# Beyond the Cutting Edge:

*Unleashing Innovation and Opportunity for the Future of Space Exploration and Science*


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Goddard Space Flight Center

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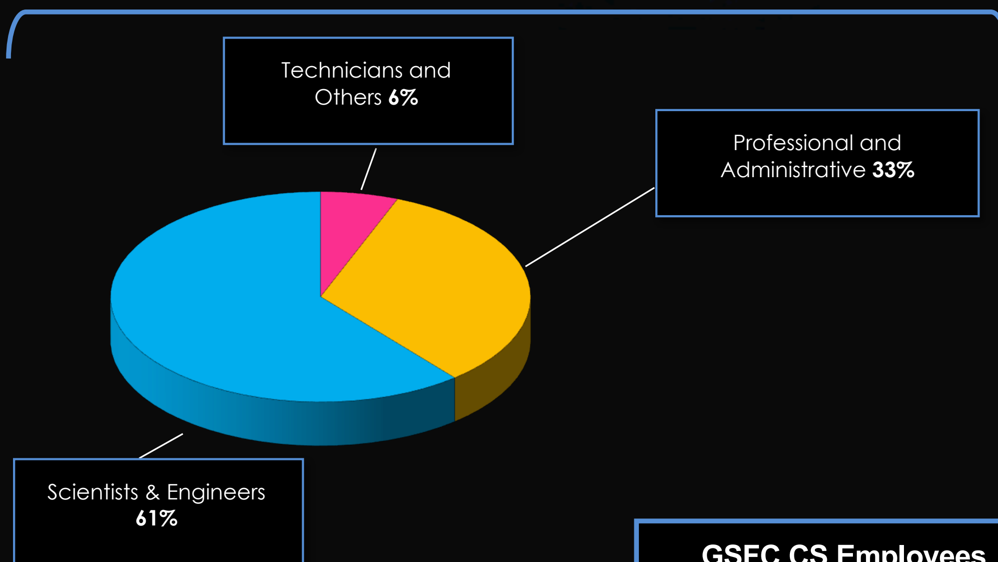
*August 23rd, 2023*

# NASA Centers

# Who We Are

A diverse community of scientists, engineers, technologists, and administrative personnel dedicated to Earth and Space Science Discovery and Exploration

## THE GODDARD COMMUNITY




**Number of Employees**
~3,000 Civil Service
~6,000 Contractor
~1,000 Other
**Total - ~10,000**

**GSFC CS Employees with Degrees**

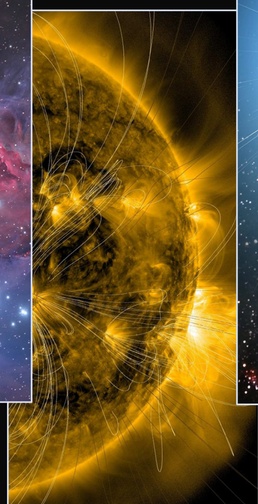
Bachelors – 37%
Advanced Degrees – 48%
Associate/Technical – 2%
High School – 13%

**Including off-site contractors, interns, and Emeritus*

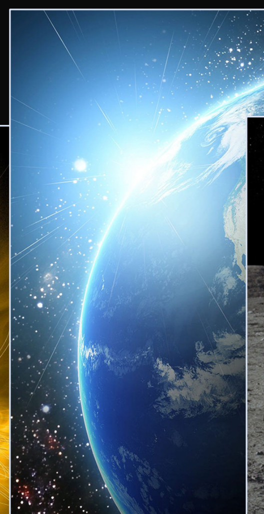
# Our Lines of Business

Astrophysics

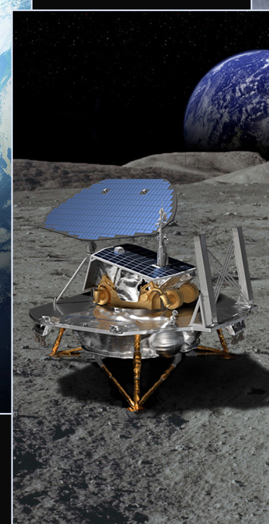
Heliophysics



Earth Science

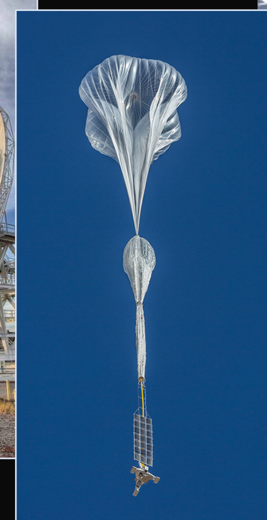


Planetary & Lunar Science



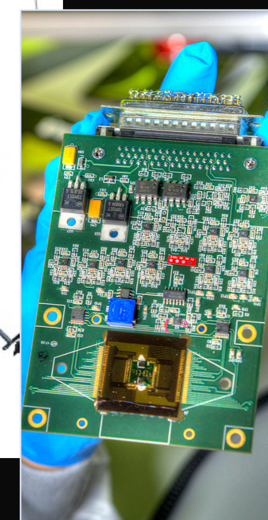
Space Communications & Navigation

Suborbital Programs & Range Services



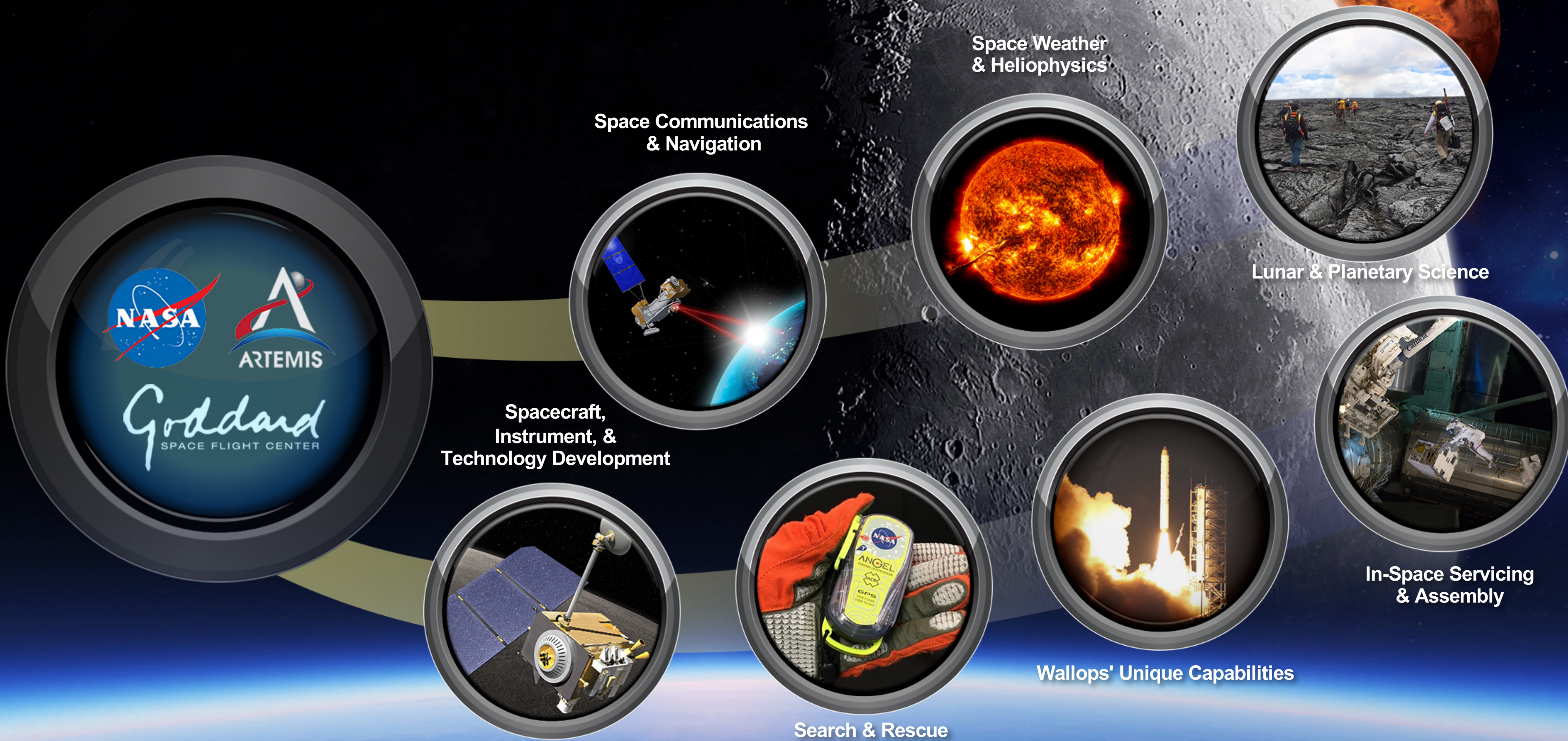
On-Orbit Servicing and Assembly*

Cross Cutting Technology And Capabilities



**= not officially listed as a LOB*

# Goddard Supports Artemis Moon to Mars

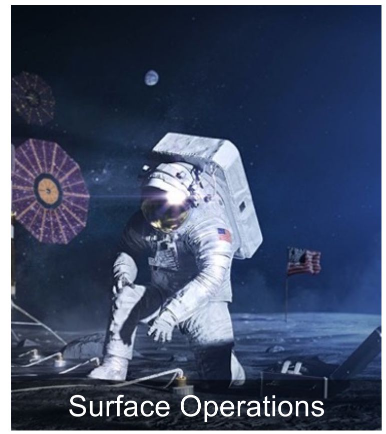


# Artemis: A Foundation for Deep Space Exploration

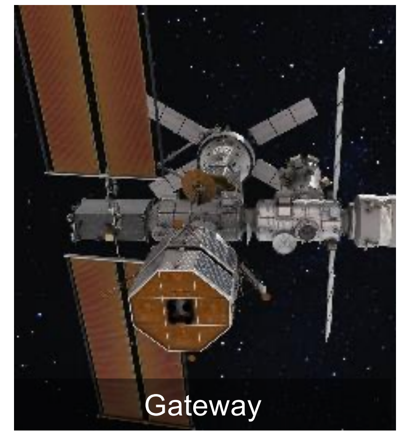
Space Launch System

Orion spacecraft

Human Landing System



Surface Operations



Gateway

Exploration Ground Systems

Space Communications & Navigation

Surface Mobility

Spacesuits

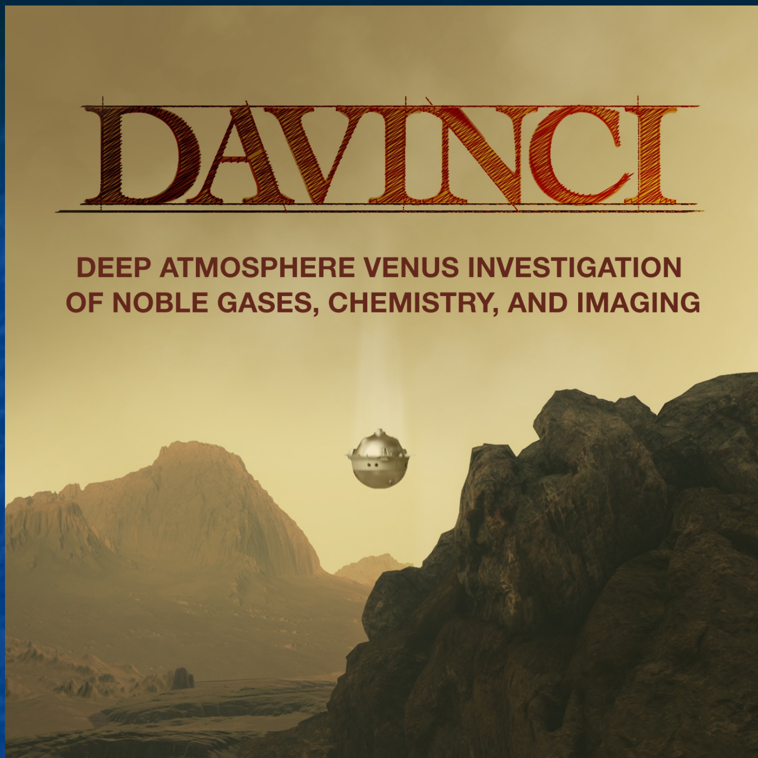
Surface Infrastructure

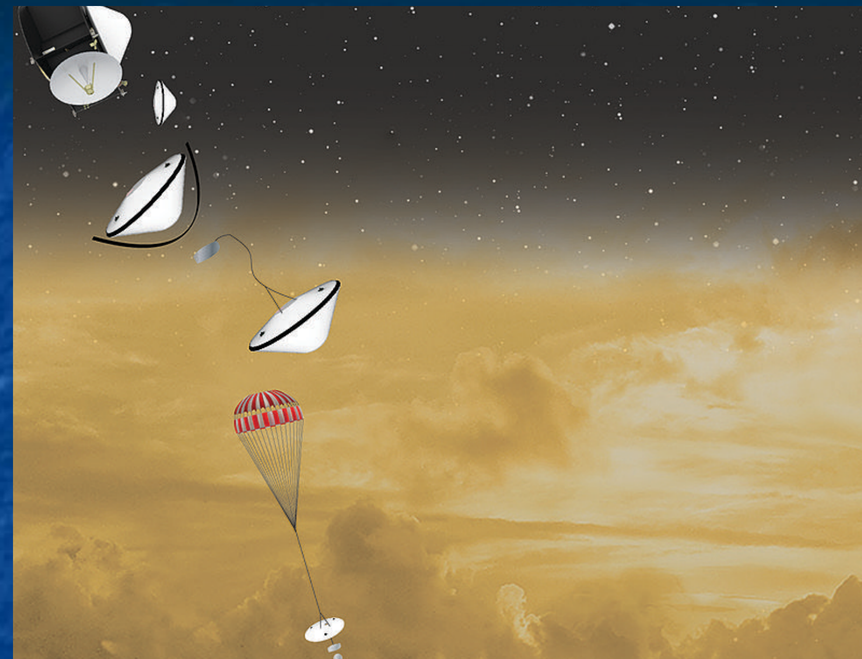
# NASA is Much More Than Launch Vehicles, ISS and Astronauts

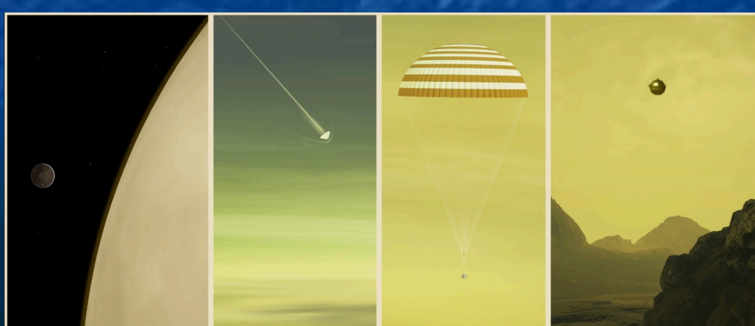
# Inspiring Future Generations

# DragonFly

NASA's Dragonfly mission, which will send a rotorcraft relocatable lander to Titan's surface in the mid-2030s, will be the first mission to explore the surface of Titan.





*"No previous mission within the Venus atmosphere has measured the chemistry or environments at the detail that DAVINCI's probe can do."*

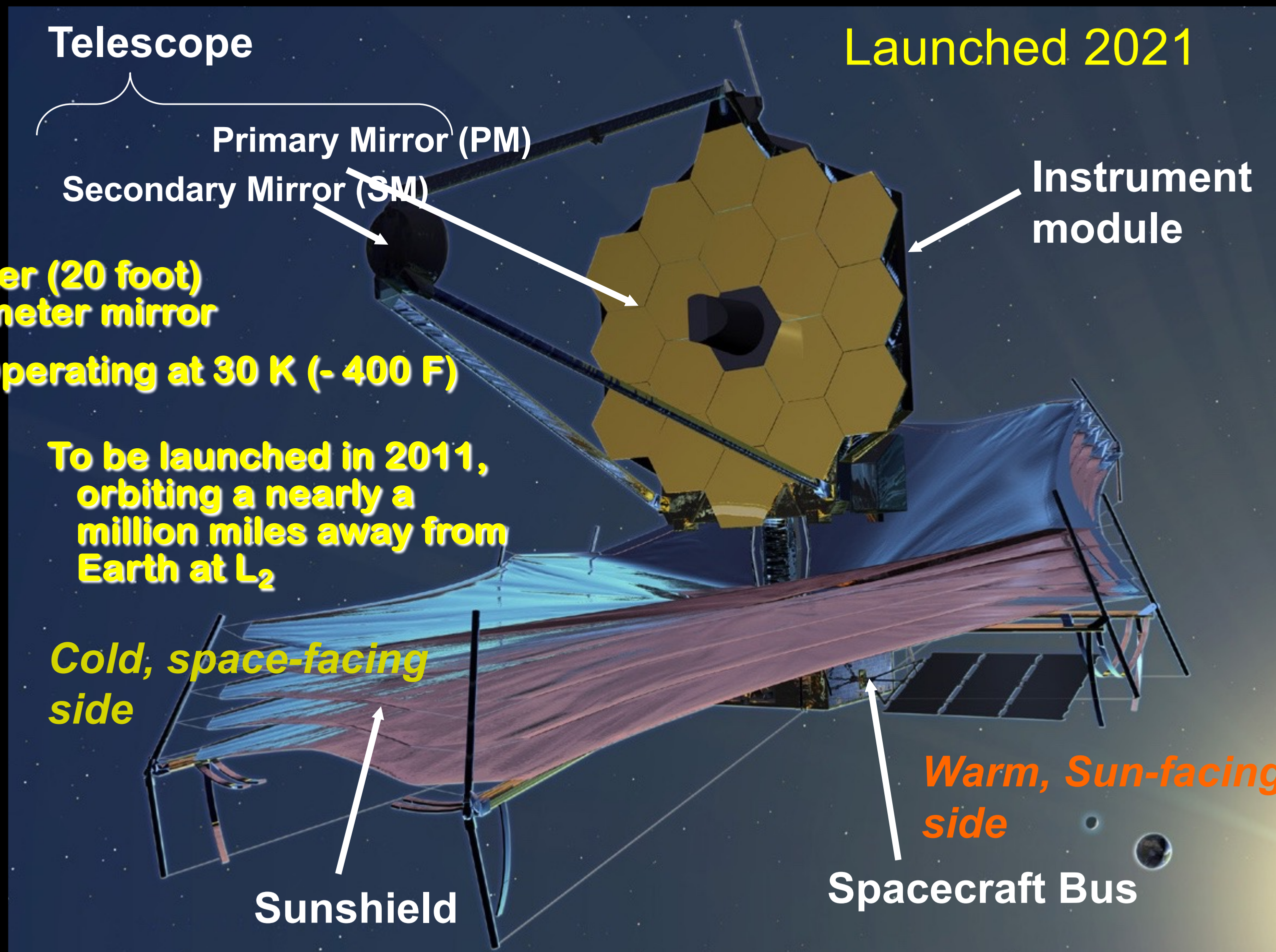
*Dr. Jim Garvin*
DAVINCI principal investigator

# OSIRIS-REx - Returning a Piece of the Ancient Solar System to Earth

- **O**rigins
  - Return and analyze a sample of pristine carbonaceous asteroid regolith
- **S**pectral **I**nterpretation
  - Provide ground truth for telescopic data of the entire asteroid population
- **R**esource **I**dentification
  - Map the chemistry and mineralogy of a primitive carbonaceous asteroid
- **S**ecurity
  - Measure the Yarkovsky effect on a potentially hazardous asteroid
- **R**egolith **Ex**plorer
  - Document the regolith at the sampling site at scales down to the sub-cm

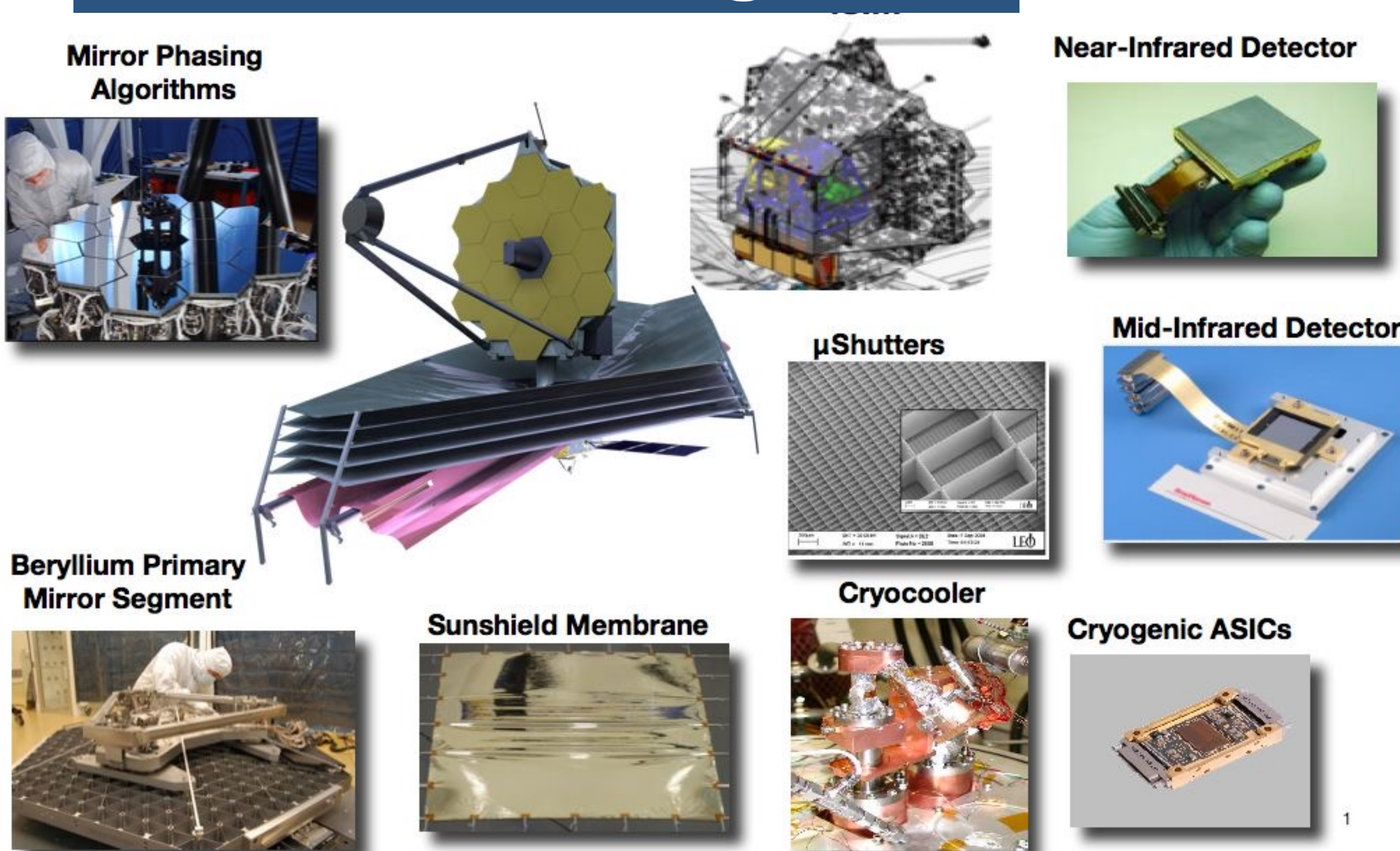
**James Web Space Telescope** - Full scale model at GSFC

# James Webb Space Telescope




First large-scale space application of deployable optics, wavefront control and passive cooling with tennis court-sized deployable structures.

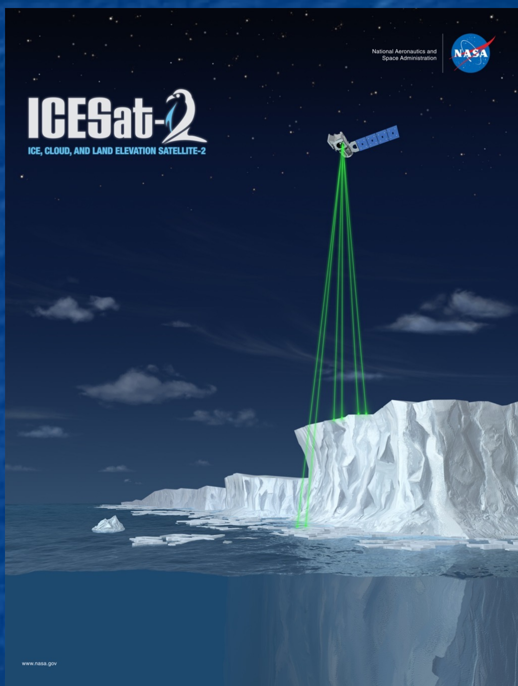
# JWST Technologies




*Unprecedented Precision to view farther back in time*

# JWST Image of the Southern Ring Nebula

# ICESAT- Observes Artic Ice Melting at an alarming rate

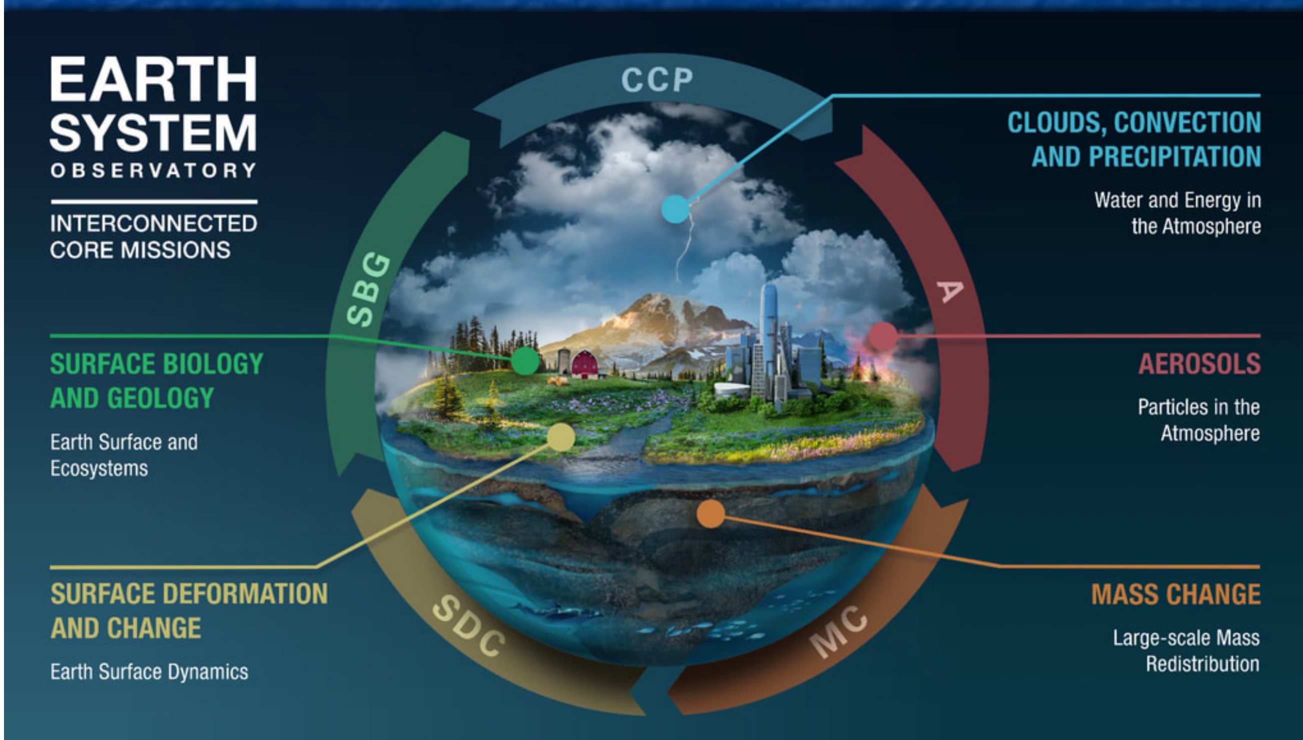


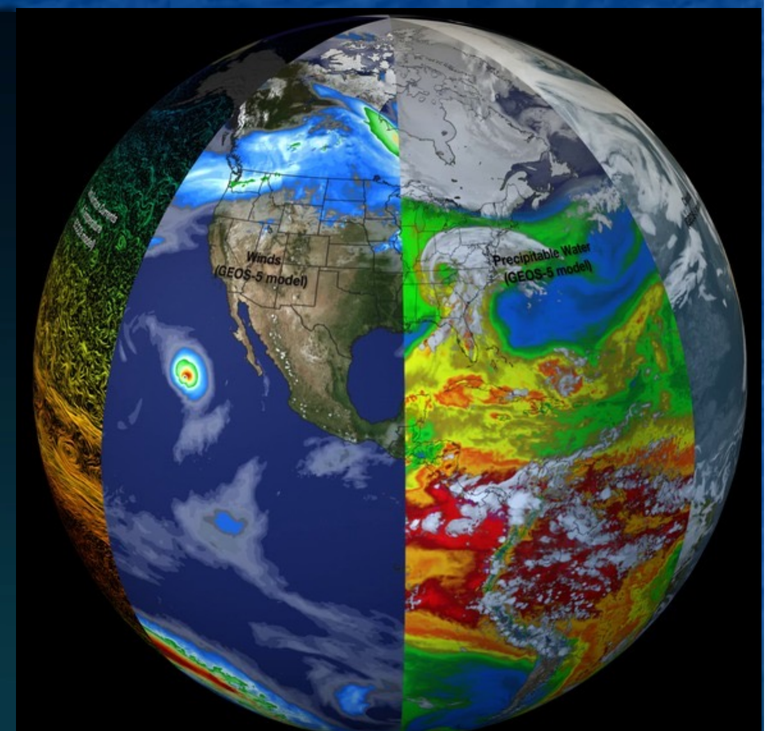

ICESat-2 (the Ice, Cloud, and Land Elevation Satellite-2) measures the height of a changing Earth.


**NASA Satellites help Scientists answer:**

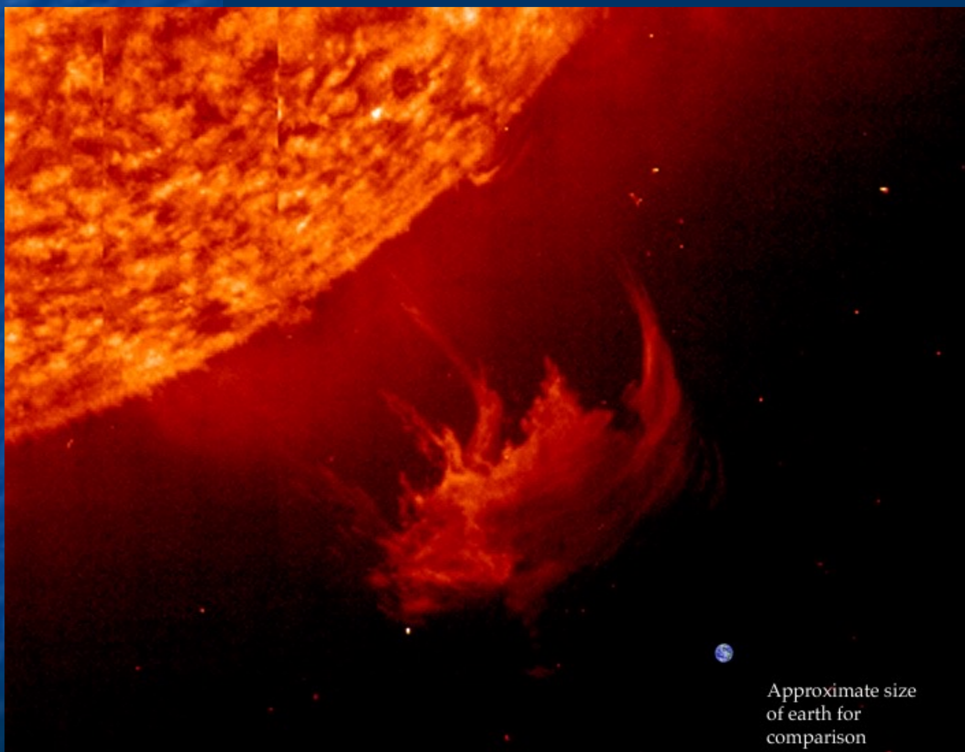
- **How does the earth system respond to natural and human-induced changes?**
- **How will the Earth system change in the future?**

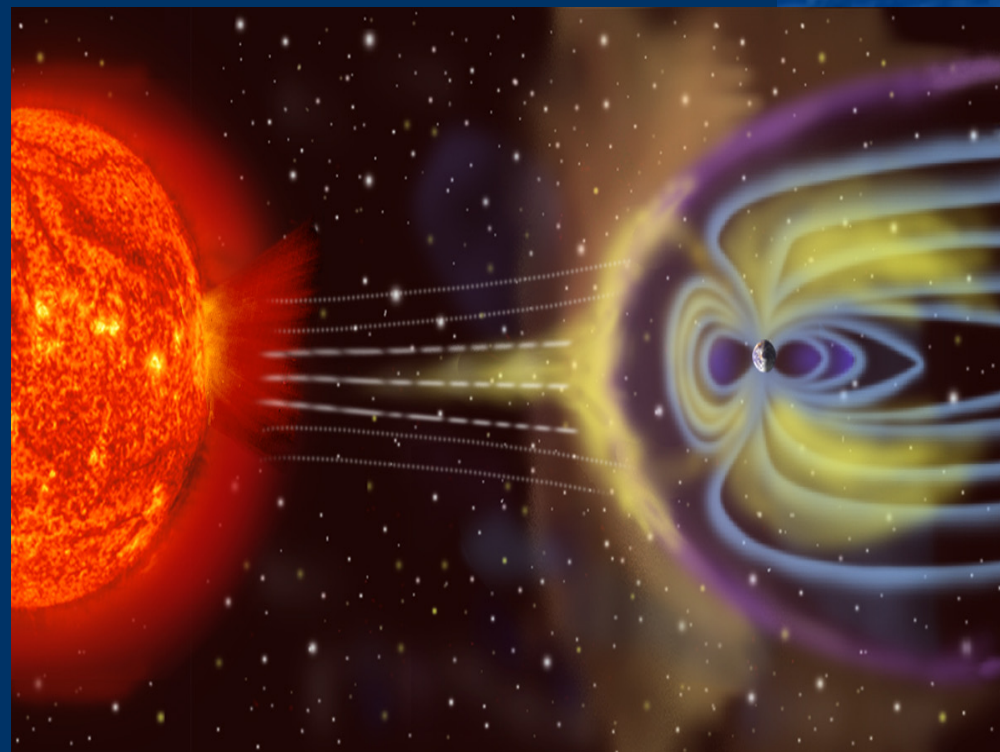
# Earth Science as an Integrated Science

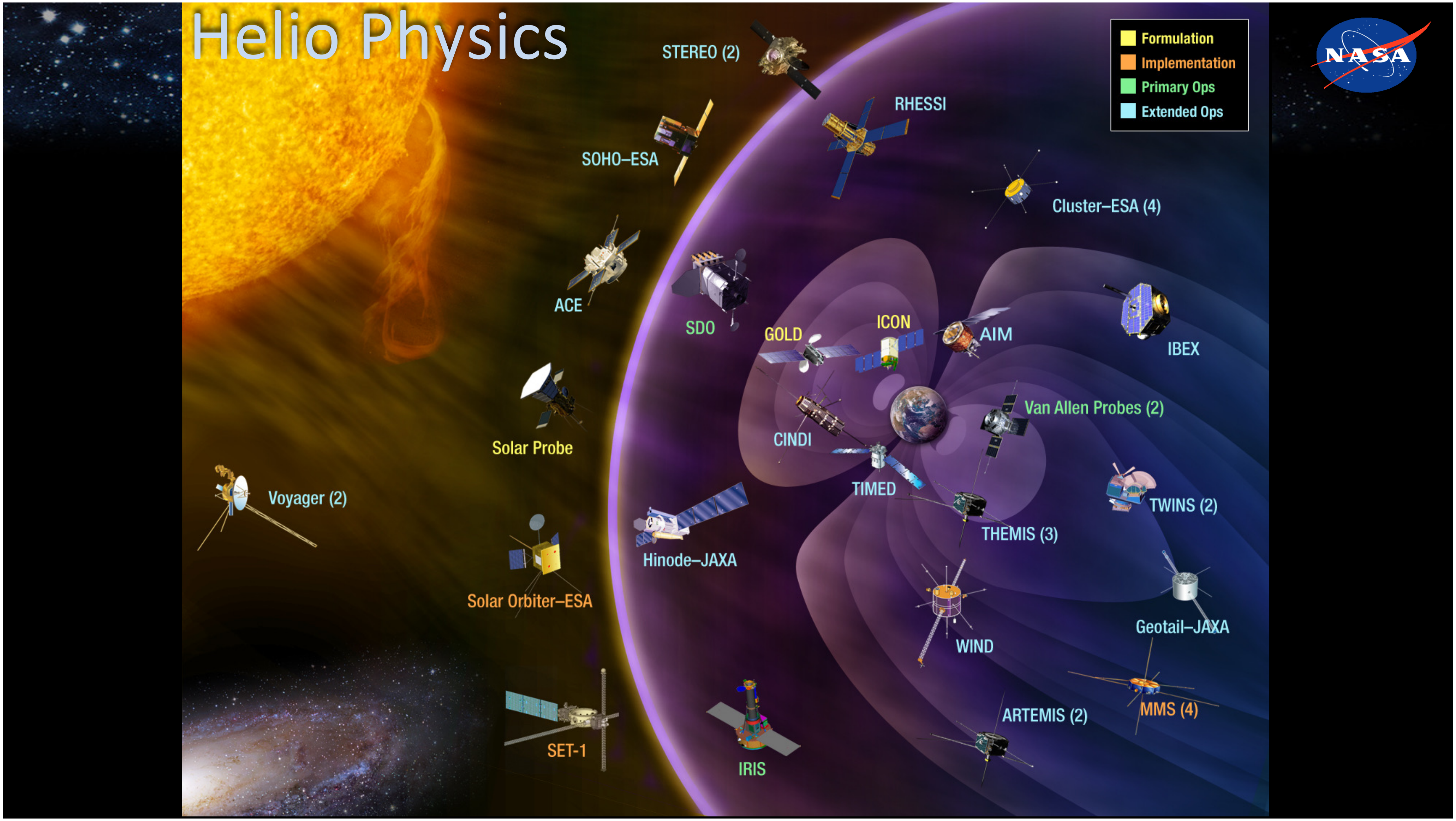


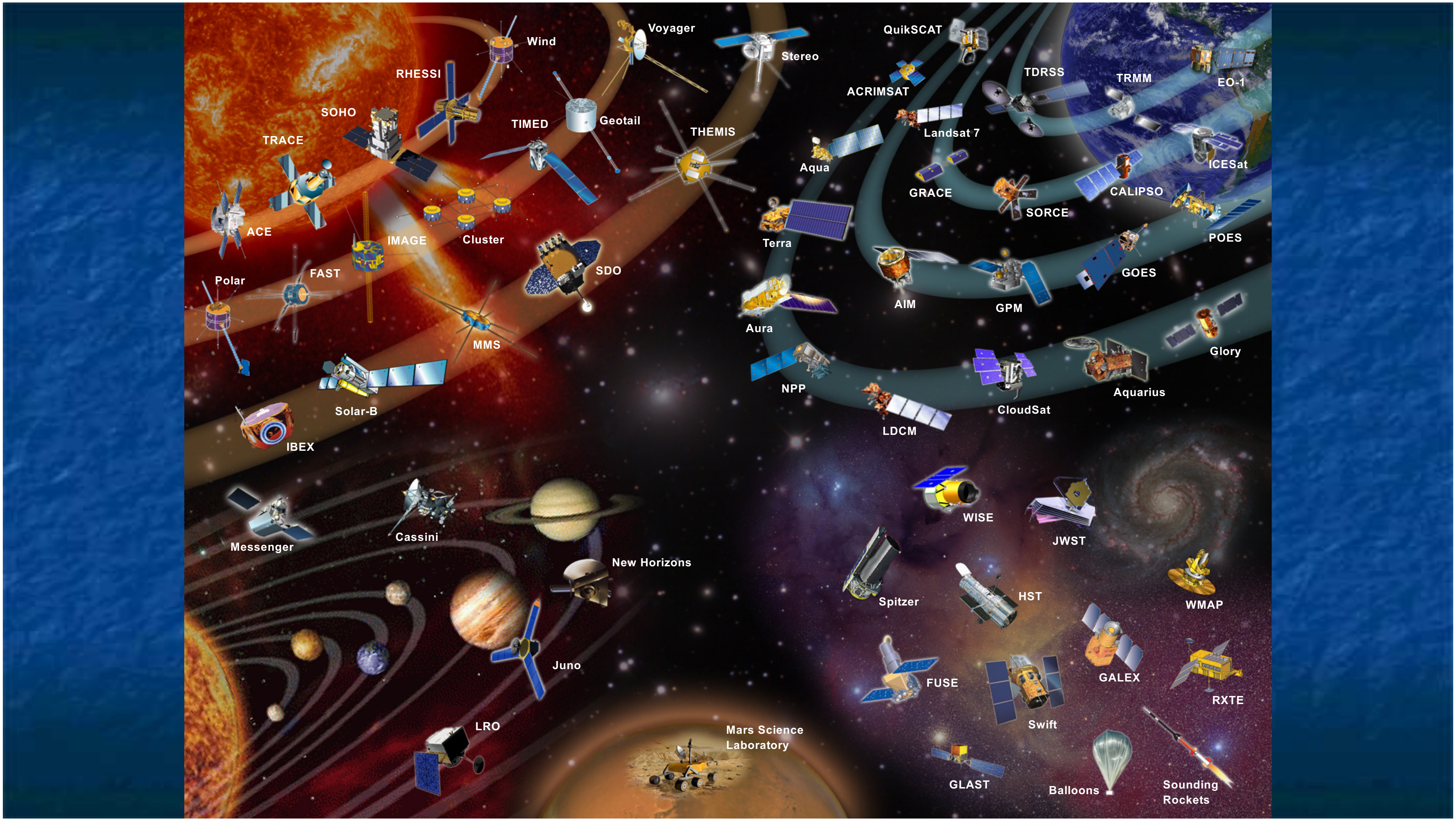



# Understanding Earth's Magnetosphere

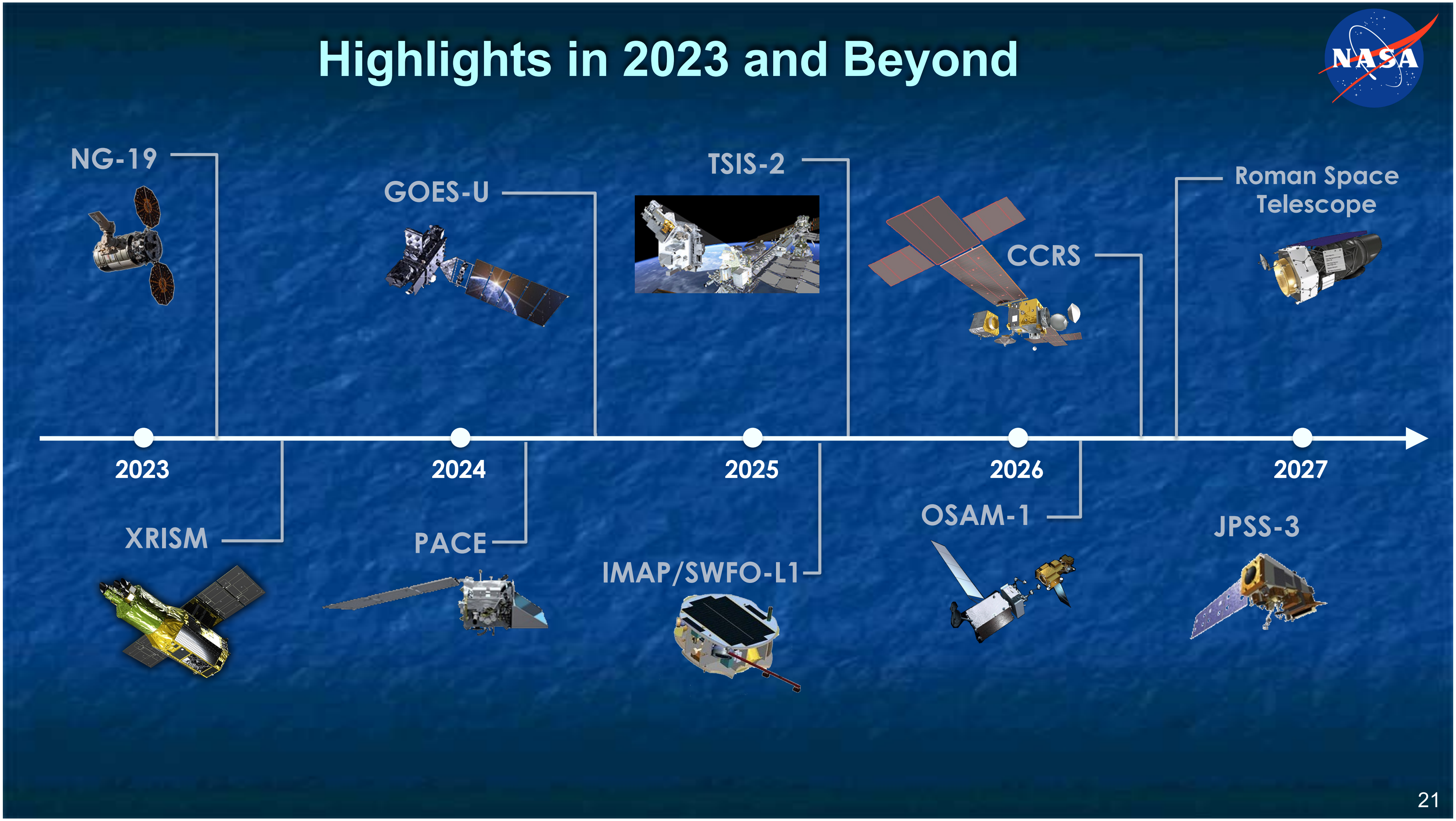



Helio Physics
Formulation
Implementation
Primary Ops
Extended Ops
STEREO (2)
RHESSI
SOHO–ESA
Cluster–ESA (4)
ACE
SDO
GOLD
ICON
AIM
IBEX
Van Allen Probes (2)
CINDI
Solar Probe
TIMED
Voyager (2)
TWINS (2)
THEMIS (3)
Hinode–JAXA
Solar Orbiter–ESA
Geotail–JAXA
WIND
MMS (4)
ARTEMIS (2)
SET-1
IRIS
NASA



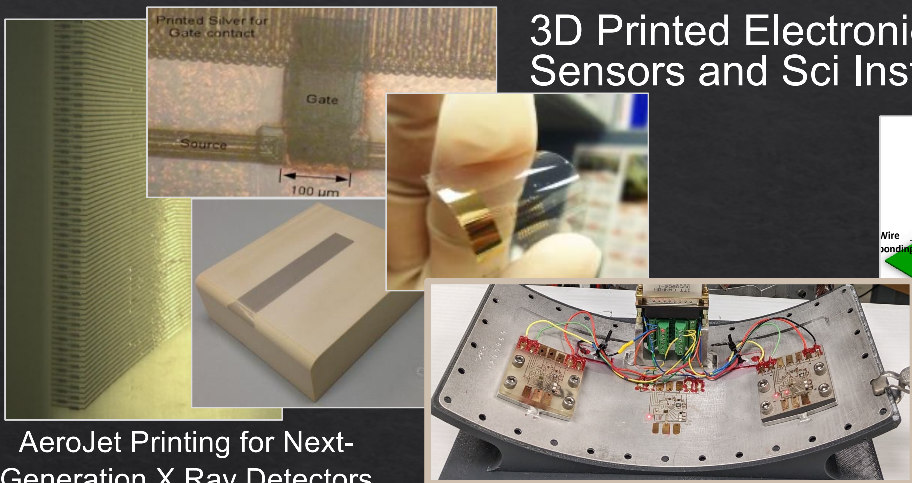
Voyager
Wind
RHESSI
SOHO
TRACE
ACE
Polar
FAST
IMAGE
Cluster
TIMED
Geotail
THEMIS
SDO
MMS
Solar-B
IBEX
Stereo
QuikSCAT
ACRIMSAT
TDRSS
TRMM
EO-1
Landsat 7
Aqua
GRACE
SORCE
CALIPSO
ICESat
POES
Terra
AIM
GPM
GOES
Aura
NPP
LDCM
CloudSat
Aquarius
Glory
Messenger
Cassini
New Horizons
Juno
LRO
Mars Science
Laboratory
WISE
JWST
Spitzer
HST
WMAP
FUSE
Swift
GALEX
RXTE
GLAST
Balloons
Sounding
Rockets



Highlights in 2023 and Beyond
NASA
NG-19
GOES-U
TSIS-2
CCRS
Roman Space Telescope
2023
2024
2025
2026
2027
XRISM
PACE
IMAP/SWFO-L1
OSAM-1
JPSS-3
21

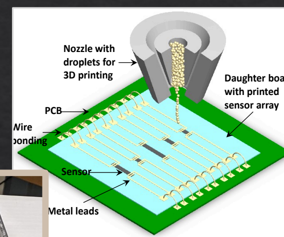
# Emerging and Critical Technologies

## 3D Printed Electronics, Sensors and Sci Instruments



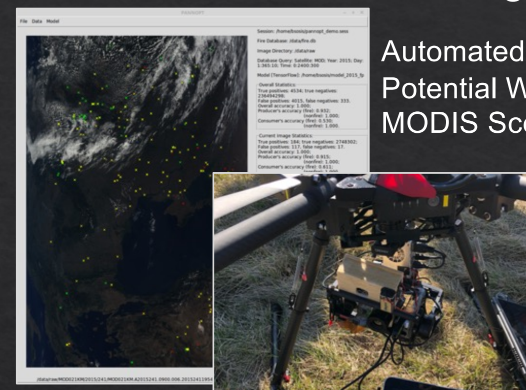

AeroJet Printing for Next-Generation X Ray Detectors on edge of 3D structure

Printed Directly Onto Curved Rocket Door & Flown in Space




3D printing of NanoSensors

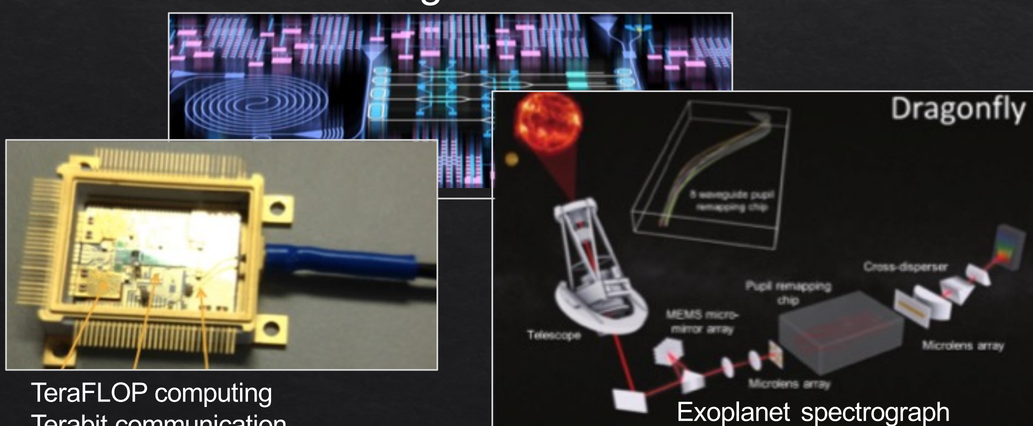
## AI & Machine Learning



Automated Discovery-Potential Wildfires in a MODIS Scene

On-board Autonomy

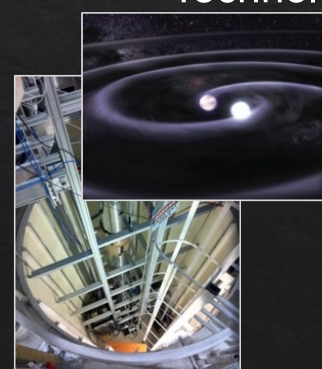
## Integrated Photonics



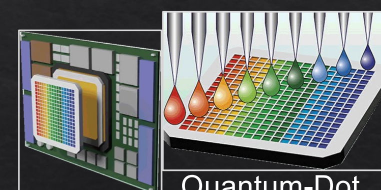

TeraFLOP computing
Terabit communication

Exoplanet spectrograph

## Quantum Technologies



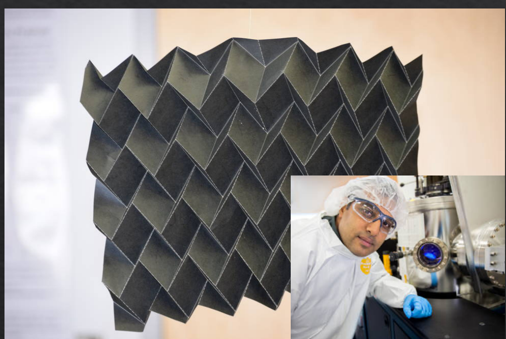
Quantum Sensors: Space-based atom interferometer



Quantum-Dot sensors

Quantum-Networks

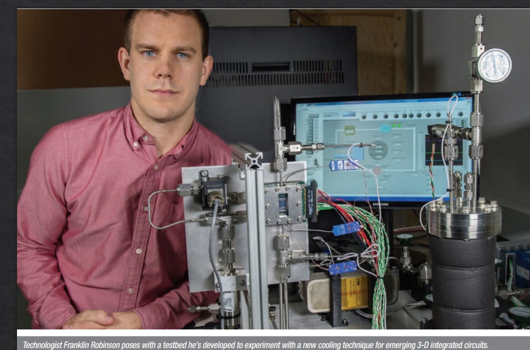
# Thermal Control Technology Investments at Goddard



Three-dimensional, foldable radiator, inspired by the art of paper folding.

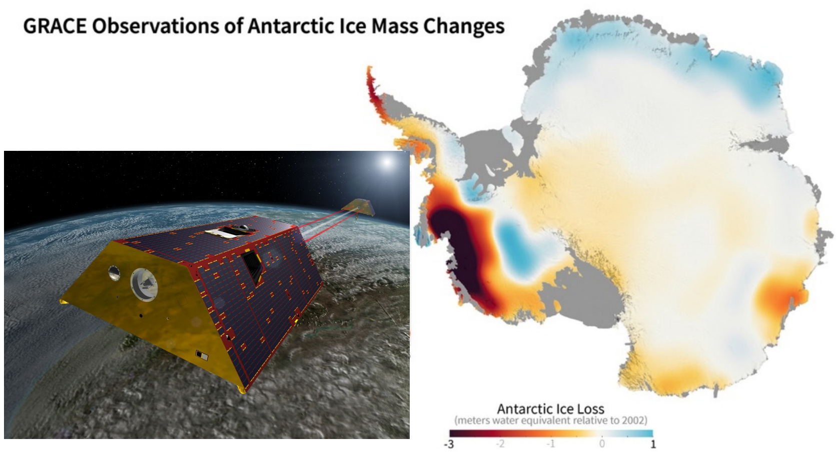
Continuous Adiabatic Demagnetization Refrigerator enabling subK detector temperatures for future astronomical instruments.


Thermal-control technology that requires no electronics and consists of louvers.




Cooling technique for 3-D integrated circuits.

# Quantum Sensors for Space: Gravity mapping




**Measuring gravity is critical to understanding changes in mass**

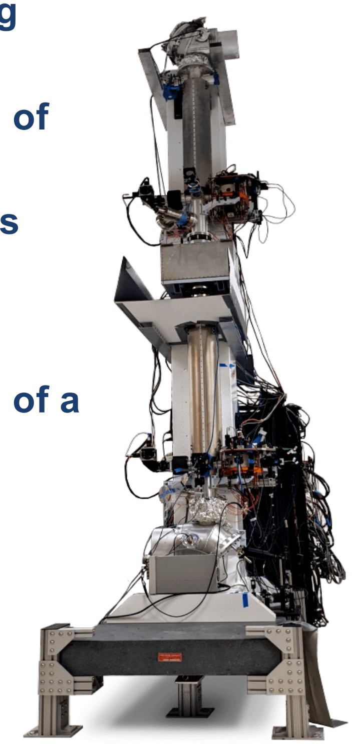
- **Water table depletion**
- **Ice sheet changes**
- **Oil/gas exploration**

**Current NASA/ESA gravity mapping missions (GRACE-FO):**

- **Spatial resolution about the size of Texas**
- **Temporal resolution about weeks**

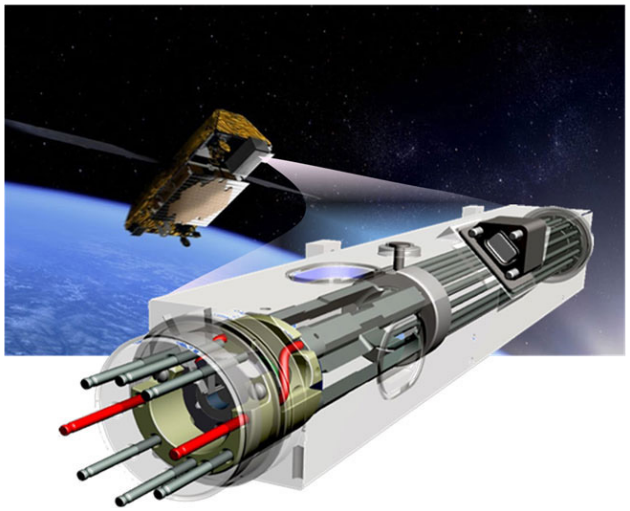
**Cold atom gravity sensor (AIGG):**

- **Spatial resolution about the size of a typical US county**
- **Temporal resolution of hours**



NASA Goddard SPACE FLIGHT CENTER

# QUANTUM SENSORS FOR SPACE: ATOMIC CLOCKS



**Precision timing:**

- **Navigation without GPS**
- **Synchronization (high speed data transfer)**

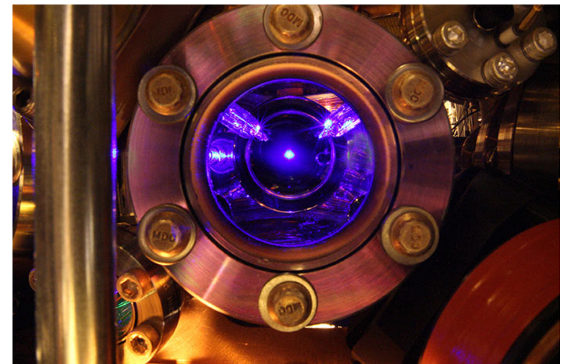
**Navigating without GPS:**

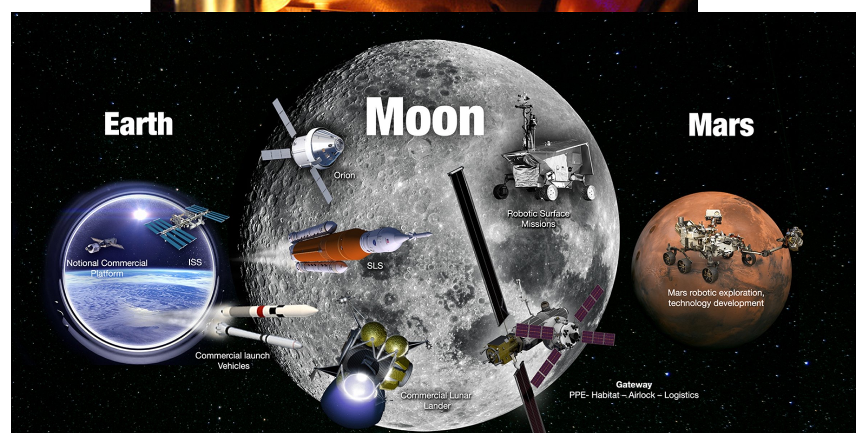
**Current state of the art chip scale clock**

- **maintain position within 1 foot for a few hours without any updates**

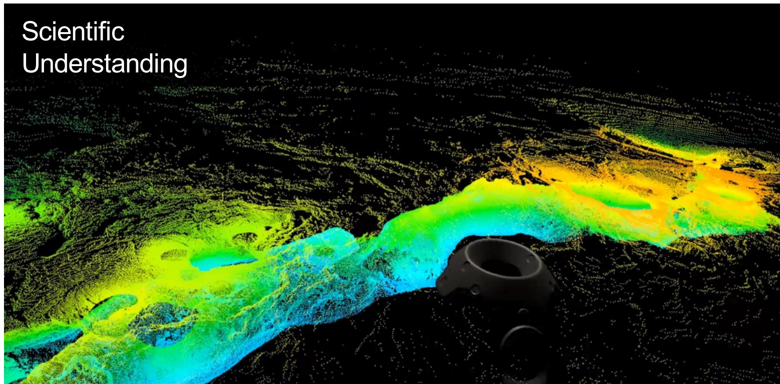
**Optical atomic clock**

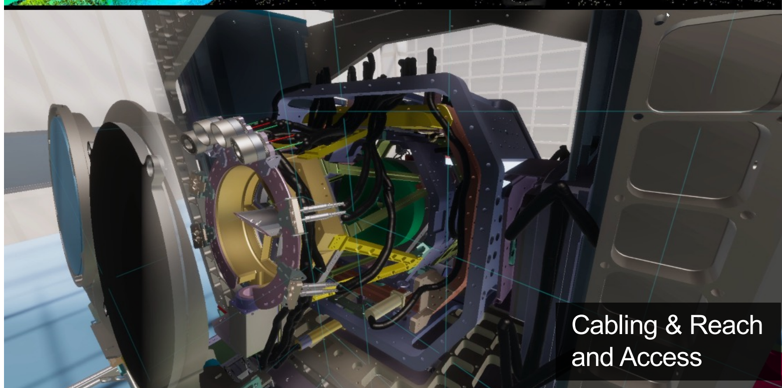
- **Maintain position within 1 foot for weeks or months without updates**

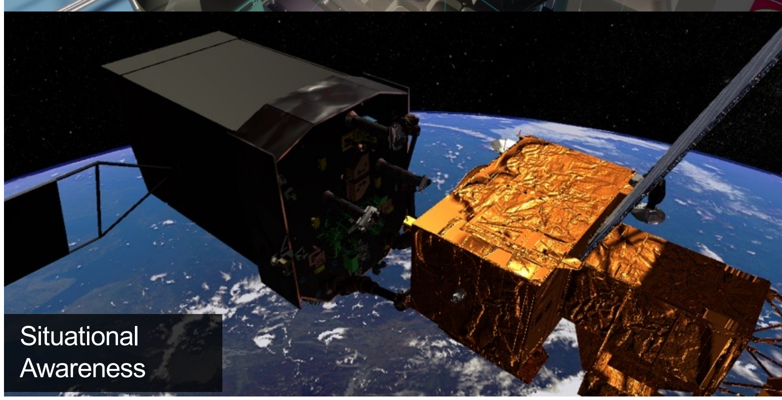





NASA Goddard SPACE FLIGHT CENTER




# **Extended Reality (XR)-** an essential tool for GSFC in the future

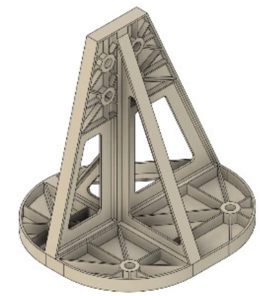
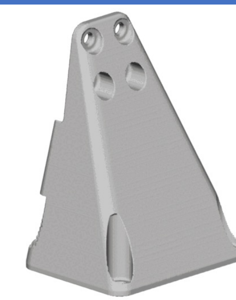
- **XR provides several advantages**
  - **Quicker and more intuitive understanding of complex, spatially related, problems and situations**
  - **Reduced time and money with remote collaboration**
- **XR can be a valuable tool throughout the mission lifecycle**
- **Data Driven XR projects can provide crucial situational awareness and foster analysis**

# Evolved Structures: AI and robots enable 10x faster/cheaper development of spaceflight structures

- Evolved Structures process
  - Design requirements are digitally encoded
  - Generative Design AI evolves optimal structures
    - Iterative design, analysis, and fabrication simulation
  - Digital Manufacturing robots fabricate parts from CAD

- Typical metallic structures – now automated
  - Requirements➡️parts for fab in 1-2 days(!)
  - Parts ~3x stiffer/lighter/stronger than human designs

- The Future
  - Make structure development 10x faster/cheaper
  - Trusses, flexures, lightweight optics

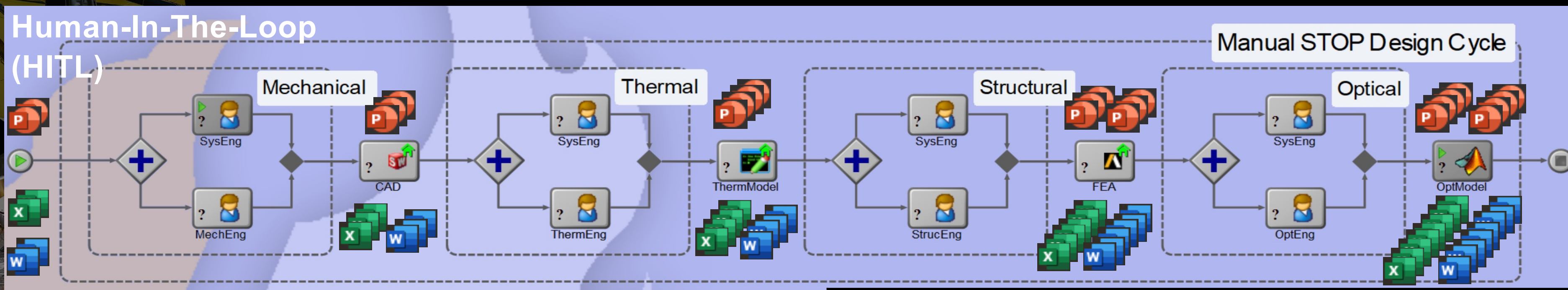
| Designer | Expert Humans (2X) | AI |
|---|---|---|
| Design |  |  |
| Design time | 2 days | 1 hour |
| Design iterations | 4 | 31 |
| Mass (kg) | 0.27 | 0.2 |
| $1^{st}$ Mode (Hz) | 65 | 147 |
| Max Stress (MPa) | 103 | 14.8 |
| Manufacturing | CNC - Difficult to machine (no quotes) | Automated CNC<br>$1000<br>3 days |

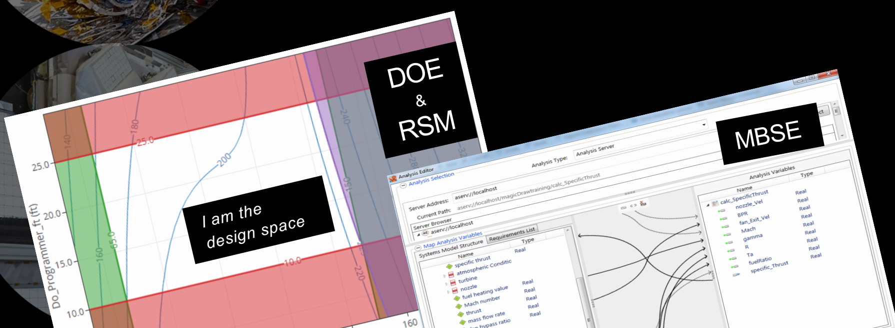
# Digital Engineering: The Future Vision of Goddard Engineering

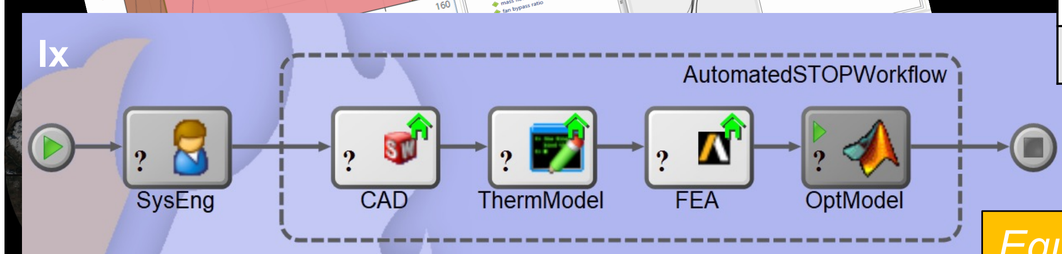
- End-to-End digitization and connectivity of models that enables seamless flow and optimization through every phase of the mission:
  - Rapid understanding of science impact from a changes in engineering specifications
  - Virtual Reality to understand assembly, integration and test, and in-space operational limitations
  - Cradle to grave integrated models, from mission conception in the Integrated Design Center to final in-space mission operations

POC: Aaron Comis

# Integrated Everything (*Ix*)




| | HITL | Ix |
|---|---|---|
| Setup time | Month(s) | Month(s) |
| Cycles completed after setup | 1 | 1 |
| Documents generated | XXXX | X |
| Design Validation of Requirements | Manual | Automated |
| Time per iteration cycle* | W/M | H/D |
| Surrogate Modeling | N | Y |
| Engineers for surrogate exploration | All | 1 |

*Equivalent to the transition from hand drafting to CAD*

# 2020 NASA Technology Taxonomy

National Aeronautics and Space Administration

- **TX01:** Propulsion Systems
- **TX02:** Flight Computing and Avionics
- **TX03:** Aerospace Power and Energy Storage
- **TX04:** Robotic Systems
- **TX05:** Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
- **TX06:** Human Health, Life Support, and Habitation Systems
- **TX07:** Exploration Destination Systems
- **TX08:** Instrumentation and Sensors
- **TX09:** Entry, Descent, and Landing
- **TX10:** Autonomous Systems
- **TX11:** Software, Modeling, Simulation, and Information Processing
- **TX12:** Materials and Structures
- **TX13:** Ground, Test, and Surface Systems
- **TX14:** Thermal Management Systems
- **TX15:** Flight Vehicle Systems
- **TX16:** Air Traffic Management System (ATMS)
- **TX17:** Guidance, Navigation, and Control (GN&C)

# NASA OCT Emerging and Disruptive Technologies



**Advanced Manufacturing** Rapid, precise, customized manufacturing

**Advanced Engineered Materials** Novel materials, creative solutions

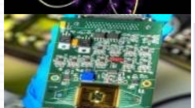
**System Autonomy** Independently-functioning machines

**Integrated Photonics** Harnessing light for the next generation systems

**AI & Machine Learning** Imitating intelligent human behavior

**Big Data Analytics** Uncover hidden patterns, correlations, and other insights

**Quantum Technologies** Quantum leaps with the quantum revolution



**Miniaturized Systems** Smaller footprint, robust function

**Power Generation/Energy** Ubiquitous access to abundant power

The nine "high interest" areas selected because of their potential to identify **outside technical advances** that can help address NASA's biggest challenges.

For each of the nine areas:

- Conducted deep dives into each area
- Identified cutting edge or transformative technology development occurring outside of NASA that could benefits its missions.
- Reviewed identified technologies with SMEs and confirmed significance and relevance to NASA.

# TechPort

- TechPort is a public portfolio of 16,000+ active and completed NASA technology development projects

- People use TechPort to:
  - Learn about NASA technology
  - Find opportunities for collaboration and partnerships
  - Analyze how the Agency is meeting its mission needs
  - …and so much more

- Use TechPort's funding opportunities tool to find opportunities that best fit your role or organization, funding needed, and technology maturity


To access TechPort, go to https://techport.nasa.gov.

# Acquisition Approach: Announcement of Collaboration Opportunity (ACO) & Tipping Point

- **ACO** (unfunded Space Act Agreements) Selections announced Apr 25, 2023

- Next ACO planned to be open continuously
  - Single step approach
  - ~$20-25M per year, pending appropriations

- **Tipping Point** (funded Space Act Agreements) selections in Spring 2023
- Tipping Point announcement every 2-3 years, pending appropriations
  - Will follow two step approach with broad and/or focused topics

# Concluding Remarks

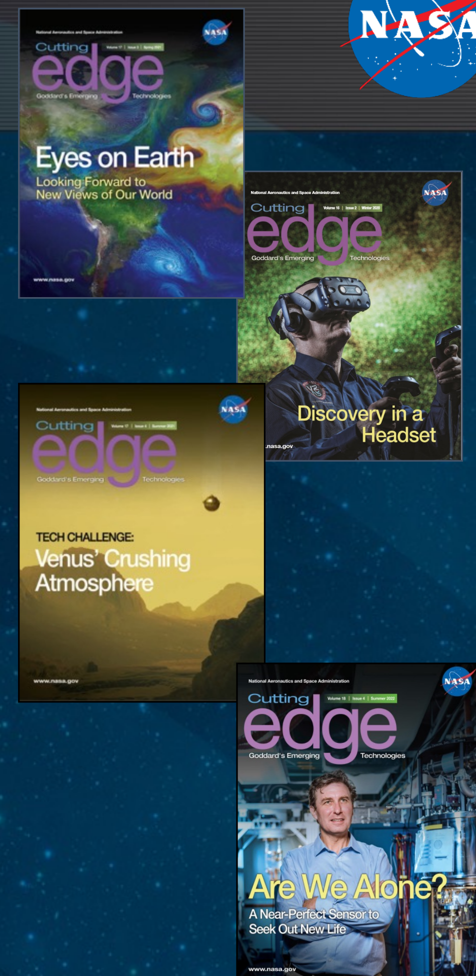
- NASA serves an integral role leading scientific discovery, exploration, pioneering the planets and enabling private industry and American citizens to live, work, and play in space

- Technology development enables future missions and discoveries and is a critical to the achievement of these goals and stimulate economic development on Earth

- A key element of technology management is the continuous identification, assessment of emerging and disruptive technologies.

- We actively balance and manage investment resources to address near-term opportunities and longer-term needs and possibilities

- We rely on partnering and collaboration




***Active technology management is a critical <u>investment</u> for our success***

The dreams of yesterday are the hopes of today and the reality of tomorrow.

— *Robert H. Goddard* —

For more information, please visit our web site:

**www.nasa.gov/goddard**

# Post Script- Generative AI- A Rapidly Emerging and Disruptive Technology

### *Generative AI and AI-enhanced Systems*

- *The NASA Office of Technology, Policy and Strategy, Office of Chief Scientist, and Office of the Chief Information Officer are teaming to lead creation of AI guidance and governance.*

  *Current hot AI topics areas include responsible and ethical AI, as well as investigating the promise and cautions associated with Generative AI such as ChatGPT and similar game-changing capabilities.*

  *In developing responsible AI guidance, NASA experts have highlighted the need for principles regarding scientific and technical robustness of AI systems – such robustness is key to using AI in accordance with NASA's scientific best practices and can help steer the federal government.*

# Backup

# 8 Rules for Managing Innovation

- Set clear goals and objectives: Define your technology and innovation goals and objectives. Ensure that your goals align with your overall business strategy.
- Foster a culture of innovation: Create an environment where your team members feel free to generate and share new ideas, and encouraged to experiment and take calculated risks.
- Focus on customer needs: Listen to your customers, understand their needs and challenges, and use their feedback to shape your innovation agenda.
- Prioritize your innovation initiatives: Evaluate and prioritize your innovation initiatives based on their potential impact, cost, and time to market. Consider both short-term and long-term goals.
- Actively manage your innovation portfolio: Monitor progress, track metrics, and regularly review and adjust your portfolio to ensure that it remains aligned with your strategic goals.
- Collaborate and partner with external stakeholders, including customers, suppliers, startups, and other organizations, to access new ideas, technologies, and resources.
- Leverage technology and data analytics: to identify new trends, opportunities, and insights that can inform your innovation and technology portfolio management strategies.
- Invest in talent and capabilities: Invest in developing the skills and capabilities of your team members to ensure that they have the tools and knowledge they need to succeed.

# 2020 NASA Technology Taxonomy

National Aeronautics and
Space Administration

- **TX01:** Propulsion Systems
- **TX02:** Flight Computing and Avionics
- **TX03:** Aerospace Power and Energy Storage
- **TX04:** Robotic Systems
- **TX05:** Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
- **TX06:** Human Health, Life Support, and Habitation Systems
- **TX07:** Exploration Destination Systems
- **TX08:** Instrumentation and Sensors
- **TX09:** Entry, Descent, and Landing
- **TX10:** Autonomous Systems
- **TX11:** Software, Modeling, Simulation, and Information Processing
- **TX12:** Materials and Structures
- **TX13:** Ground, Test, and Surface Systems
- **TX14:** Thermal Management Systems
- **TX15:** Flight Vehicle Systems
- **TX16:** Air Traffic Management System (ATMS)
- **TX17:** Guidance, Navigation, and Control (GN&C)

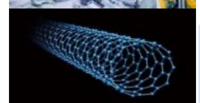
# Studies of Emerging & Disruptive Technologies

National Aeronautics and Space Administration

Center Chief Technologist team identified, verified, and assessed nearly 500 technology trends from around the world covering a broad spectrum of technology areas.

From the trends collected, Center and Mission Directorate representatives selected 9 "high interest" technology trend areas to further investigate.

**Advanced Manufacturing** Rapid, precise, customized manufacturing



**Advanced Engineered Materials** Novel materials, creative solutions

**System Autonomy** Independently-functioning machines

**Integrated Photonics** Harnessing light for the next generation systems

**AI & Machine Learning** Imitating intelligent human behavior

**Big Data Analytics** Uncover hidden patterns, correlations, and other insights

**Quantum Technologies** Quantum leaps with the quantum revolution

**Miniaturized Systems** Smaller footprint, robust function

**Power Generation/Energy** Ubiquitous access to abundant power

# Where We Are Located

## ONE World-Class Science and Engineering Organization

## SIX Distinctive Facilities & Installations

**Greenbelt Main Campus**
*1,270 Acres*

**Executing NASA's most complex science missions**

Est. 1959

MARYLAND

**Wallops Flight Facility**
*6,188 Acres*

**Launching Payloads for NASA & the Nation**

Est. 1945

VIRGINIA

**Goddard Institute for Space Studies**

**Understanding our Planet**

Est. 1961

NEW YORK

**Independent Validation & Verification Facility**

**Providing Software Assurance**

Est. 1993

WEST VIRGINIA

**White Sands Complex**

**Communicating with Assets in Earth's Orbit**

Est. 1963

NEW MEXICO

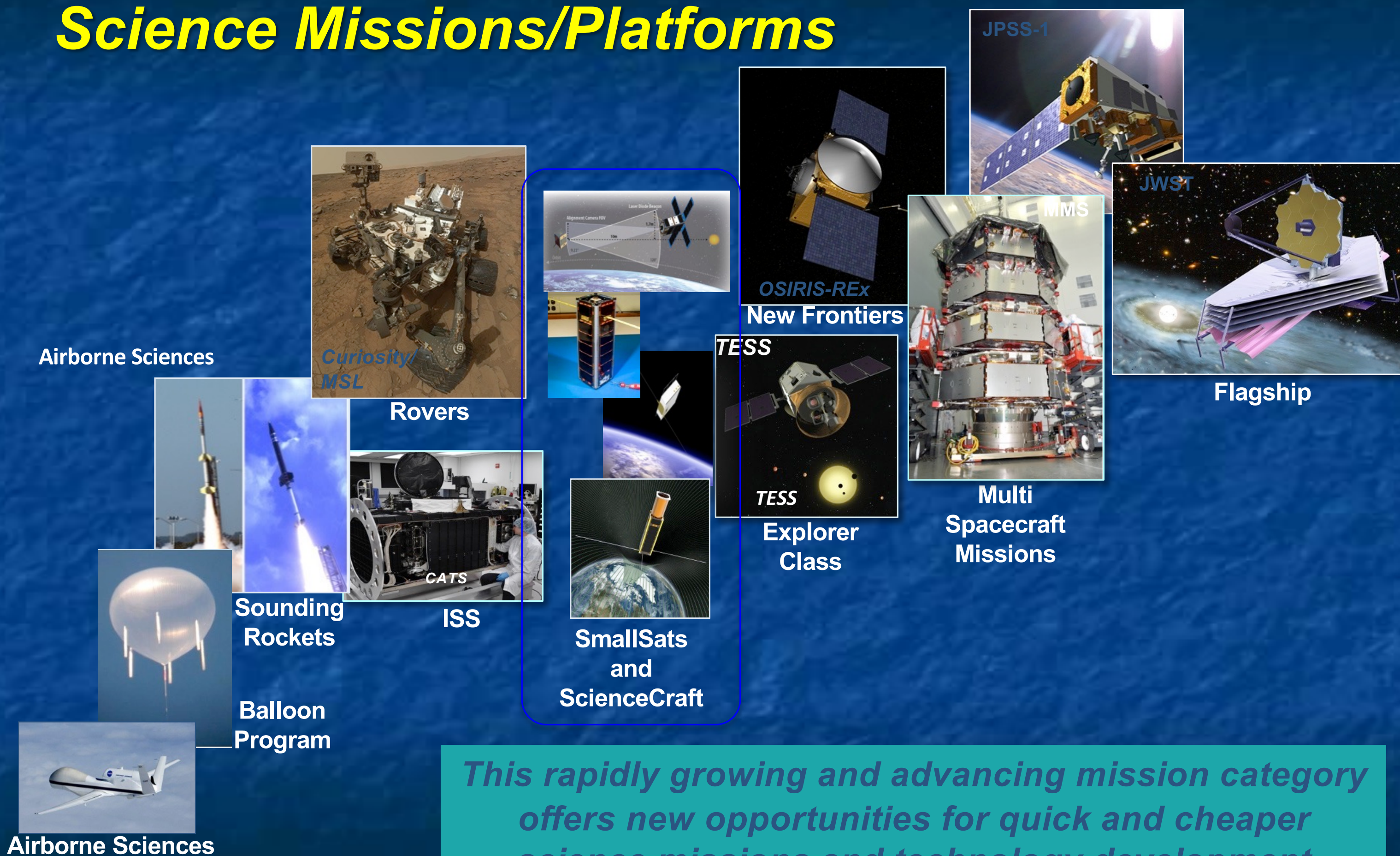
**Columbia Scientific Balloon Facility**

**Directing High Altitude Investigations**

Est. 1982

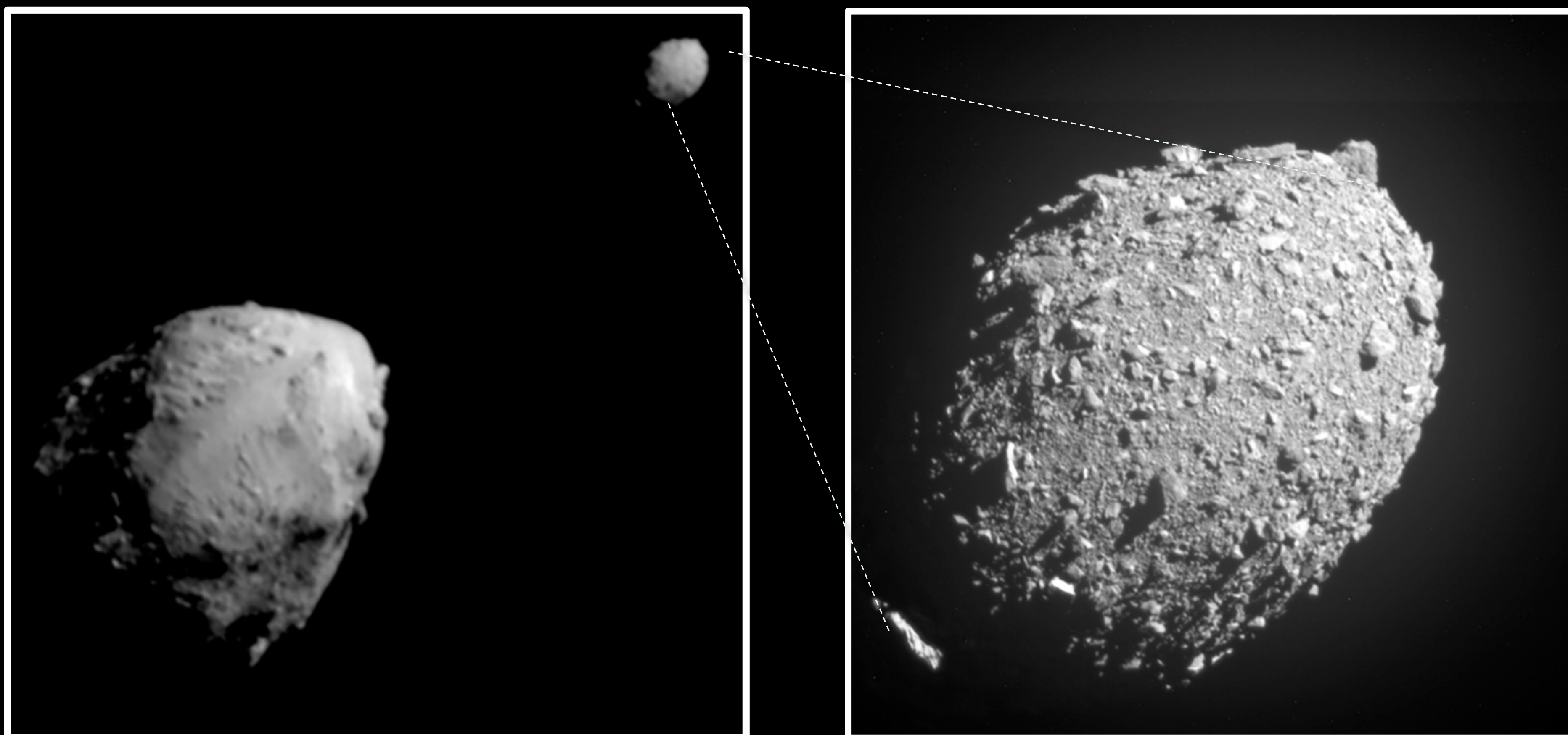
TEXAS

# Goddard Supports Full Range of Science Missions/Platforms




*This rapidly growing and advancing mission category offers new opportunities for quick and cheaper science missions and technology development*

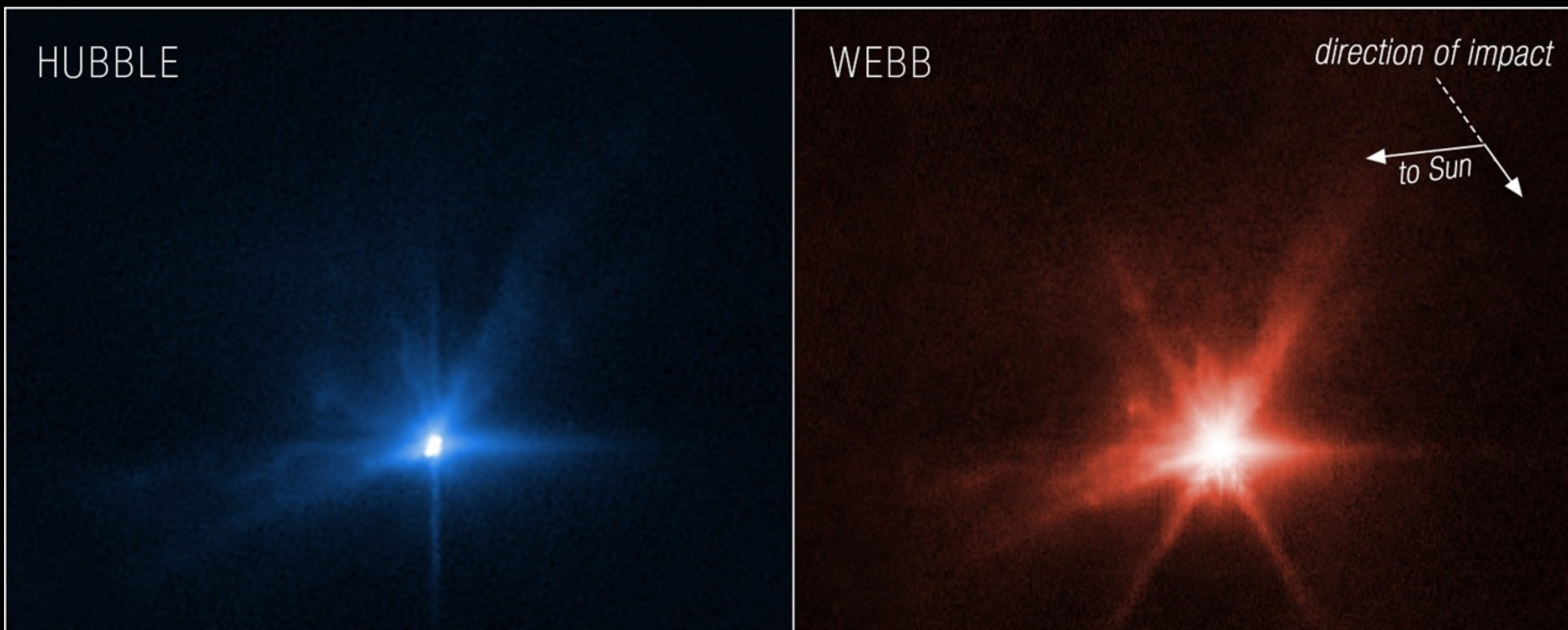
# Didymos and Dimorphos, target of DART – A planetary defense experiment



Asteroid Didymos and Moonlet Dimorphos

Dimorphos

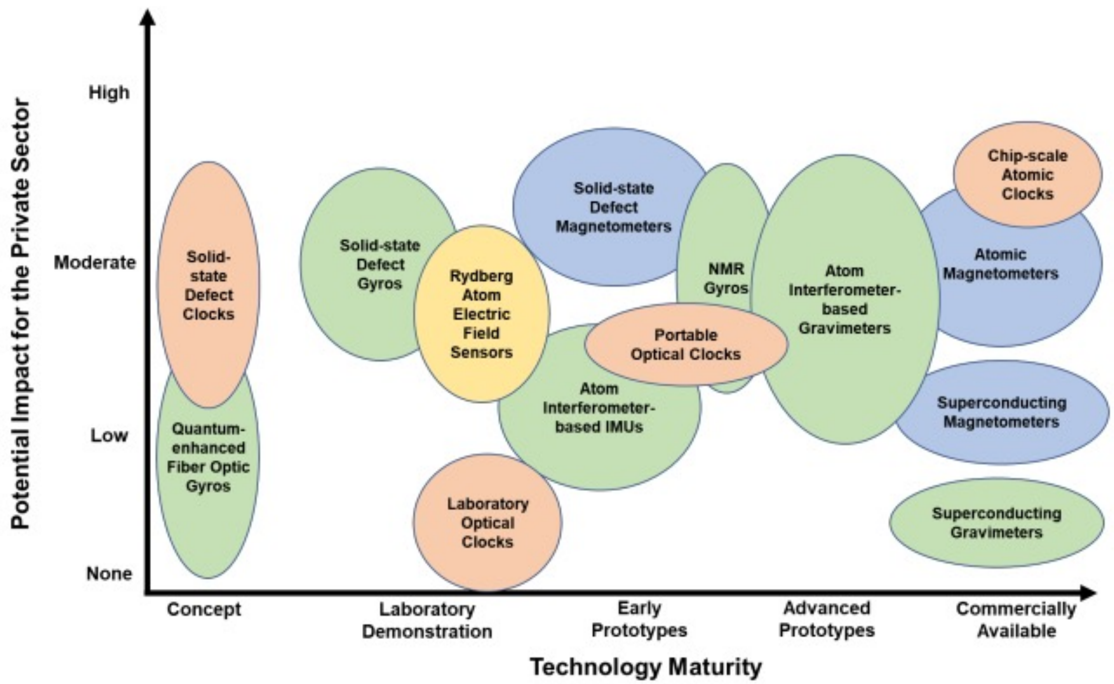
# HST and JWST Observe DART impact



# Quantum Engineering

## Quantum Engineering: using the basic properties of atoms and fundamental physics to build sensors and systems from the ground up

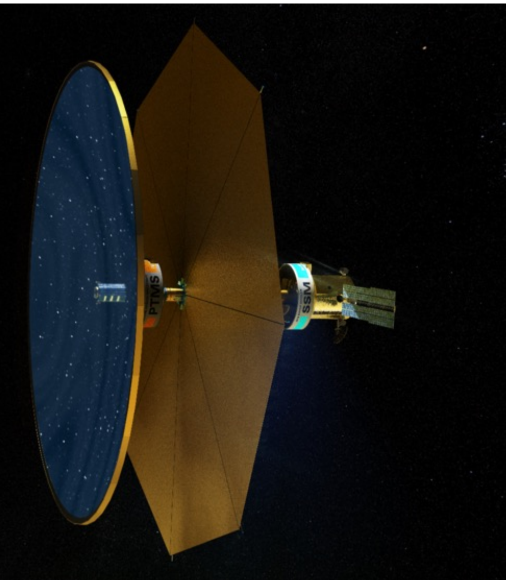
- **Not science fiction! Advances in materials science and laser engineering of last 50 years enable the manipulation of single atoms in small, robust devices**
- **Quantum Sensors: can measure and access information that is not achievable in any other way**




Source Quantum Economic Development Consortium (QED-C), *Quantum Sensing Use Cases (2022)*

SPACE FLIGHT CENTER

# Reflective Fluidic Optics




General Objective: Developing a reflective liquid for telescope mirroring applications via the assembly of metal nanoparticles at the surface of a polymer/ionic liquid solution.

The Fluidic Telescope (FLUTE) project team, jointly led by NASA and Technion – Israel Institute of Technology, envisions a way to make huge circular self-healing mirrors in-orbit to further the field of astronomy.

How: An Ion gel (or Ionogel) is a composite material consisting of an *ionic liquid* immobilized by an inorganic or a polymer matrix. Ionic liquids are a new class of purely ionic, salt-like materials that are liquid at unusually low temperatures. Having a low vapor means that these liquid mirror in the ultra high vacuum in space will be stable with negligible mass loss.

**Ionic Liquid Mixture**

+


+

**UV Exposure**

→

UV wavelength and time dictates final surface