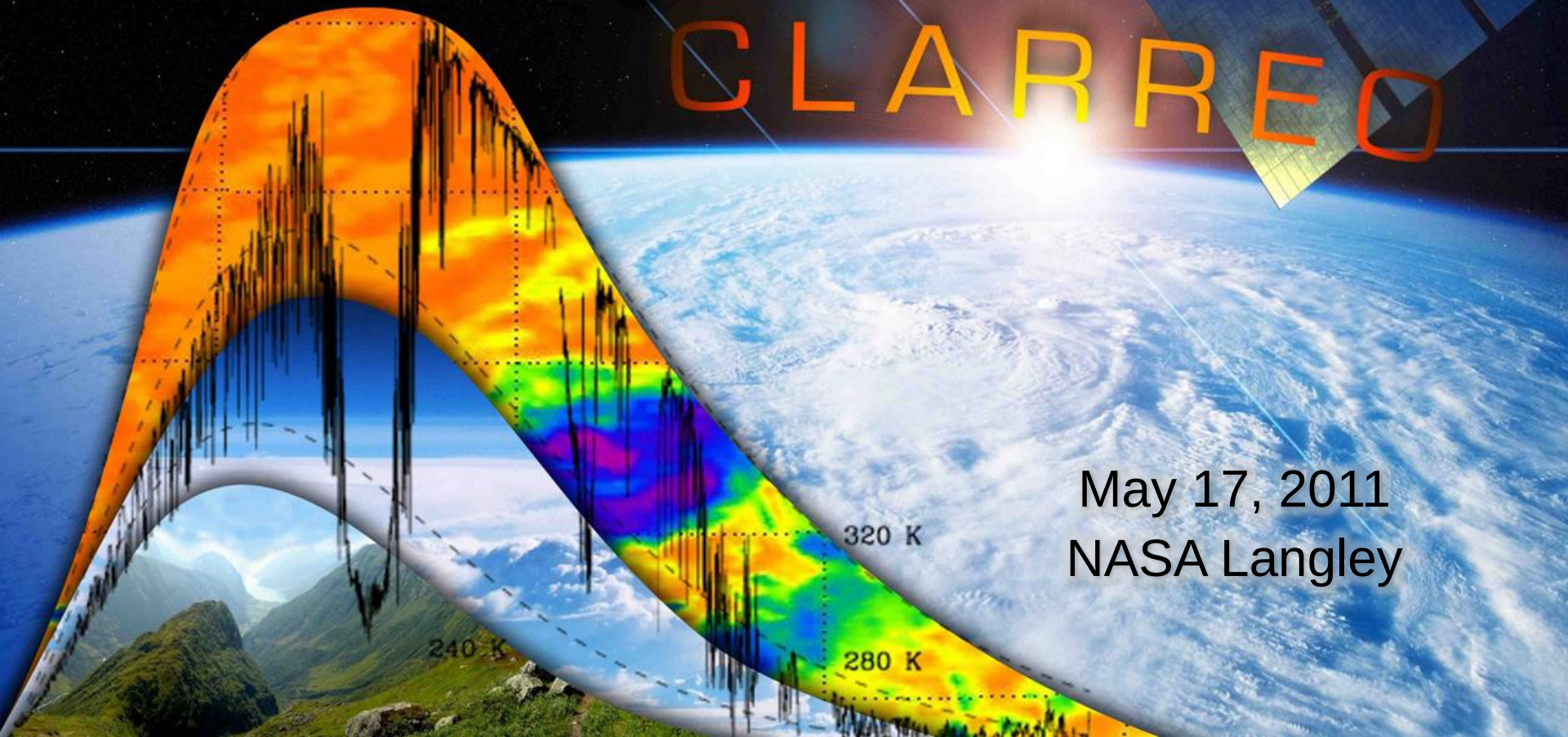
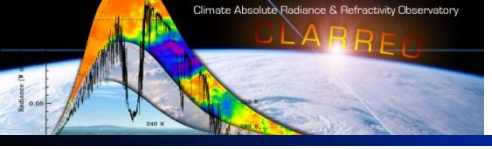
CLARREO MCR MISSION ARCHITECTURE

Climate Absolute Radiance & Refractivity Observatory MCR

Jim Corliss– CLARREO Chief Engineer



May 17, 2011
NASA Langley



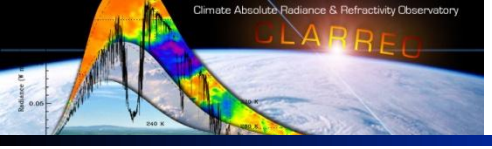
Mission Design Overview

Mission Design Objective

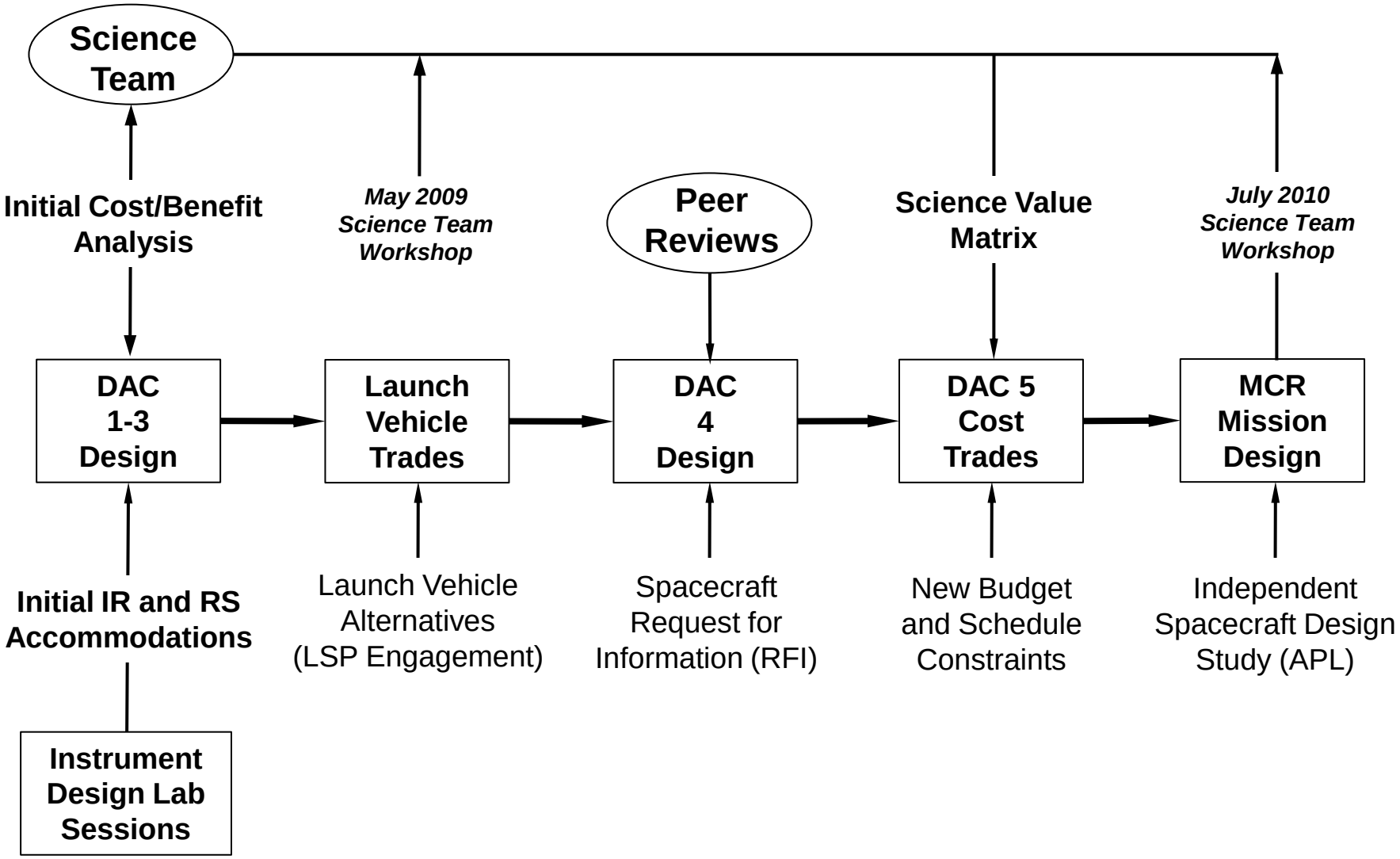
- Conduct trade studies leading to the selection of a feasible CLARREO mission design that cost-effectively meets the science objectives
  - Adhere to the Decadal Survey science objectives, but re-evaluate the:
    - Quantity of each instrument type (IR, RS, GNSS-RO)
    - Number of orbits
    - Number of observatories
    - Access to space (launch vehicle) strategy

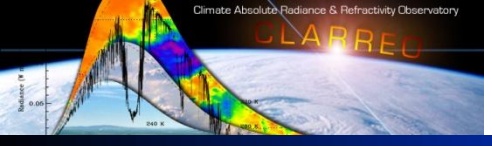
Approach

- Thoroughly examine the mission design trade space in a systematic manner
  - Iteratively mature the mission concept through five consecutive Design and Analysis Cycles (DAC's)
  - Maintain close coordination with the science team and conduct cost-benefit analyses of alternative mission designs to evaluate the relative science values and costs of the different mission concepts
  - Analyze launch vehicle options to determine the most robust and cost-effective access-to-space strategy



Mission Design Progression





DAC 1-3 Mission Designs (Jan-Aug 2009)

Science Team

Initial Cost/Benefit Analysis

May 2009 Science Team Workshop

Peer Reviews

Science Value Matrix

July 2010 Science Team Workshop

DAC 1-3 Design → **Launch Vehicle Trades** → **DAC 4 Design** → **DAC 5 Cost Trades** → **MCR Mission Design**

Initial IR and RS Accommodations

Instrument Design Lab Sessions

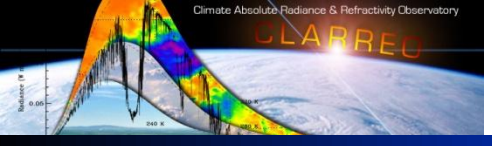
Launch Vehicle Alternatives (LSP Engagement)

Spacecraft Request for Information (RFI)

New Budget and Schedule Constraints

Independent Spacecraft Design Study (APL)

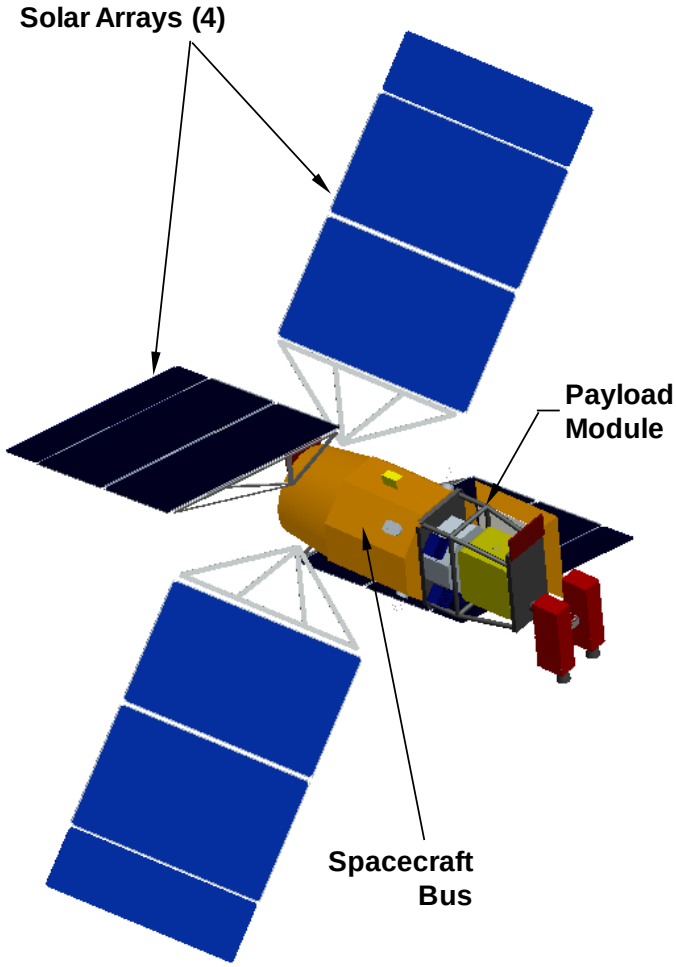
Jan 2009 — **Nov 2010**



DAC-1 Mission Design

DAC-1 DESIGN FEATURES

- Two identical observatories, two orthogonal polar orbit planes
- Dual manifested launch on an EELV using new Dual Satellite System (DSS)
- Infrared and reflected solar spectrometer suites mounted together on ram face as a “payload module”
- 2-box reflected solar instrument suite mounted on a 2-axis gimbal
- **Observatory Budgets (CBE):**
  - **Mass: 764 kg**
  - **OA Power: 636 W**
- Observatories drift to their final science orbits one year after launch, but acquire data while drifting

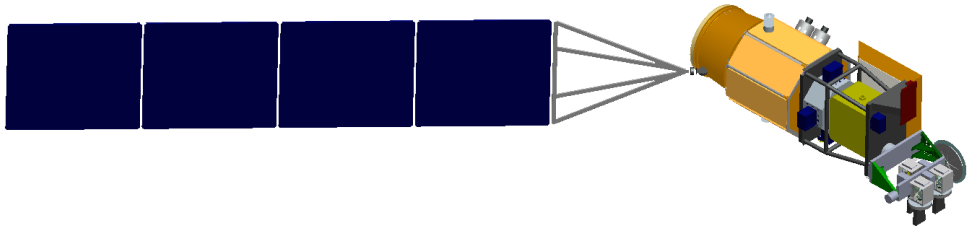


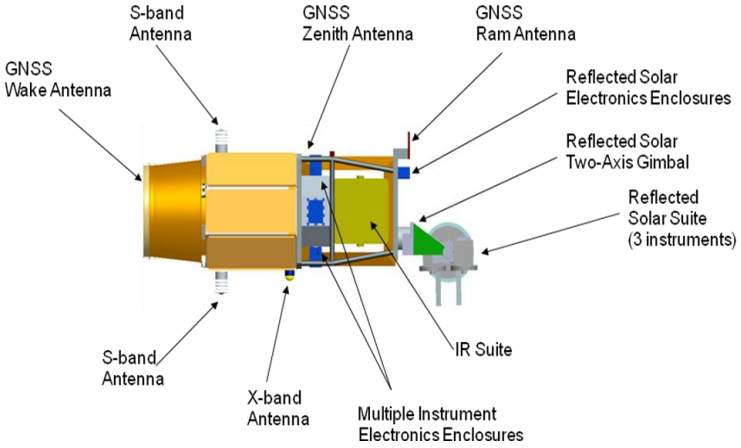
Atlas V Launch Vehicle

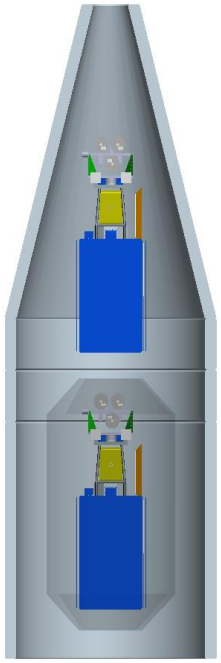
DAC-2 / 3 Mission Design

DAC-2 / 3 DESIGN FEATURES

- Two identical observatories dual manifested on an EELV using DSS
- Solar array reconfigured to eliminate conflicts with instrument fields-of-view
- Infrared and reflected solar spectrometer suites mounted together on ram face as a “payload module”
- 3-box reflected solar instrument suite mounted on a 2-axis gimbal
- **Observatory Budgets (CBE):**
  - **Mass: 831 kg**
  - **OA Power: 750 W**
- Observatories drift to their final science orbits one year after launch, but acquire data while drifting

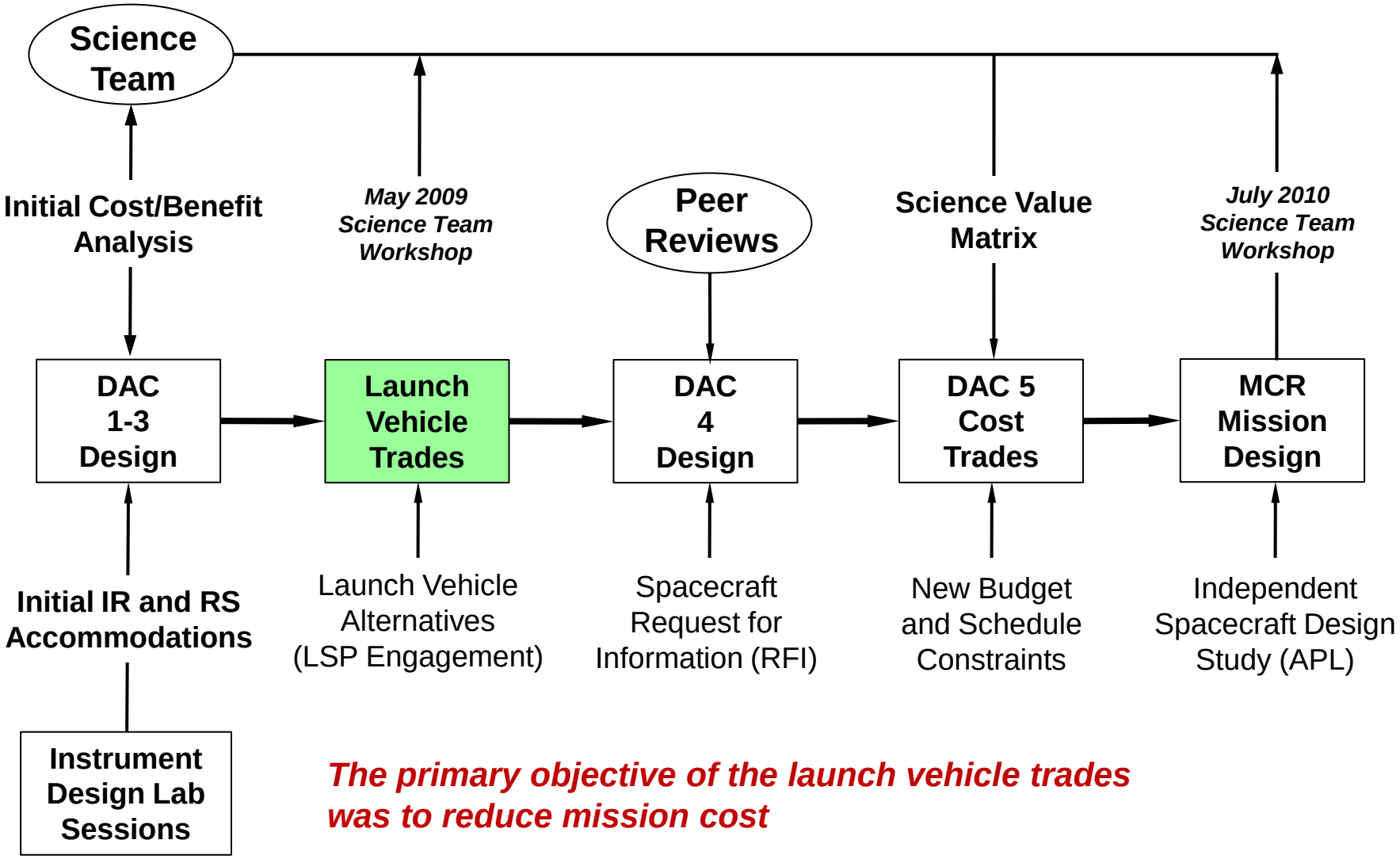




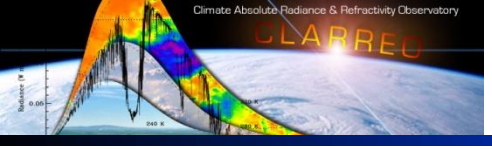


DSS Configuration in EELV

Launch Vehicle Trades (Fall 2009)



The primary objective of the launch vehicle trades was to reduce mission cost



Launch Vehicle Trade Study

Objective

Evaluate access-to-space options for implementing the baseline mission design (IRS+IRS) and down-select a launch vehicle strategy

Options Considered

- Individual launches
  - Falcon 1 and 1e
  - Pegasus XL
  - Taurus XL
  - Minotaur I and IV+
  - Taurus 2
  - Falcon 9
- Single launch with dual manifest on an EELV (Atlas V or Delta 4) using the Dual Satellite System (DSS) currently under development

Launch Vehicle Trade Study

Launch Vehicle Compatibility

Launch Vehicle	Upmass Capability (kg)	Static Envelope (cm)	Observatory Wet Mass* 1,224 kg	Observatory Min. Dia. 196 cm
Falcon 1	185_{NLS}	137.2		
Pegasus XL	250_{NLS}	115.3		
Minotaur 1	365_{VEN}	119.4		
Falcon 1e	620_{VEN}	154.9		
Taurus XL 3210	770_{NLS}	197.9		
Minotaur IV+	$1{,}274_{VEN}$	197.9		
Delta II 2320-10	$1{,}640_{NLS}$	254.0	**Being Phased Out**	
Taurus II	$2{,}575_{VEN}$	345.4		
Atlas V 401	$7{,}000_{NLS}$	370.8	***Dual Manifest with DSS***	
Delta IV 4040-12	$7{,}125_{NLS}$	374.9		
Falcon 9	$7{,}782_{NLS}$	440.0		

NLS: Certified Mass Capability from NLS Website

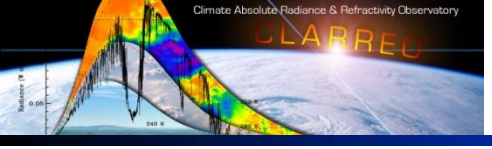
VEN: Mass Capability from Vendor (not certified by NLS)

**Wet Mass Includes Contingency and Margin*

Pre-Phase A Trade Space

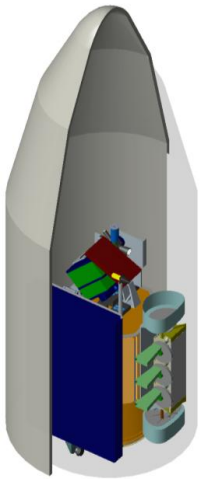
Feasible with Current Design

Not Compatible

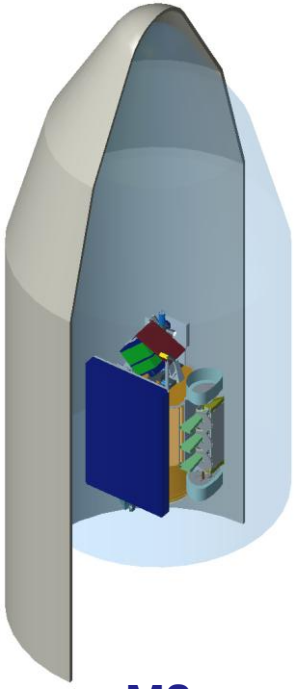


Launch Vehicle Costs

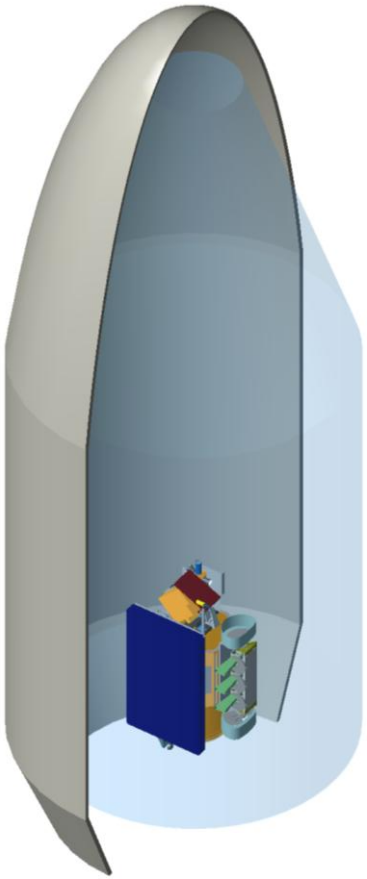
The CLARREO "IRS" observatory mass and volume make it compatible with mid-size launch vehicles and EELV's (present and future).



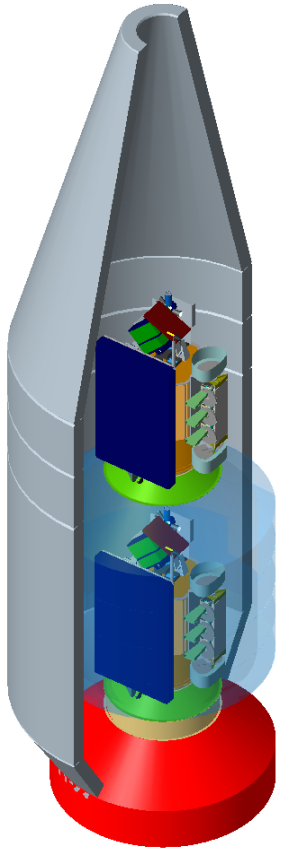
M1
Minotaur IV+



M2
Taurus 2

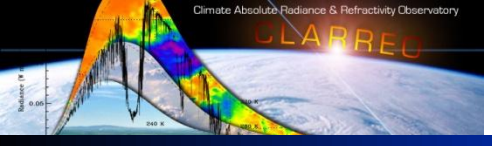


M3
Falcon 9



M4
EELV w/DSS

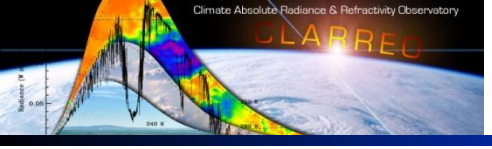
Minotaur IV+ offered the lowest cost CLARREO mission and was selected for DAC-4 design



Minotaur IV Implementation

NASA HQ Guidance

- The Commercial Space Act of 1998 imposes limitations on NASA procuring non-commercial launch services
- In July 2010 the NASA Administrator agreed that the Decadal Survey Tier 1 missions (SMAP, CLARREO, and DESDynI) could baseline the Minotaur IV launch vehicle
- The Space Operations Mission Directorate (SOMD) initiated the process of acquiring a Minotaur IV+ for SMAP



DAC-4 Mission Design (Feb. 2010)

Science Team

Initial Cost/Benefit Analysis

May 2009 Science Team Workshop

Peer Reviews

Science Value Matrix

July 2010 Science Team Workshop

DAC 1-3 Design → **Launch Vehicle Trades** → **DAC 4 Design** → **DAC 5 Cost Trades** → **MCR Mission Design**

Initial IR and RS Accommodations

Instrument Design Lab Sessions

Launch Vehicle Alternatives (LSP Engagement)

Spacecraft Request for Information (RFI)

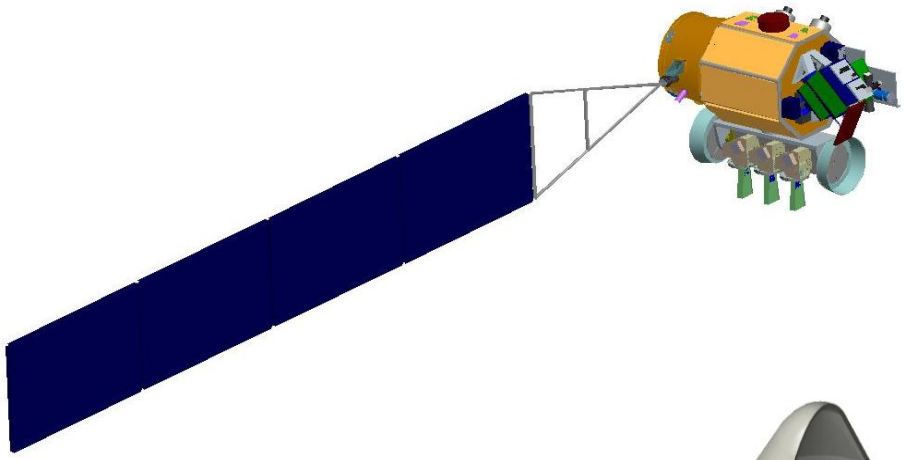
New Budget and Schedule Constraints

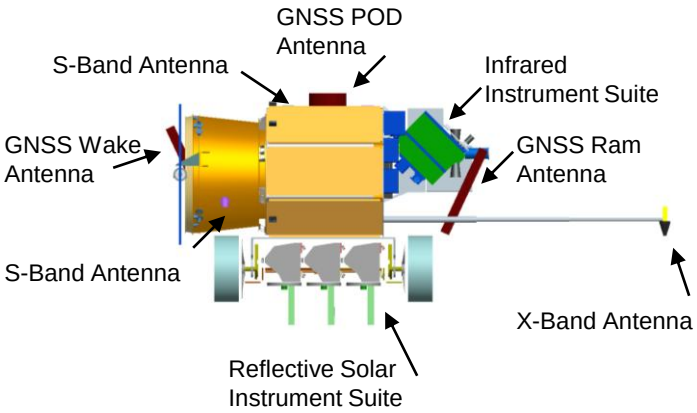
Independent Spacecraft Design Study (APL)

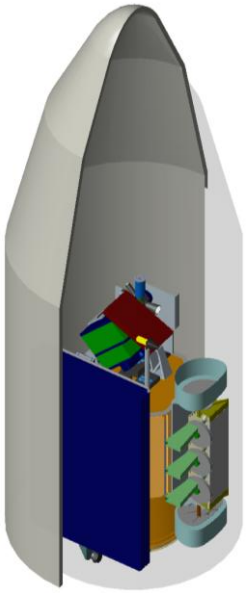
DAC-4 Mission Design

DAC-4 DESIGN FEATURES

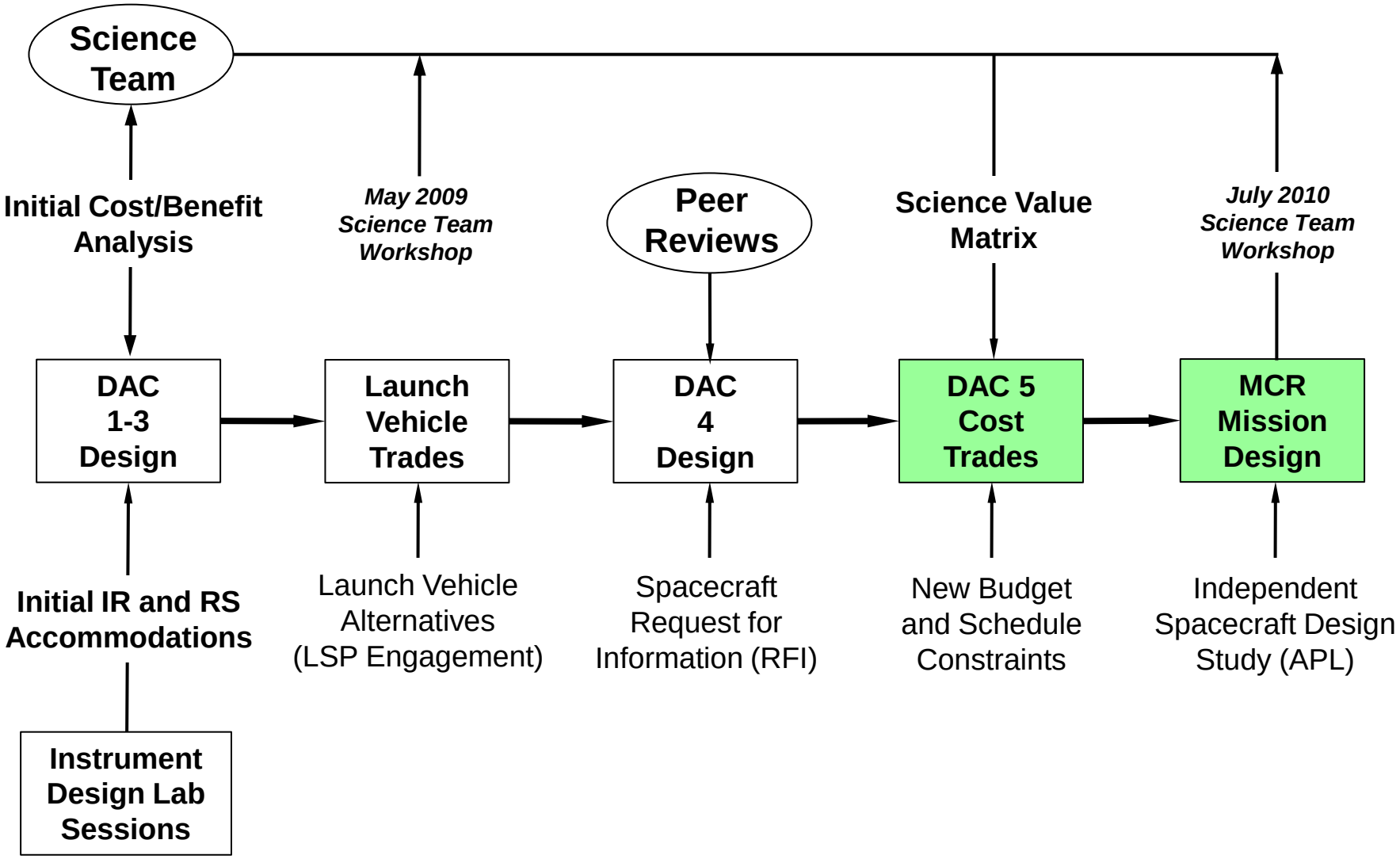
- Two identical observatories launched individually into orthogonal polar orbits on Minotaur IV+ launch vehicles
- Reflected solar instrument relocated to nadir deck for improved reference intercalibration operations
- Dual radiator configuration added to reflected solar instrument
- **Observatory Budgets (CBE):**
  - **Mass: 814 kg**
  - **OA Power: 691 W**
- Spacecraft Request for Information (RFI) released to industry to verify spacecraft concept and ROM costs
- Extensive peer reviews conducted







DAC-5 Cost Trades (Feb-Aug 2010)

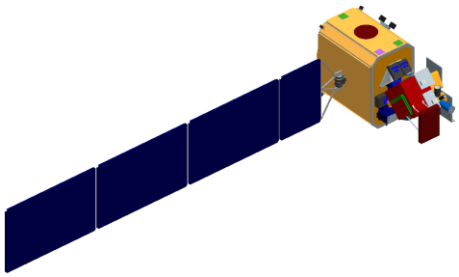


DAC-5 / MCR Mission Designs

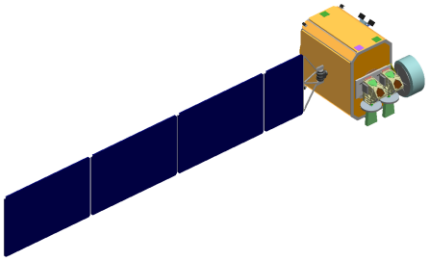
DAC-5 DESIGN FEATURES

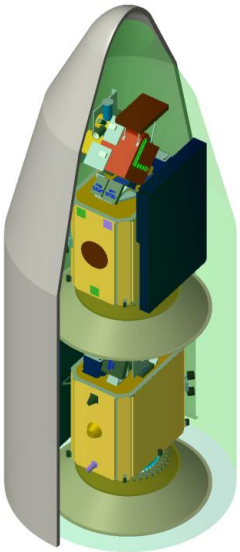
- Four observatories launched two at a time on a Minotaur IV+
  - Two infrared observatories
  - Two reflected solar observatories
- Two concepts developed:
  - DAC-5: IR & RS in 2018, IR & RS in 2020 *(Two polar orbit planes)*
  - MCR: IR & IR in 2018, RS & RS in 2020 *(One polar orbit plane)*
- Both concepts are within the cost cap, but the DAC-5 concept does not meet the cost profile due to the earlier RS instrument development required
- **Observatory Budgets (CBE):**
  - **Mass: 381 to 389 kg**
  - **OA Power: 400 to 437 W**

Infrared (IR) Observatory

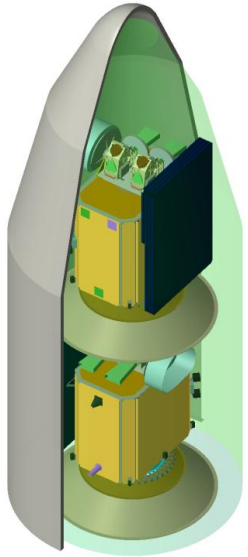


Reflected Solar (RS) Observatory





2018 Dual IR Launch

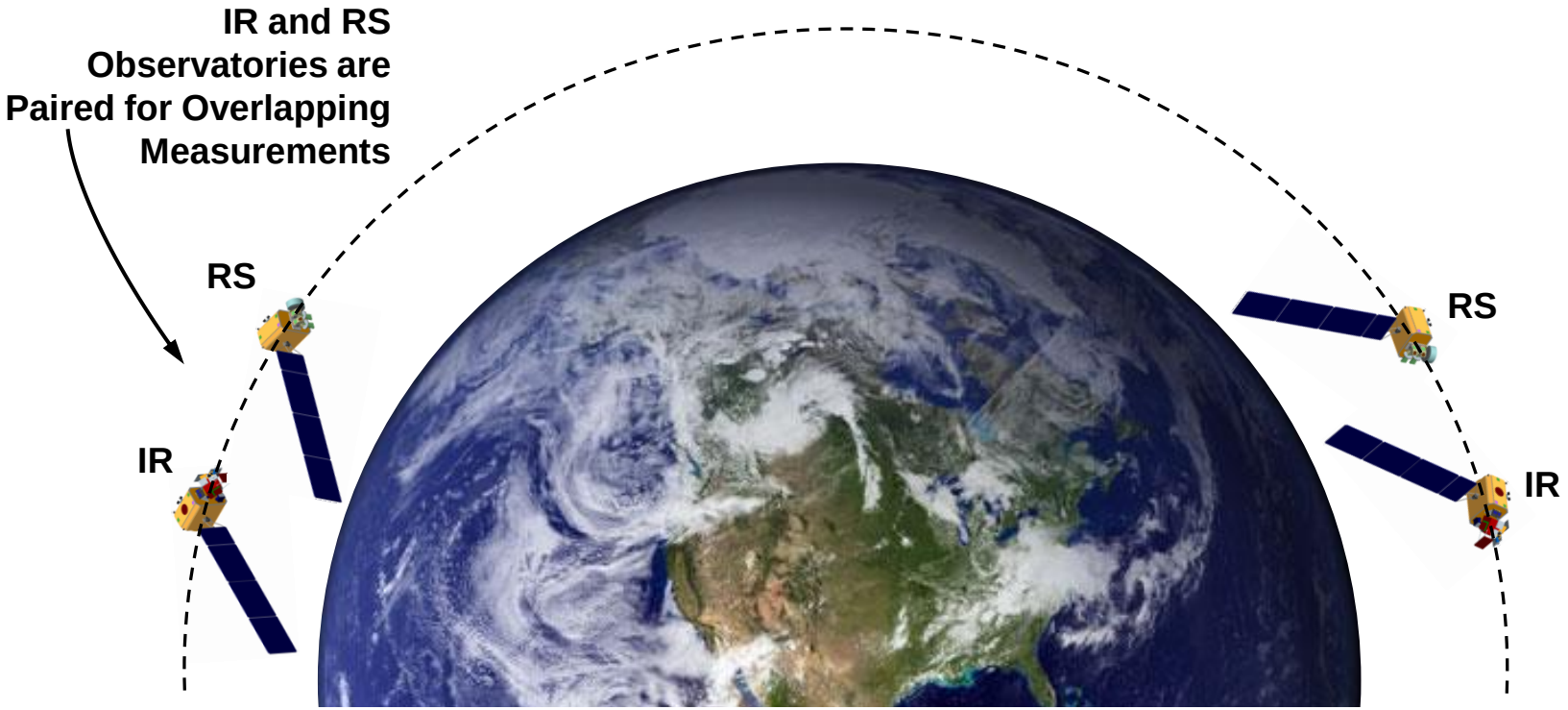


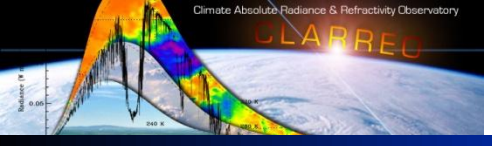
2020 Dual RS Launch

Orbit Selection

Orbit Parameters:

- Mean Altitude = 609 km (61-day ground track repeat cycle)
- Period = 5812.4 ± 0.25 secs (orbit maintenance requirement)
- Inclination = 90°
- RAAN = 0° or 180° (for reference inter-calibration)





Mission Design Next Steps

- **CLARREO's mission concept maximizes science value within the programmatic constraints and provides mission flexibility**
  - Small observatories provide the flexibility to be launched individually on smaller launch vehicles if the Minotaur IV+ is not available
  - Small observatories provide a path for sustaining the climate measurements

- **Future work would have included:**
  1. Revisit mission performance and costs based on launch vehicles from the recently awarded NLS-II contract and Air Force Minotaur IV+ discussions
  2. Optimize orbit selection based on Phase A science studies
  3. Pursue options to launch IR and RS together in 2018 within the budget profile