National Aeronautics and Space Administration

Athena

NASA Langley Research Center

Future Earth Radiation Budget Observations Utilizing Agile Sensorcraft

Kory Priestley, *NASA PI*

Chad Rice, *NASA PM*

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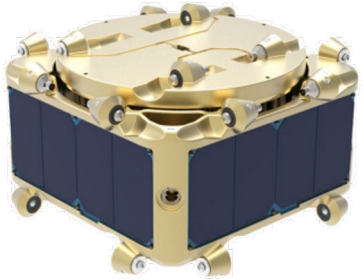
Opportunity

Demonstrate Intelligent and Strategic Collaboration and Integration of both hardware and partners (USSF/NOAA/NASA/NovaWurks)

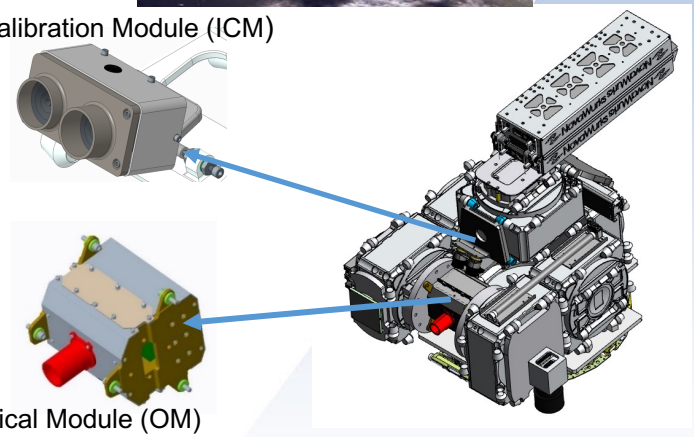
- **What is Athena?**
  - Athena is a Pathfinder mission of the NovaWurks Hyper Integrated Satlet (HISAT) conformable small-satellite platform for making *earth science remote sensing measurements*
  - LaRC provides a demonstration payload utilizing spare CERES flight hardware to integrate into a series of HISAT's to create a free-flying sensorcraft
  - Demonstrate ability to complete ERB Outgoing Longwave Radiance (OLR) observations from a conformable bus
- **Why Athena and why now?**
  - Leveraging opportunities with key partners and makes use of hardware LaRC has on-hand; provides LaRC the chance to use this technology for innovative science measurements
- **Flight plan: 1 month checkout + 11 month operation for NASA**
  - Then transferred to SSC for follow-on evaluation

~ Sapientia Opportuna ~

Measures 20 x 20 x 10 cm



Internal Calibration Module (ICM)



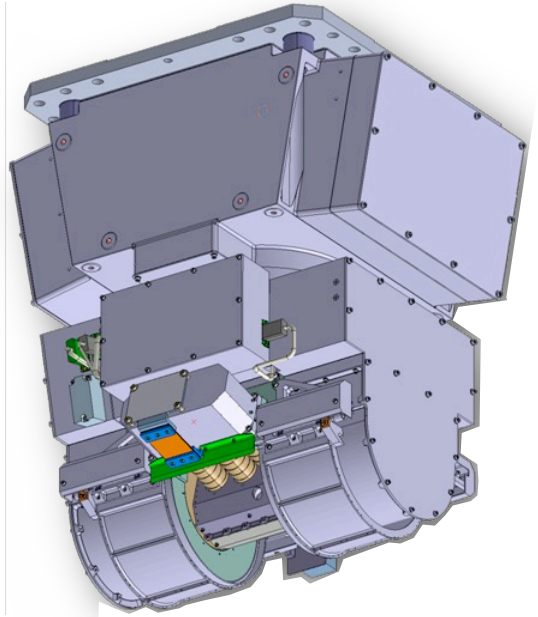
Optical Module (OM)

Operational and Programmatic Demonstration Goals

- **Scalable innovation for science observations utilizing multi-agency investments**
  - Lead Agency in demonstrating key technologies for small remote sensing platforms and in-space Assembly
    - Pathfinder for Commercial Launch Service implementation (*Virgin orbits* and SpaceX)
    - Reduce technical and cost risk for persistent observations of critical parameters
    - Alternative to traditional cubesat or small-sat form-factors as orbiting platforms for science
    - Enabling component for in-space assembly in support of exploration and commercialization of space
- **Operational Demonstration**
  - Validate Novawurks HISats for Multi-mission platforms (Sensorcraft, Payloads, In Space Assembly, LEO and GEO)
  - Craft Maneuverability to support temporally and spatially matched observations from other on-orbit assets
  - Craft Fine pointing control w/ & w/out torque disturbance input
  - Mechanical/Electrical Lifetime for carousel
  - Autonomous geo-targeting capability
  - Celestial body targeting capability
- **Programmatic Demonstration**
  - Pathfind future synergistic collaborations where each organization brings their centers of expertise
  - Leverage resources between the agencies to achieve common goals
  - Sustain critical observations upon failure, or unique missions/orbits that require coverage on-demand

Evolution : CERES/Aqua to Athena

1993
CERES



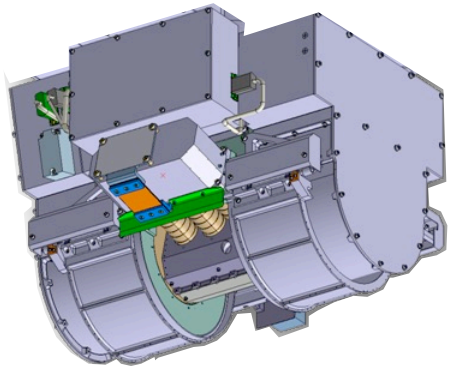
Size (cm): 60x60x70
Mass(Kg): 50

2003
ERBS

Preserve

- Elevation Gimbal
- Processors
- Optical Module
- Calibration Module

(Concept only)

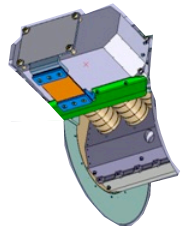


60x60x35
30

2019
Athena

Preserve

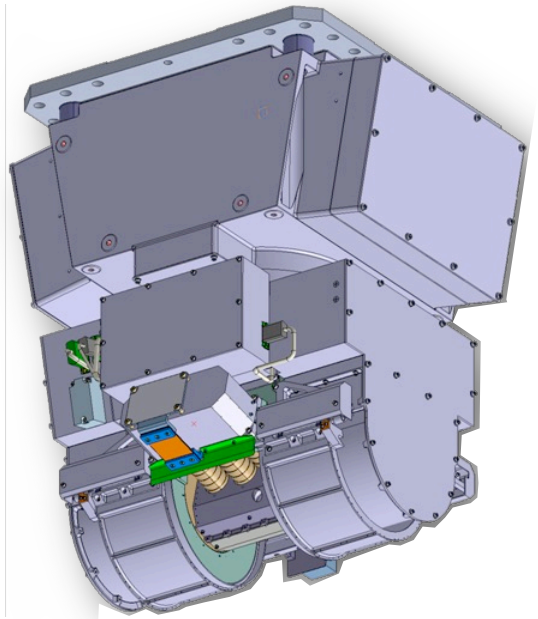
- Optical Module
  (one channel)
- Calibration Module
  (Blackbody)



~15x15x15
<3

Evolution : CERES/Aqua to Athena

1993
CERES



2003
ERBS

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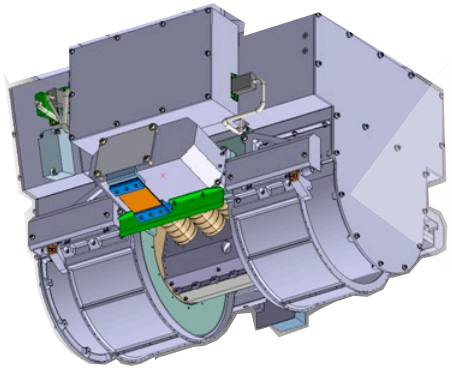
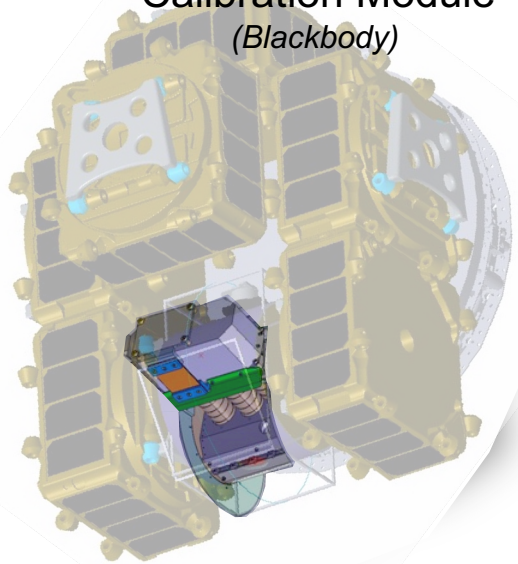


2019
Athena

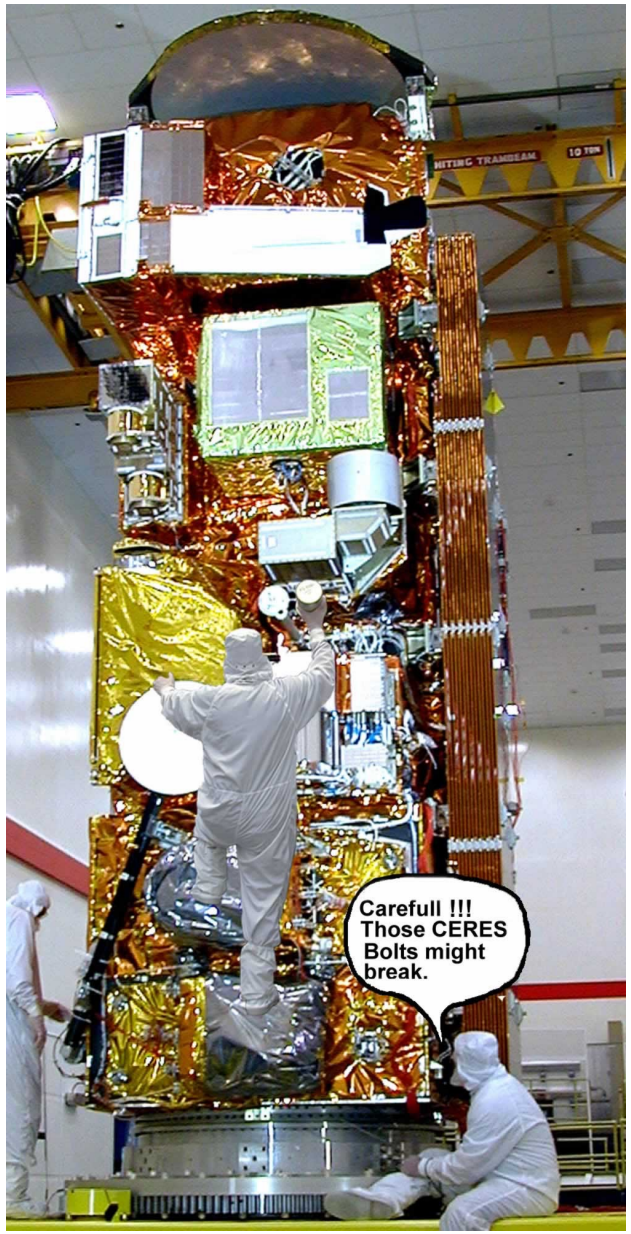
Preserve

- Optical Module
  (one channel)
- Calibration Module
  (Blackbody)



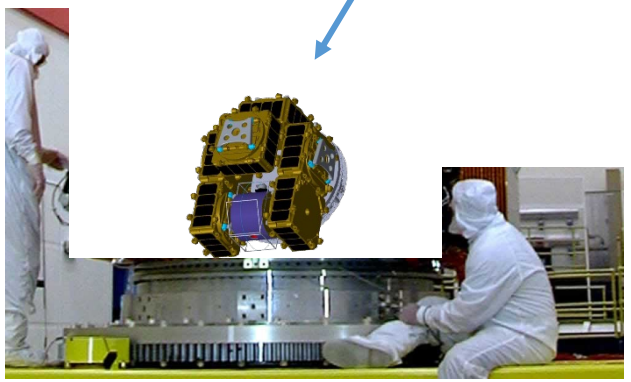
Size (cm):	60x60x70	60x60x35	~15x15x15
Mass(Kg):	50	30	<3

Evolution : CERES/Aqua to Athena

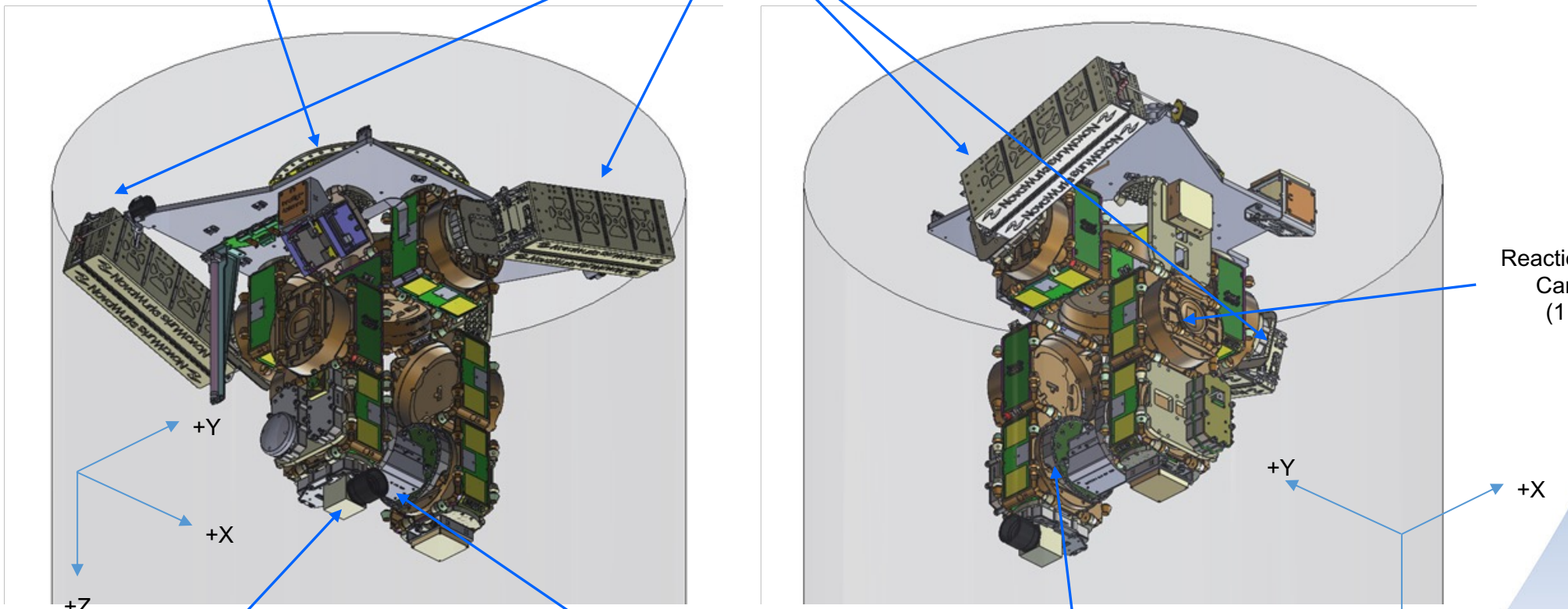


Aqua (2001)

Athena (2019)



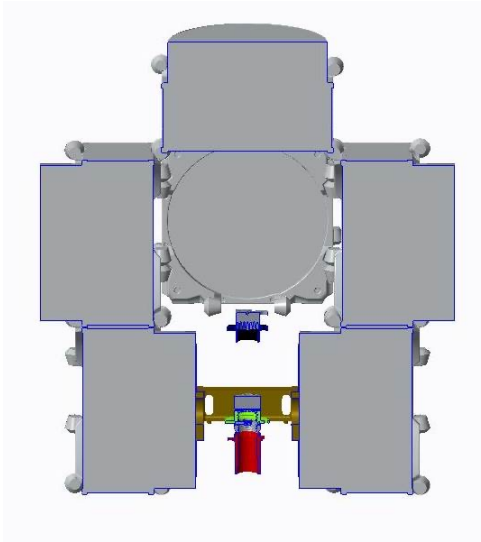
Sensorcraft Launch Configuration



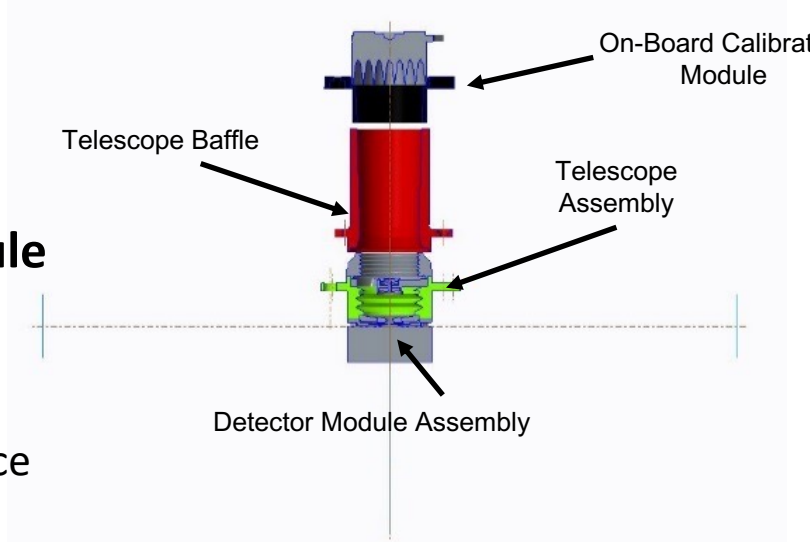
Note: Calibration Module not visible

Payload - Athena Optical and Calibration Modules

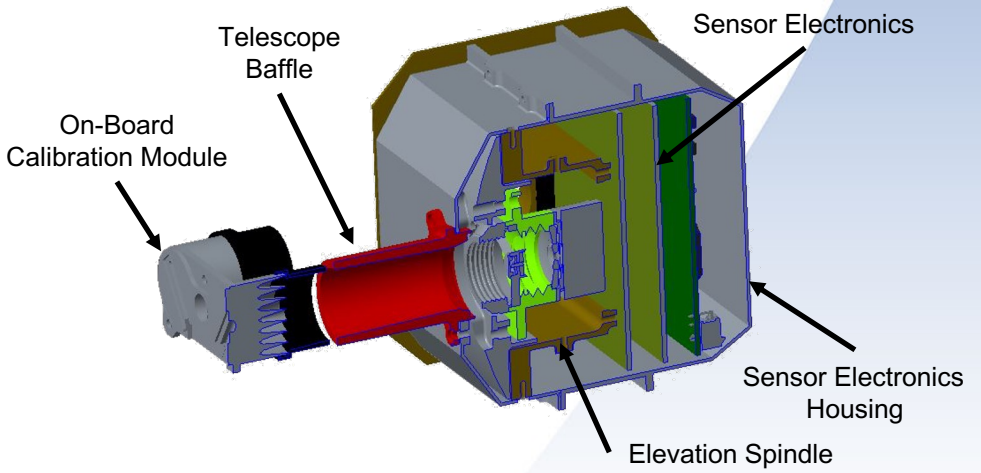
- **Payload developed by Langley integrated into NovaWurks spacecraft**
  - PAC will spin optical module at a constant 60-deg/sec
  - Aggregate payload distributed across multiple HiSats/UDAs
- **Sensing and acquisition performed in the payload Optical Module (OM) and Internal Calibration Module (ICM)**
- **Control of the payload provided and performed by the HISat's**
  - HISat's parse digital data from Optical Module to compute Bridge Balance Offset (algorithm provided by Langley)
  - HIAT's monitor Blackbody temperature and controls heater set-point(s)



Telescope/Sensor Assembly



Optical Module



Hardware in the Loop

Athena/EPIC – Mission Architecture

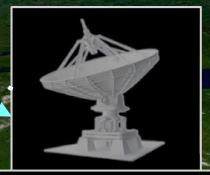
Space Segment

Athena/EPIC SensorCraft

Athena/EPIC
Multi-Agency Integrated Science payload/bus demonstration platform utilizing a conformable bus architecture to demonstrate rapid configurability and on-orbit performance capability

Ground Segment

Commands
Science Data, Telemetry



MMC -Mission Management Center
SMD – Stored Mission Data Center
NovaWurks Los Alamitos, CA

Space/Ground Communications
Location: Multiple

Commands
Science Data, Telemetry

POT – Payload Operations Team (POT)
The POT manages the operation of Athena remotely from LaRC. NASA LaRC, Hampton, VA

Payload Planning
Science Data, Telemetry

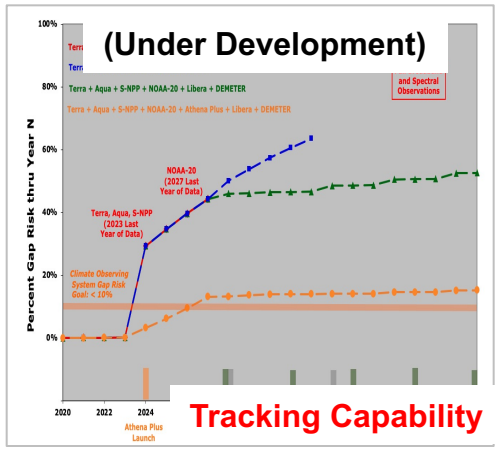
SIPS - Science Investigator Processing System
Responsible for the processing, archival and distribution of Athena data. NASA LaRC, Hampton, VA

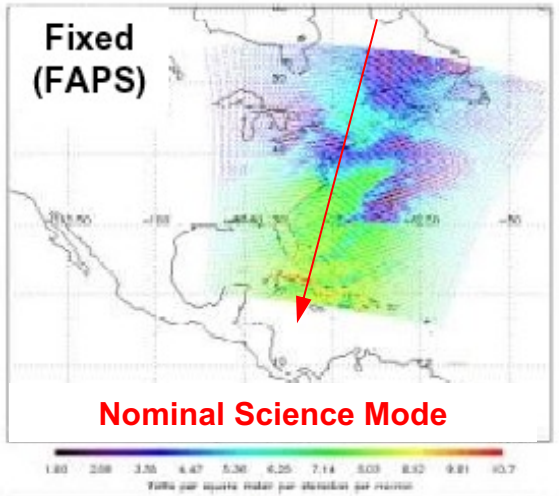
Launch Segment
Vehicle: SpaceX Falcon-9
Location: Vandenberg, CA

Athena Operational Scanning Demonstrations

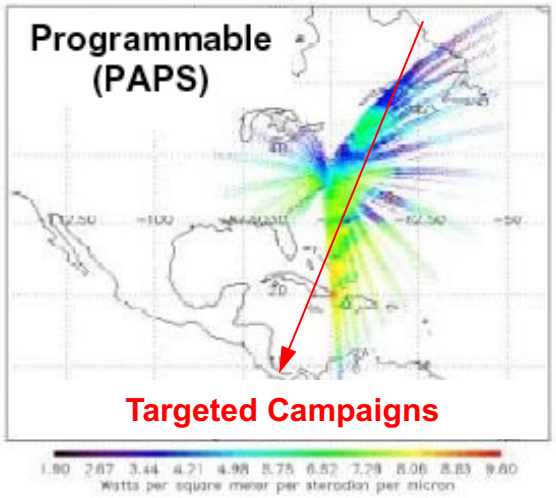
Bus carousel and native pitch/yaw capability replaces need for 2-axis instrument gimbal

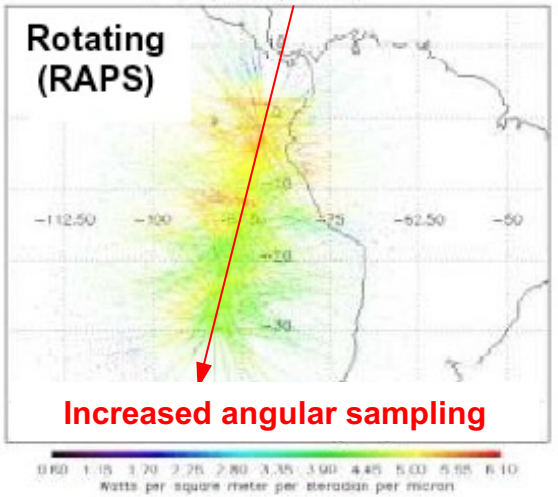
Variable yaw rate





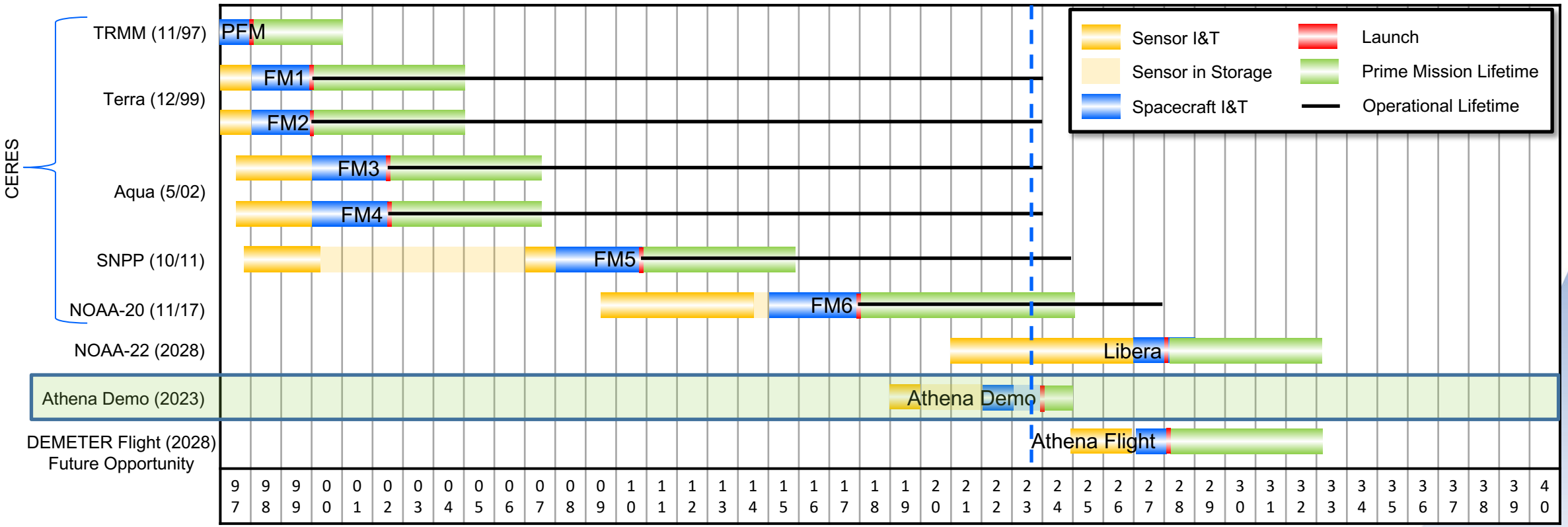
Stepped yaw angles

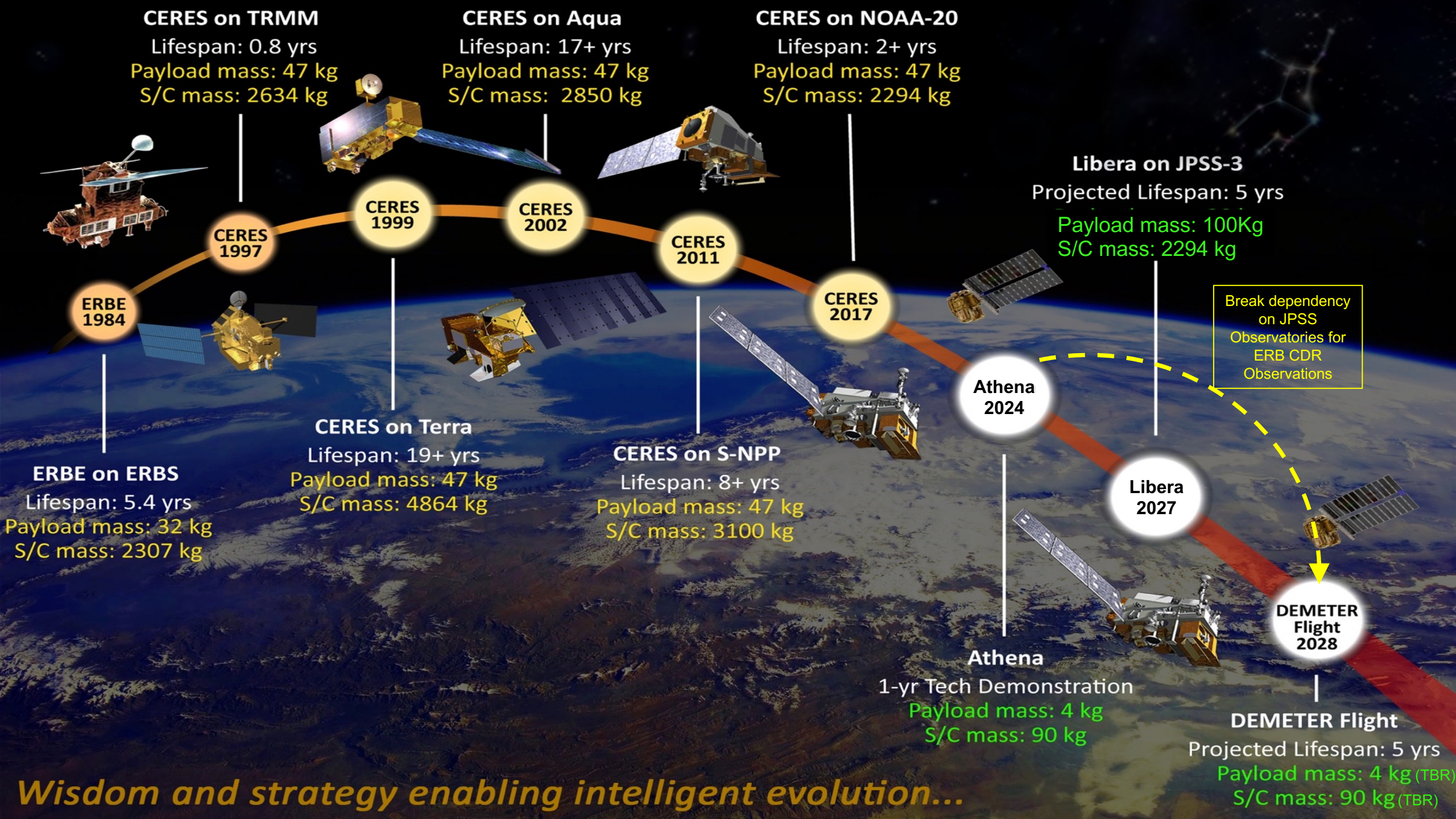




Yaw = ~6-deg/s

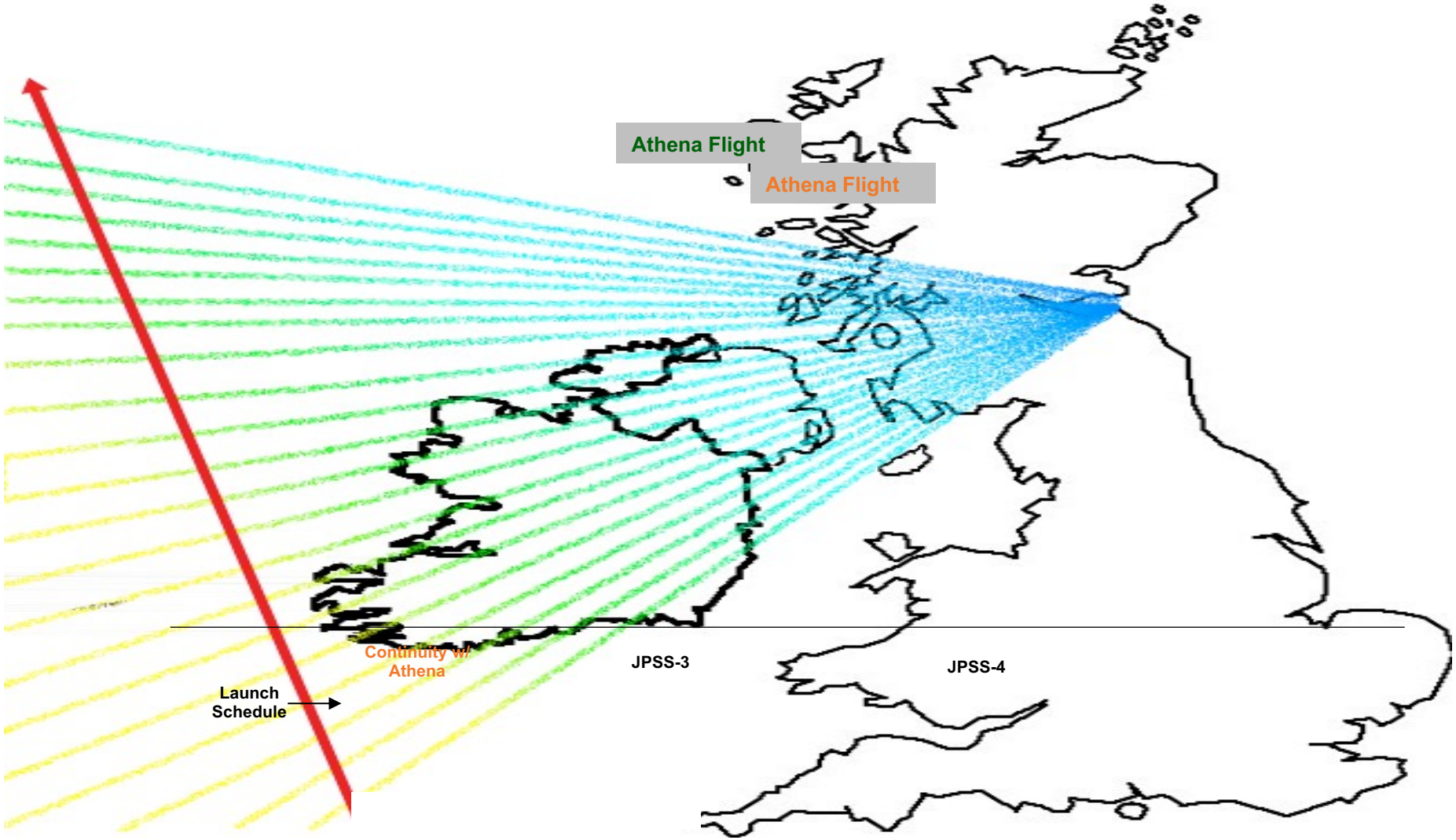
Earth Radiation Budget Mission Timelines




CERES on TRMM
Lifespan: 0.8 yrs
Payload mass: 47 kg
S/C mass: 2634 kg
CERES on Aqua
Lifespan: 17+ yrs
Payload mass: 47 kg
S/C mass: 2850 kg
CERES on NOAA-20
Lifespan: 2+ yrs
Payload mass: 47 kg
S/C mass: 2294 kg
Libera on JPSS-3
Projected Lifespan: 5 yrs
Payload mass: 100Kg
S/C mass: 2294 kg
ERBE 1984
CERES 1997
CERES 1999
CERES 2002
CERES 2011
CERES 2017
Athena 2024
Libera 2027
DEMETER Flight 2028
Break dependency on JPSS Observatories for ERB CDR Observations
ERBE on ERBS
Lifespan: 5.4 yrs
Payload mass: 32 kg
S/C mass: 2307 kg
CERES on Terra
Lifespan: 19+ yrs
Payload mass: 47 kg
S/C mass: 4864 kg
CERES on S-NPP
Lifespan: 8+ yrs
Payload mass: 47 kg
S/C mass: 3100 kg
Athena
1-yr Tech Demonstration
Payload mass: 4 kg
S/C mass: 90 kg
DEMETER Flight
Projected Lifespan: 5 yrs
Payload mass: 4 kg (TBR)
S/C mass: 90 kg (TBR)
Wisdom and strategy enabling intelligent evolution...

Sensorcraft Provide Observational Robustness

Example : Global ERB CDR Data Gap Risk



Flagship Missions ($200M in Payload $2B in Observatory)

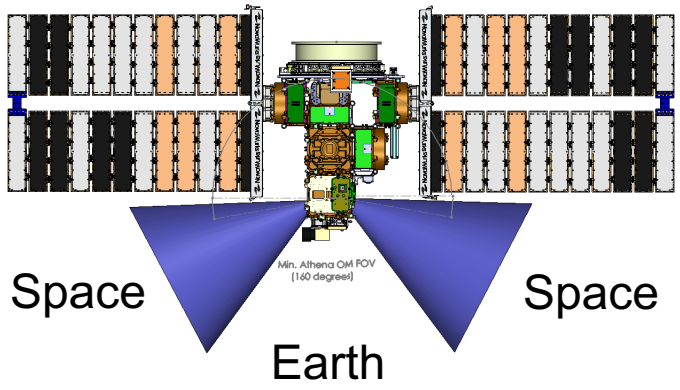
DEMETER Sensorcraft Missions ($200M Total Cost)

DEEMTER (Early launch) Sensorcraft Missions ($230M Total Cost)

Note: Sensorcraft Assumption, 5-year lifetime, 3 year launch cadence

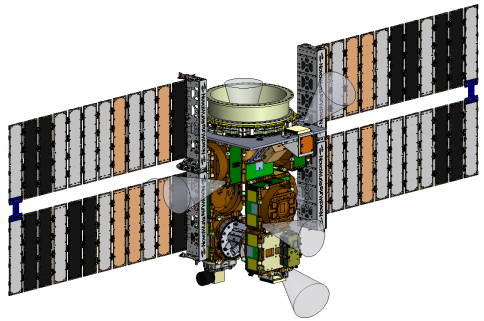
Sensorcraft Flight Configuration

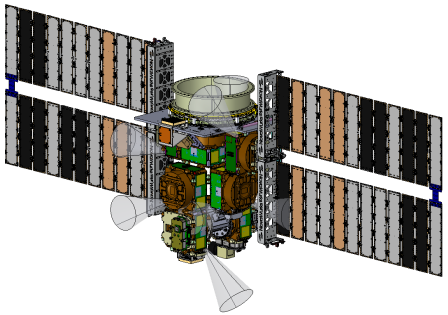
- **EPIC/Athena FOV**

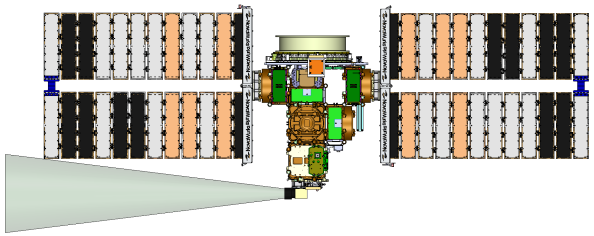


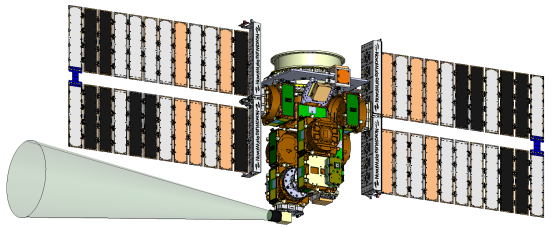
- **Orbit is 400-500km at 97° inclination**
  - 1330 and 1800 LTAN configurations complete
- **1 month Checkout, 11 months of operations**
- **Optical Module Rotates continuously at 60deg/sec**
- **Nearly 180° FOR for CERES-like scanning (desired)**
- **Perform multiple scanning profiles as part of characterizing vehicle on-orbit performance**

- **Camera and Star Tracker FOV**







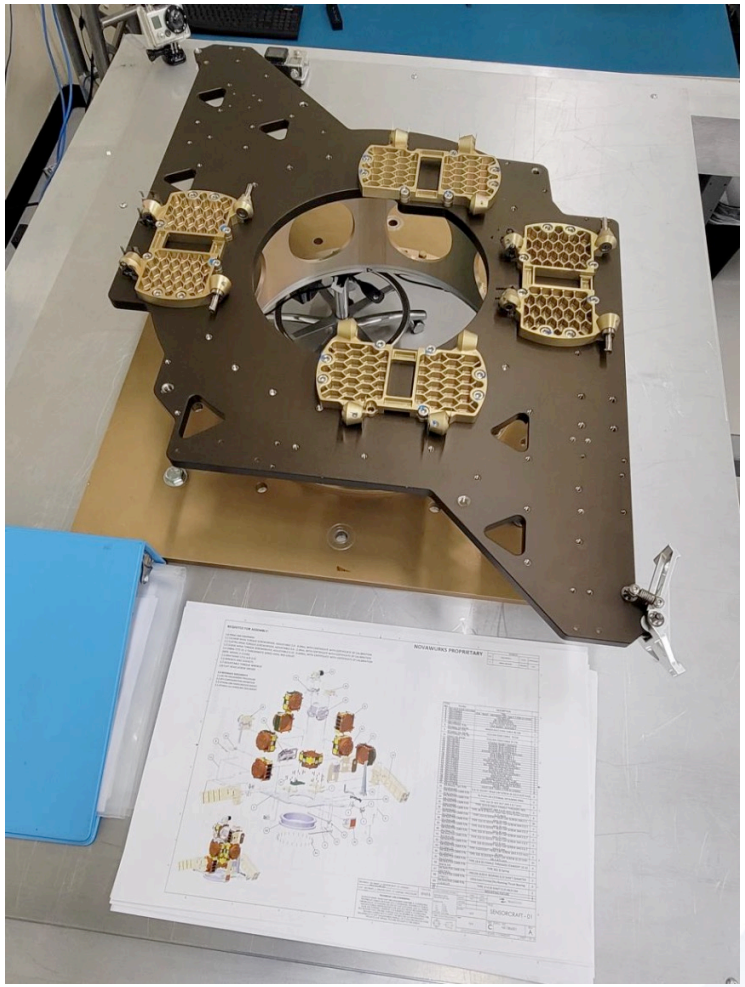


Sensorcraft Integration Activities

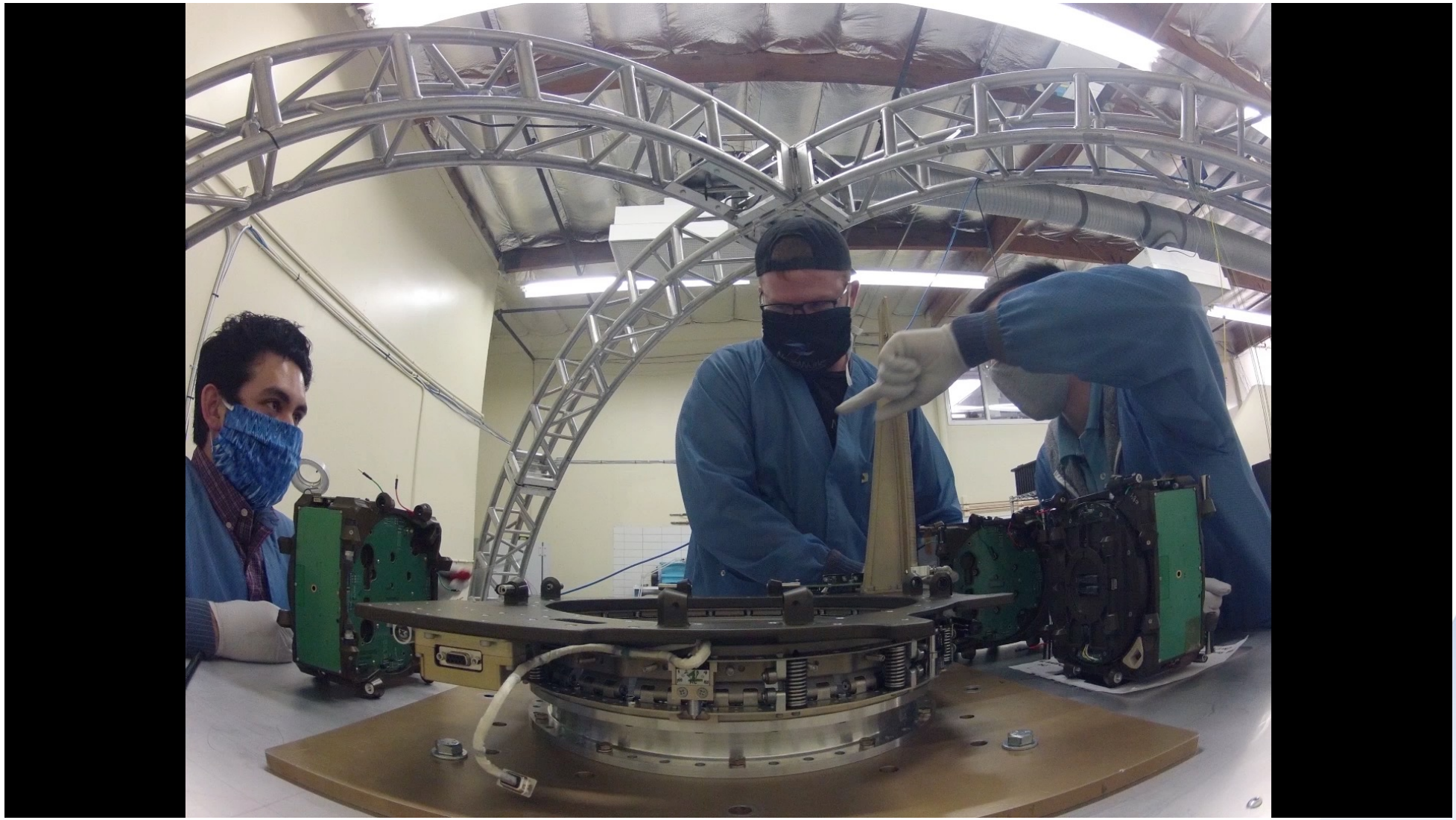
HiSat Assembly Complete and ready for functional testing

Started Sensorcraft Integration process with:

- Baseplate and 4 User Defined Adaptor's (UDA's)
- Sitting on "Placeholder" launch Adaptor Ring until the lightband is delivered



Package of Aggregated Cells (PAC) Assembly

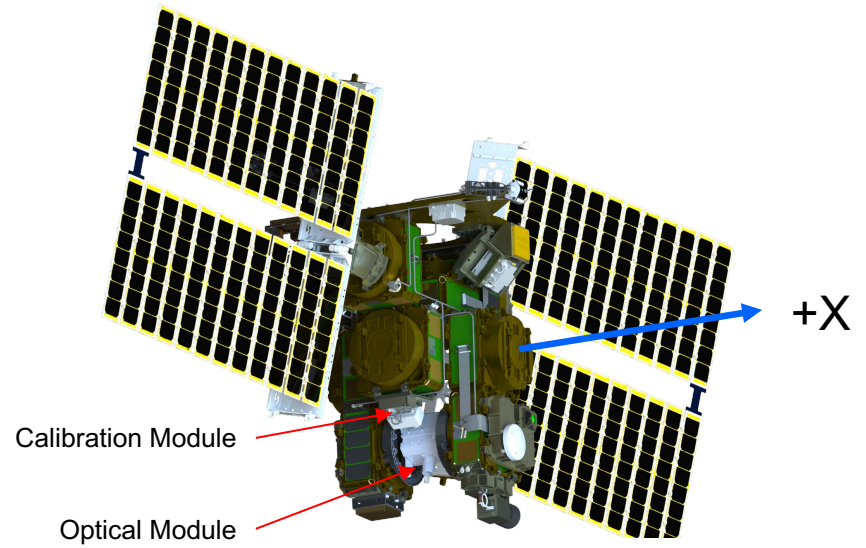


Athena – The Goddess of Wisdom and Strategy

PI: Kory Priestley, LaRC

Objective

- Develop, launch and operate an Earth Radiation Budget technology demonstration sensorcraft.
- Demonstrate viability of NovaWurks Sensorcraft architecture to support future USSF/NOAA/NASA missions
- Serve as a pilot opportunity for Transformational activities within LaRC (SPIN, FIREFLY) and across Agencies
- On-orbit demonstration of CONOPS and observational capability
- ***Risk reduction opportunity for future Athena + and DEMETER science missions***



Approach

- Leverage investments from partner agencies
- Launch with SpaceX
- NASA/LaRC delivers to NovaWurks an Athena Payload consisting of:
  - Optical Module (Single CERES Total Channel sensor)
  - Calibration Module (CERES Internal Blackbody)
  - Sensor Electronics Assembly (New Development)

Partners

NASA LaRC – Payload (in house development)
NOAA/NESDIS – Funding for System integration and Test
NovaWurks – Sensorcraft (Prime vendor and integrator)
USSF/SSC – Sensorcraft contract

Key Milestones

• Engineering Design Studio Session	4/2/19
• ATP for LaRC effort	5/7/19
• Payload Design Review	9/26/19
• Payload delivery to NovaWurks	4/30/22 (2-year COVID delay)
• Payload need date	4/30/20 (OBE)
• Sensorcraft Complete	11/30/23
• SpaceX Launch	2/30/24 (TBR)

National Aeronautics and Space Administration

NASAfacts

Science

NASA Langley Research Center

Athena

As Agencies Align, Athena Brings Wisdom and Strategy

NASA, the U.S. Space Force and NOAA have strategically aligned efforts to gain wisdom from Athena — a SmallSat that will demonstrate the ability of NovaWurks SensorCraft architecture to support future missions. Athena serves as a pilot opportunity for transformational activities by demonstrating energy budget measurements at the top-of-atmosphere (TOA) from space on a new type of satellite host.

> Athena will demonstrate the critical science measurement, but also an architecture that is adaptable and more cost-effective for the taxpayer and the government - Kory Priestley, principal investigator for Athena at Langley.

Athena teams at each organization are gaining technical knowledge from the hardware, but also in conducting business with partners and streamlining processes for a more robust and rapid development.

New Architecture, Big Rewards

Taking cues from human biology, specifically the structure and interactions of cells, NovaWurk's Hyper-Integrated Satlets, or HISat's, are engineered to aggregate, share resources, and conform to different sizes and shapes. The cellular architecture of the craft allows greater flexibility with payload designs and concepts, dropping the price-point, yielding greater access to space and multiple orbits to exploit observational capability.

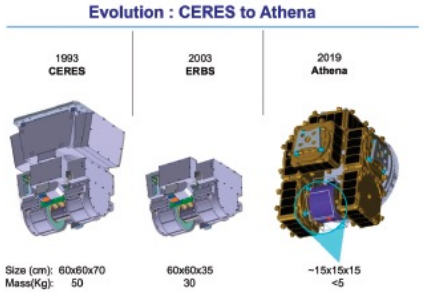
"We're really merging the capabilities of the HISat's and the payload," Priestley said. "So, our payload doesn't need to bring as many resources to the overall effort."

Given the seamless integration of the payload, sensor and the host craft, teams are easily finding new and needed science applications and collaborations that Athena can provide for future science missions.

A Small Science Payload Evolved from CERES

Satellites such as Terra and Aqua were as big as school buses. "The complete Athena HISat platform will be about as big as the electric toy car my granddaughter drives around in," Priestley said.

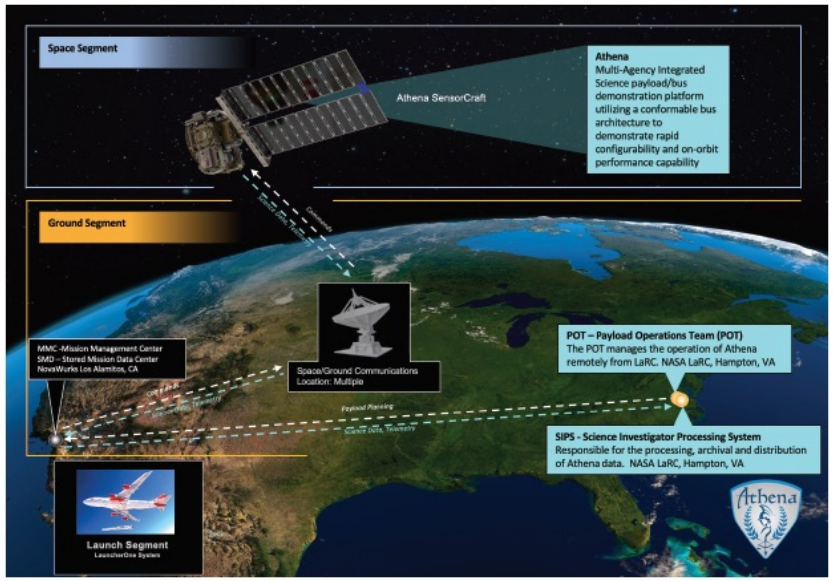
In 2020, NASA Langley delivered the Athena payload to NovaWurks. The payload consists of an Optical Module and a Calibration Module built with spare parts from NASA's CERES mission, and a newly developed Sensor Electronics Assembly.



New Path to Launch

Athena is a one year mission that was selected to launch on the Virgin Orbits LauncherOne system tentatively in summer/fall 2023. LauncherOne is a two-stage orbital launch vehicle developed and flown by Virgin Orbit that began operational flights in 2021. It is an air-launched rocket, designed to carry smallsat payloads of up to 300 kg (660 lb) into Sun-synchronous orbit (SSO), following air launch from a carrier aircraft at high altitude.

Once in orbit, NASA's Athena will collocate measurements with CERES instruments on other NASA spacecraft to demonstrate the capability of sustaining critical Earth Radiation Budget observations measurements well into the future.



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NP-2022-08-034-LaRC

NASA Facts

Back-up

~ Opportuna Sapienta ~

NovaWurks Hyper Integrated Satlet Building Blocks

Individual HISats are connected to aggregate performance as a PAC (Package of Aggregated Cells)

Advantages and Characteristics

- High Performance Bus can be built in months, not years
- Satellite bus is a configuration, low NRE, not a design
- Supports all orbits (LEO-GEO) with scalable life (2, 5, 8+ Year life)
- Payload Centric : Configured to adapt to payload and Launch Vehicle
- Integrated processor, memory, carousel, thrusters, cameras in each HISat
- HISat's Share power, fuel, data, and thermal fluids
- n of m improvement from "primary/redundant"
- Open source Simplified Interface – Plug-n-Play by design
- Mass produced, driving quality and cost efficiencies
- Design provides Significant radiation shielding