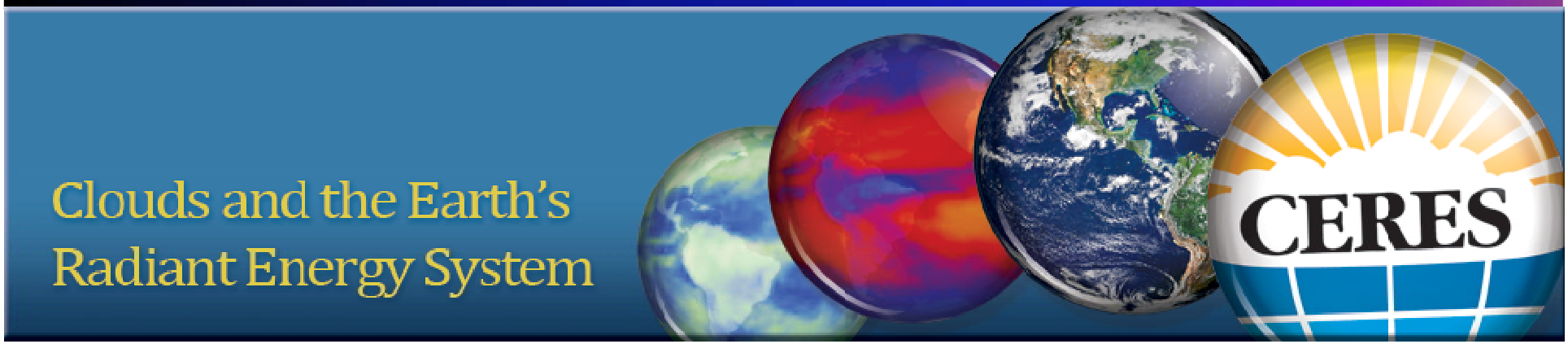
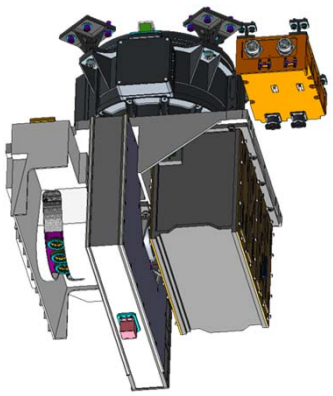


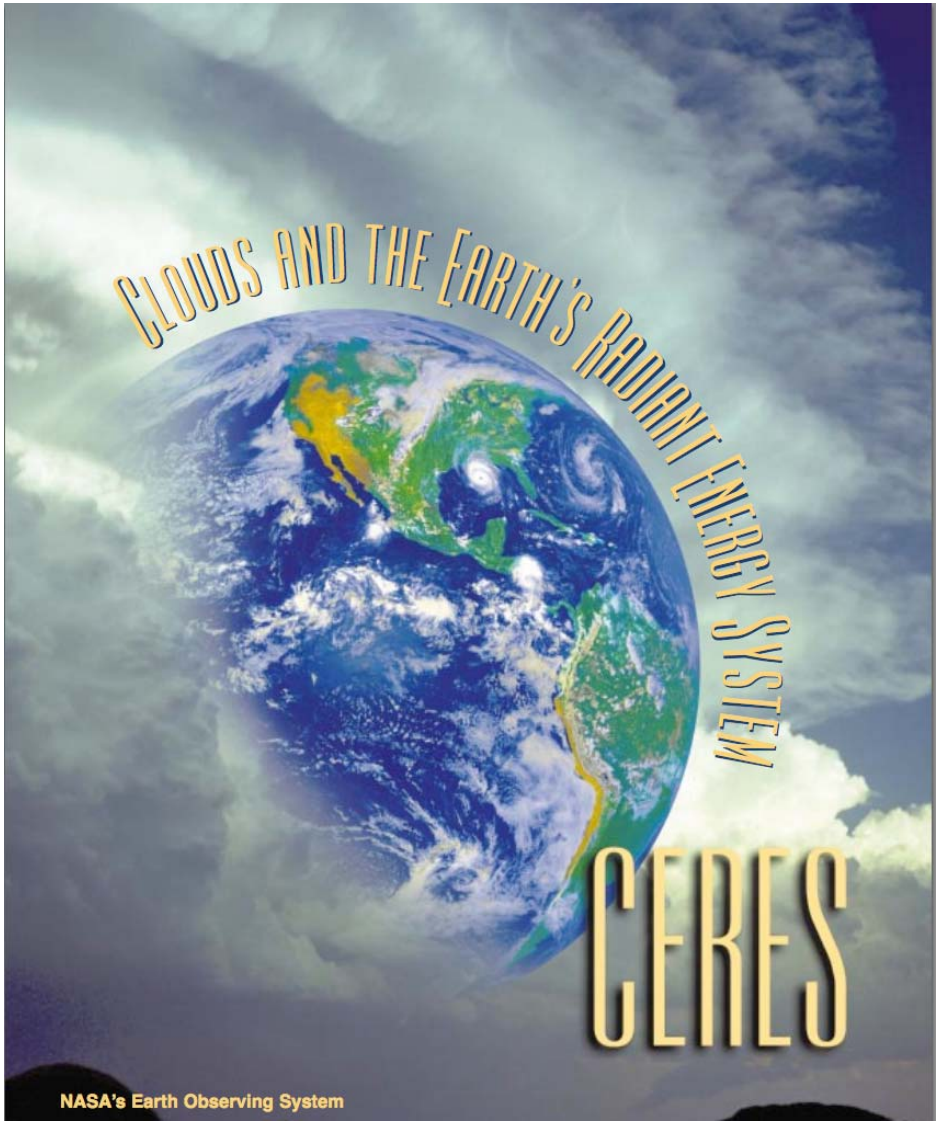
CERES Flight Model 6 & Radiation Budget Instrument (RBI) Status



Kory Priestley

CERES Science Team Meeting
Langley Research Center
Hampton, VA
May 5th, 2015

Discussion Topics

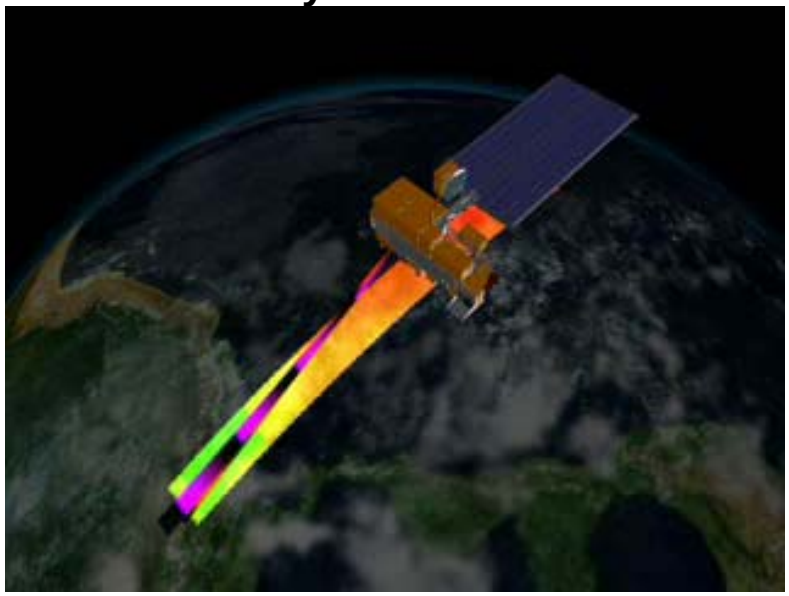


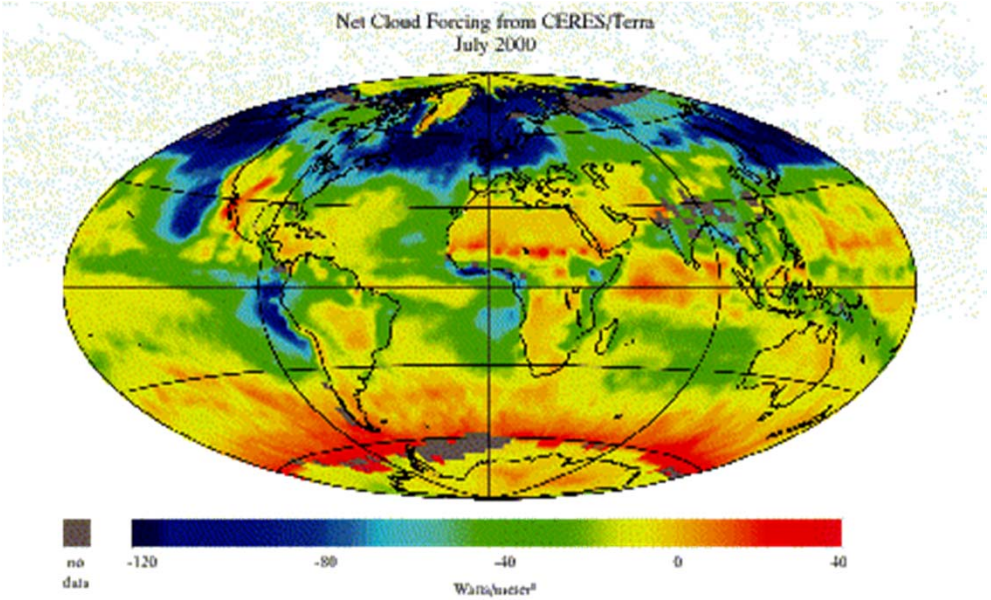
- **CERES Overview**
  - Measurement objectives
  - Instrument description
  - Flight history/future
- **Instrument Status**
  - FM-6 on JPSS-1
  - RBI on JPSS-2
- **Summary**

Measurement Objectives

Clouds and the Earth's Radiant Energy System

- **Mission Goal** – **Produce long-term climate data records or *maps* of radiation budget at the top-of-atmosphere (TOA), within the atmosphere and at the surface with consistent cloud and aerosol properties at climate accuracy.**
- **CERES – Clouds and the Earth's Radiant Energy System**
  As a NASA EOS sensor, it is a broadband radiometer outfitted with three spectral observation channels for monitoring Earth's radiant energy system for decadal climate study

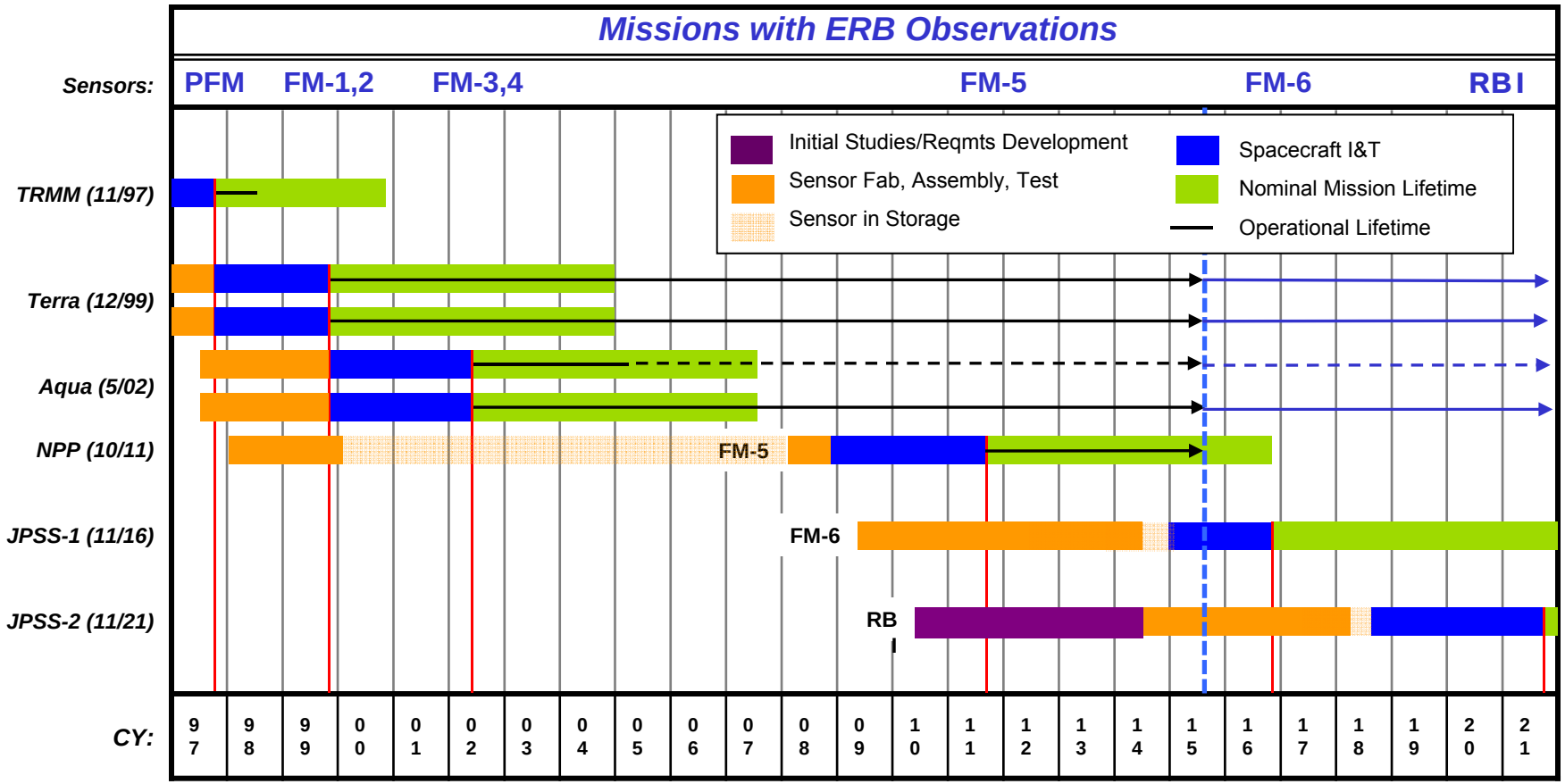




Climate Data Record Continuity

Clouds and the Earth's Radiant Energy System

CERES/RBI Flight Schedule



We now have over 61 years of flight experience with the CERES instruments

CERES FM-6

CERES FM-6 Activities

ICM Resolution (Complete)

- Isolate Performance Problems
  - ICM Vacuum Test determined the Lamp and PD performance issues are confined to the ICM
  - ICM Diagnostic Test to further isolate performance issues
- Select replacement flight Lamp and PD from CERES parts

MAM Resolution (Complete)

- Isolate Performance Problem
  - Diamond-Turned Tooling marks have been identified as the source of MAM performance issue
- Select replacement flight MAM from CERES heritage MAMs
  - Pre-condition MAM using AO asher from GRC

- Verify ICM performance in vacuum **(Complete)**
- Verify Instrument Performance (January-March 2014) **(Complete)**
- Conduct SAR/PSRR (April 2013) **(Complete)**
- Shipped to BATC in Boulder, CO (June 2014) **(Complete)**

JPSS-1 Satellite I&T Overview

- **Ball Aerospace & Technologies Corporation (BATC) in Boulder, CO is the JPSS-1 spacecraft provider and satellite integrator**
  - BATC was also NPP S/C provider and integrator
- **NGST will run first Bench Acceptance Test at BATC**
- **NASA LaRC personnel will perform CERES I&T activities at BATC**
- **JPSS will coordinate launch operations through NASA KSC**
  - Launch will be from Vandenberg Air Force Base, CA (same as NPP)
  - Launch vehicle provider has not been selected yet
- **I&T will heavily leverage success accomplished on NPP**
  - Reuse NPP I&T flow & procedures minimizing changes
  - Integrate lessons learned from NPP for JPSS-1 I&T

CERES FM-6 Upcoming Activities

• CERES Delivery to BATC	June 2014
• CERES Bench Acceptance Test	June 2014
• First Instrument Integrated (CERES):	October 2014
• Last Instrument Integrated:	May 2015
• Satellite Pre-Environmental Review:	August 2015
– Dynamics Testing Complete	November 2015
– EMI – EMC Complete	February 2016
– TVAC Complete	March 2016
• Satellite I&T Complete:	May 2016
• Ship to Launch Site:	September 2016
• Launch Readiness Date:	October 2016

CERES FM-6 I&T Team

- **CERES I&T Activities for integration to JPSS-1 are being planned**
  - **Activities and documents are being coordinated with BATC**
- **CERES Project expects to retain most key I&T personnel from CERES FM5 on NPP**
  - **Some new personnel will be added and young team members to be mentored to gain experience for longevity**
- **I&T staffing levels are planned and conflicts with other LaRC Projects seems manageable**
- **CERES Team personnel have already been participating in I&T discussions with JPSS and BATC**

CERES Team will be ready to support JPSS-1 Satellite I&T

Radiation Budget Instrument (RBI)

Discussion Topics

- **RBI Acquisition management structure**
- **RBI Award Status**
- **Exelis proposed instrument architecture & Schedule**
- **Implementation and Near-term Activities**

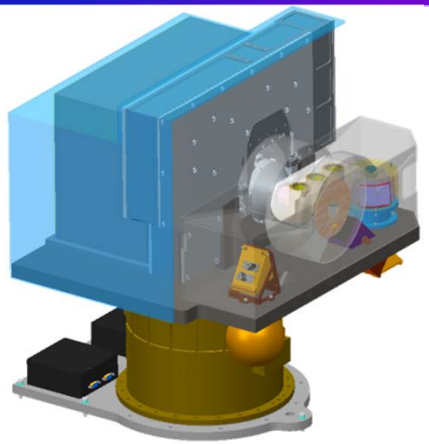
RBI Award Status

- **RBI competitive procurement has been awarded to Exelis**
  - NASA provided extensive debriefings to all offerors
  - Protest period closed with no protests

- **If anyone asks anything about the proposal and evaluation process, refer them to Contracting Officer, Connie Snapp, and NASA standard debriefing process**
  - All feedback is through the NASA debriefing

RBI Project Overview

Clouds and the Earth's Radiant Energy System



Partnerships and Team

- NASA/ NOAA
  - NOAA provides JPSS-2 satellite for accommodation of RBI
  - NASA provides/funds RBI instrument and support through spacecraft I&T and launch/activation
  - NASA funds RBI earth radiation budget science data analysis and generation of science products
- NASA Langley
  - Manages prime contractor development of RBI instrument, provides management, technical, and mission assurance insight and oversight / takes ownership upon delivery to spacecraft and provides I&T and launch plus activation support
- Exelis Inc.
  - RBI Instrument provider/prime contractor with sub-contractors providing key elements and support (SDL for Calibration, JPL for Thermopile detectors, Sierra Nevada for Azimuth Rotation Assembly)

- Category 3 Mission per NPR 7120.5E
- Risk Classification B per 8705.4
- Follow-on instrument to the Clouds and the Earth's Radiant Energy System (CERES)
- Flight Instrument Complete – February 2018
- Flight Instrument Delivery – November 2018
- JPSS-2 launch planned for November 2021

- **Science Goal:**
  - To continue the measurements from the last two-plus decades in support of global climate monitoring.
  - RBI extends the ERB measurements of the Earth Observing System (EOS) and Joint Polar Satellite System (JPSS)

Key Driving Requirements

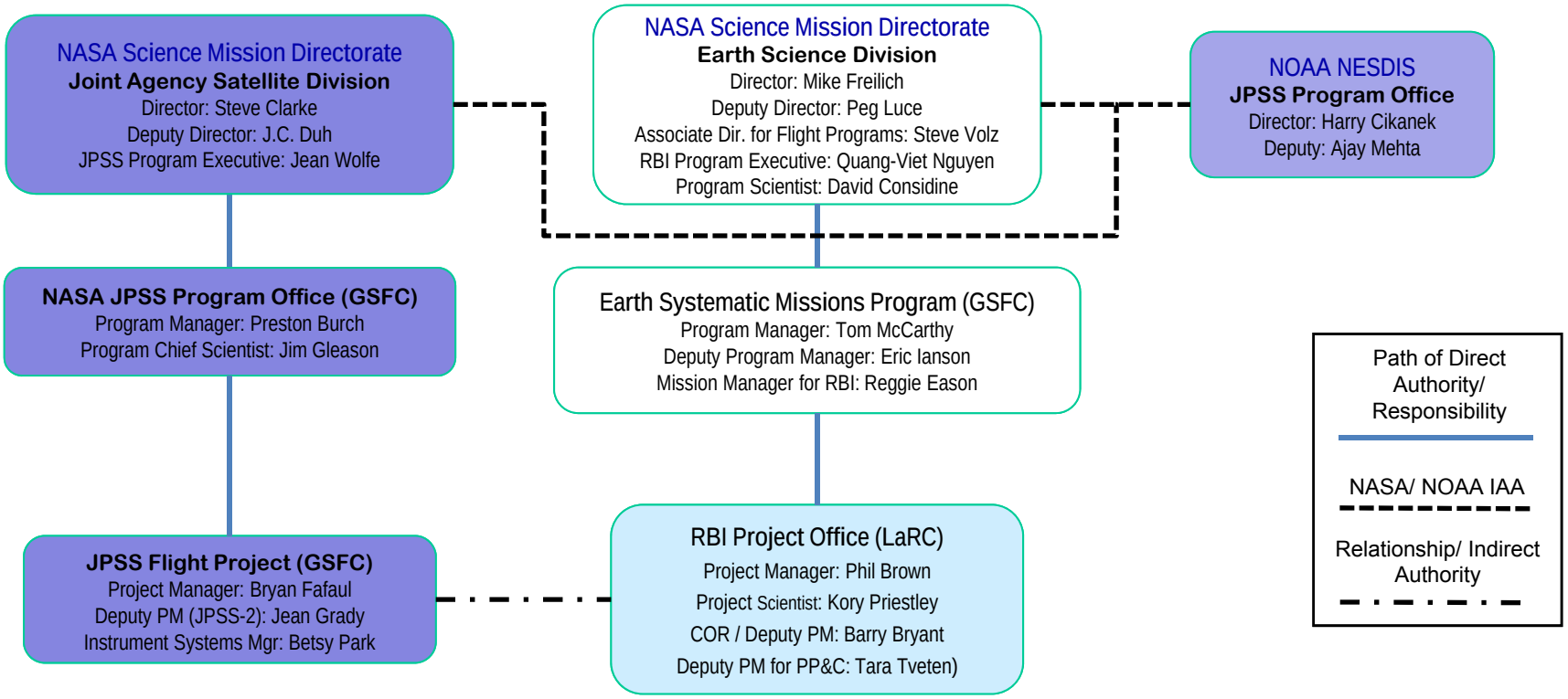
Parameter	Requirement
Mass	≤ 80 kg
Power	Orbital Average: ≤ 90 W Peak: ≤ 195 W Survival: ≤ 60 W
Static Payload Envelope	815mm x 567mm (Height x Diameter - Cylindrical)
Data Bus and Rate	SpaceWire Orbital Average: ≤ 3000 kbps Peak: ≤ 4000 kbps Safe: ≤ 2 kbps
Spectral Coverage	0.2-100 microns (Shortwave-SW, Total, and Longwave-LW)
Orbit	JPSS-2 Altitude: 824 km +/- 17 km Sun-Synchronous Ground Repeat Cycle: < 20 days Nominal Ascending Equator Crossing Time : 1330 Local
Field of Regard (FOR)	Entire Earth
Field of View (FOV)	2.6° x 1.3 ° (Three Channels)

Project Deliverables

- **Deliverables**
  - RBI Instrument including GSE
  - RBI FVTS Simulators
    - Requirements from JPSS are TBD
    - ROM estimate included in PPBE submit
  - Dummy "flight" mass simulator as back-up to RBI instrument
    - Per the NASA/NOAA Inter-Agency Agreement (IAA); provide a flyable mass model for RBI in the event RBI cannot meet schedule
    - ROM estimate included in PBBE submit
  - Products supporting JPSS-2 spacecraft development
    - Ex. -- Instrument CAD models, structural and thermal models, C&T database, drill template

NASA-NOAA Partnerships

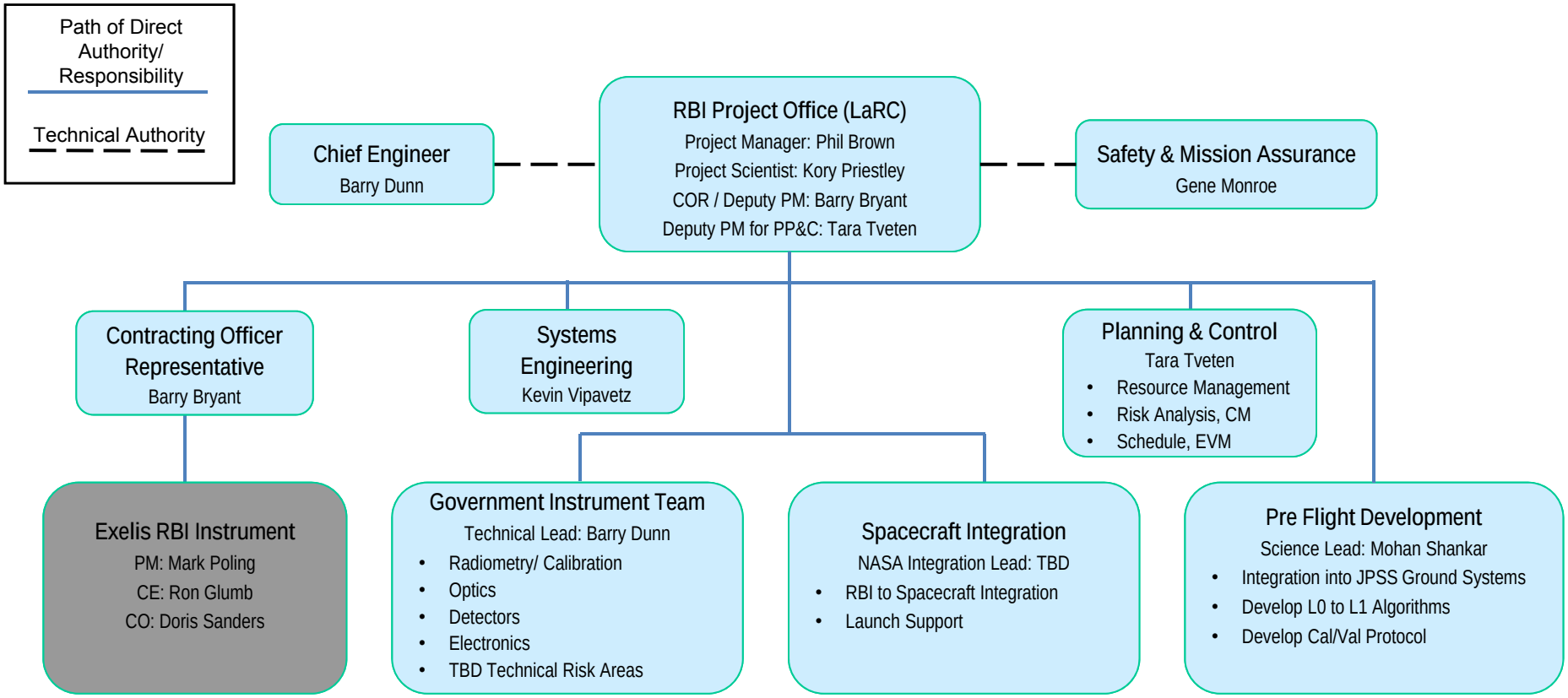
Clouds and the Earth's Radiant Energy System



RBI funded by NASA thru SMD/ESD/ESMP
Radiation, Ozone, & Atmospheric Measurements (ROAM)

LaRC RBI Organization

Clouds and the Earth's Radiant Energy System

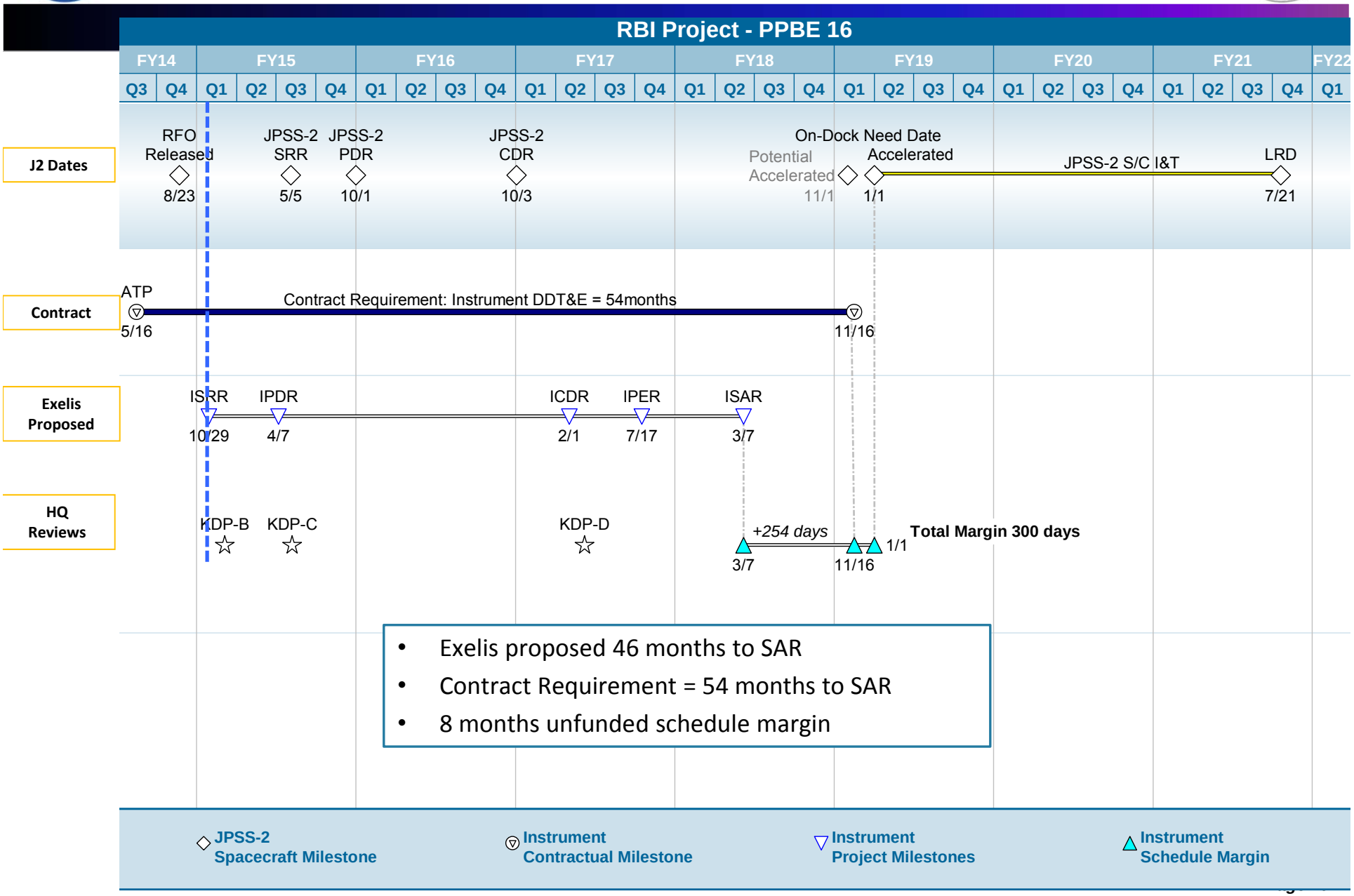


Programmatic Driver - Schedule

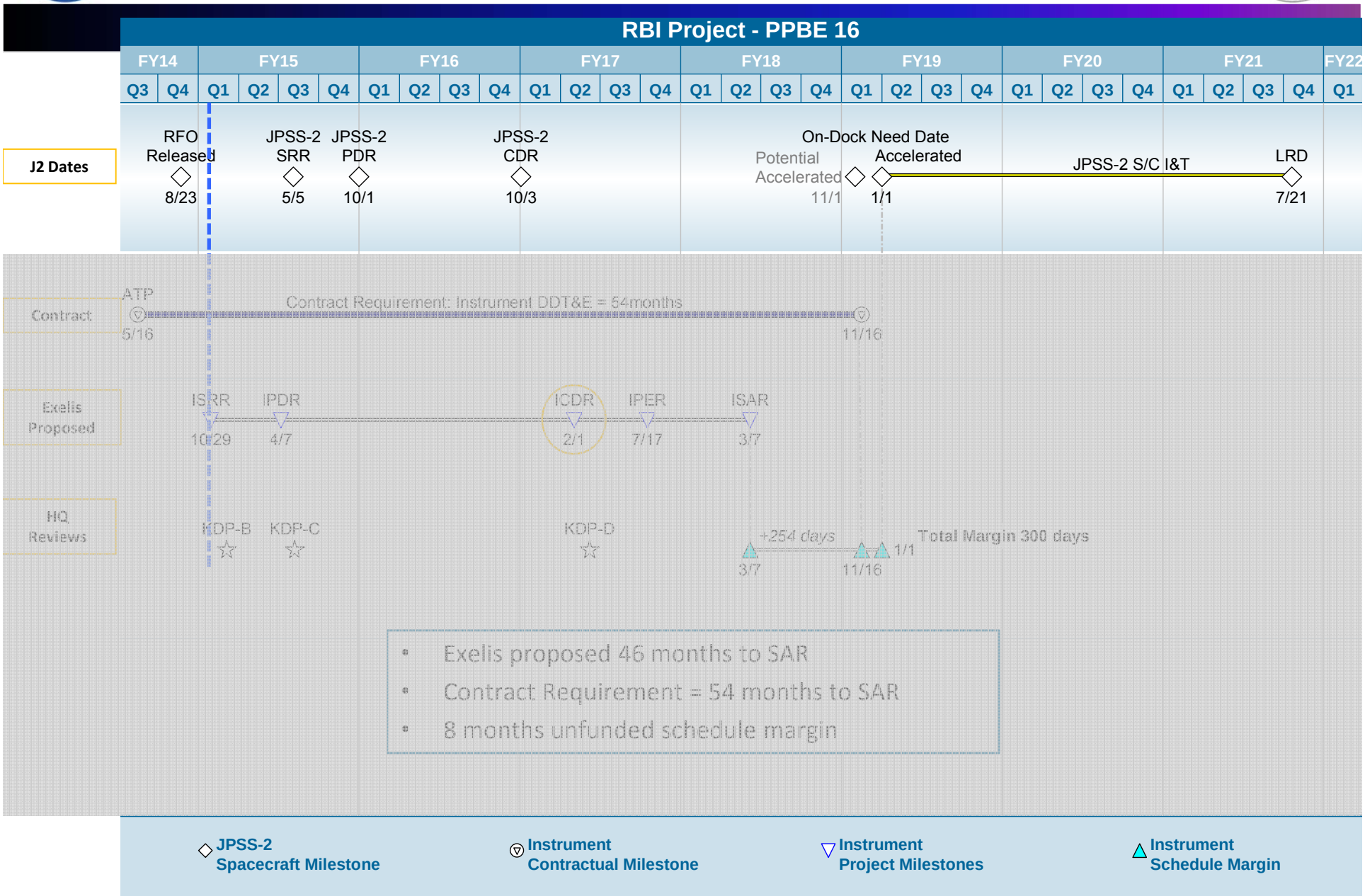
- **NASA / NOAA Inter-Agency Agreement (from draft):**

- NASA will develop and deliver the RBI on a timeline that is tied to JPSS-2 mission milestones as documented in the JPSS Program Integrated Master Schedule (IMS), however it evolves over time, and ***in a manner that does not interfere with, or add consequential risk to the overall JPSS-2 mission development and timely launch***
- RBI considerations ***shall not drive any JPSS planning or baselined schedules*** other than to allow for nominal integration to the spacecraft if RBI is delivered prior to the last weather instrument delivered plus nominal integration time.

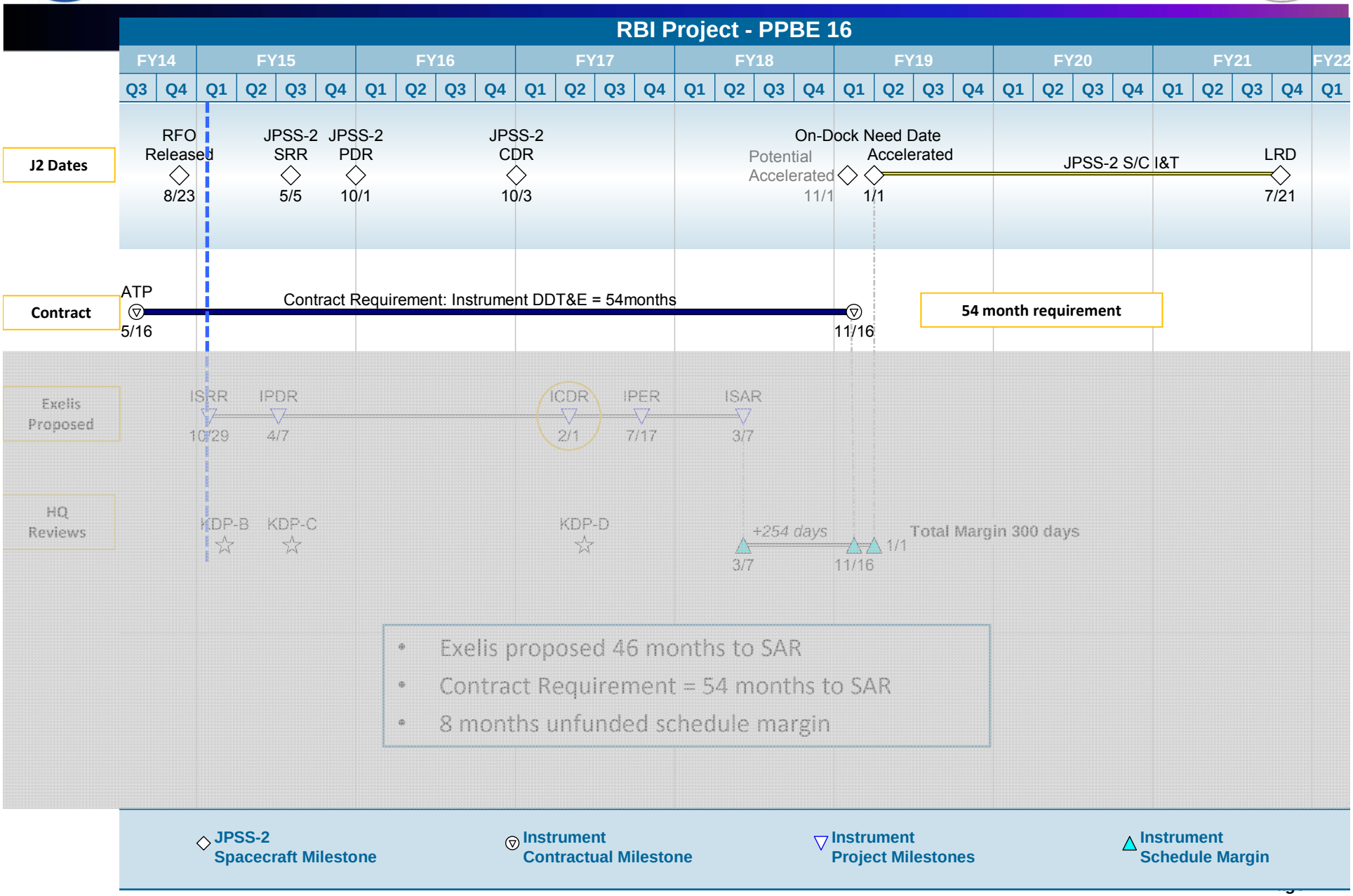
RBI Reference Schedule and Review Plan



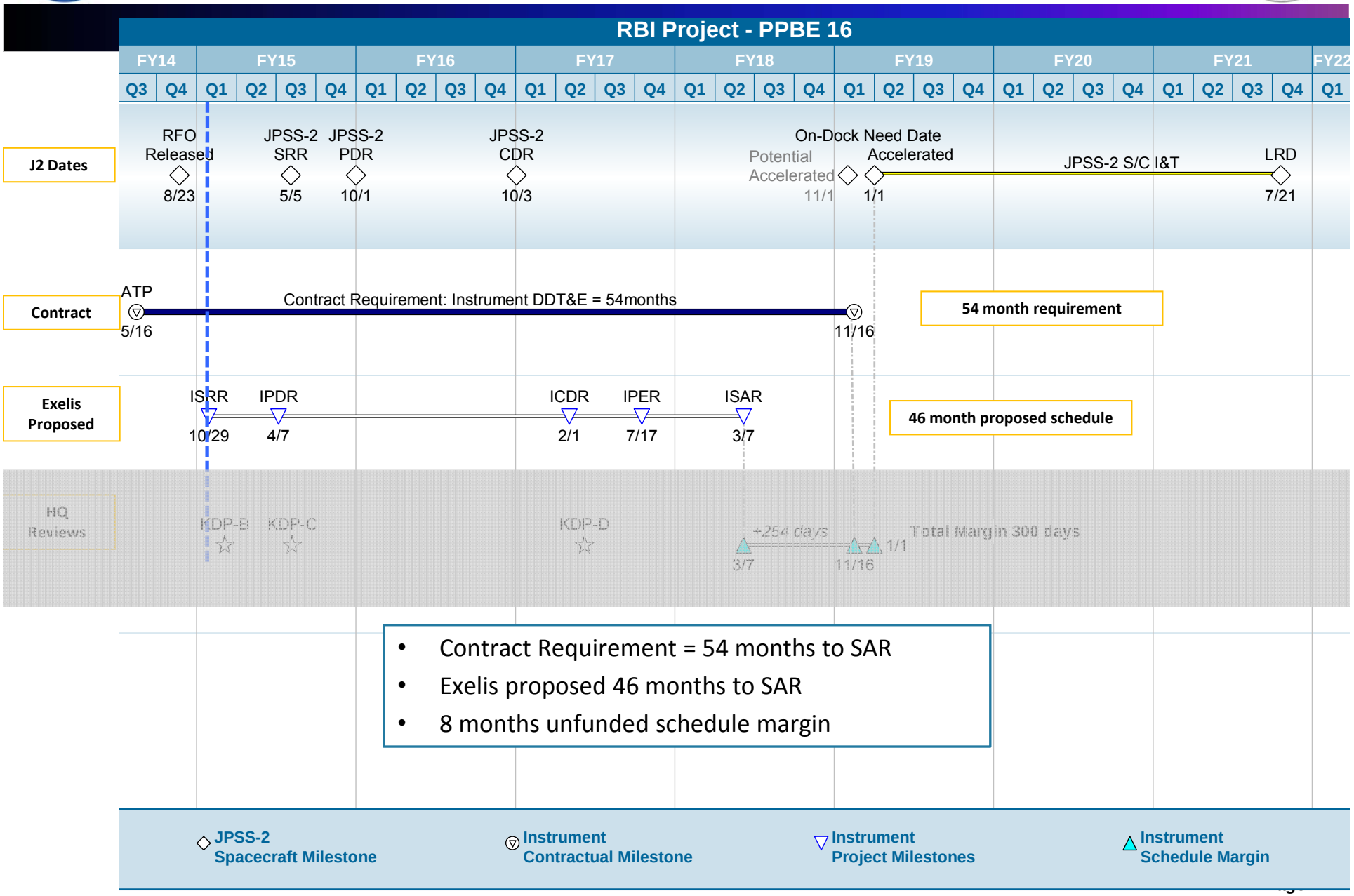
RBI Reference Schedule and Review Plan



RBI Reference Schedule and Review Plan

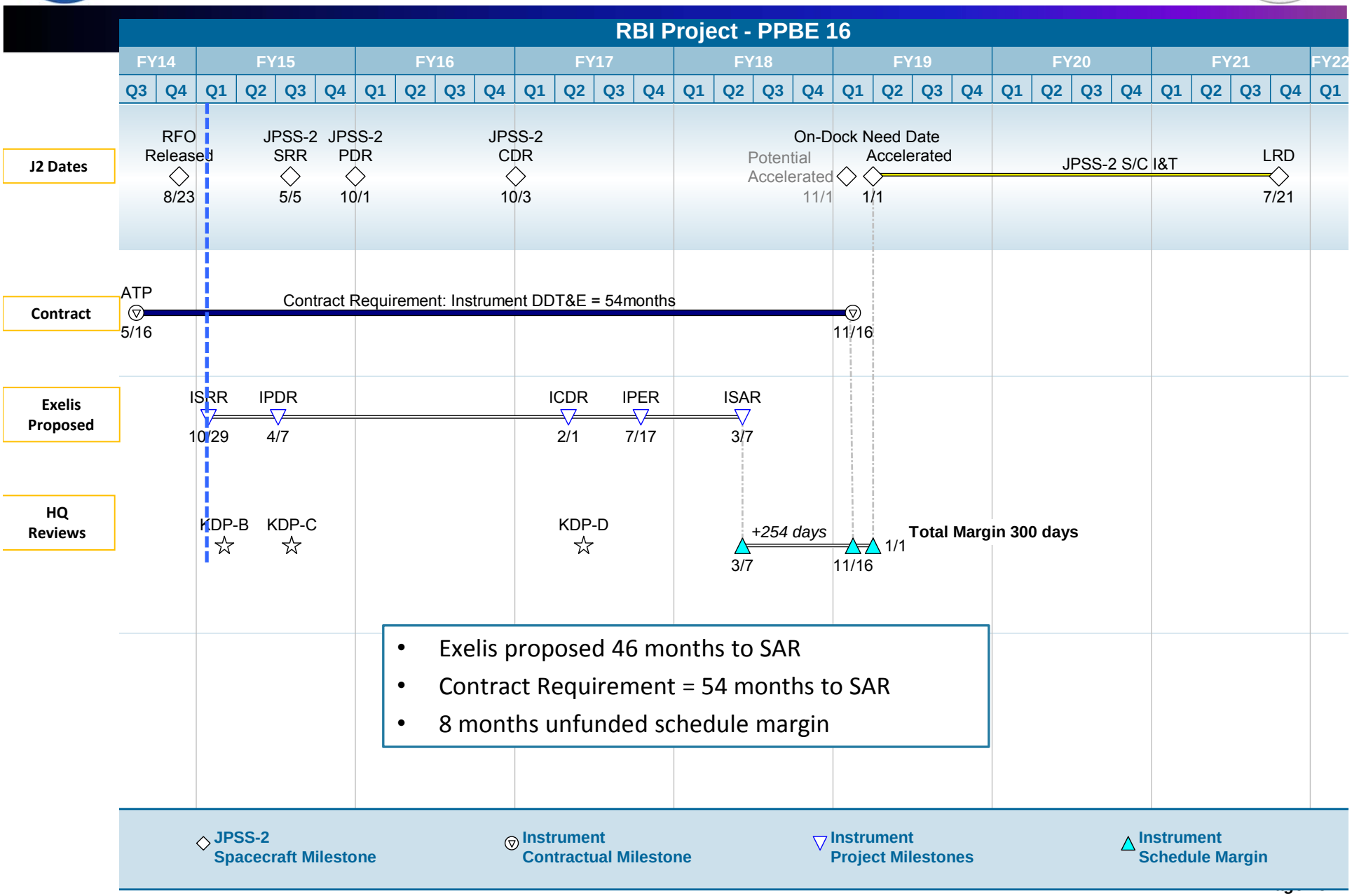


RBI Reference Schedule and Review Plan



- Contract Requirement = 54 months to SAR
- Exelis proposed 46 months to SAR
- 8 months unfunded schedule margin

RBI Reference Schedule and Review Plan



Summary of Activities to Date

- **RBI Procurement**
  - 16 May: Contract awarded to Exelis
  - 30 May: All offeror debriefings complete
  - 9 June: Protest period closed with no protests
- **LaRC / Exelis**
  - 5 June: RBI Core management team kickoff held at Exelis in Ft Wayne, In
  - 23-24 July: RBI Team Kick-off at Langley
  - Established weekly technical and management telecoms
  - Worked with Exelis on updates to JPSS-2 interface needs for mass, power, data rate, pointing ,…
  - (8/18- 8/20): Conducting detailed walk-thru of all requirements as part of road to SRR
  - Provided Exelis with feed back on first 2-months of performance
- **ESD/ROAM**
  - 24 June: Kick-Off Meeting with ESD/ROAM
  - Provided updated PPBE-16 (Note: RBI has received all of its requested FY14 funding)
  - Providing weekly status to ESMPO
- **JPSS Flight Project Office**
  - Reviewed RBI concept with JPSS
  - Updated JPSS-2 Spacecraft interface requirements documents to reflect proposed RBI design in support of JPSS-2 Spacecraft RFO
  - Coordinating with JPSS-2 on schedule and products needed to support the JPSS-2 spacecraft development lifecycle
  - Providing weekly status to JPSS via weekly Instrument Staff telecoms

Implementation and Near-term Activities

- **Execution activities started**
  - Core team kickoff held at Exelis (Project office, CE, SE)
  - Weekly management and technical tag-ups established
  - Communication Plan – PM to PM, CE to CE
- **Develop Project Implementation Plan**
- **Standing Review Board (SRB) Established**
  - Coordinate review manager assignment with SRB chair
  - Develop/coordinate master Terms of Reference (TOR) with review manager
  - Review SRR/PDR schedule with Exelis based on TOR
- **June**
  - Langley Staffing based on technical needs of proposed design
  - Review and assess Exelis SRR/PDR plans and schedule
- **Aug – Langley 60 Day review (Staffing and SRB establishment, SRR readiness)**
- **Sept/Oct – Requirements Changes/Updates/Clarifications**
- **Dec– Systems Requirements Review (SRR)**
- **Jan/Feb– Integrated Baseline Review (IBR)**

Requirements Updates - I

- **During the LaRC-Exelis Requirements walkthrough in late August several classes of proposed changes were discussed**
  - Requirement values, clarifications, verification method or level, and deletions
- **LaRC compiled the proposed changes and evaluated them with SME inputs**
  - Reviewed and comments compiled
  - First draft provided to Exelis on 9/19
  - Second draft provided on 10/3
  - Review with Exelis to be scheduled
  - CCB scheduled for 10/15

857 PRD requirements
- 85 have new proposed text
- 23 new proposed changes to the verification method
- 5 changes from Observatory to Instrument level of verification
- 17 requirements noted for deletion.
- There are 34 items pending clarification or review by LaRC. Most involve scrubbing the J2 ICD, MAR, CCP, and DFRD.
- There are other changes to figures, captions, and equations

- **Several changes are being worked to provide more user flexibility than was presented in the RFP**
  - The number and duration of ground uploaded commands
  - Covers unique Science needs currently available for CERES instruments

Requirements Updates - II

- **RBI PRD and J2-to-RBI ICD are being synchronized**
  - Many ICD items were included in the JPSS provided template (September 2012) used to develop the PRD
  - These items need to be identified and considered for removal from the PRD
  - Exelis and JPSS have both provided inputs with duplicates identified
  - LaRC Mechanical, Electrical, Software, SMA, and Contamination Control leads providing additional inputs
- **LaRC also conducting scrub of J2 Data Format Requirements Document (DFRD), J2 Mission Assurance Requirements (MAR), and J2 Contamination Control Plan (CCP)**
  - Need to confirm compatibility with JPSS-2 requirements since original documents were based on JPSS-1

Key Hardware Trades

- **Single vs Three Telescope Approach**
  - Co-registration during Earth Stare and ADM modes
- **Micro-bolometer Array vs Single Element Thermopile detector**
  - Manufacturability and performance
- **Silver vs Aluminum Mirror Coatings**
  - Spectral response in the UV for certain scenes
- **±90 vs ± 180 Azimuth Range**
  - Ability to perform Earth Stare and ADM mode
- **SpaceWire vs. 1553**
  - Signal transfer across rotating AZ interface
- **Flex Cables vs Slip Rings vs Polytwist**
  - Signal and power transfer across rotating Az and El interfaces

Trade Study Updates

- **Dialogue with Exelis has led to down-select of a 3-telescope concept on 9/12**
  - Proposed single-telescope concept could not meet two of the four operational mode requirements and a third would have little margin
  - Co-registration error of the three measurement channels would either exceed or would meet requirement with little margin for other system errors
- **New concept also makes the change from the micro-bolometer array to JPL thermopile detectors**
  - Backups are thermopiles from Dexter or a discrete micro-bolometer from INO
- **Exelis proposed a solar avoidance concept using Spacecraft attitude and position information**
- **Aluminum vs silver mirror trade was completed**
  - Aluminum selected but will potentially require requirements waiver (TBD)

Exelis is refining 3-telescope concept as go-forward approach for SRR-MDR (No earlier than first week of December)

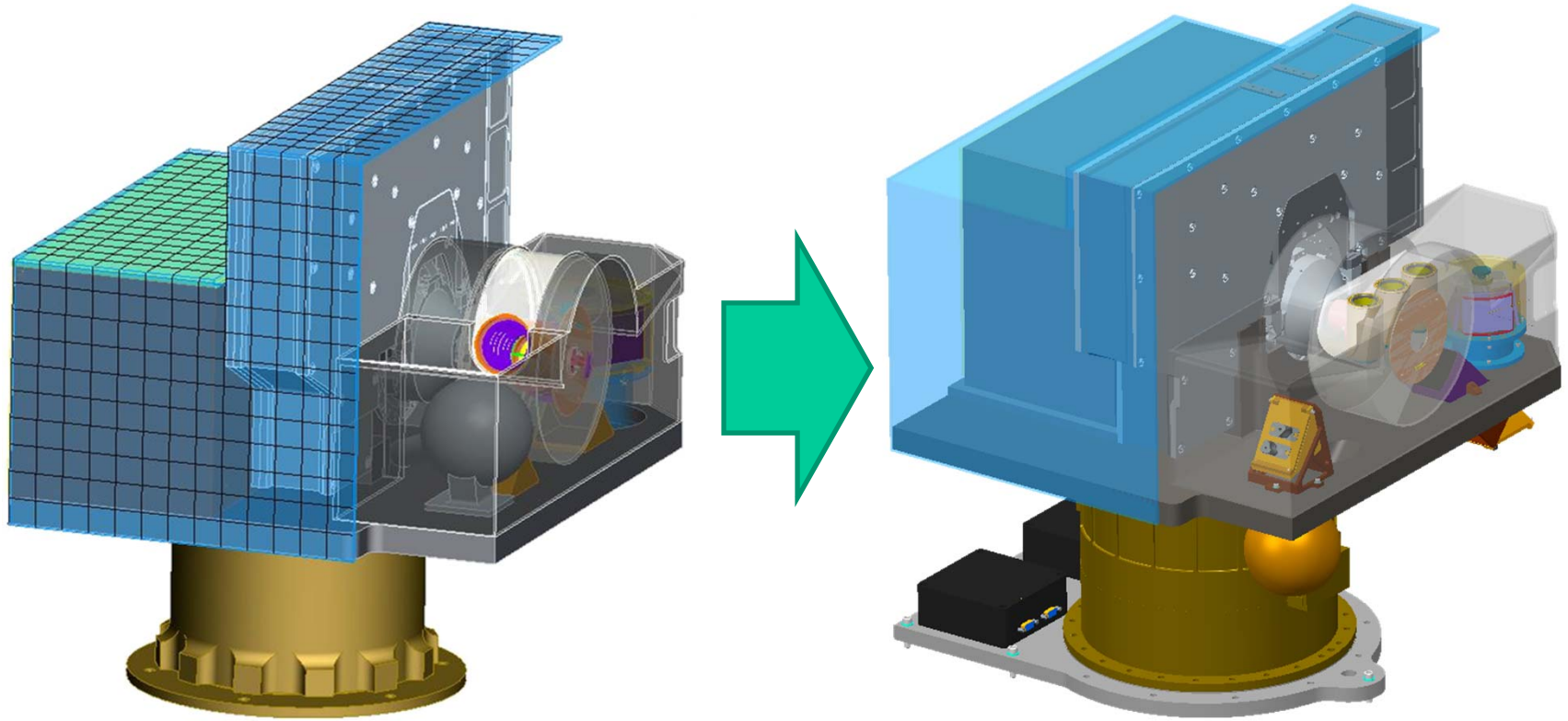
Finalizing SpaceWire vs 1553

- **Exelis proposed the use of SpaceWire for RBI based on CrIS**
- **After additional analysis it appears that SpaceWire cabling cannot handle the number of cycles required to transfer power and data across the rotating azimuth interface**
  - > 1 million cycles for flight instrument
  - > 2 million cycles for life-test unit
- **1553 offers other cabling options but would reduce the RBI data rate by about a factor of 10**
  - ~300 kbps vs ~3 Mbps
  - JPSS has indicated that there may be some additional capacity for 1553 due to scheduling of peak data usage
- **Exelis is currently evaluating options for 1553 or an additional deck mounted electronics box to convert signals to SpaceWire**
- **Closure expected by 10/10**

Three-Telescope Concept Currently Meets Accommodation Requirements

Proposal Single-Telescope Concept

Current Three-Telescope Concept

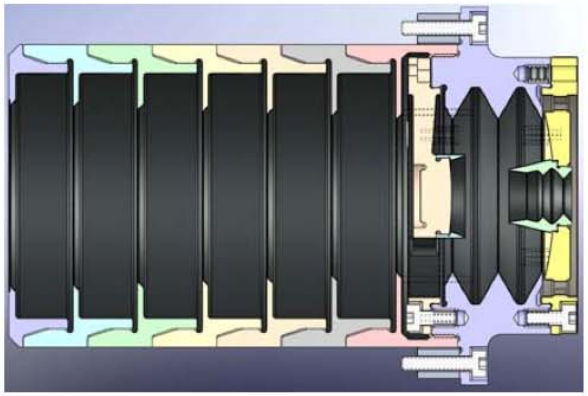


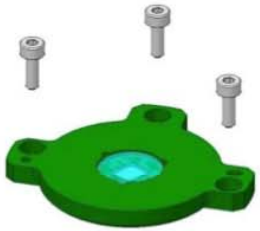
Exelis refining concept for mass and power

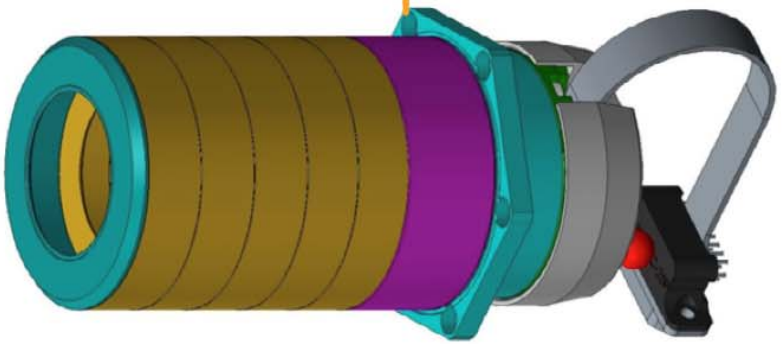
Uses same scan mechanism (CrIS) as the single-telescope concept

Three-Telescope Concept Currently Meets Accommodation Requirements

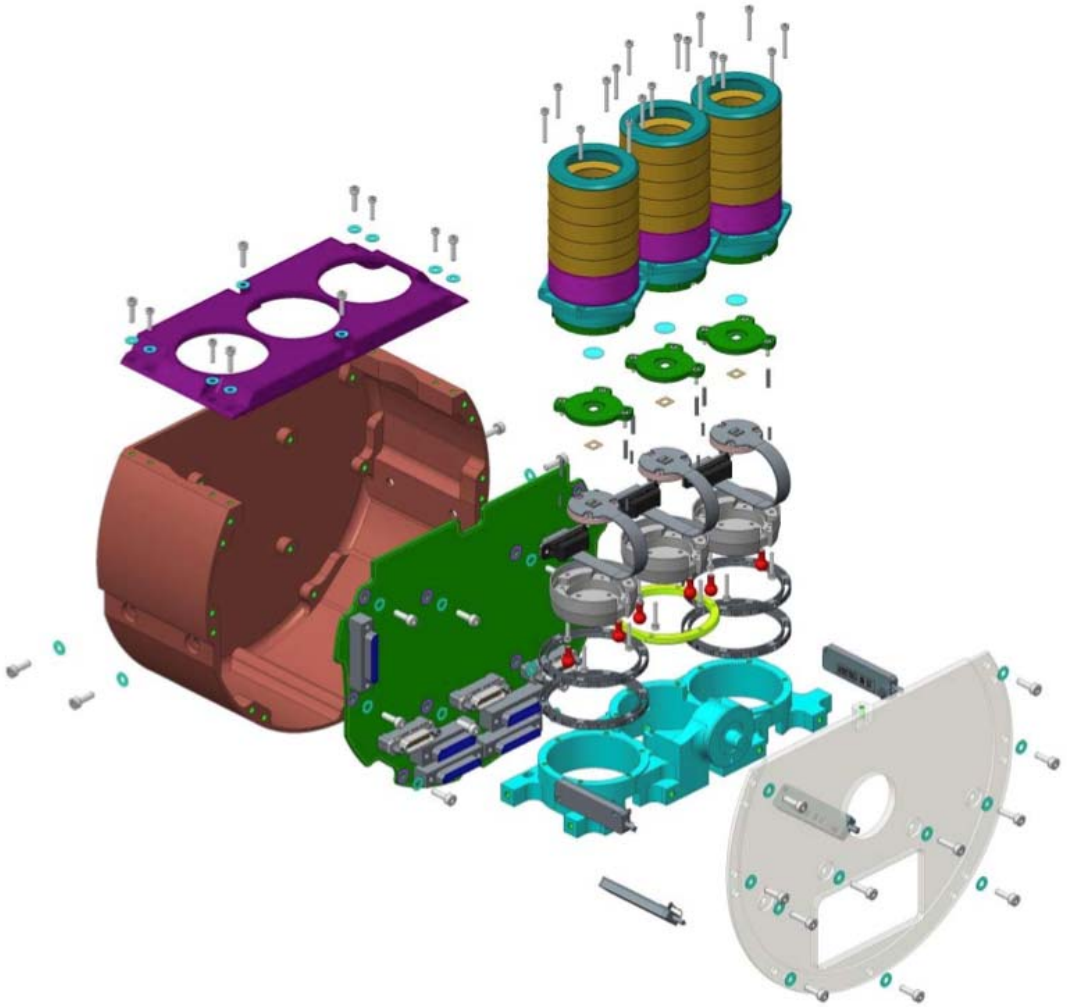
Radiance in → Fore Baffle → Telescope *Includes Primary & Secondary Baffles* → Spectral Filter *SW and LW* → Detector → Electrical signal out



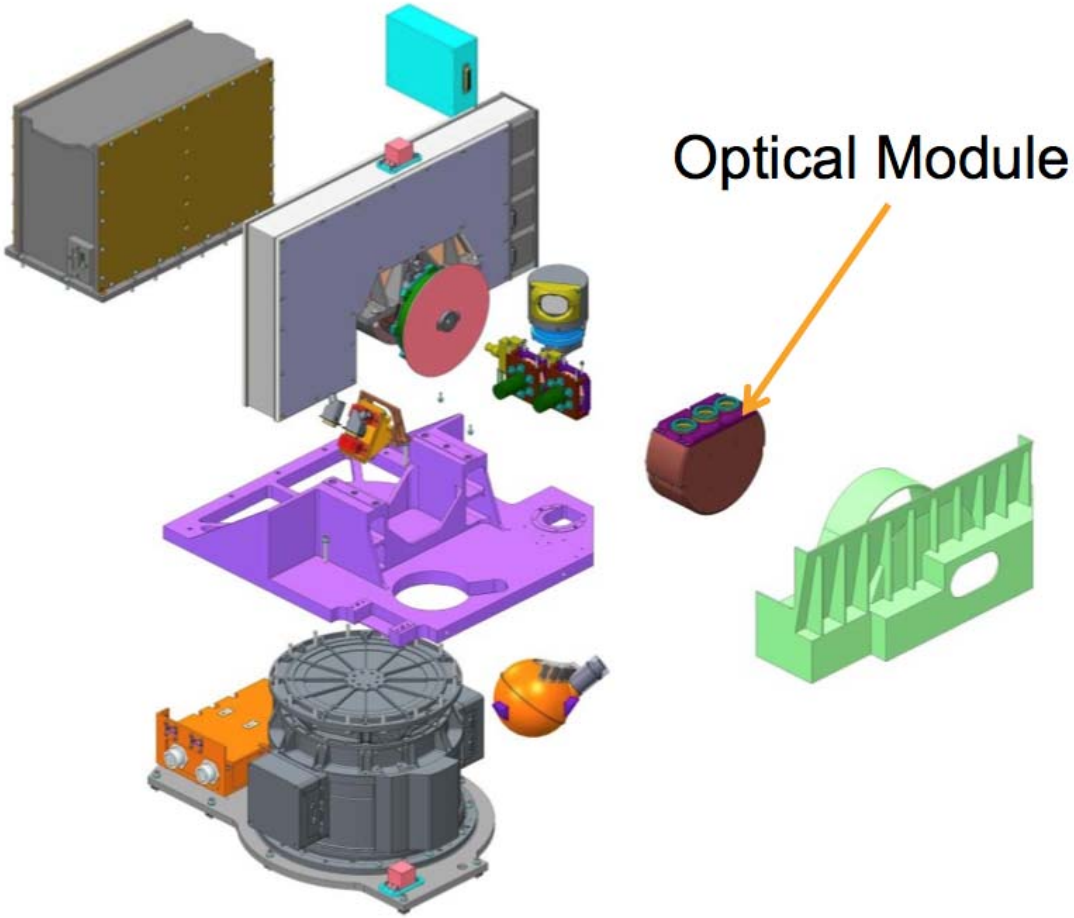


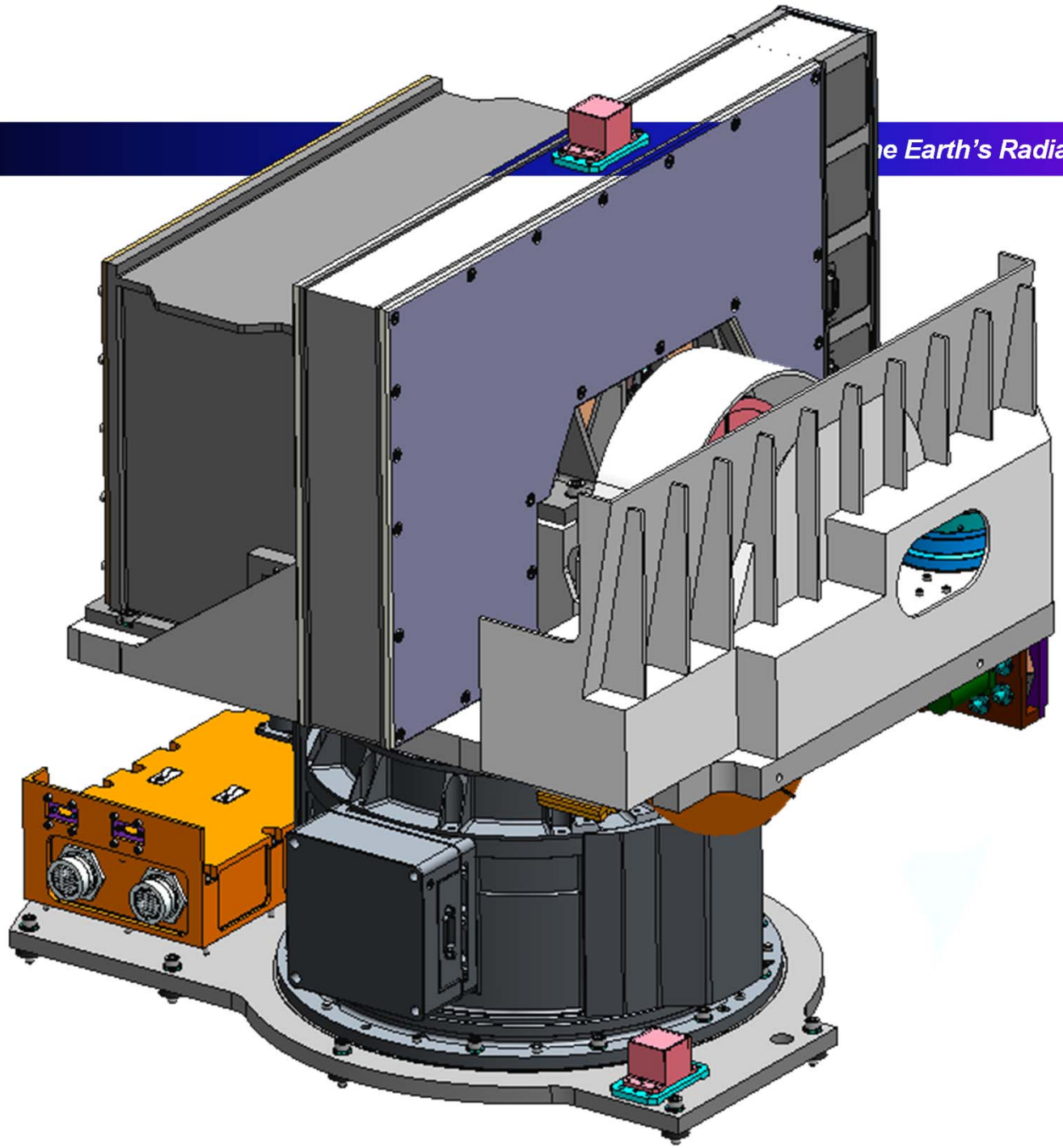


Three-Telescope Concept Currently Meets Accommodation Requirements

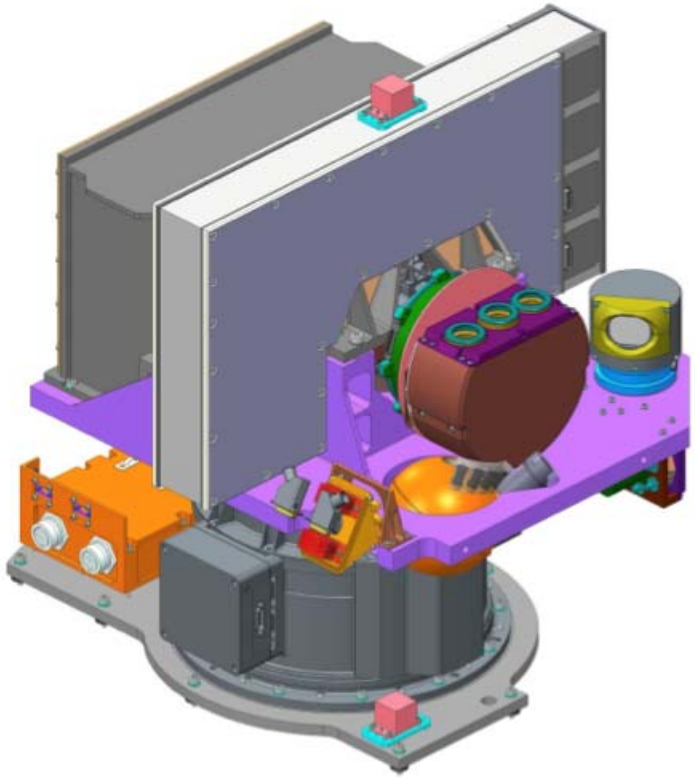


Three-Telescope Concept Currently Meets Accommodation Requirements

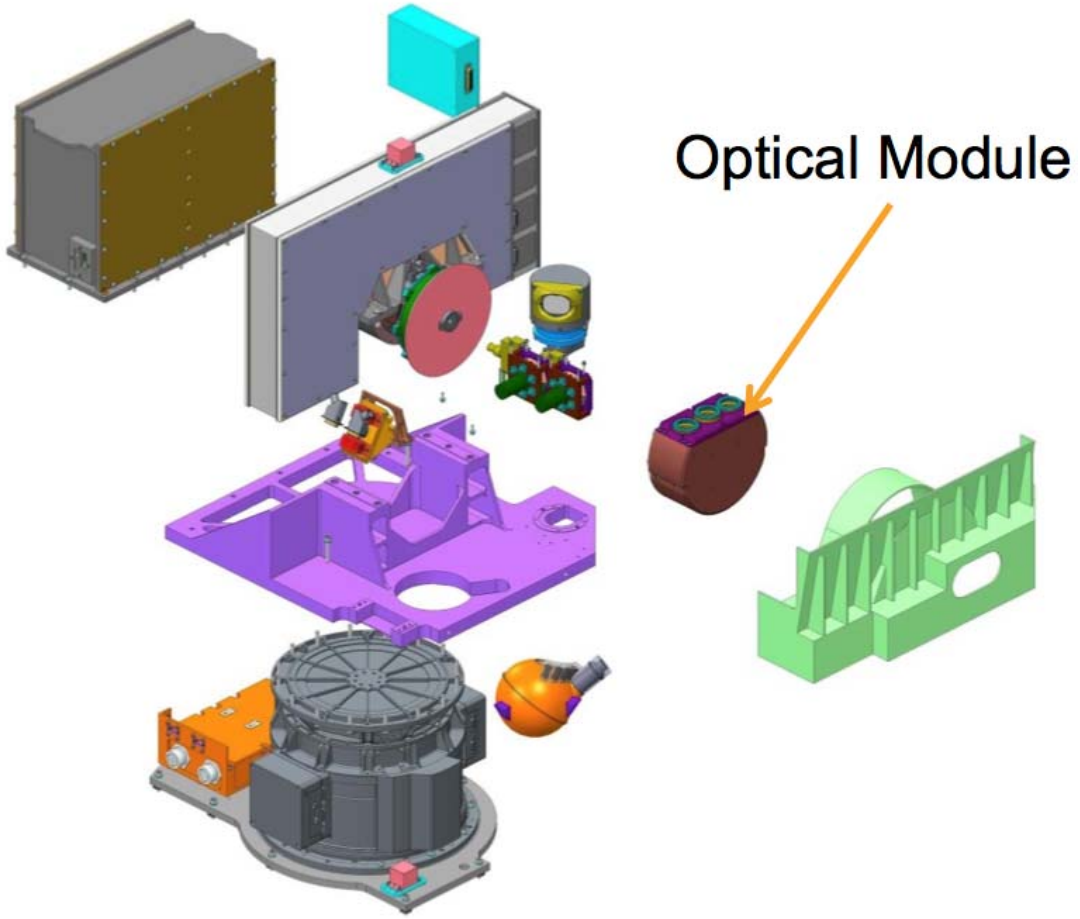




Three-Telescope Concept Currently Meets Accommodation Requirements



Instrument Shroud Hidden



Path Forward to SRR

- **LaRC Project Office stance is that having the 3-telescope concept identified is necessary but not sufficient to plan for SRR readiness**
  - Need to have concept minimally at a "proposal level"
    - MEL and mass allocations
    - Power allocations
    - Con-ops
    - Heritage documentation
    - TRL identified with maturation plans and backup alternates
    - SpaceWire or 1553 selection
- **Need programmatics in order**
  - Updated cost, schedule, and risks
- **Exelis is refining 3-telescope concept as go-forward approach for SRR-MDR (No earlier than first week of December)**

Questions?

RBI Overview and Scope

Clouds and the Earth's Radiant Energy System

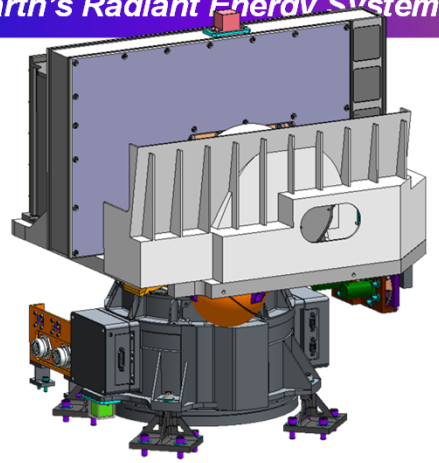
Radiation Budget Instrument (RBI)

Partnerships and Teams

- **NASA/ NOAA Partnership**
  - NOAA provides JPSS-2 satellite for accommodation of RBI
  - NASA provides RBI instrument and support through spacecraft I&T and launch/activation
  - NASA funds radiation budget science data analysis and generation of science products (RBM Project)
- **NASA Langley**
  - Manages prime contractor development of RBI instrument, provides management, technical, and mission assurance insight and oversight; provides support to spacecraft I&T thru launch and early on-orbit checkout (thru Phase D)
  - Hand-over and release of RBI instrument ownership by RBI Project occurs at the JPSS-2 Operational Hand-over Review (OHR). For Phase E, the Langley Science Directorate (SD) Radiation Budget Measurement (RBM) Project assumes responsibility for RBI for mission planning and operations
- **Exelis Inc.**
  - RBI Instrument provider/prime contractor with sub-contractors providing key elements and support (SDL for Calibration, JPL for Thermopile Detectors, Sierra Nevada for Azimuth Rotation Module)
- **JPSS-2 Spacecraft and Mission Interface**
  - -- Interface Control (ICD & MICD) and Data Format

RBI scanning radiometer measuring three spectral bands at top of Atmosphere (TOA)

- Total 0.3 to > 50+ μm
- Shortwave 0.3 to 5.0 μm
- Longwave 5.0 to 50 μm



Science Goal

- To continue the measurements from the last two decades in support of global climate monitoring.
- RBI extends the Earth radiation budget measurements of the Earth Observing System (EOS) and Joint Polar Satellite System (JPSS)

- Category 3 Mission per NPR 7120.5E
- Risk Classification B per 8705.4
- Follow-on instrument to the Clouds and the Earth's Radiant Energy System (CERES)
- Flight Instrument Complete – Exelis CBE is May 2018
- Flight Instrument Delivery – NLT April 2019 (per NOAA/NASA IAA)
- "Notional" JPPS-2 on-dock delivery date – Nov 2018 (TBR after JPSS-2 spacecraft is awarded, April 2015)

National Aeronautics and Space Administration

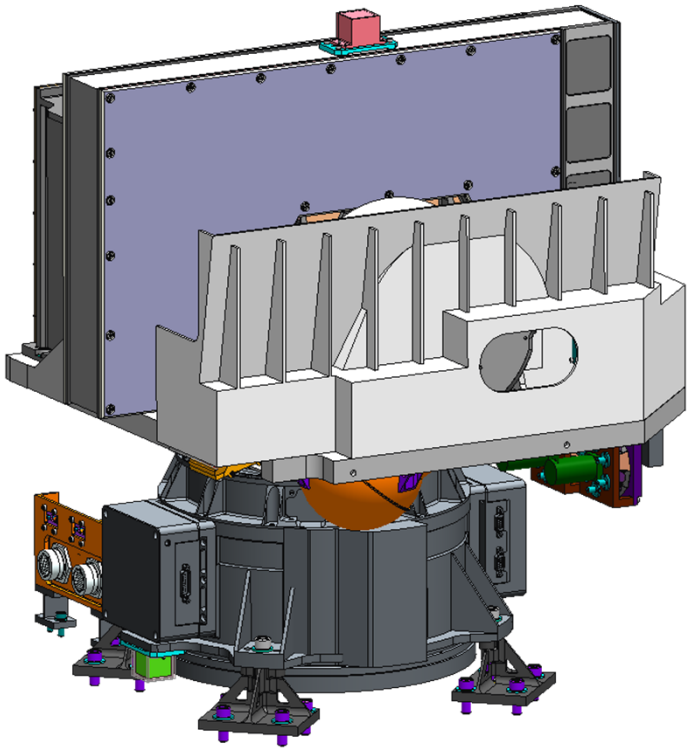
RBI Instrument Overview

Barry Dunn, *Chief Engineer*

TBD, 2015

barry.j.dunn@nasa.gov

RBI is a New Instrument Developed as a Follow-on to the CERES Instruments Flown on EOS, NPP, and JPSS-1



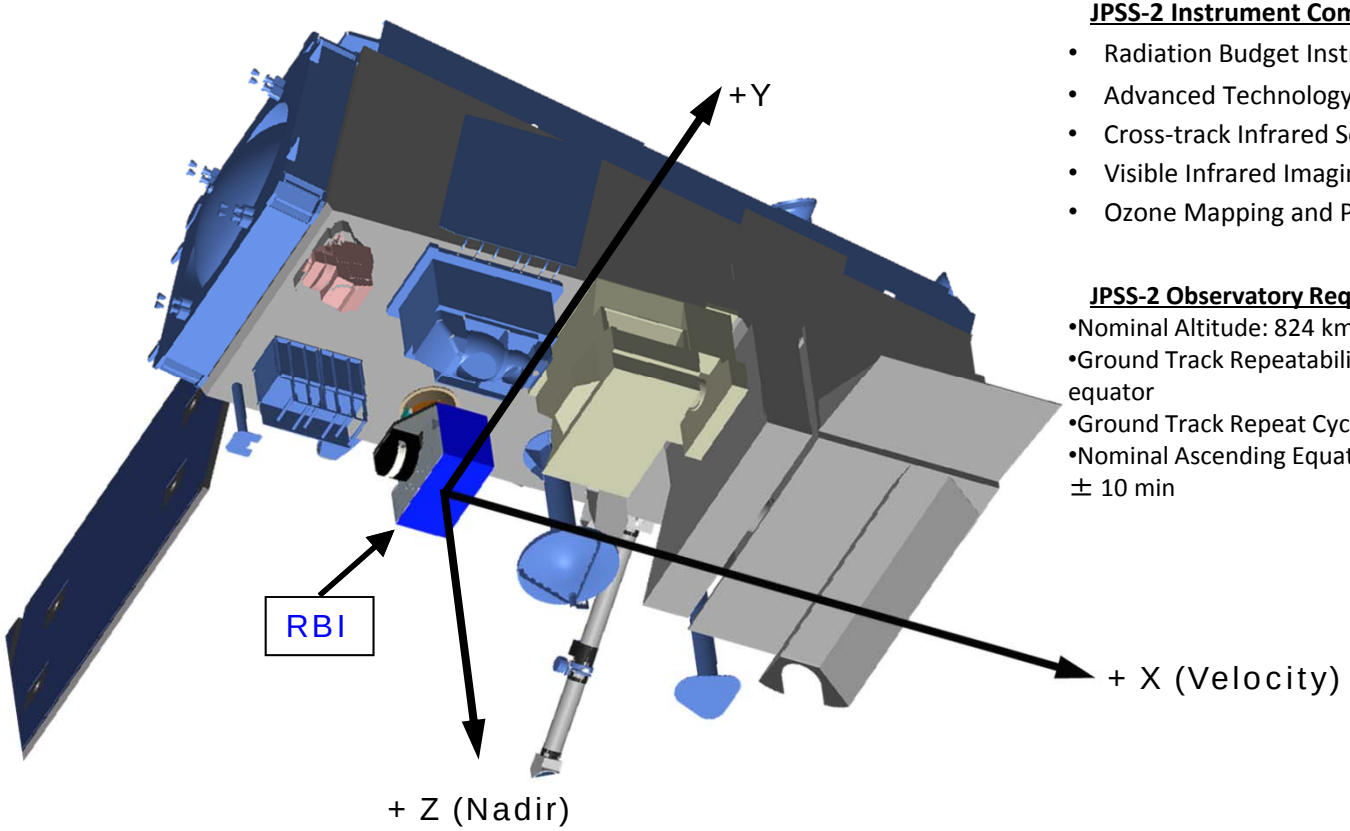
Instrument Description:

- A Three-Channel three-telescope broadband scanning radiometer designed to measure the solar reflected and Earth emitted thermal radiation at the top of the atmosphere
- Electrically redundant design to meet Level 1 life and reliability (7 years at 85%)
- Leverages the CrIS cross-track scan module (CSM) for Earth scanning and calibration target selection
- Utilizes one Infrared Calibration Target (ICT) with phase-change cells, one Visible Calibration Target (VCT), one Solar Calibration Target (SCT), space views, and Lunar views as flight calibration sources
- Each telescope utilizes redundant thermopile detectors

Characteristics:

- Spectral Range: ~ 320 nm – 100 microns
- Field of View (FOV): ~1.3 x 2.6 degrees
  - ~19 x 37 km at nadir
- Geolocation: < 2.5 km at nadir
- Data Interface: MIL-STD-1553
  - <300 kb/sec (Average) / <400 kb/sec (Peak)
- Instrument including redundant electronics
  - Mass: ~68 kg (CBE) 80 kg (allocation)
  - Power: ~66 W (Cross-track mode)
- Envelope: ~815x640x375 (circular) cm^3

RBI Accommodated on JPSS-2 Spacecraft Nadir Deck



JPSS-2 Instrument Complement

- Radiation Budget Instrument (RBI)
- Advanced Technology Microwave Sounder (ATMS)
- Cross-track Infrared Sounder (CrIS)
- Visible Infrared Imagining Radiometer Suite (VIIRS)
- Ozone Mapping and Profiler Suite (OMPS)

JPSS-2 Observatory Requirements

•Nominal Altitude: 824 km ± 17 km
•Ground Track Repeatability Accuracy: ±20 km at the equator
•Ground Track Repeat Cycle: <20 days
•Nominal Ascending Equator Crossing Time: 1330 (local time) ± 10 min

Spacecraft design and Instrument locations are notional and representative of JPSS-1 JPSS-2 configuration has not been determined