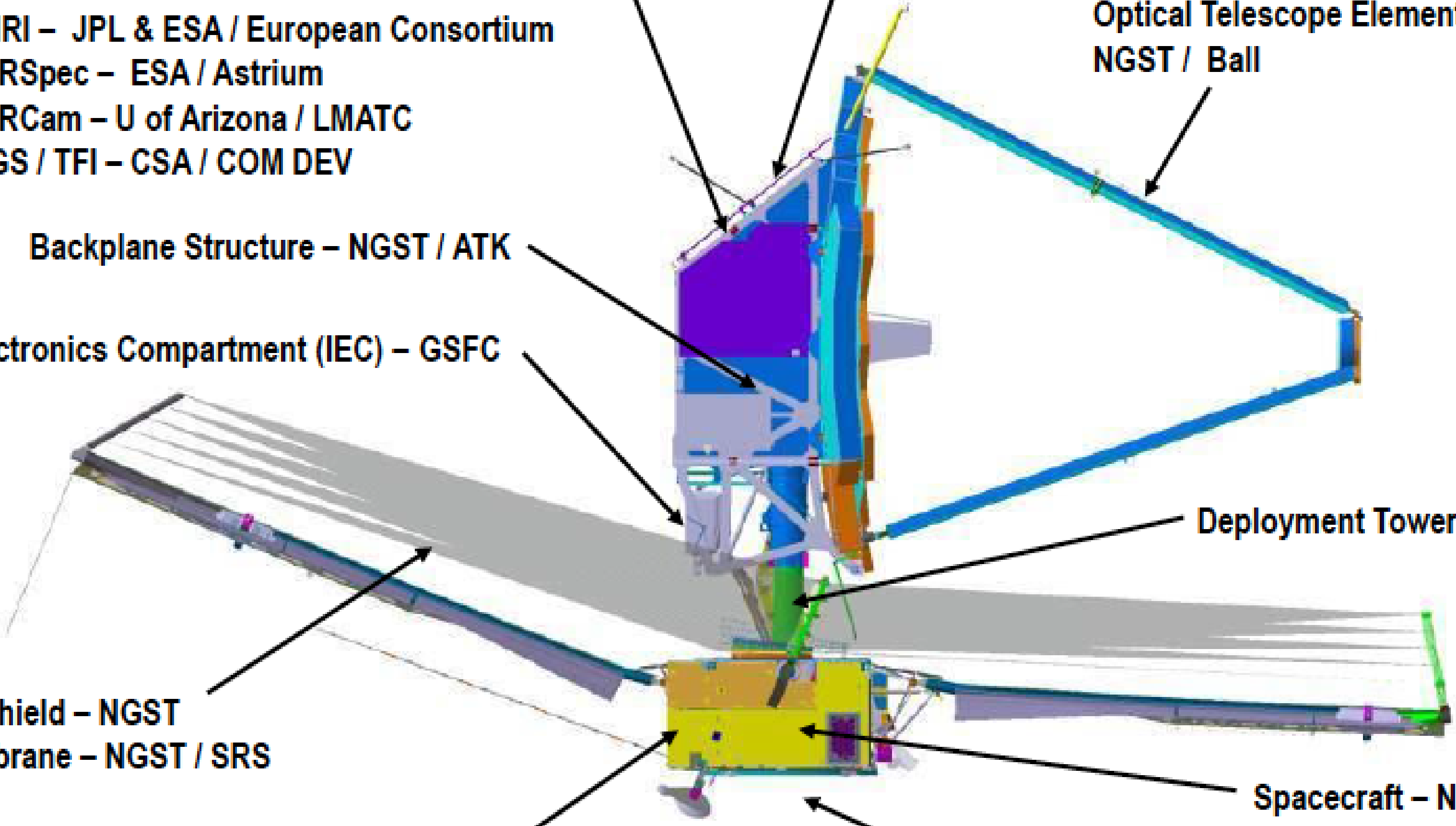

ISS/RRM


JPSS-2


CUBE-SATS


Landsat 9

James Webb Space Telescope



Integrated Science Instrument Module (ISIM) – GSFC
Structure – GSFC / ATK
MIRI – JPL & ESA / European Consortium
NIRSpec – ESA / Astrium
NIRCam – U of Arizona / LMATC
FGS / TFI – CSA / COM DEV

ISIM Radiators – NGST / Ball

Optical Telescope Element (OTE) – NGST / Ball

Backplane Structure – NGST / ATK

ISIM Electronics Compartment (IEC) – GSFC

Deployment Tower – NGST

Sunshield – NGST
Membrane – NGST / SRS

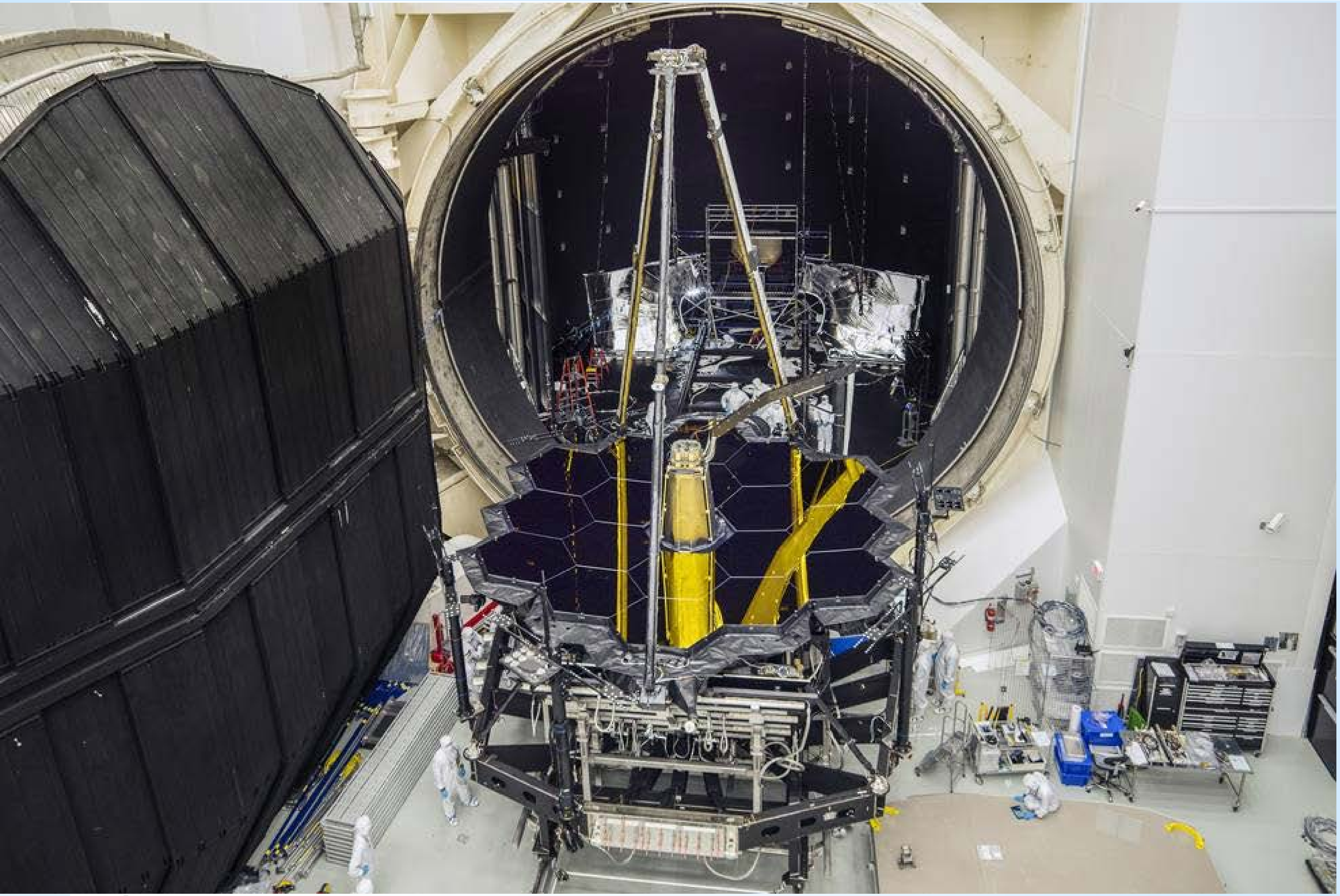
Spacecraft – NGST

MIRI Cryocooler – JPL / NGST
Instrument C&DH – GSFC

Launch Vehicle & Adapter – ESA / Arianespace

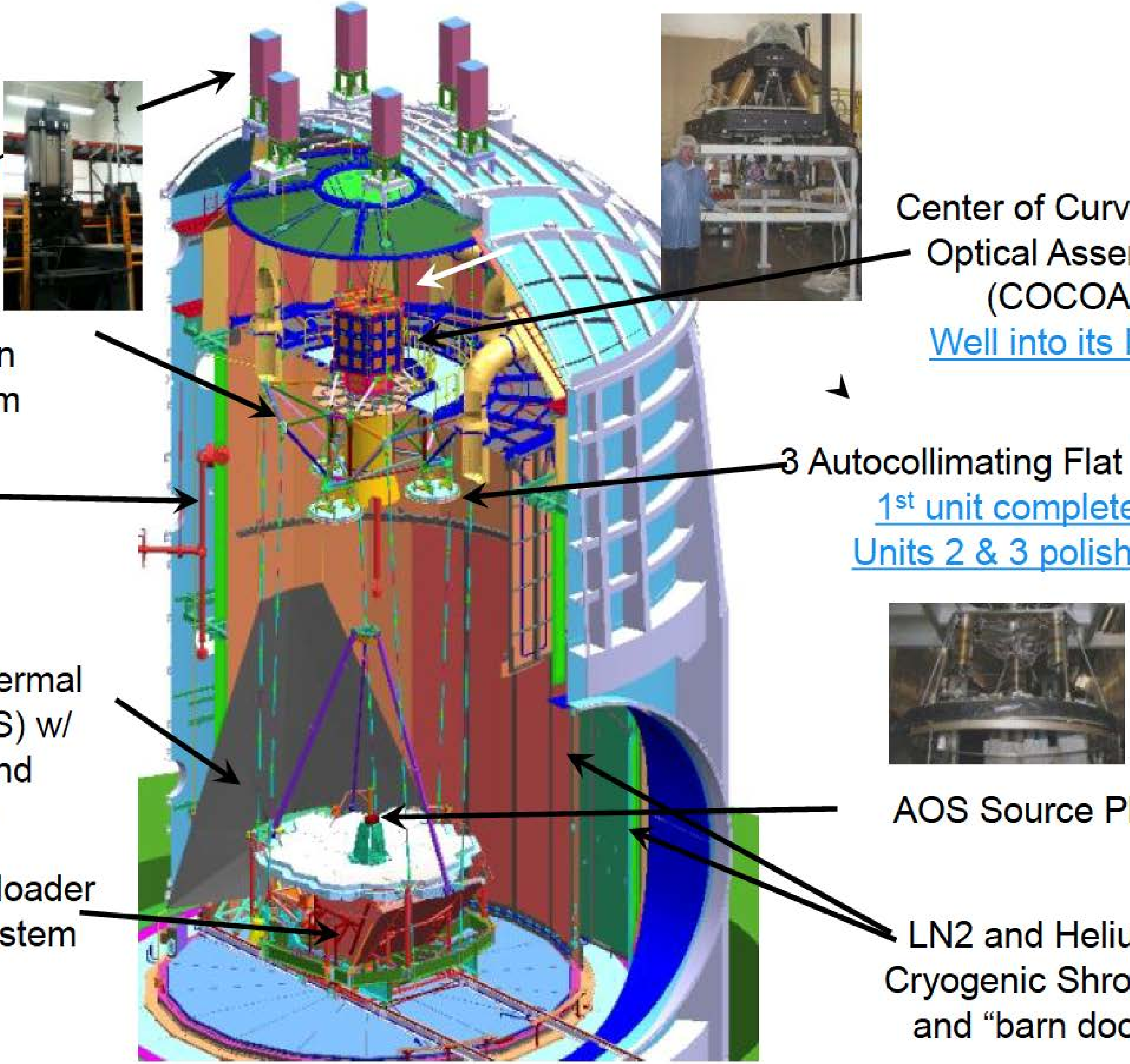
Overall Observatory – NGST

JWST testing at JSC, 2017 during Hurricane



Cryo-TV Test of integrated Mirror and instrument assembly in JSC Chamber A was successful! There is NO test of all up S/C, sunshield, mirror, and instruments. S/C bus will be tested in Spring/Summer 2018

JSC Chamber A fits perfectly!



Chamber Isolatior
1st unit tested

Suspension
Subsystem

Photogrammetry
Windmills

Space Vehicle Thermal
Simulator (SVTS) w/
cryo-cooler and
electronics

Hardpoint Offloader
Support System

Center of Curvature
Optical Assembly
(COCOA)
Well into its I&T

3 Autocollimating Flat Mirrors
1st unit complete.
Units 2 & 3 polished

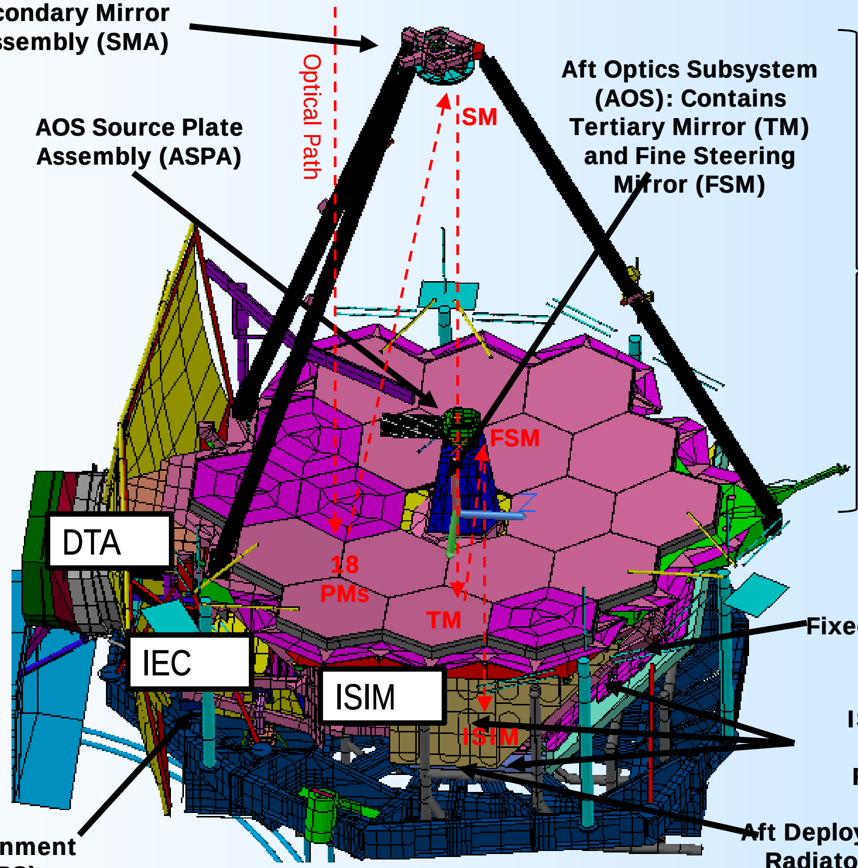
AOS Source Plate

LN2 and Helium
Cryogenic Shrouds
and "barn door"

Optical telescope and integrated science instrument module (OTIS)

DTA: Deployable Tower Assembly
IEC: ISIM Electronics Compartment
ISIM: Integrated Science Instrument Module, contains:

- Near-Infrared Camera (NIRCam)
- Near-Infrared Spectrograph Optical Assembly (NIRSpec OA) and Focal Plane Assembly (NIRSpec FPA)
- Fine Guidance Sensor (FGS/NIRISS)
- Mid Infrared Instrument (MIRI)



Secondary Mirror Assembly (SMA)

AOS Source Plate Assembly (ASPA)

Aft Optics Subsystem (AOS): Contains Tertiary Mirror (TM) and Fine Steering Mirror (FSM)

Secondary Mirror Support Structure (SMSS)

Primary Mirror Segment Assemblies (PMSAs), 18 total

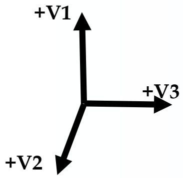
Primary Mirror Backplane Support Structure (PMBSS)

Fixed ISIM Radiator (FIR)

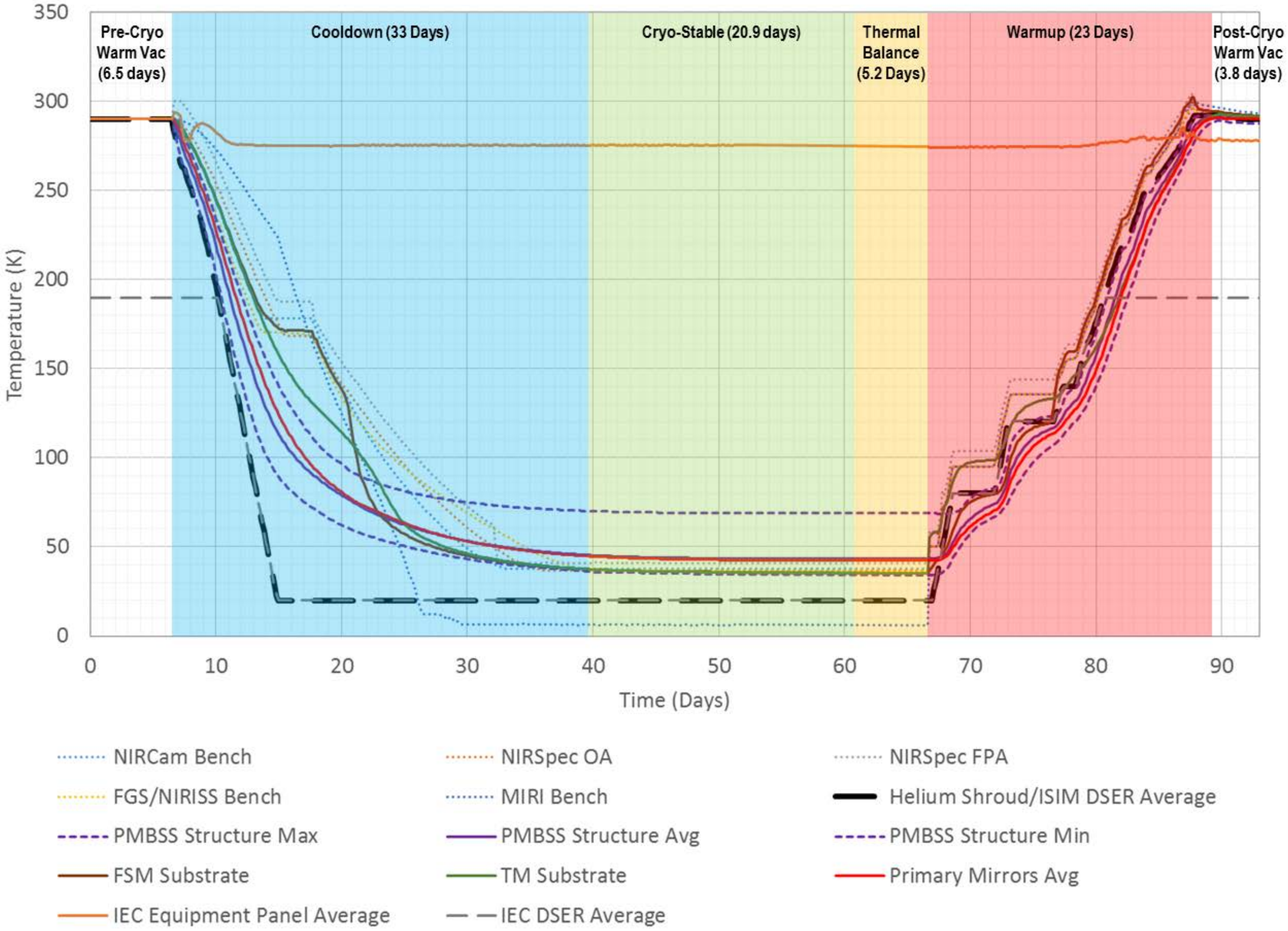
ISIM Deep Space Environment Radiators (ISIM DSERS)

Aft Deployable ISIM Radiator (ADIR)

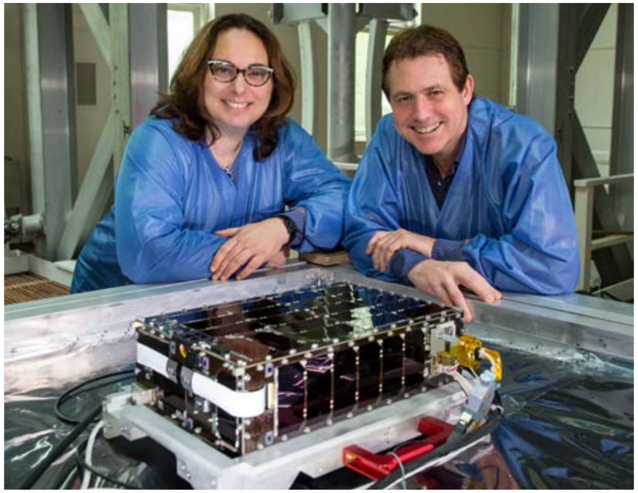
IEC Deep Space Environment Radiators (IEC DSERS)



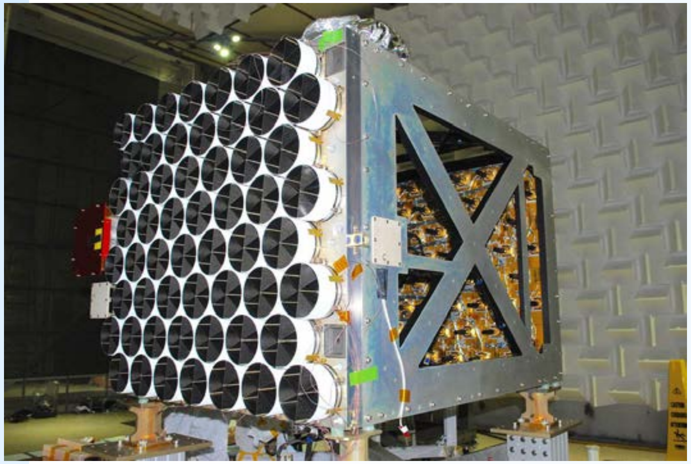
OTIS TV Test Profile



Project Updates



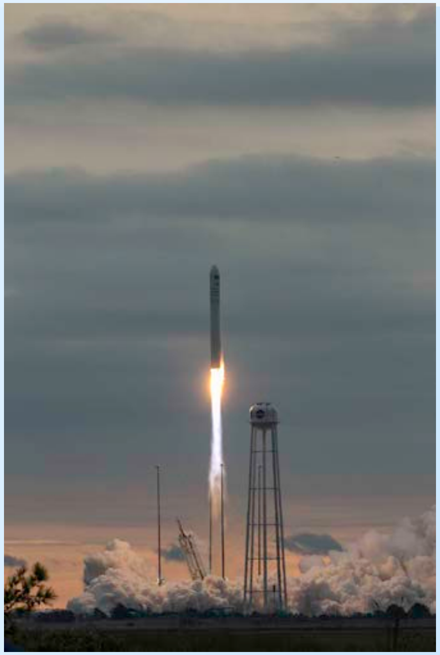
GSFC's first Cubesats were launched in 2017, ICECUBE and Dellingr. Both operating successfully in orbit - ICECUBE uses Phase Change Material (PCM) for thermal control. Dellingr shown in pic on left.



NICER X-ray instrument launched to ISS in 2017 and working well, uses PCM for thermal control. Also has SEXTANT instrument that provides first GPS like Navigation for anywhere in the solar system via Pulsars.

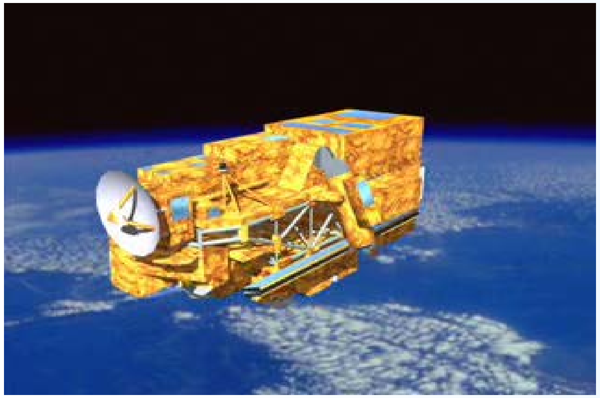
Project update (cont)

JPSS-1 successfully launched 11/17
Has passively cooled VIRS instrument Cryocooler



Orbital Antares successful return to flight to ISS from Wallops, 11/17

Update on Early Missions with Capillary Pumped Loops (CPL's)



- **Terra launched 12/1999**

Two-phase loops (CPLs) are on SWIR, TIR and MOPPIT instruments

All 3 CPLs continue to demonstrate reliable, stable thermal control for their instruments

SWIR set temperature reset 3 times to prolong cryocooler life

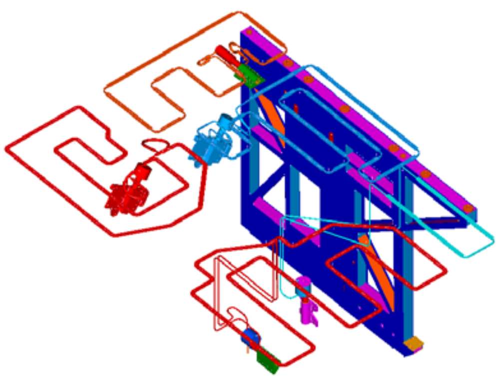
HST Servicing Mission-3B; NICMOS Cryo-cooler (with CPL) installation

Launch Feb, 2002

– The cryo-cooler ceased functioning late in CY08; attempts to restart the cryo-cooler were unsuccessful, CPL was working fine

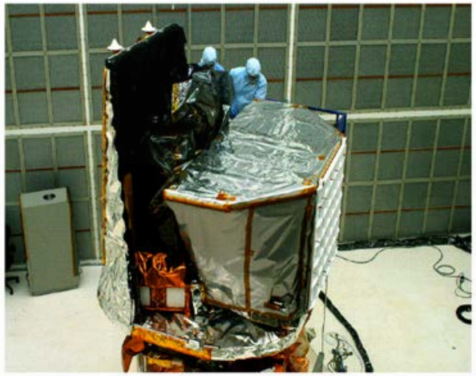
Update on Early Missions with Loop Heat Pipes (LHP's)

ICESAT-1/GLAS, 2 LHPs, 1st NASA
Mission with LHP's, 01/2003 launch
Used LHP to adjust optical bench temp for
optical alignment (Unplanned)
Mission ended in 2009 after lasers failed



AURA/TES instrument with 5 LHP's
Launched 7/04
JPL Mission
Still working, numerous LHP on/off cycles
due to instrument needs

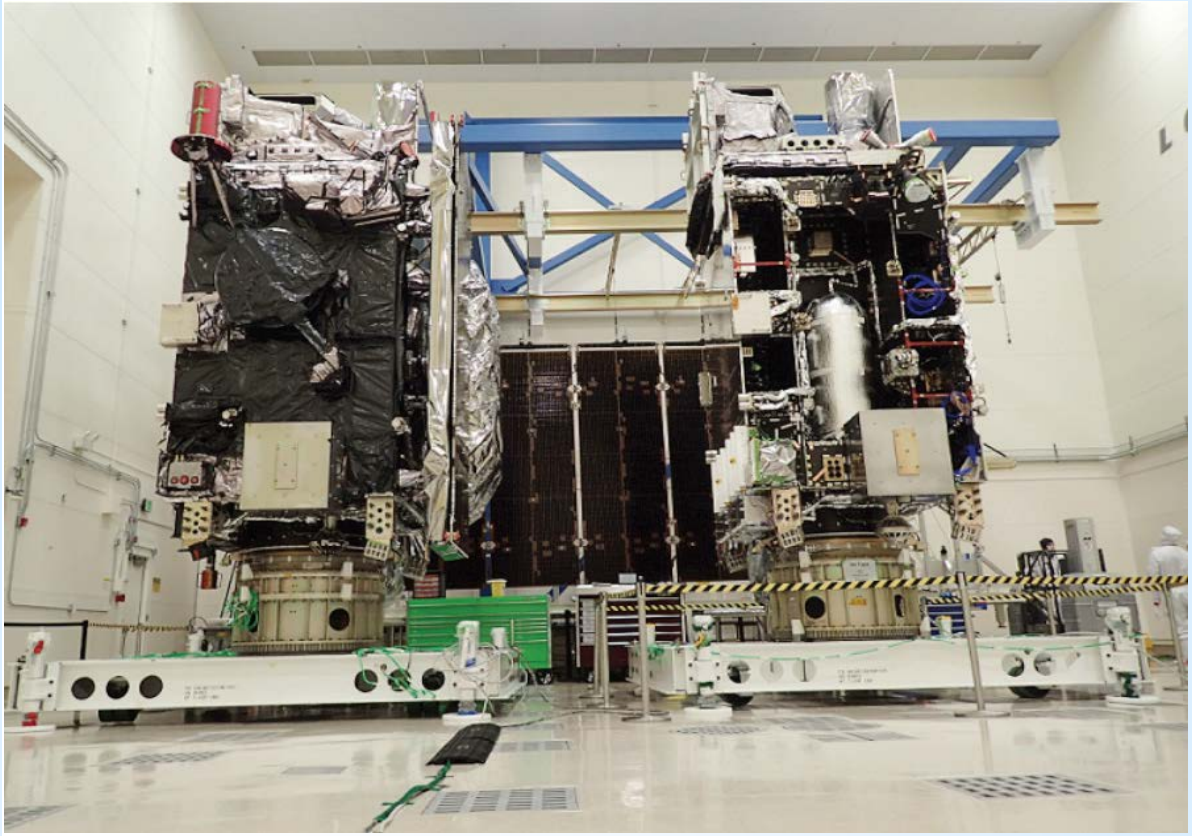
Update on Missions with LHP's (continued)



SWIFT/BAT x-ray instrument, 2 LHPs,
Launched 11/04
Still working, using backup reservoir
Temperature controller

GOES N-Q Weather
Spacecraft; 2 LHP's for S/C component
Temperature control
GOES N Launched 05/06
GOES O 6/09, GOES P 3/10

GOES-R and GOES-S in High Bay (Lockheed Martin, Denver CO)



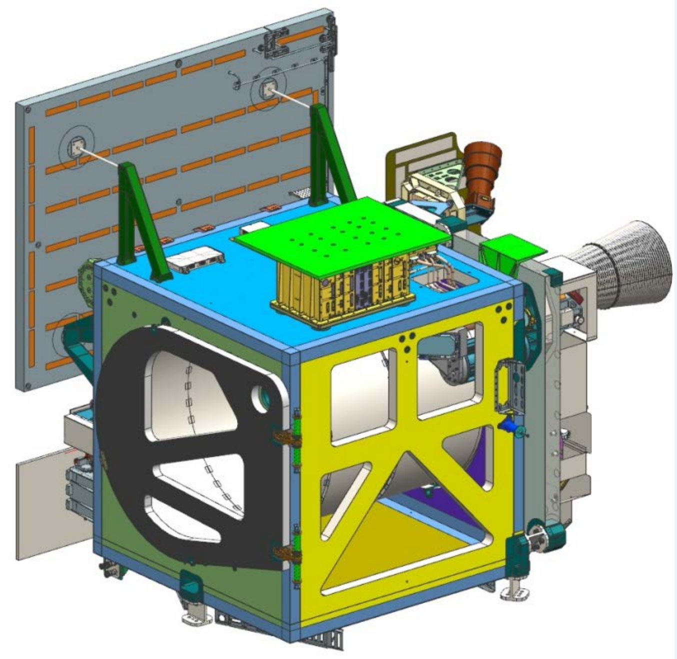
LHP’s used for thermal control of ABI and GLM instruments.

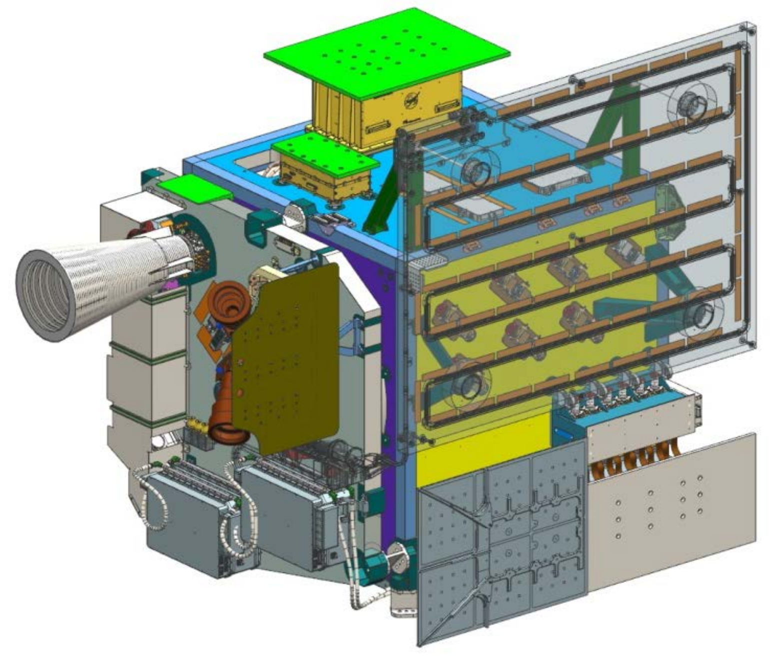
GOES-R successfully launched and in orbit, 10/16

GOES-S Launch planned For 3/18

GOES-T,U in the 2020’s

ICESAT-2/ATLAS Instrument with Loop Heat Pipe Cooling System

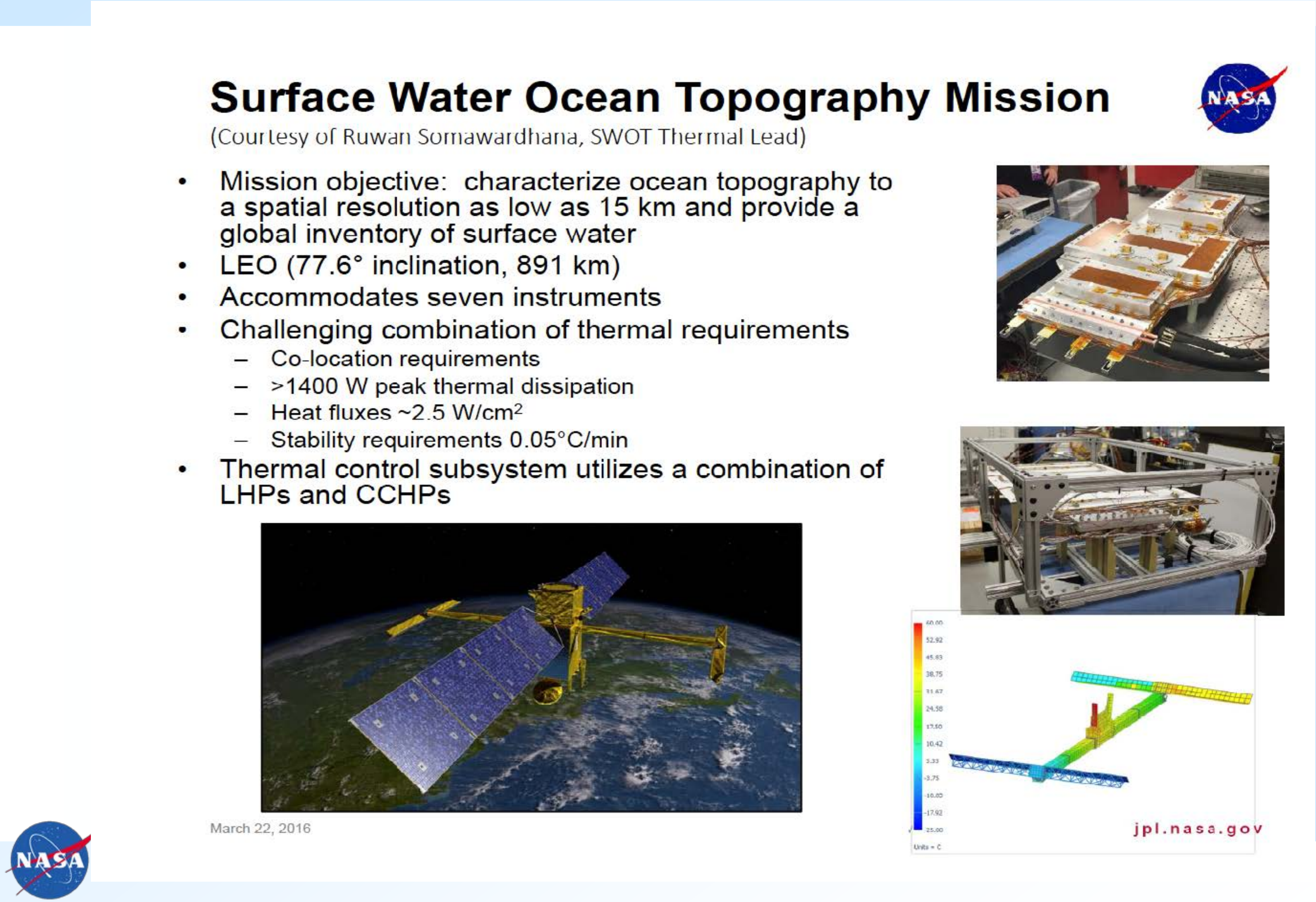




Recently completed Instrument TV test,
launch planned for fall ‘18

JPL SWOT Mission with LHP's; Launch 2021

(chart courtesy Eric Sunada/JPL)



Surface Water Ocean Topography Mission

(Courtesy of Ruwan Somawardhana, SWOT Thermal Lead)

- Mission objective: characterize ocean topography to a spatial resolution as low as 15 km and provide a global inventory of surface water
- LEO (77.6° inclination, 891 km)
- Accommodates seven instruments
- Challenging combination of thermal requirements
  - Co-location requirements
  - >1400 W peak thermal dissipation
  - Heat fluxes ~2.5 W/cm^2
  - Stability requirements 0.05°C/min
- Thermal control subsystem utilizes a combination of LHPs and CCHPs

March 22, 2016

jpl.nasa.gov

Thermal Technology Development

- GSFC’s SBIR Thermal Subtopic had a robust 2017 with 4 Phase 1 Awards
    - Participation from 3 NASA centers – GSFC, MSFC, and JPL
    - JPL will address their SBIR’s in their talk
- GSFC’s SBIR Thermal Subtopic has been “rotated out” for 2018 call, hope to get back in 2019
    - JSC SBIR Thermal Subtopic still in 2018 call
- Modest IRAD, Project and HQ funding received for other activities

NASA SBIR/STTR Technologies

S3.07-8563 – Loop Heat Pipe Manufacturing via DMLS for CubeSat Applications

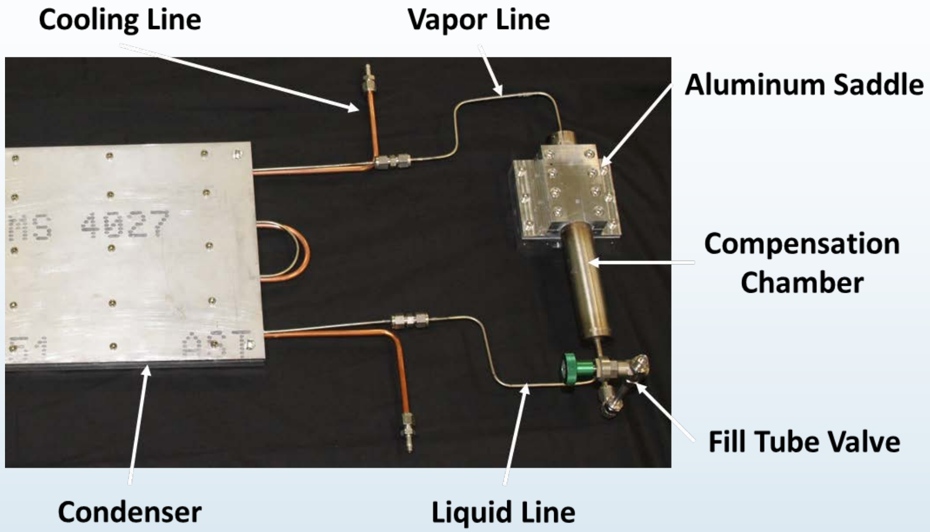
PI: William Anderson

Advanced Cooling Technologies, Inc. – Lancaster, PA

Identification and Significance of Innovation

It is estimated that the cost to produce a Loop Heat Pipe (LHP) pump assembly accounts for approximately 75% of the total system's manufacturing cost. By 3D printing an evaporator envelope with an integral porous primary wick structure, the overall complexity and cost of the design can be significantly reduced. One advantage is that the Direct Metal Laser Sintering (DMLS) method offers is that many aspects of the fabrication process can be simplified and dissimilar metal joints can be eliminated. In addition to the direct benefits, this novel fabrication method enables additional enhancements due to the inherent advantages of the additive manufacturing method which eliminates some restrictions of traditional machining, enabling structures that are more favorable from a thermal and hydrodynamic perspective. In Phase I, a LHP with a DMLS evaporator was built using ammonia as the fluid, and carried the predicted 45W.

Estimated TRL at beginning and end of contract: (Begin: 4 End: 6)



Technical Objectives and Work Plan

The overall objective of the Phase I and Phase II programs is to develop a low cost LHP, where the pump is fabricated by DMLS technology. In Phase I a proof of concept LHP was built with a 3D printed evaporator envelope with integrated primary wick. The overall objective of the Phase II program is to further develop the fabrication process for performance optimization with demonstration of a full scale LHP. A second LHP will be fabricated that is suitable for testing on the ISS. The 9 technical tasks listed below:

1. Define Requirements
2. Pore Radius and Permeability Study (to optimize DMLS parameters)
3. Scaling Study (to scale LHP evaporator)
4. Accelerated Life Testing
5. LHP Miniaturization (to fit on CubeSat/SmallSat)
6. Graded Wick Fabrication (to improve performance)
7. Secondary Wick Fabrication
8. Prototype Design of Complete LHP
9. LHP Fabrication and Testing (including thermal vacuum, and shock and vibration testing)
10. Flight LHP Fabrication and Testing (using working fluid that would allow for testing on the ISS)

NASA Applications

Ammonia and propylene LHPs are currently used in most NASA and commercial satellites. In comparison with Constant Conduction Heat Pipes (CCHPs), they carry much higher powers (1kW vs. 100W) over longer distances (10m vs. 2-3m). Their main drawback is that they are two orders of magnitude more expensive to fabricate and test than CCHPs. A major benefit of the proposed evaporator/wick fabrication will be a significant reduction in cost of LHPs supplied to NASA for SmallSat/CubeSat applications.

Non-NASA Applications

The benefits for the Air Force are similar to the benefits for NASA. The commercial communications satellite market is the current primary market for LHPs. Universities are able to fabricate their own CubeSats for research in space; however, their budgets are much too limited to allow them to use traditionally fabricated LHPs making inexpensive 3D printed LHPs desirable.

Firm Contacts

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Fax: (717) 295-6064

NASA SBIR/STTR Technologies

S3.06-8747 - Asymmetric Conductance Thermoelectric Cooling Modules for Cryogenic Applications

PI: Geoffrey Campbell
microVection, Inc. - Broomfield, CO

Identification and Significance of Innovation

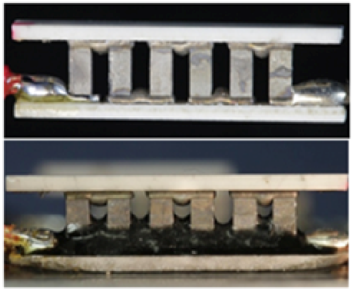
- Thermoelectric coolers (TECs) noted for lightweight compact construction, high reliability, and clean quiet operation
- Ohmic heating limits performance at high currents
- Biasing internal conduction toward hot side improves performance at high currents (Asymmetric Conductance)
- microVection developing Asymmetric Conductance TECs for higher temperature lift and reduced energy usage

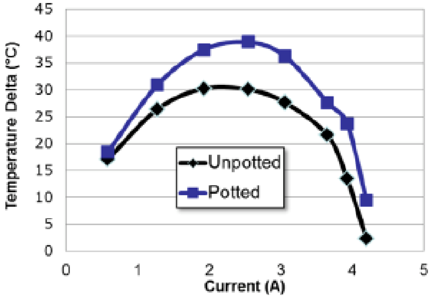
- Phase I results show significant performance improvements

- 30% increase in temperature lift at high currents

- 30% reduction in energy usage

Estimated TRL at beginning and end of contract: (Begin: 3 End: 6)





Technical Objectives and Work Plan

Objectives

- Complete development of Asymmetric Conductance TECs
  - Advancd Designs; Fab & test; NASA app demo; Evaluate scale-up
- Initiate evaluation of Reduced Resistance concept
  - Paramteric performance analysis; Fab trials; Prototype fab & test

Work Plan

Task 1. Analytic Design Studies

- Reduced scale design evaluation (Asymmetric Conductance)
- Reduced Resistance design trades
- Evaluation of combined Asymmetric Conductance/Reduced Resistance design

Task 2. Fabrication Studies & Prototype Development

- Fab studies for Asymmetric Conductance & Reduced Resistance designs
- Prototype fab for both designs
- Evaluation of production scale-up approaches

Task 3. Experimental Evaluation

- Bench testing
- NASA application demonstration

NASA Applications

Space science instruments require dedicated/localized cooling. TECs have small size, long life, and no moving parts. This enabling technology could impact NASA programs including:

- Explorer
- Earth Venture Suborbital
- DRM 6 (Crewed to Near Earth Asteroid)
- DRM 7 (Crewed to Lunar Surface)
- DRM 8 & 9 (Crewed to Mars Moons and Mars Surface)

Non-NASA Applications

TECs used throughout military, aerospace, electronics, and consumer markets

- Residential refrigeration is untapped market
- Replace vapor compression (heavy, noisy, environmental issues)
- Provide localized, personalized cooling in compact form factor
- Market potential large with significant civic & environmental benefits

Firm Contacts

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PHONE: (303) 941-8091

NASA SBIR/STTR Technologies

S3.06-9496 - Variable Conductance Radiator: A Novel Lightweight, High Turndown Spacecraft Radiator Using Variable Heat Conductors

PI: Scott Dye

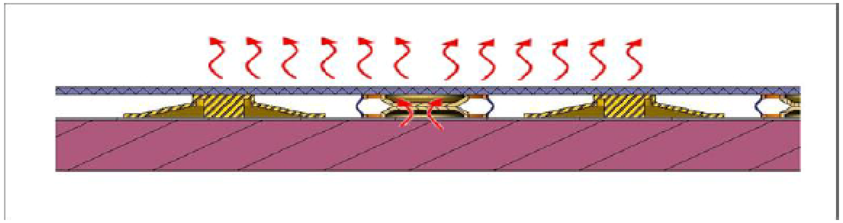
Quest Thermal Group - Arvada, CO

Identification and Significance of Innovation

Spacecraft thermal control is critical to maintain proper temperatures for humans, instruments & electronics. As spacecraft power levels increase and mission environments become more complex, more flexible thermal control is needed. The NASA Thermal Management Roadmap states radiator advancement is critical thermal technology for future spacecraft. NASA is seeking variable radiator technology capable of 6:1 turndown ratios. Quest Thermal is proposing a novel Variable Conductance Radiator that uses variable actuated heat conductors within an IMLI structure to control heat conduction. The Variable Conductor Radiator could provide turndown ratios of 80:1, and can act as high performance insulation as well as an effective radiator.

- VCR could provide heat rejection variable from 2W to 380W/m2 of radiator
- VCR could provide a high turndown ratio of 80:1
- VCR uses lightweight IMLI layers & SMA actuators to provide a variable radiator with mass of 0.6 to 2.1 kg/m2, compared to standard radiators at 5.2 kg/m2

Estimated TRL at beginning and end of contract: (Begin: 1 End: 3)



Technical Objectives and Work Plan

Technical objectives are:

- Develop a Variable Conductance Radiator (VCR) using variable actuated heat conductors through an Integrated MLI structure.
- Refine thermal analysis to optimize and guide VCR design.
- Design, fabricate and test a 2 layer VCR prototype, performing thermal measurements of heat rejection with various heat conductors actuated.
- Evaluate VCR prototype performance, compare to modeled heat rejection levels (9 W/m2 to 370 W/m2 & turndown ratio of 40:1 for 2-layer system).
- Evaluate VCR for feasibility and suitability for future NASA spacecraft and mission needs.

The VCR prototype should demonstrate:

- A novel variable conductor radiator using variable conductance within IMLI is feasible.
- VCR can provide good maximum heat rejection, low minimum heat rejection, and a large turndown ratio (40:1 for 2 layers).
- VCR could provide a simple, low mass, durable variable radiator design.

NASA Applications

- Science & Space Technology Mission Directorates are looking for new variable heat control technology
- NASA has need for variable radiators for more complex thermal environments.
- Science missions need more capable thermal control, including variable radiators with high turndown ratios & improved insulation for deep space cold environments
- Exploration vehicles need variable thermal control for different mission

Non-NASA Applications

- Improved thermal control for high power commercial & other satellites
- VCR could provide variable heat rejection & reduce heater power
- VCR is a high performance, variable, low mass radiator, could be installed on any new satellite
- Of interest to spacecraft radiator suppliers such as Lockheed Martin, Orbital ATK, SSL & Sierra Nevada

Firm Contacts

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PHONE: (303) 395-3100
FAX: (303) 395-3101

NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S3.06-9615 - 3D Manufacturing of Integrated Heat Exchangers

PI: Jian Liu
Polaronyx, Inc. - San Jose, CA

Identification and Significance of Innovation

Current capillary heat transfer devices require tedious processes to insert the porous wick into the evaporator and to seal the wick ends for liquid and vapor separation, especially for miniature thermal systems for CubeSat/SmallSat applications. NASA desires to reduce the cost and skill required to manufacture integrated heat exchangers for pumped fluid loops in order to increase heat transfer performance through more efficient use of raw materials along with a reduction of machining, multiple setups, and labor hours.This NASA SBIR Phase I proposal presents an unprecedented Additive Manufacturing (AM) of high thermal conductivity materials (e.g. Al alloy 7075) to make integrated heat exchangers with high pulse repetition rate (PRR) femtosecond (fs) mode-locked fiber laser. It is the enabling technology for manufacturing complex capillary heat transfer devices.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 5)

Technical Objectives and Work Plan

Objective 1: To optimize fs fiber laser based AM & SM system for heat exchanger fabrication.
Objective 2: To test feasibility of making a capillary heat exchanger. Various laser processing conditions will be tested. The quality of AM will be examined under microscope and scanning electron microscope (SEM).
Objective 3: To model the process for AM. This will help us understand and optimize the AM process. A commercial model will be selected as the simulation tool.
Task 1: AM system optimization and modeling for Al powders.
Task 2: AM using Al powders to form capillary heat exchangers.
Task 3. Control Electronics and Software

NASA Applications

In addition to NASA's integrated heat exchangers manufacturing, the proposed short pulse high power fiber laser AM and SM process can also be used in other applications, such as space vehicle, aircraft, and satellite manufacturing. PolarOnyx will develop a series of products to meet various requirements for NASA/military deployments.

Non-NASA Applications

This technology will be directly applied in the 3D printing area with combined market share of $10(s) of billions. 3D printing uses various technologies for building the products for all kinds of applications from foods, toys to battery, rockets and cars. The global market for 3D Printing is projected to reach $2.99 billion by year 2018.

Firm Contacts

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NON-PROPRIETARY DATA

Atomic Layer Deposition (ALD)

Vivek.H.Dwivedi@nasa.gov - PI

Atomic
Layer
Deposition

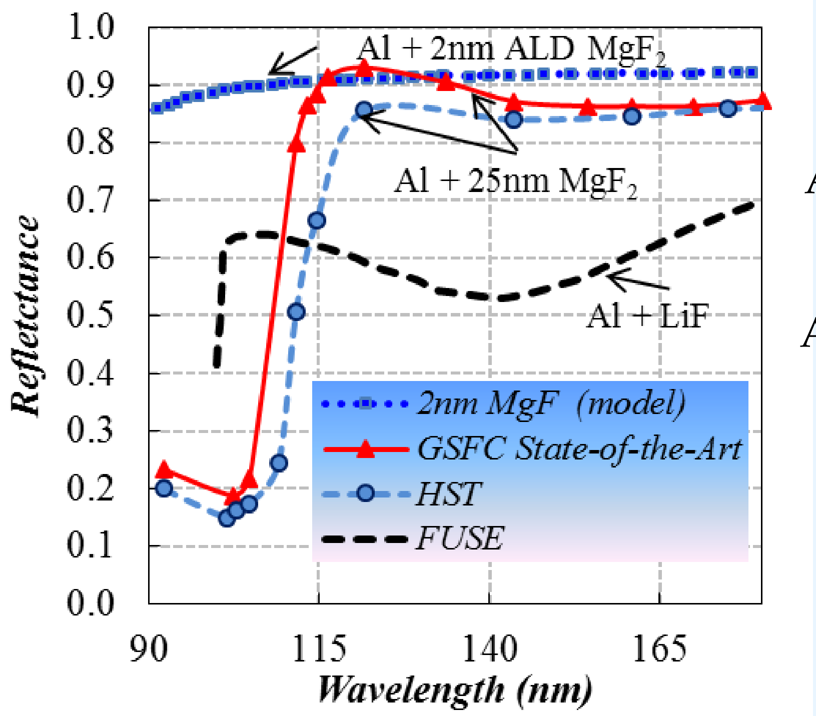
A thin film"nanomanufacturing" tool that allows for the conformal coating of materials on a myriad of surfaces with precise atomic thickness control.

Based on:

- Paired gas surface reaction chemistries
- Benign non-destructive temperature and pressure environment
  - Room temperature -> 250 ° C (even lower around 45 ° C)
  - Vacuum

Astrophysics Research Program – Far Ultra-Violet (FUV) –Reflectance Coating

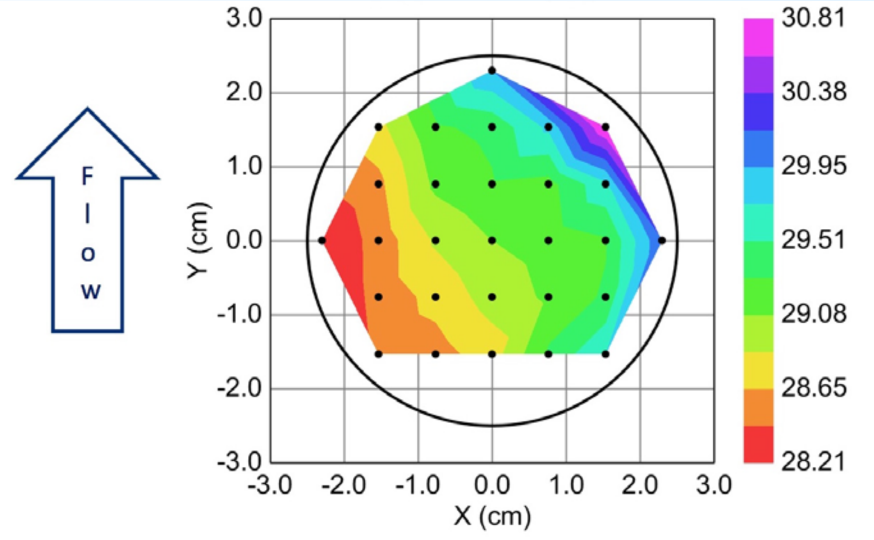
Ultraviolet (LUV) range of 90-130 nm is one of the biggest constraints on FUV telescope and spectrograph design, and it limits the science return of FUV-sensitive space missions. Improved reflective coatings for optics, particularly in the LUV spectrum, could yield dramatically more sensitive instruments and permit more instrument design freedom.



ALD Film Deposition of AlF3 utilizing TaF5 and TMA (Al(CH3)3)

ALD Film Deposition of AlF3 on etched coupons of XeF2

FUV –Reflectance Coating



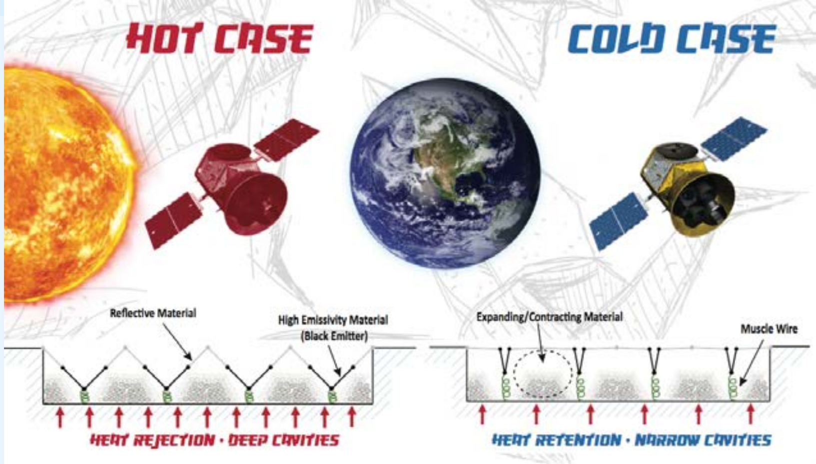
Utilization of Trimethyl Aluminum and TiF4 to Make films of AlF3

Thermal Vacuum Test of Origami Inspired Radiators

Description and Objectives:

Conventional thermal control systems often result in a design that is mass prohibitive. By testing a passive, multifunctional, modulating “smart” radiator device (SRD) based on origami folds along with a charge mitigating coating will verify a 3D state-of-the art thermal control structure, resulting in a decrease in the overall spacecraft power budget with an estimate savings of 10-15%. The work that is being proposed is in collaboration with Brigham Young University and NASA Glenn Research Center (GRC) where each is sharing in development cost.

The objective of this work is to demonstrate via thermal vacuum testing radiators that have a unique three-dimensional geometry based on origami fold patterns.



Approach

The testing of the radiator concepts will be carried out at the NASA/GSFC Thermal Laboratory. We first plan to determine the heat load and environmental conditions needed via modeling the experimental setup and getting test predictions including thermal gradients across the radiator surface. The development plan is as follows:

Design and Construction of the Test Setup: Multiple radiators will be tested at the same time with a constant heat load to each one. By measuring temperature effect in a predefined thermal environment will allow for its design verification including efficiency and passive performance.

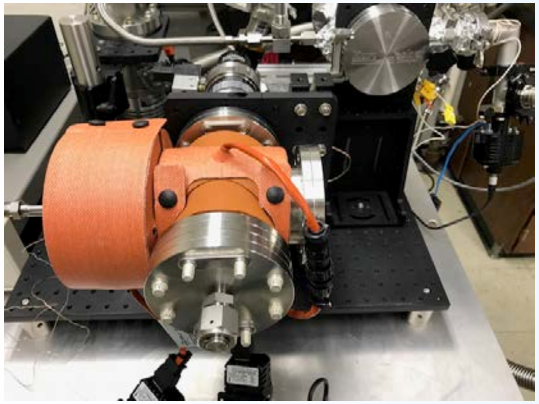
Development and Construction of Dynamic Radiator: The dynamic radiator will be constructed and delivered for testing by BYU with the passive actuation Shape Memory Alloy provided by NASA GRC.

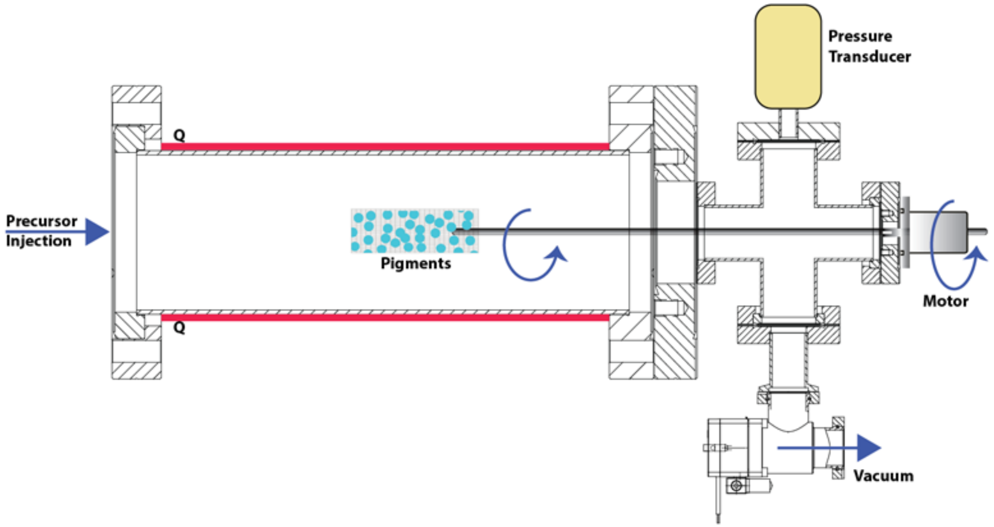
ALD for Radiator Coatings – Pigment Modification

- Most white pigments do not dissipate electrical charge without a dopant or additive
- Two most commonly used dissipative thermal coatings (Z93C55 and AZ2000) rely on indium hydroxide or tin oxide as charge dissipative additives utilizing sol gel wet chemistry
- Indium Tin Oxide (ITO) formed locally on a macroscopic scale due to seeding and ITO crystal formation on the boundaries of the pigment grains and thickness and dispersion throughout the coating were difficult to control.
- Patent Pending
- 2018 MISSE Flight to ISS

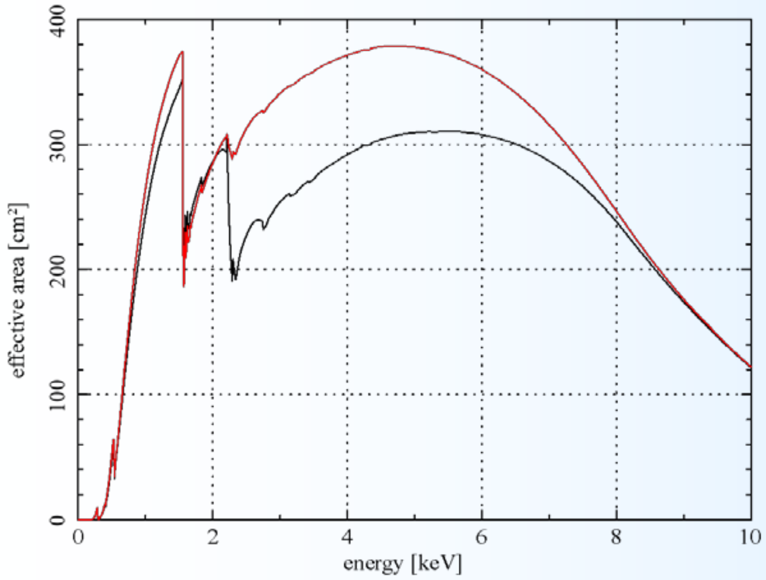
Solution – ALD ITO for Pigments

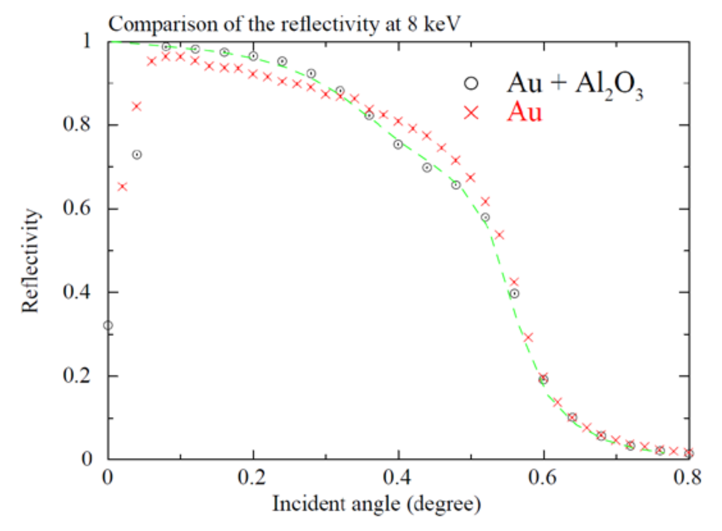
Create ALD supercycle of Indium Oxide and Tin Oxide – Vary Tin Oxide to modify conductivity.





Room Temperature ALD for X-ray Applications





***5 nm thick ALD Aluminum Oxide (Al2O3) layer is applied on the gold surface**

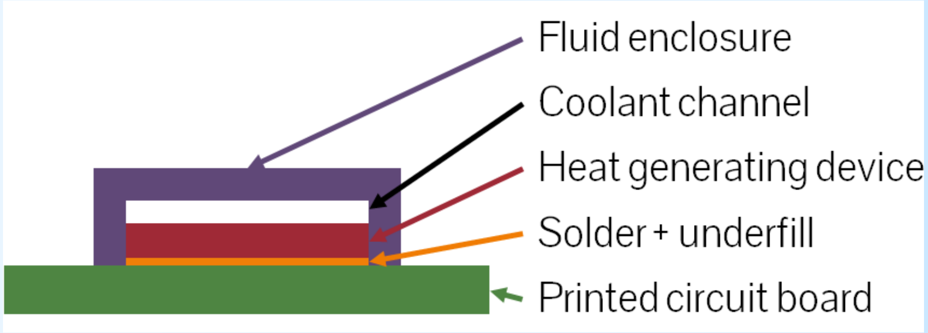
***Reflectivity can be increased quite bit in soft X-ray band**

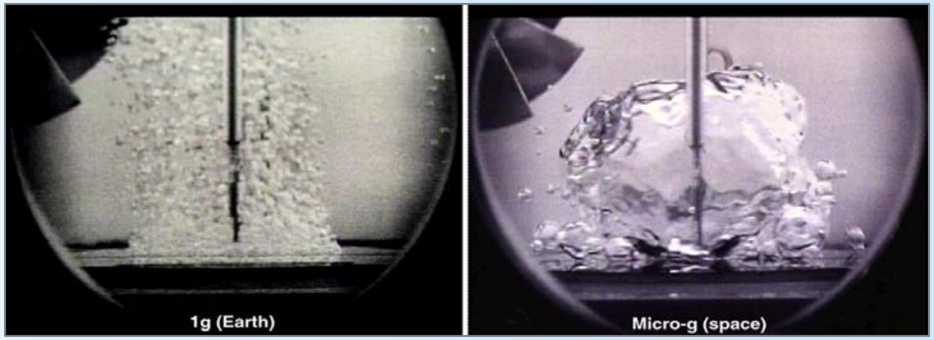
Flow Boiling in Microgap Coolers - Validation via Suborbital Flight

Franklin.L.Robinson@NASA.gov
Principal Investigator
Co-I: Dr. Avram Bar-Cohen,
University of Maryland

Motivation

- Electronic devices thermally-limited by remote cooling
- Embedded cooling extracts dissipated heat on-site
- Two-phase flow offers better performance, adds complexity
- Gravity-insensitive behavior would streamline technology development process





Dhir and Warrier, 2011

Program Plan

Ground-based Testing

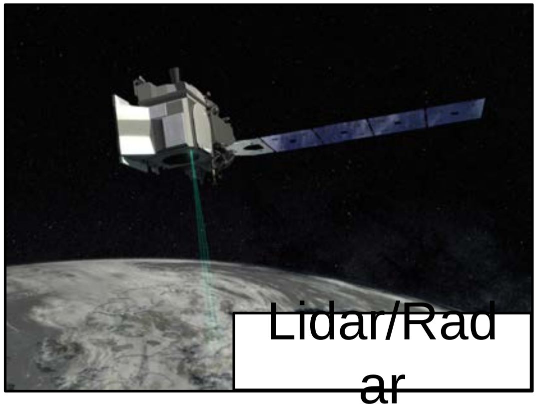
Characterize parameters that govern thermofluid behavior

Suborbital Flight

Establish effects of high-g and microgravity environments

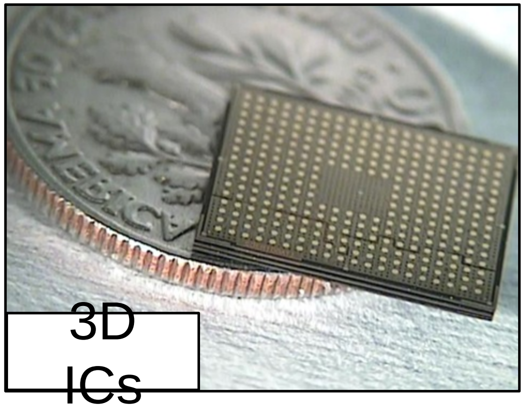
Integration with Flight Projects

Complete technology maturation process



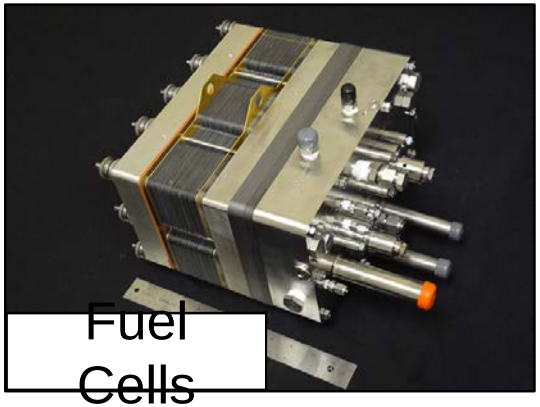
Lidar/Radar

NASA, 2014



3D ICs

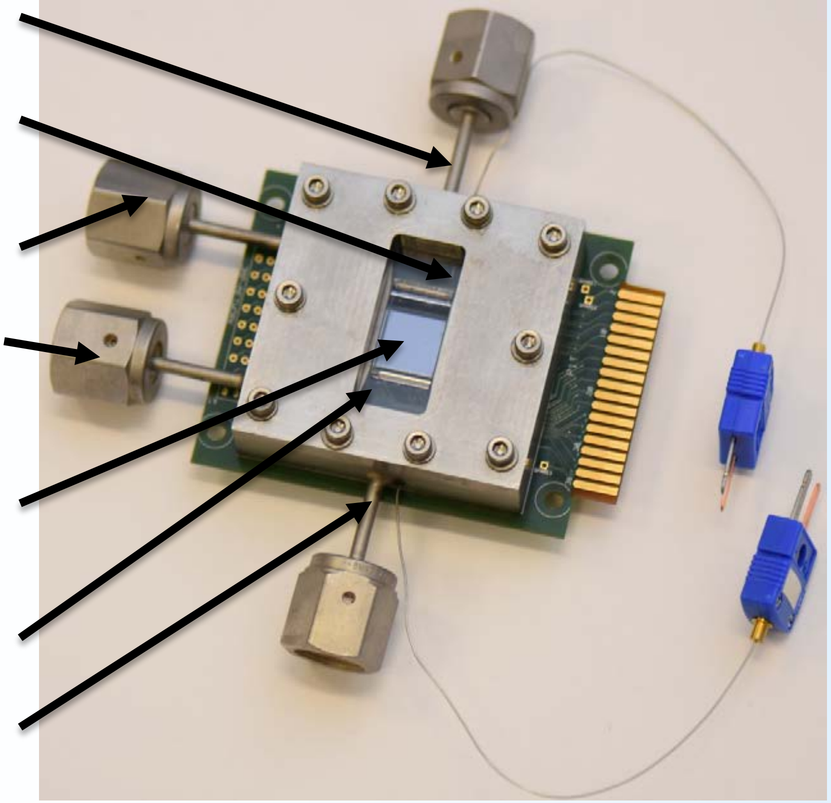
Aurora Semiconductor, 2017



Fuel Cells

Teledyne Energy Systems, 2017

Microgap Cooler Assembly



Pressure tap

Temperature probe

Fluid outlet

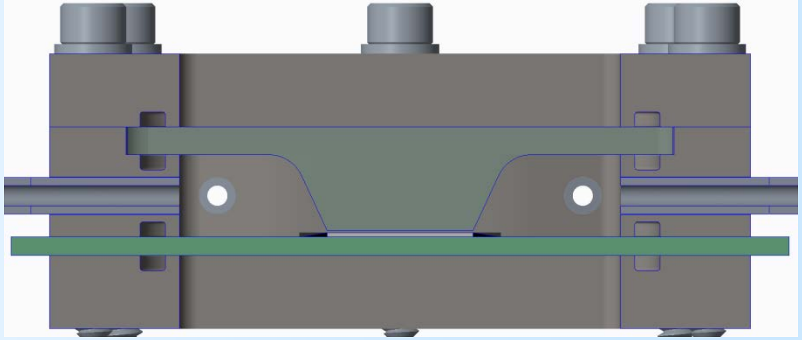
Fluid inlet

Thermal test chip

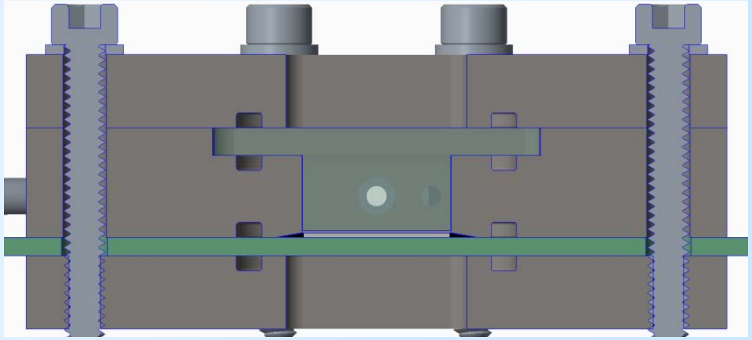
Polycarbonate cover

Pressure tap

Thermal test chip: 12.7 by 12.7 by 0.6 mm

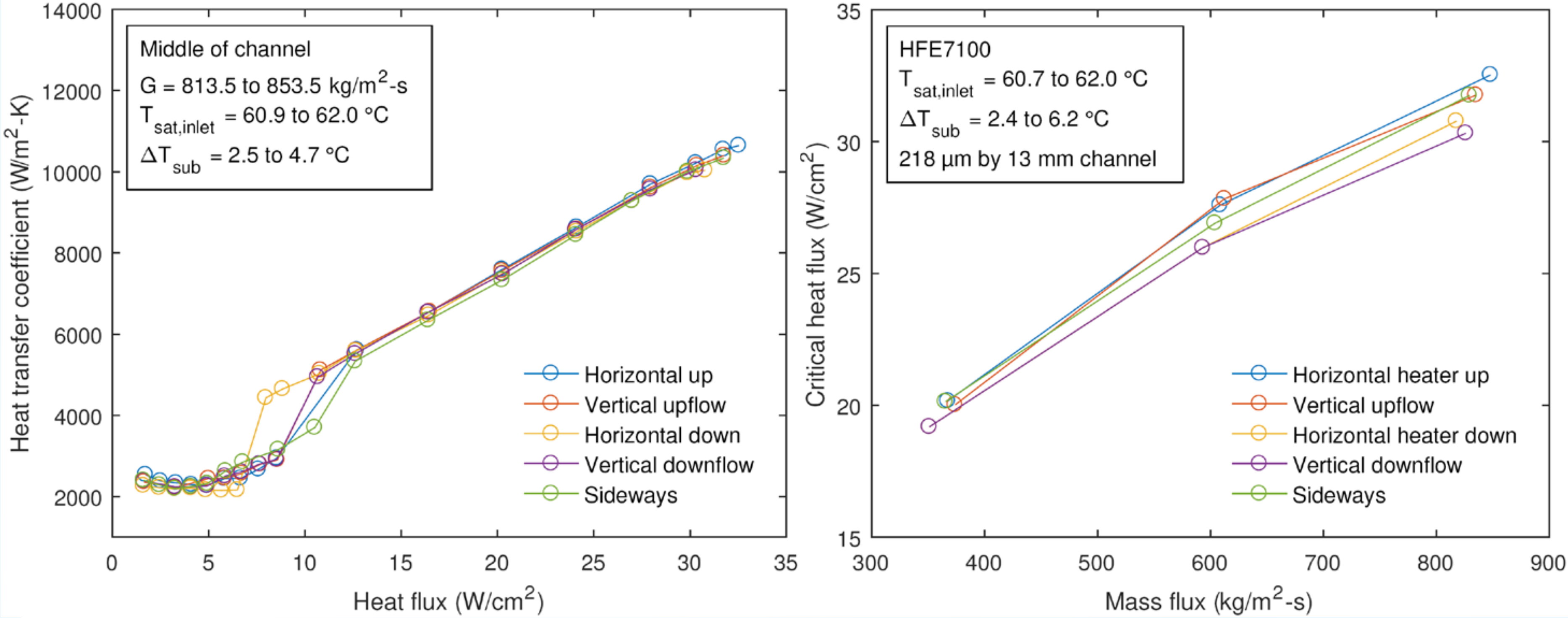


Axial Cross Section



Transverse Cross Section

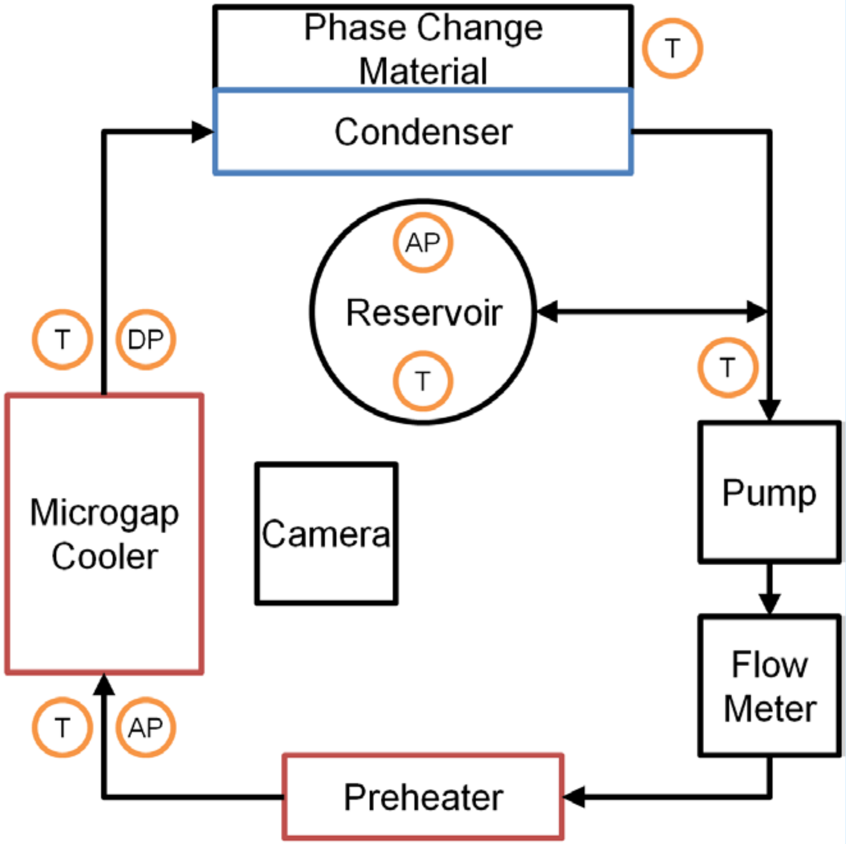
Ground Test Results



During ground tests, heat transfer coefficients and critical heat flux showed minimal variation with changes in evaporator orientation

Suborbital Flight Test

- First flight: Q3 2018
  - 2+ minutes of microgravity
  - 4 g during re-entry
- As similar as possible to ground test flow loop
  - Identical evaporator assembly
  - Same pump and transducers
- Constant flow rate, heat flux
  - Heat applied after achieving microgravity

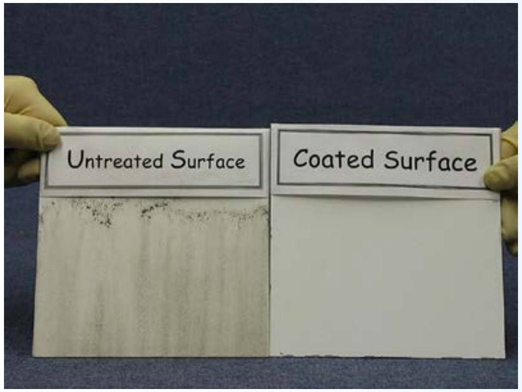


Thermal Coatings Technology

Mark.M.Hasegawa@nasa.gov
Coatings Group Leader

Lotus: Super Hydrophobic Coating

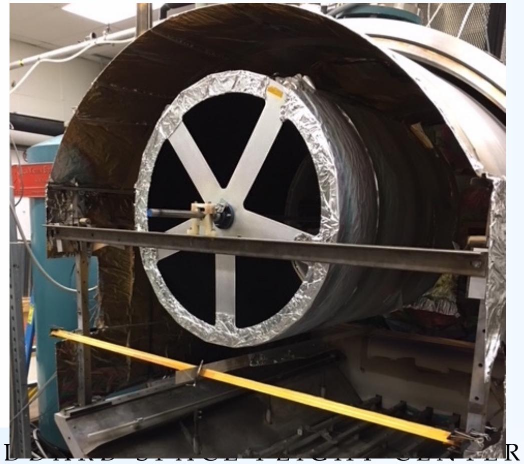
- **Nano-texture with overcoat - low surface energy for dust and contaminant mitigation – super-hydrophobic**
- **Two different overcoat technologies – Fluorinated Silane (wet chemistry), FEP (vacuum deposition) with patterning (Patent Pending)**
- **Part of technology roadmap development**
- **Significant improvements in optical clarity with reduction in streaking and smudging, use of less harsh reagents in process.**
- **Terrestrial Commercial Interest (Two Space Act Agreements)**
  - **Various glass manufacturers**
  - **Automotive – reduced obscuration on back up camera covers**
  - **Tooling uses**

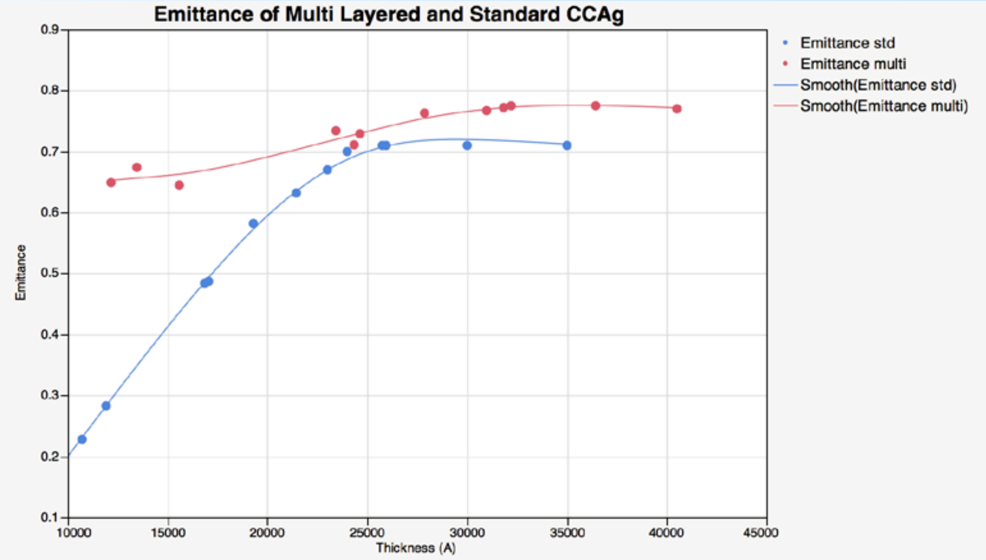


Uncoated radaitator surface and Lotus Coated surface after exposure to JSC-1 Lunar Simulant

Goddard Composite Coating Variants

- Development of multi-layered silver composite coating (CCAg) and silicate over-coated coated variants (provisional patent)
- Increased IR emittance with thinner oxide coatings (less than 2 microns)
- Hemispherical emittance values exceeding 0.80
- Low solar absorptance (a < 0.09) dependent on emittance requirements
- Available on flexible substrates - Kapton
- Coated films can co-cured onto composite substrates or applied like tapes
- Heritage material flown on GEO and LEO missions
- Charge dissipative
- Fabricated in 8’x2’ sheets



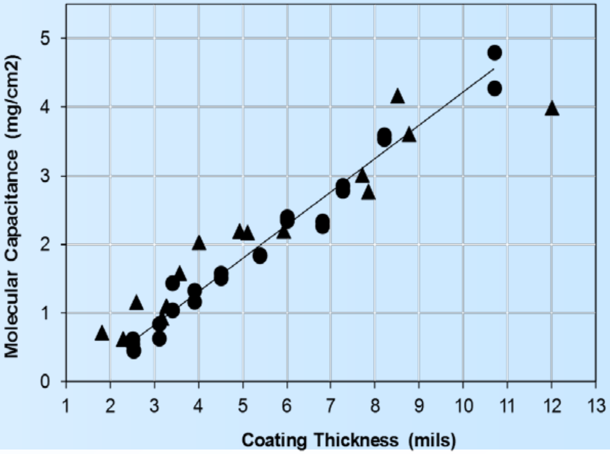


Materials International Space Station Experiment (MISSE-10)

- 1 year LEO exposure on ISS with return: Ram (28 samples), Nadir (14 Samples), Zenith (14 Samples)
  - Atomic Oxygen, Ultra-Violet and thermal cycling exposures on RAM: UV and Thermal on Nadir and Zenith faces
  - 0.625” diameter exposed coupons.
- Selection of materials for use on GSFC projects
  - Improved White SBIR II Silicate Coatings (5)
  - Variants of Composite Coatings
  - SBIR II Thermochromic Vanadium Oxide systems (2)
  - Molecular adsorber systems (2)
  - Lotus Super Hydrophobic Development Systems (5)
  - Encapsulated Z93C55
  - Indium Tin Oxide Encapsulated white pigment
  - Diffuse black polyurethane
  - New transparent conductive coatings Z93C55 and Z93P Controls
- November 2018 Launch

Molecular Adsorber Coating (MAC) reduces contaminants

- White and Black in color, zeolite based system (Patent pending)
- Applied to rigid (aluminum) or flexible (tape) substrates
- On ICON and GEDI hardware for contamination control of molecular outgassed products
- Used in JSC Chamber A as a diffusion pump oil getter for JWST tests
- Considered for use on terrestrial systems
  - Smithsonian: Reduces degradation of stored items and documents



MAC Barn Door Panels

Cryogenic Helium Shroud & Barn Door

Photo Credit: NASA/Chris Gunn

Base perimeter along barn door on external wall of cryogenic helium shroud

Main Level of Chamber A

- **"Barn Door" – Cryogenic Helium Shroud**
  - During testing, the cryogenic helium shroud reaches temperatures as cold as **-241°C** and as warm as room temperature
  - The internal wall of the shroud is painted with a black thermal/optical coating
  - The external wall of the shroud is made of an aluminum finish
- **Proposed MAC Location**
  - MAC samples were placed against the base of the external wall on the shroud to cover some of the exposed gaps near the perimeter along the barn doors of Chamber A
    - *This proposed MAC location helps capture vacuum chamber contaminants that may have migrated from the plenum and prevent them from depositing on the sensitive JWST test equipment housed internal to the cryogenic helium shroud*

MAC Barn Door Panels

Substrate Information	
Thickness	0.0625 inch
Material	6061-T6 Aluminum Alloy
Height	6 inch
Width	11 - 46 inch (varies)
Border Edge	0.50 - 0.75 inch (varies)

Photo Credit: NASA/Chris Gunn

Installation of a white MAC barn door panel on the external wall of the cryogenic helium shroud covering the gap along the base perimeter of Chamber A

6 inch by 12 inch black MAC and white MAC barn door panels

Photo Credit: NASA

Photo Credit: NASA

A border was implemented on samples to reduce possible coating damage due to handling and installation activities

Electro-hydrodynamic (EHD) Technology Development

High Heat Flux, High Temperature Heat Acquisition

Jeffrey.R.Didion@nasa.gov
Senior Thermal Engineer
Manager, Nanotechnology Facility

– Details can be found in Jeff’s Presentation

SUMMARY

- New Technology program underway at NASA, although funding is limited.
  - Recently released Earth Science Decadal Survey recommended increase in Technology funding from 3% to 5% of Earth Science $.
  - Projects are the best source for applied technology funding.
  - SBIR science thermal subtopic discontinued in FY 18, we hope for revival in FY 19
  - Limited Technology development underway via IRAD, NASA HQ, other sources
- NASA/GSFC's primary mission of science satellite development is healthy overall, new missions are in work – push for return to the moon will affect program
  - Recommendations by the administration still need congressional concurrence
- Future mission applications promise to be thermally challenging