
Athena
National Aeronautics and Space Administration
NASA
Athena
NASA Langley Research Center
Athena Overview
Kory Priestley, Principal Investigator
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October 30, 2019
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SMC
NRO
GSFC
NOAA
NovaWurks
Goddard
Space Flight Center
NovaWurks
SPACE FOR EVERYONE

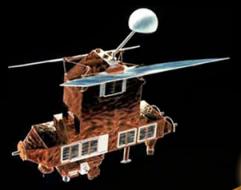
ERB Observations at LaRC

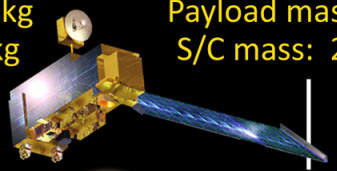
Past, Present and Future opportunities

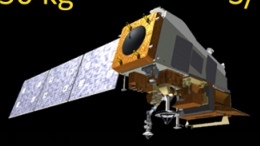
CERES on TRMM
Lifespan: 0.8 yrs
Payload mass: 47 kg
S/C mass: 2634 kg

CERES on Aqua
Lifespan: 17+ yrs
Payload mass: 47 kg
S/C mass: 2850 kg

CERES on JPSS-1
Lifespan: 2+ yrs
Payload mass: 47 kg
S/C mass: 2294 kg







CERES 1997

CERES 1999

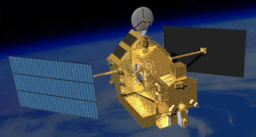
CERES 2002

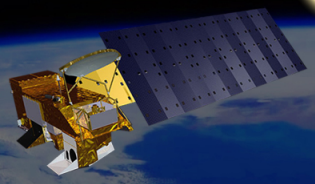
CERES 2011

CERES 2017

ERBE 1984

ATHENA+ Concept
Projected Lifespan: 3 yrs
Payload mass: 8 kg
S/C mass: 60 kg





ATHENA 2022

ATHENA + 2025

DEMETER 2028

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 Technology Demonstration
Payload mass: 4 kg
S/C mass: 50 kg

DEMETER
Projected Lifespan: 5 yrs
Payload mass: 4 kg
S/C mass: 45 kg

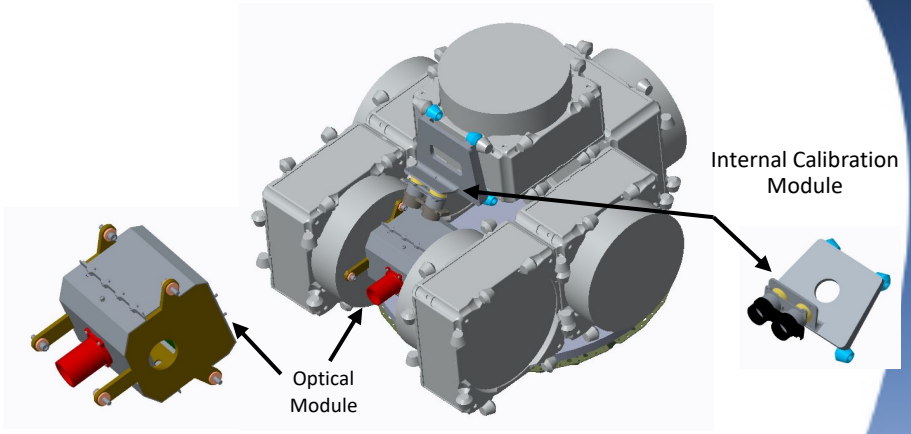
Wisdom and strategy enabling intelligent evolution...

Athena

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 USAF/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 JPSS-2 as a secondary ESPA small satellite
- 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 – Rideshare Opportunity (JPSS-2)
NovaWurks – Sensorcraft (Prime vendor and integrator)
USAF/SMC – 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	3/31/20
Payload need date	4/30/20
Sensorcraft Complete	6/30/20
JPSS-2 Launch	3/15/22

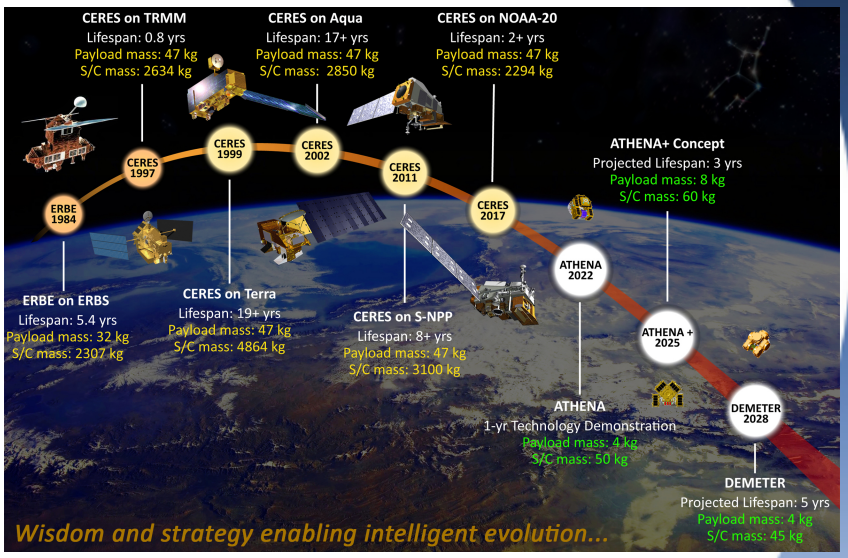
DEMETER

DEMonstrating the Emerging Technology for measuring the Earth's Radiation

PI: Anum Ashraf, LaRC

Objective

- Develop a sensorcraft that demonstrates a **game-changing** approach for measuring the Earth Radiation Budget Fundamental Climate Data Record.
- Exploit the science capability and greatly exceed data quality of current measurement by:
  - Increasing spatial resolution by factor of 10
  - Incorporating **intelligent** on-board data processing
- **Innovative** and **integrated** solution that reduces mass, power, risk, and cost, by an order of magnitude over current state-of-the-art techniques.
- Drastically reduced form-factor enables low cost flight opportunities providing more complete global diurnal sampling of radiation fields and significant risk reduction of a gap in the multi-decadal climate data record.



Approach

- Leverage 100+ years of direct experience to pro-actively influence the design and address trades involved in an integrated and intelligent manner
- Design and build a non-scanning wide-angle telescope with a linear detector array that reduces IFOV and increases spatial resolution
- Build and test a technology demonstration unit consisting of the wide-angle telescope integrated with sensorcraft elements

Co-I's: Kory Priestley, Wenying Su, Seiji Kato, Dave Doelling, Paul Stackhouse, Mohan Shankar, J. Robert Mahan, Alexander Halterman
Collaborator: Norman Loeb
Partners: Science Systems and Applications Inc., Quartus Engineering Incorporated, NovaWurks Inc., Virginia Tech.

Key Milestones

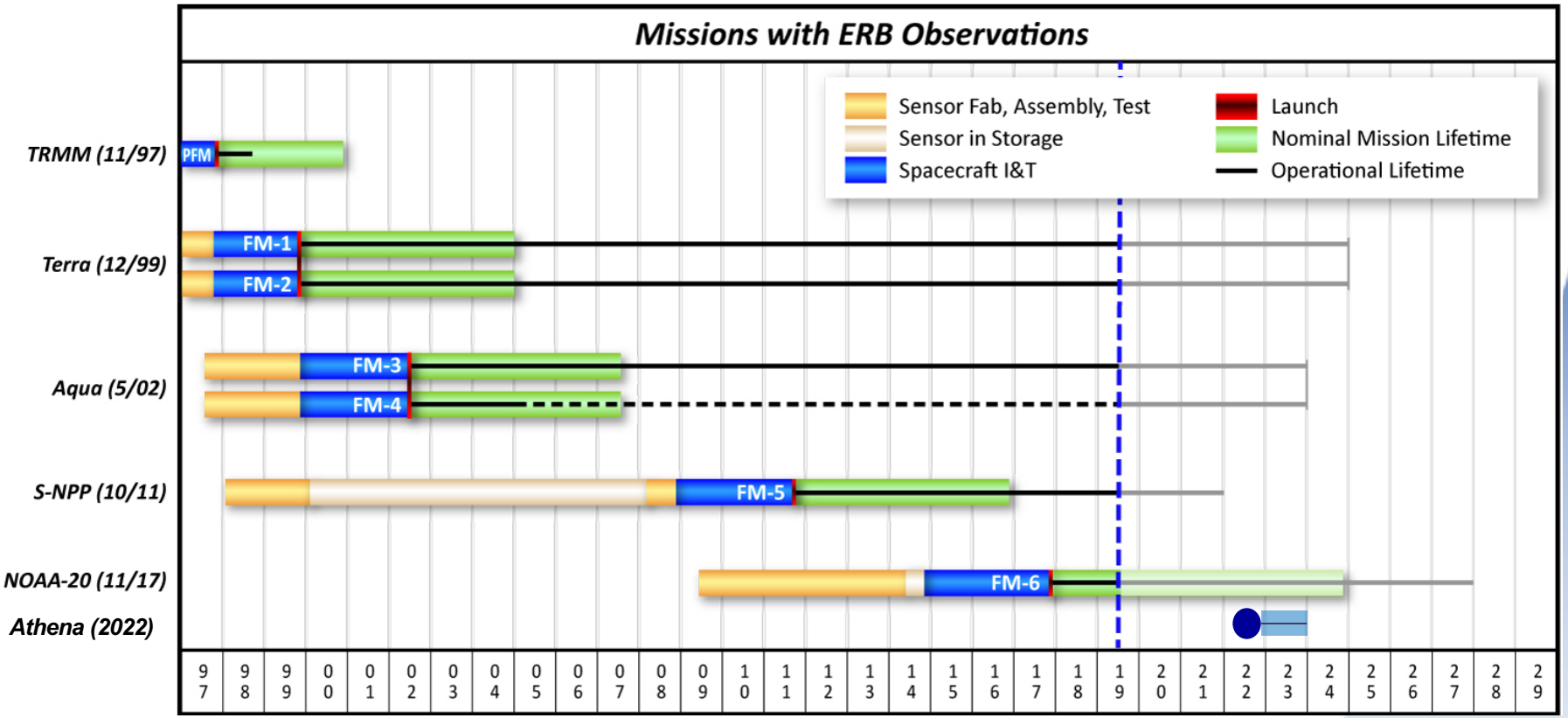
• Project Kick-off	01/20
• Requirements Definitions Complete	03/20
• Downselection of optical architecture	05/20
• Design Review I	09/20
• Breadboard Testing Complete	06/21
• Downselection of Detector Array	08/21
• Design Review II	12/21
• Brassboard Testing Complete	09/22
• Project Close-Out Review	11/22

$TRL_{in} = 2$ $TRL_{out} = 4$

ESTO Earth Science Technology Office

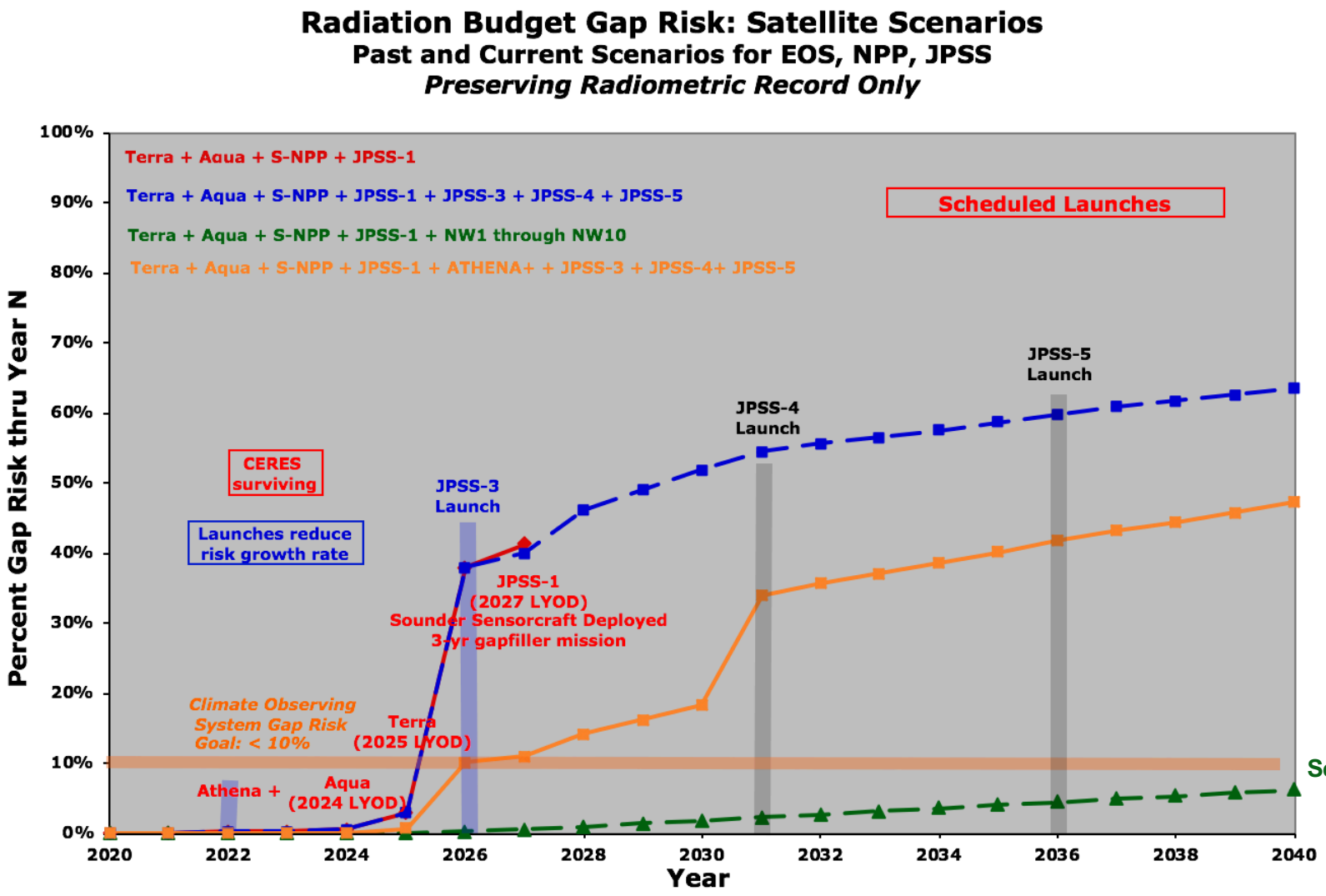
Critical Products Require Persistent Observations

CERES Flight Schedules



We now have over 80 years of flight experience with the CERES instruments

Sensorcraft Provide Observational Robustness



Flagship Missions
($200M in Payload
$6B in Observatory)

Sensorcraft Missions
($200M Total Cost)

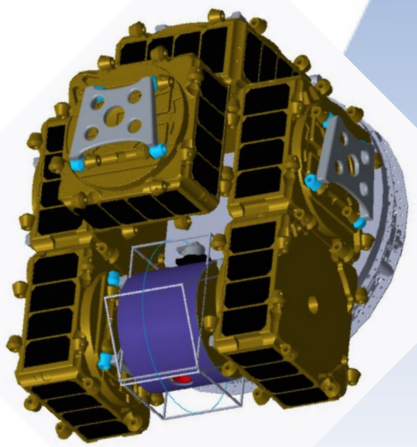
Current Athena Opportunity

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

- **Goals**
  - Demonstrate viability of NovaWurks Sensorcraft architecture to support future USAF/NOAA/NASA missions
    - Athena-Plus
    - DEMETER
  - Serve as a pilot opportunity for Transformational activities within LaRC (SPIN, FIREFLY) and across Agencies

- **Implementation**
  - Launch with JPSS-2 as a secondary ESPA small satellite (NOAA and USAF select secondary payloads)
  - ***On-orbit demonstration of CONOPS and observational capability*** to address risks identified by LaRC SME's
  - NASA/LaRC delivers to NovaWurks (1 Feb 2020) Athena Payload consisting of:
    - Optical Module (Single CERES Total Channel sensor, Bonded Stores)
    - Calibration Module (CERES Internal Blackbody, Bonded Stores)
    - Sensor Electronics Assembly (New Development, Legacy Functionality)

- **Timeline**
  - 4/2,4,8/19 - Engineering Design Studio Session – **COMPLETE**
  - **5/7/19 – ATP for LaRC effort - COMPLETE**
  - 3/27/20 - Payload delivery to NovaWurks - (4/30/20 need date TBR)
  - 6/30/20 – Sensorcraft Complete – 'Ready for Launch'
  - 3/15/22 - JPSS-2 Launch



~ Sapientia Opportuna - Wisdom and Strategy ~

Athena – the Goddess of Wisdom and Strategy

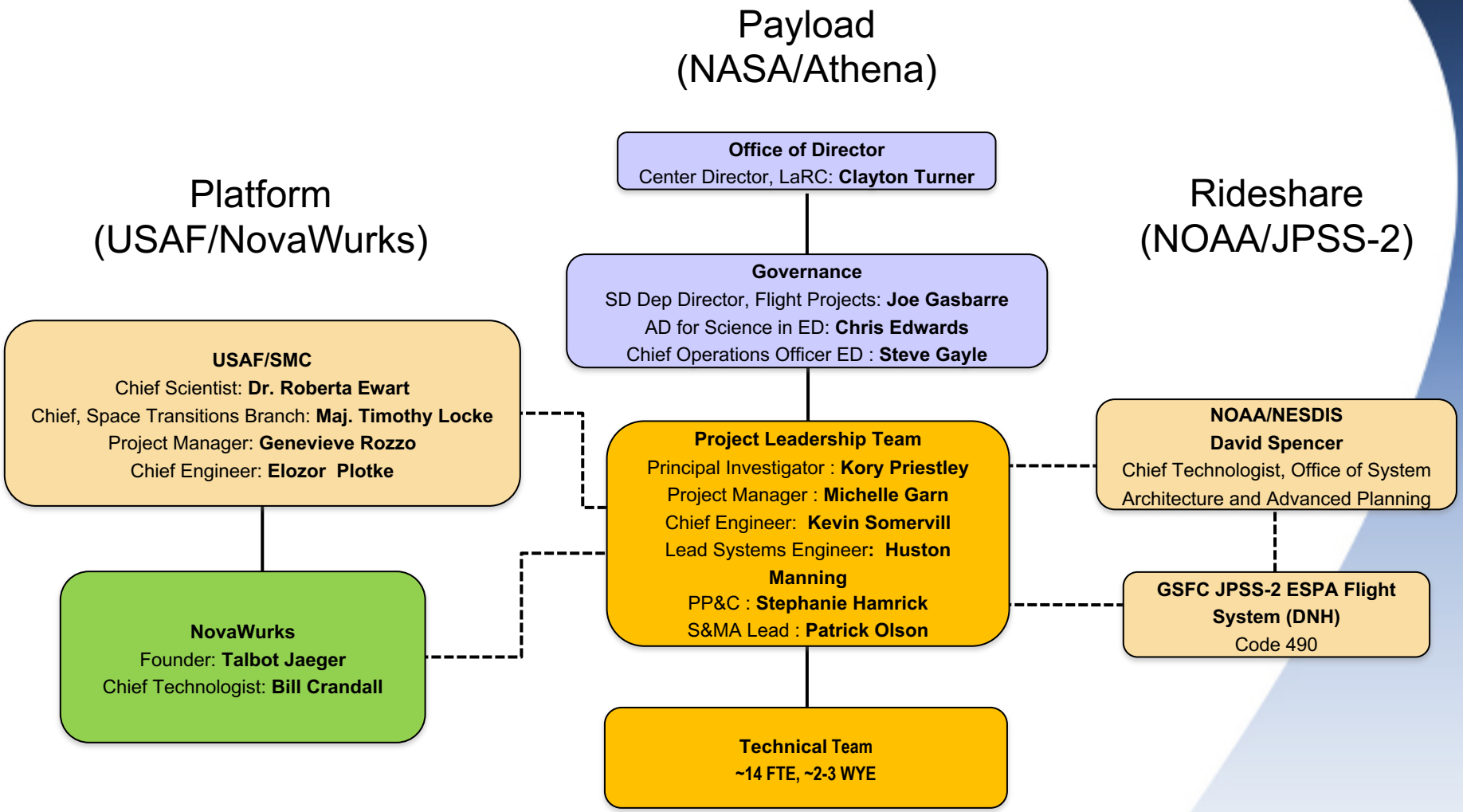
- **Athena is the Goddess of Wisdom and Strategy, two qualities that fit perfectly with the aligned goals of this partnership.**
  - **Wisdom:** not only will we gain technical knowledge/wisdom from the hardware but also in new ways of conducting business with partners and streamlining processes and procedures for robust rapid development
  - **Strategy**: The cellular architecture of the craft aligns perfectly for science missions, allowing greater flexibility in payload design/concepts, dropping the price-point, yielding greater access to space and multiple orbits to exploit observational capability, the partnerships are opening doors across organizations and directorates allowing the opportunity to capitalize on investments for the taxpayer.
- **Seamless integration of a payload/sensor and the host craft represents an entirely new paradigm and positive mental challenge for our team**
  - The team is actively pursuing new implementations for other observational missions (Athena Plus, DEMETER)
  - This is a game changing capability
- **The Athena payload/sensor will work in conjunction with the USAF craft to demonstrate the viability of a *Sensorcraft* platform to execute the conops necessary for sustainable Earth Radiation Budget observations.**

Partnerships

We have a powerful opportunity that benefits all partners with aligned goals.

- **USAF/SMC/NovaWurks (Platform)**
  - SMC has a $2.8M Rapid Integration Fund (RIF) contract with NovaWurks for a complete Sensorcraft stored in a “launch ready” configuration at NovaWurks.
  - Goal is demonstrating rapid re-configurability prior to environmental testing to support launch
  - SMC and LaRC are developing a Space Act Agreement supporting programmatic cross-agency Integration with Athena as the primary payload
- **LaRC (Payload)**
  - Provides Athena payload to USAF at no-cost
- **NOAA/NESDIS (Rideshare)**
  - The Athena Sensorcraft has been chosen by NOAA to be one of the ESPA secondary payloads on the JPSS-2 launch

Partnership Structure

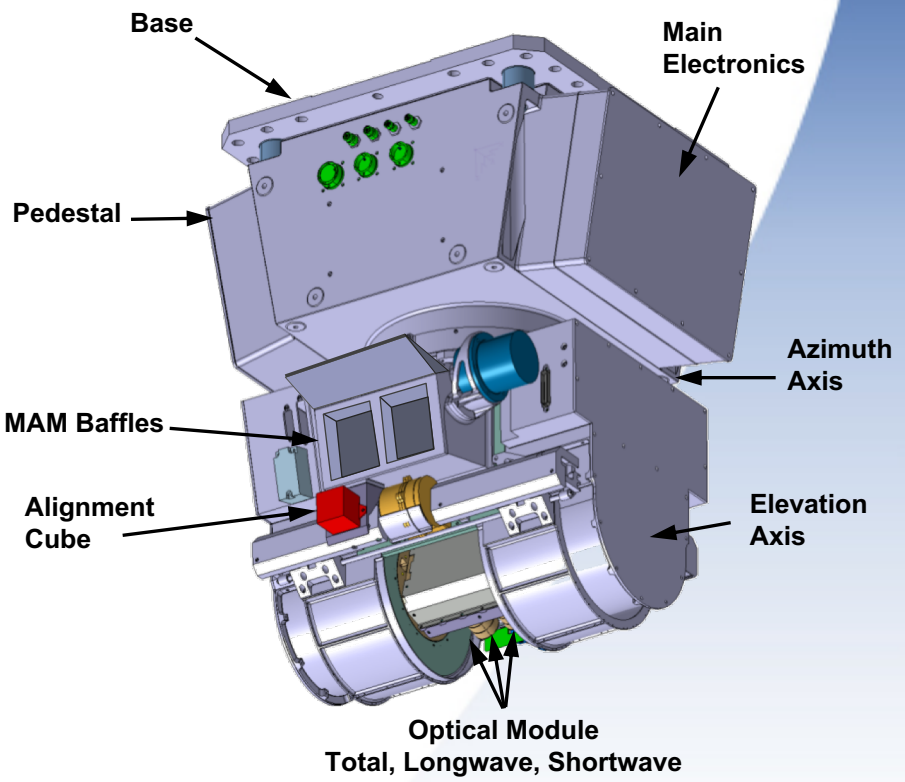


Three independent opportunities have aligned
~ Reconciliation of independent schedule dependencies is ongoing ~

Athena's Predecessor : CERES

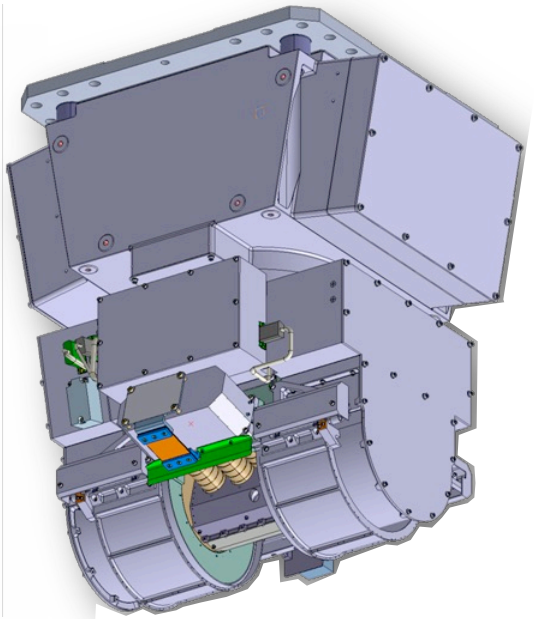
- Designed, manufactured and tested by TRW, Redondo Beach, CA (currently Northrop Grumman Aerospace Systems)
- Contains three sensor assemblies with cassegrain optics and thermistor bolometer detectors
- Sensors measure thermal radiation in the near-visible through far-infrared spectral region
- Sensor channels are coaligned and mounted on a spindle that rotates about the elevation axis
- Hemispherical sampling obtained with an azimuthal axis drive system

Orbits	705 km altitude, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (PM-1), sun-synchronous, near-polar; 350 km altitude, 35º inclination (TRMM)
Spectral Channels	Solar Reflected Radiation (Shortwave): 0.3 - 5.0 µm Window: 8 - 12 µm Total: 0.3 to > 100 µm
Swath Dimensions	Limb to limb
Angular Sampling	Cross-track scan and 360º azimuth biaxial scan
Spatial Resolution	20 km at nadir (10 km for TRMM)
Mass	50 kg
Duty Cycle	100%
Power	45 W
Data Rate	10 kbps
Size	60 x 60 x 70 cm (deployed)
Design Life	6 years



Evolution : CERES to Athena

1993
CERES

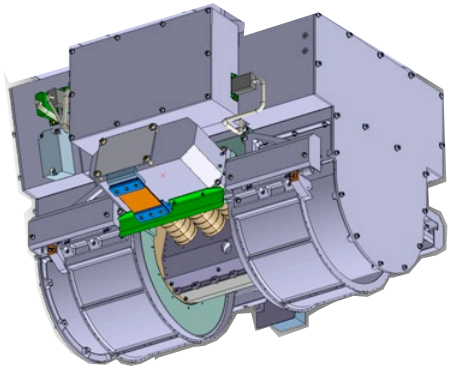


2003
ERBS

Preserve

- Elevation Gimbal
- Processors
- Optical Module
- Calibration Module

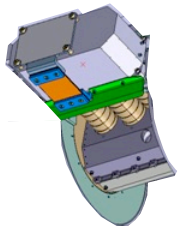
(Concept only)



2019
Athena

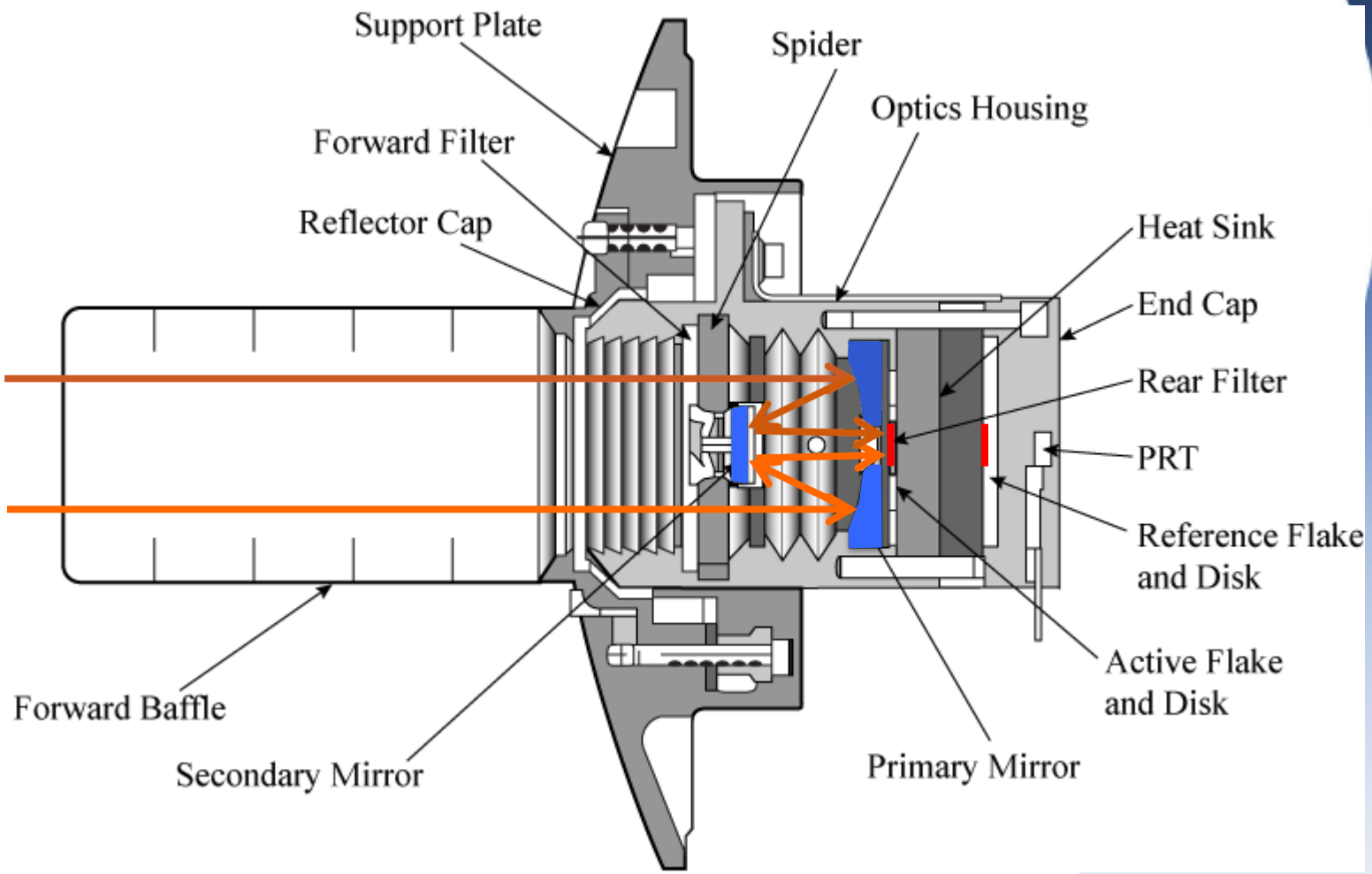
Preserve

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



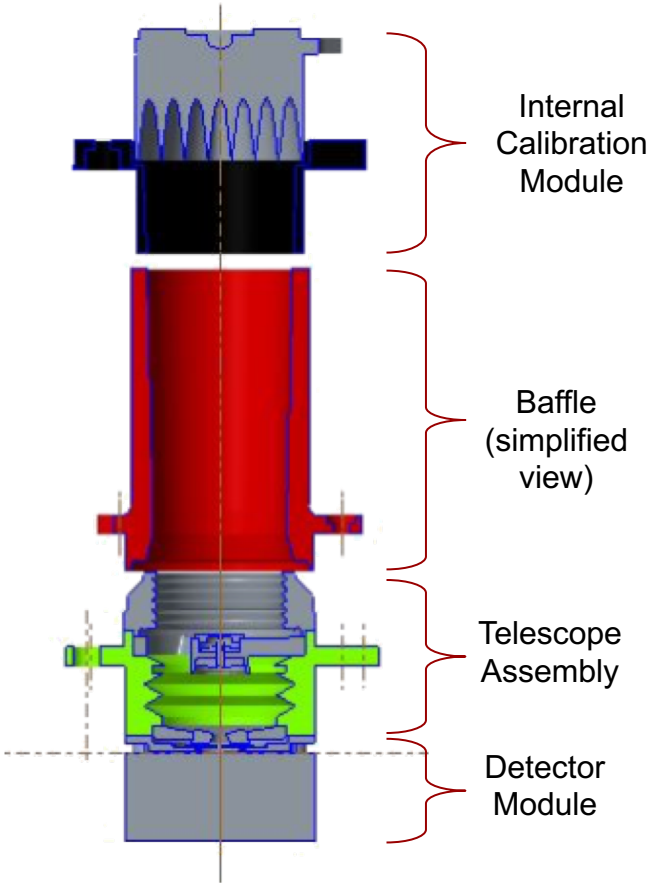
Size (cm):	60x60x70	60x60x35	~15x15x15
Mass(Kg):	50	30	<5

Athena/CERES Sensor Assembly

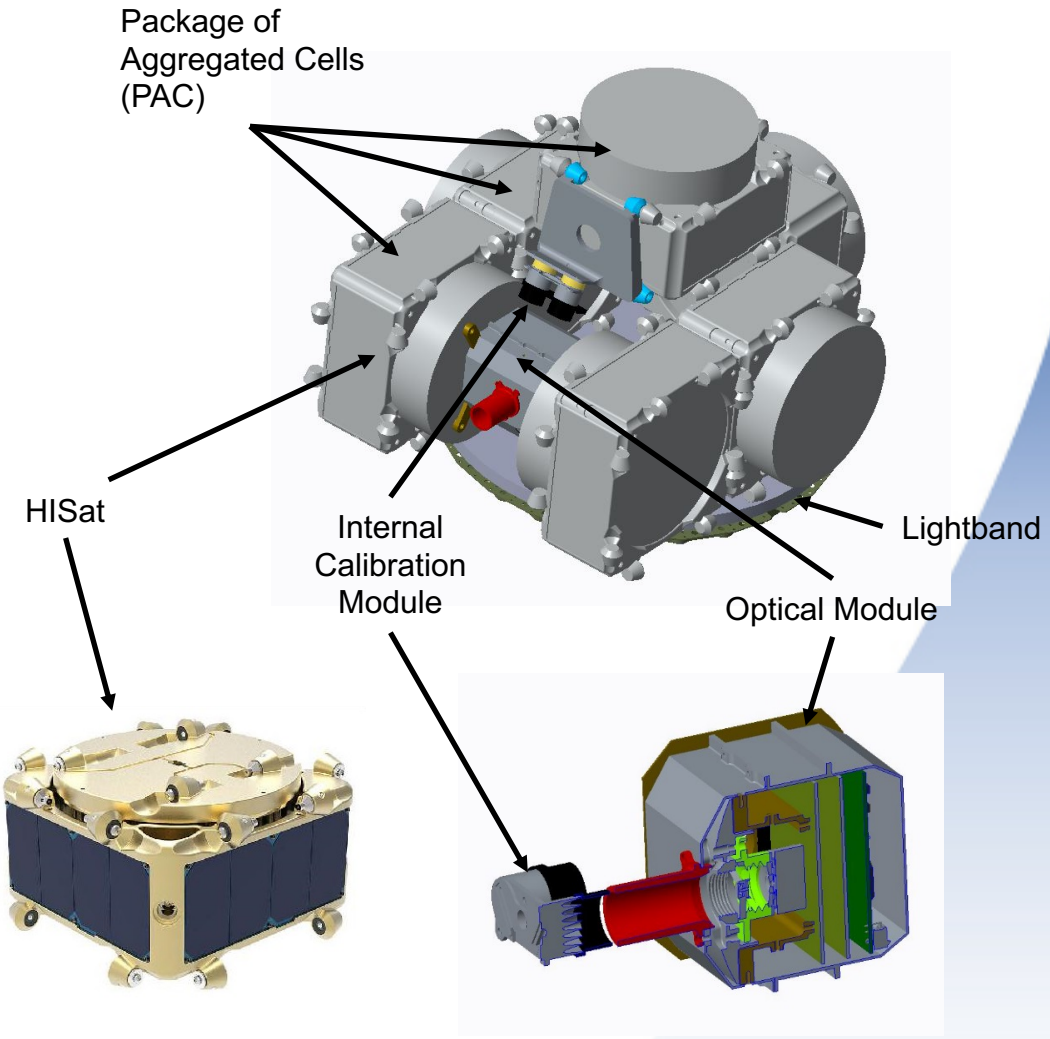


Athena Hardware

Key Sensor Components



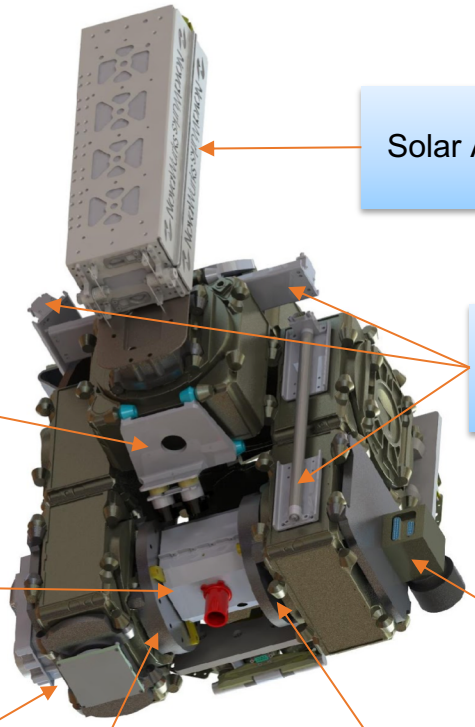
Athena Conceptual Payload HISat Configuration



Athena Sensorcraft Description

Spacecraft

Payload



Solar Array

Internal Calibration Module

Torque Rods & Securements

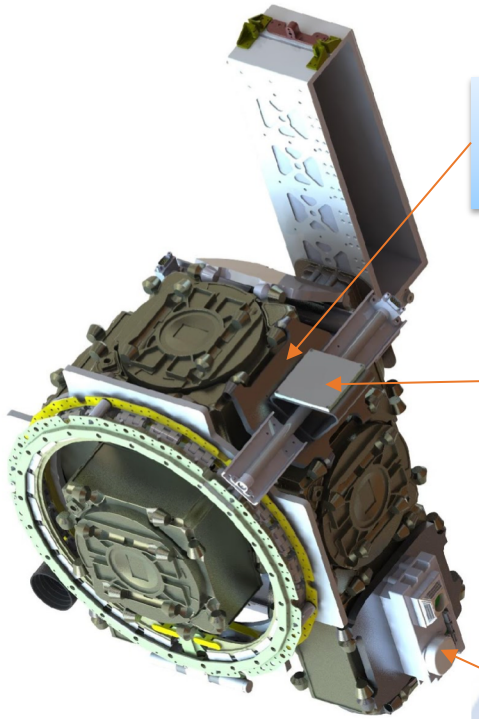
Optical Module

Star Tracker

Antenna

HISat Carousel (Active)

HISat Carousel (Passive)

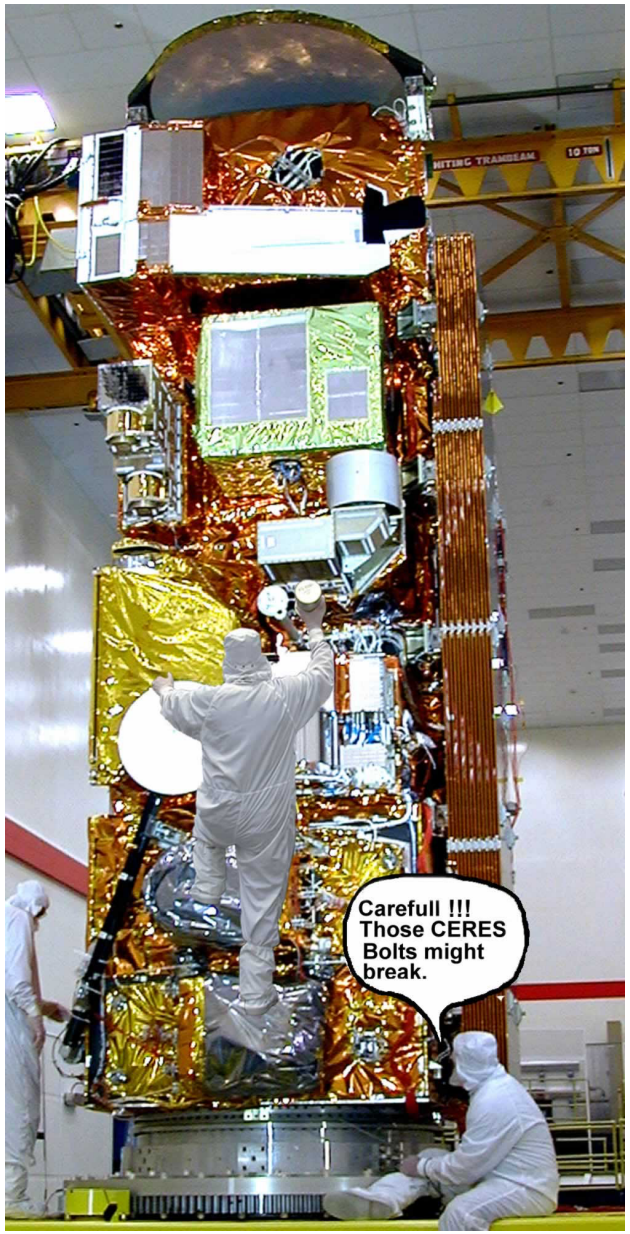


Comm Module

Antenna

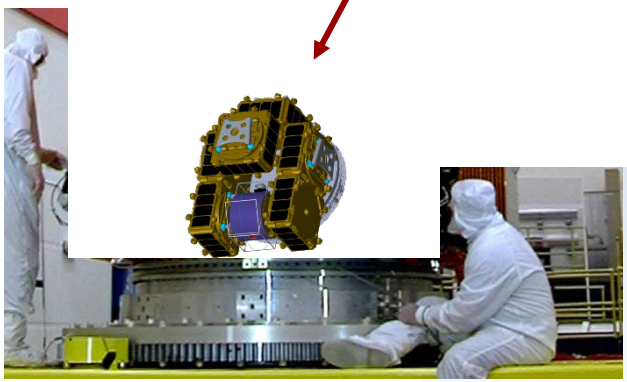
GPS SunSensor

Evolution : Aqua to Athena

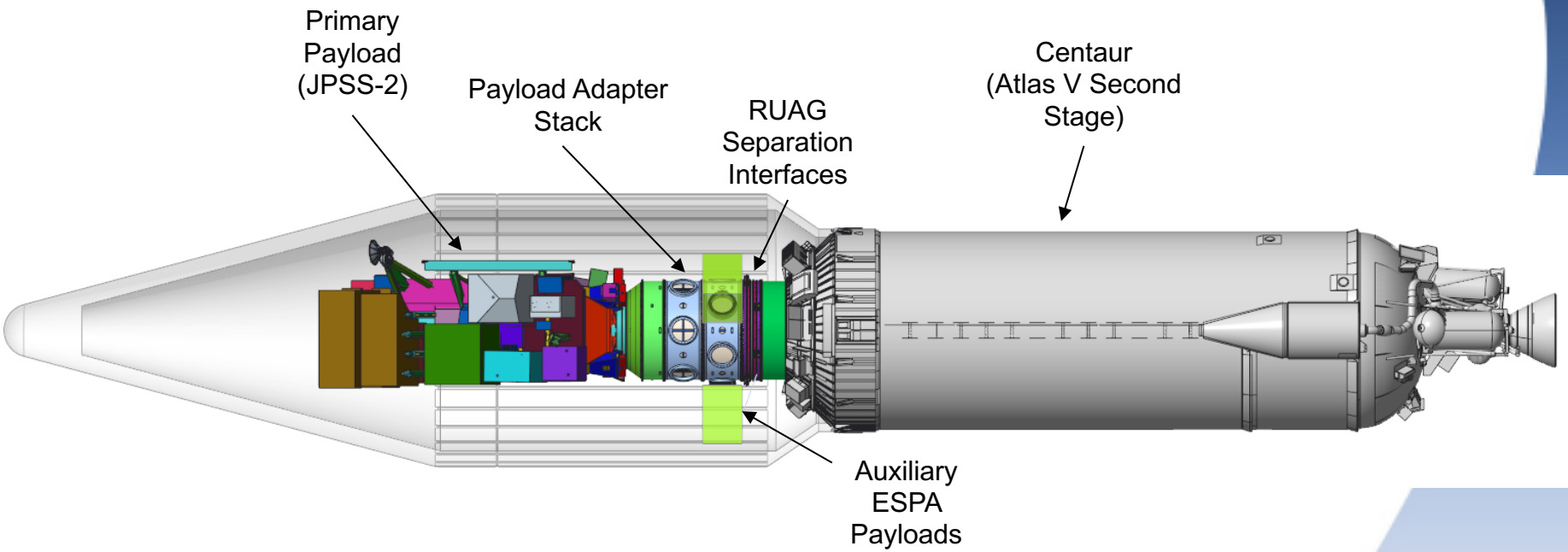


Aqua (2001)

Athena (2019)

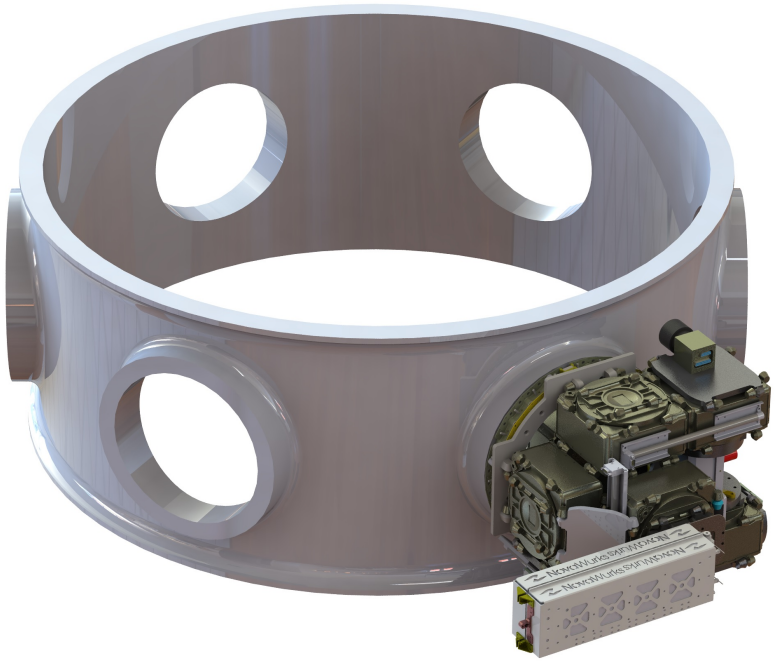


JPSS-2 Launch Vehicle Payload Configuration

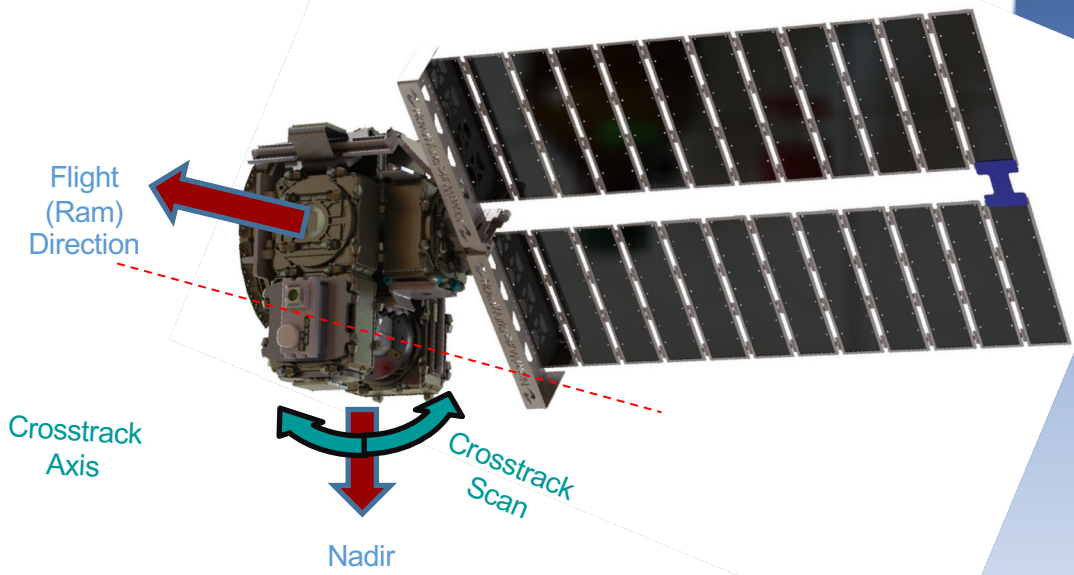


Athena Sensorcraft
Launch and Flight Configurations

Launch



Flight



Con-Ops Demonstration Examples

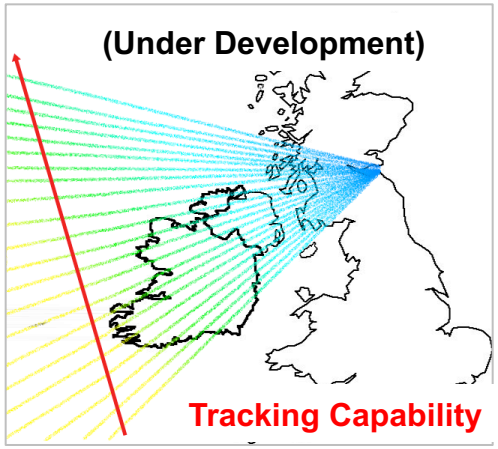
Operational

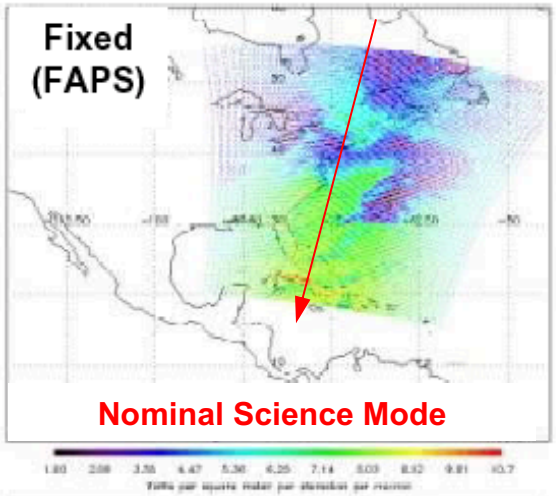
- Validate Novawurks HISats for Multi-mission platforms (Sensorcraft, Payloads, In Space Assembly)
- Maneuverability to support temporally and spatially matched observations from other on-orbit assets
- Fine pointing control w/ w/out torque disturbance input
- Mechanical/Electrical Lifetime for carousel
- Autonomous geo-targeting capability
- Celestial body targeting capability

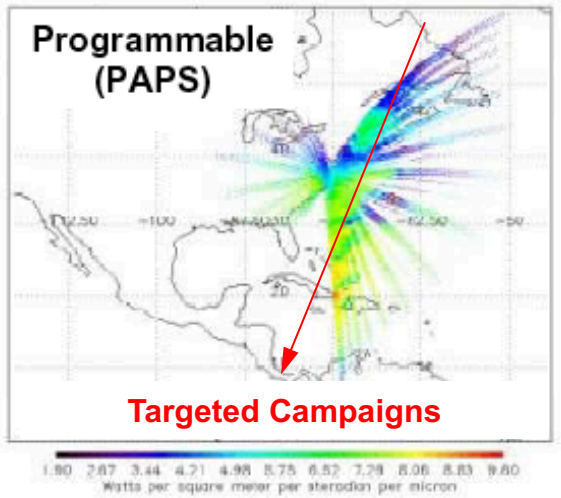
Programmatic

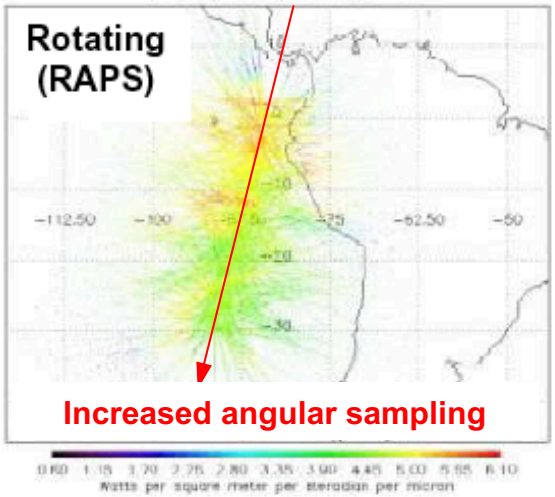
- Pathfind future synergistic collaborations where each organization brings their centers of expertise
- Leverage resources between the agencies to achieve common goals
- Sustain critical observations upon failure, or unique missions/orbits that require coverage on-demand (disaster mitigation, war fighter in the field)
- LaRC rapid development transformation - Small Payload Integration Network (SPIN)
- NASA desires USAF and NOAA as synergistic partners to define con-ops demonstration activities

CERES Operational Scanning Capabilities



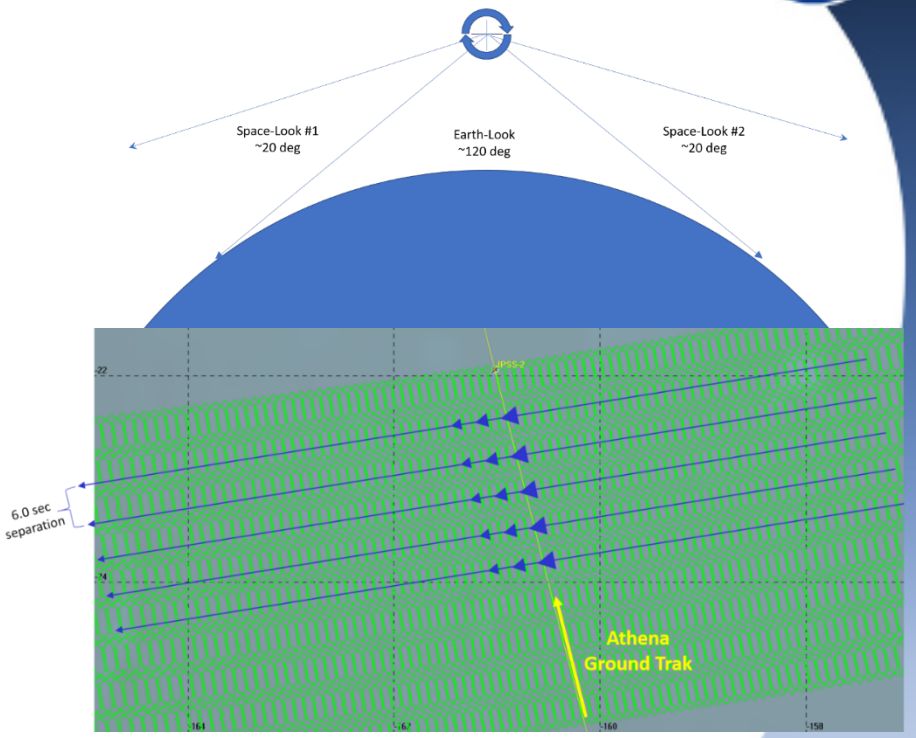


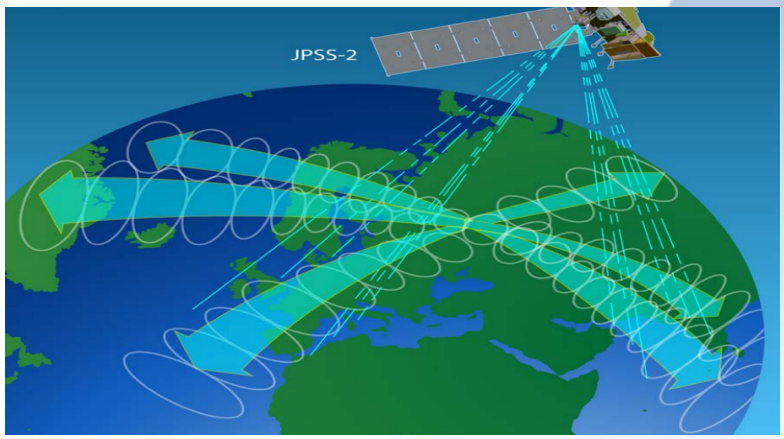




Athena Scanning Operations

- **Three candidate scanning operations:**
  - Cross/Along-Track
  - Bi-axial
  - Calibration (“staring”)
- **These scanning operations are typical of orbital science observation**
- **They require coordinated control and maneuvering of the spacecraft and the payload**
- **Allow us to explore and evaluate dynamic response to various payload operations and potential system stability, pointing accuracy, etc. needed for on-orbit remote sensing systems**



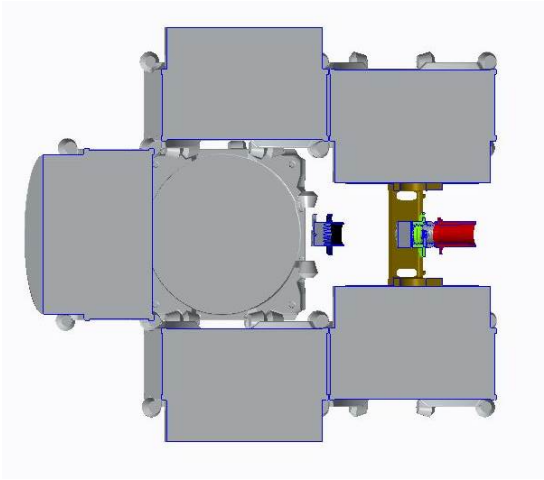


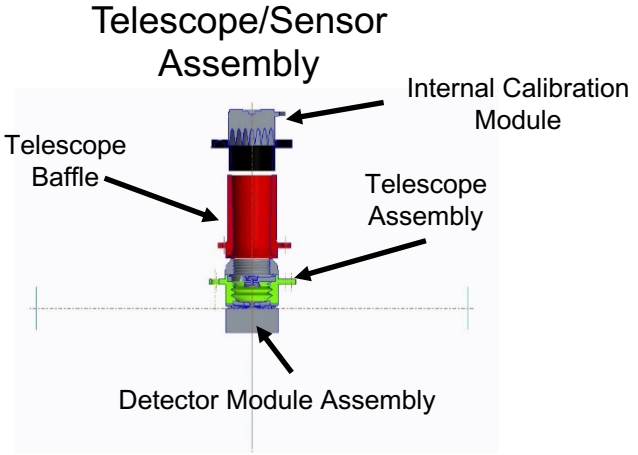
Reference images

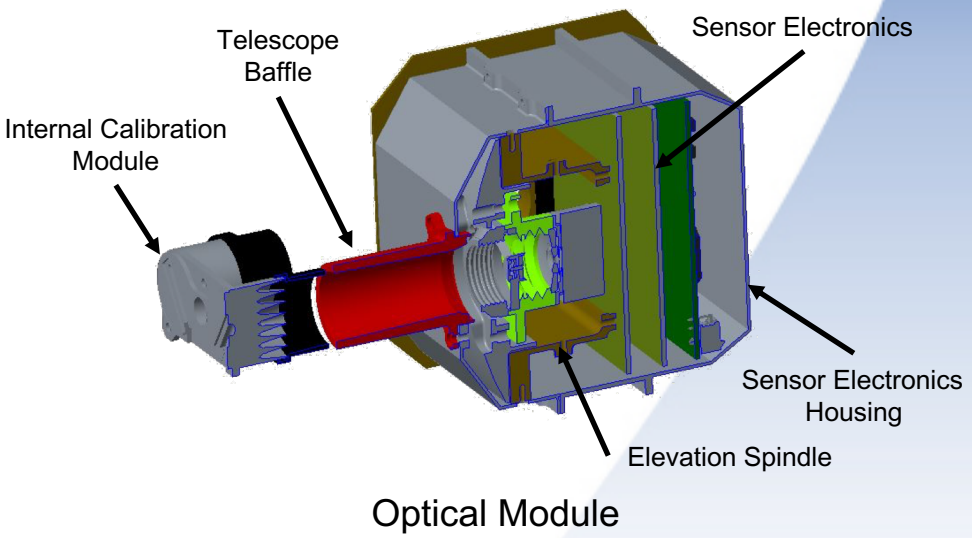
BACKUP

Athena Payload

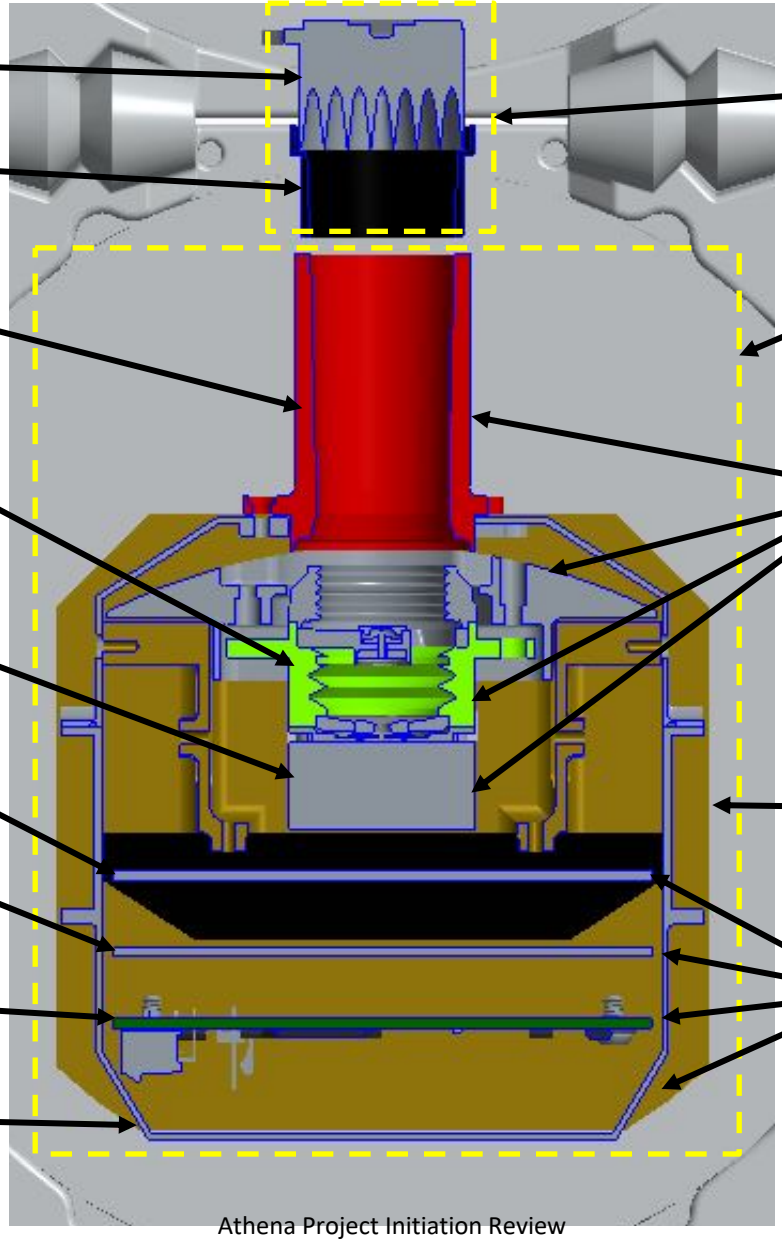
- **Payload developed by Langley integrated into NovaWurks spacecraft**
  - Aggregate payload distributed across multiple spacecraft UDAs
- **Sensing and acquisition performed in the payload Optical Module (OM) and Internal Calibration Module (ICM)**
- **Control of the payload provided and performed by the Spacecraft**
  - Spacecraft parses digital data from Optical Module to compute Bridge Balance Offset (algorithm provided by Langley)
  - Spacecraft monitors ICM temperature and controls ICM heater set-point(s)



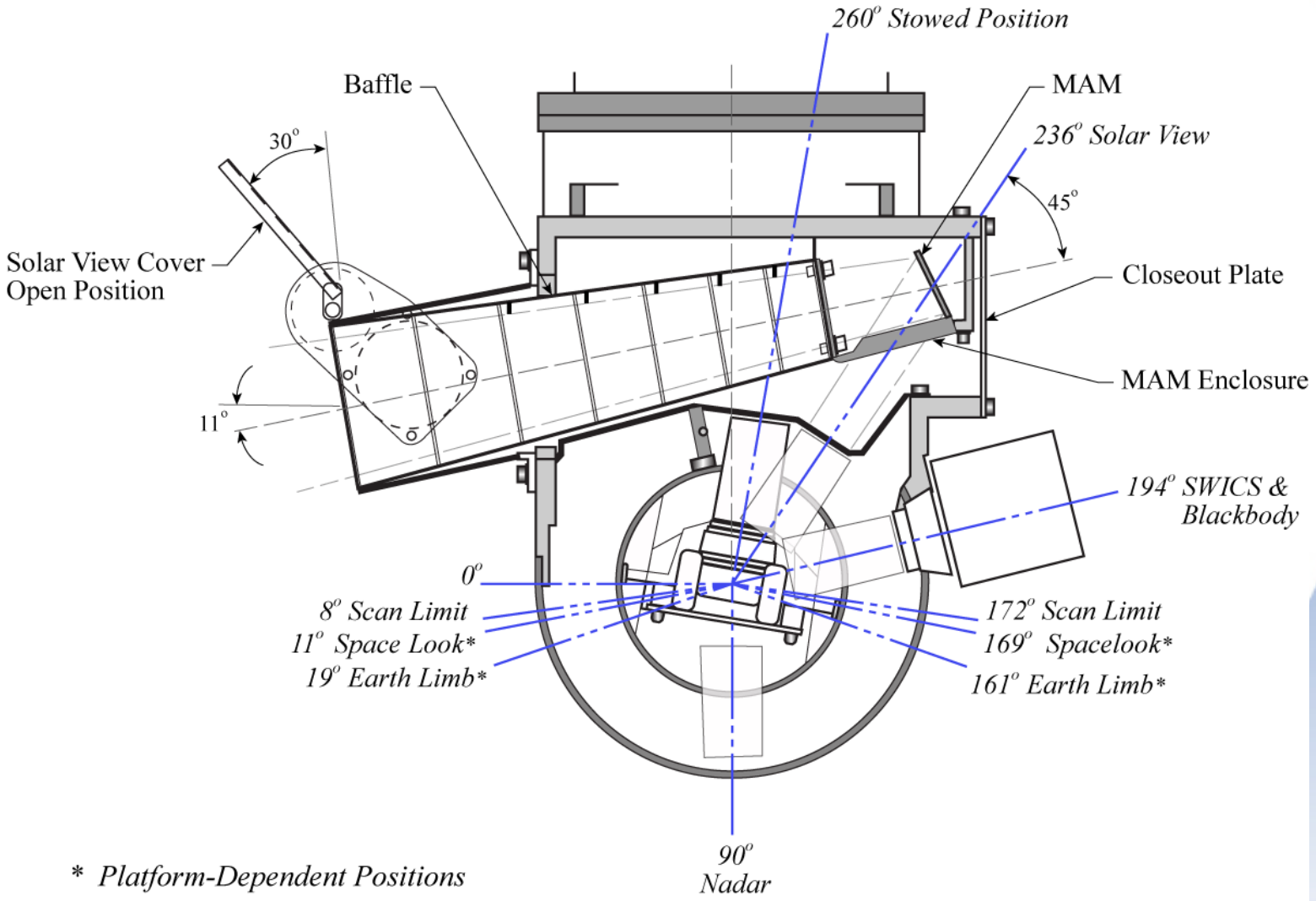




Athena Payload



CERES Scan Geometry



In 6.6 Seconds, CERES completes a single elevation scan, which comprises a single packet of data.

Athena Payload Requirements

- **Primary sources: goals and objectives, concept of operations, interfaces, launch vehicle, and "Do No Harm" requirements**
- **In early phases of requirement definition process**
  - This is a technology demonstration not a science mission, the requirements will reflect the project goals and objectives
- **Current Payload Design**
  - Mass: CBE ~3 kg
    - Allocated 20 kg total (8 kg rotating)
  - Power: CBE <5 W
  - Data Rate: <10 kbps (downlink: <2 kbps)
    - Conservative estimate based on CERES performance
  - Pointing Goals (based on CERES)
    - Pointing Stability: <360 arcsec/sec
    - Pointing Accuracy: <1440 arcsec
    - Pointing Knowledge: <720 arcsec