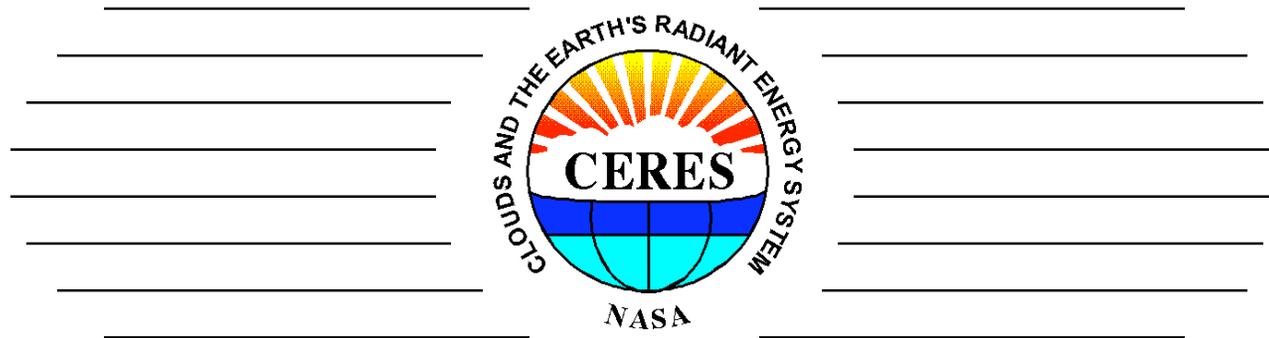




# CERES Instrument and Calibration Status



~ The entire Instrument Working Group Team ~

Presented by:  
Kory Priestley

Marriott at City Center  
Newport News, VA  
April 26, 2011



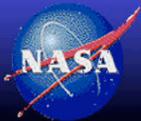
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**Atmospheric**  
SCIENCES

# Outline

## CERES FM1-FM6 Instrument Status Report (Priestley)

- EOS Flight Hardware Performance & Status
- EOS Data Product Status
- Climate Data Record Continuity Path Forward
  - FM5 on NPP
  - FM6 on JPSS - 1
  - ERBS on JPSS -2



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# Instrument Working Group Personnel

## Science

- Susan Thomas -  
Audra Bullock  
Janet Daniels  
Phil Hess  
Suzanne Maddock  
Mohan Shankar  
Nathaniel Smith  
Nitchie Smith  
Peter Szewczyk  
Robert Wilson

## Data Management

- Denise Cooper -  
- Dale Walikainen -  
Thomas Grepiotis  
Nelson Hillyer  
Jeremie Lande  
Dianne Snyder  
Richard Spivak  
Mark Timcoe

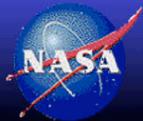
## Mission Operations

- Bill Vogler -  
- James Bailey -  
Christopher Brown  
~ *Jim Donaldson* ~  
John Butler  
William Edmonds  
Kelly Teague

## S/C Integration & Test

- Roy Zalameda -  
James Adams  
Mike Tafazoli  
Eugene Sutton  
Bruce Wolff

*Significant increases have been necessary to implement new FM5 and FM6 work*

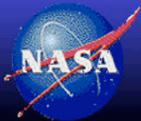
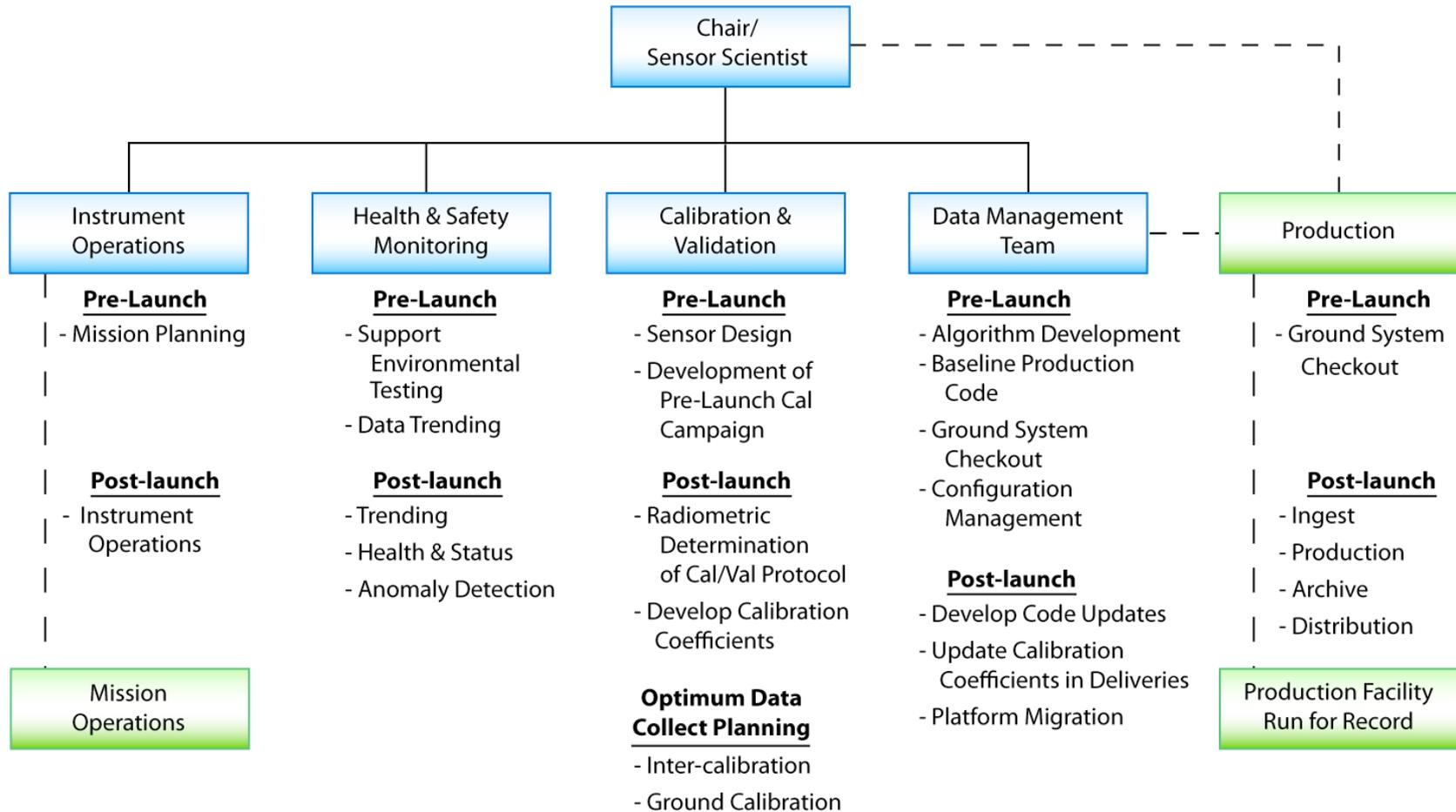


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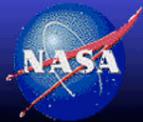
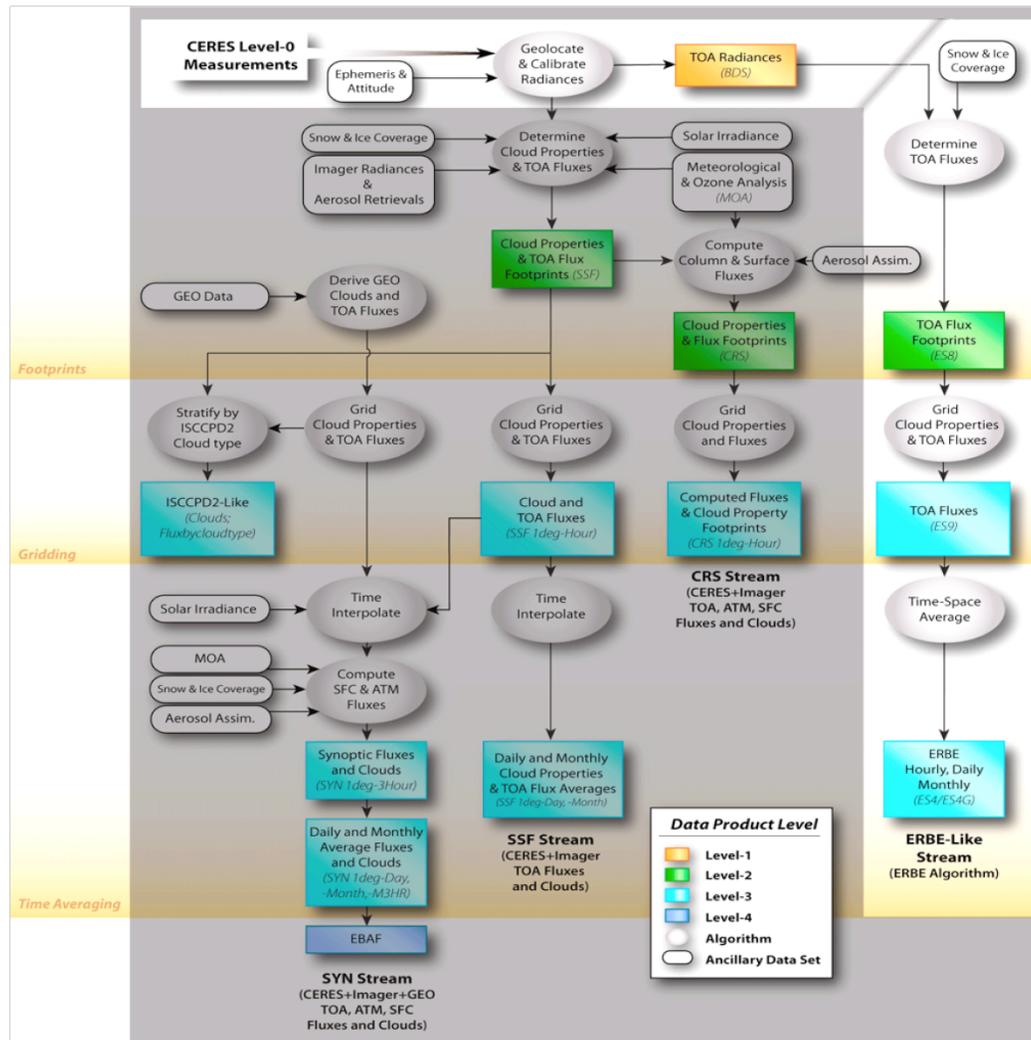


# Instrument Working Group Roles & Responsibilities

— Authority  
 - - Coordination



# Instrument and ERBE-Like Processing Stream



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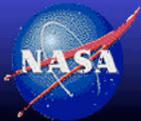
# Radiometric Performance Requirements

**CERES is defined as a class 'B' Mission  
5-year design Lifetime**

Spectral Regions	Solar		Terrestrial		Atmospheric Window
	Wavelengths	0.3 - 5.0 $\mu\text{m}$	5.0 - 200 $\mu\text{m}$	8 - 12 $\mu\text{m}$	
Scene levels	<100 w/m <sup>2</sup> -sr	>100 w/m <sup>2</sup> -sr	<100 w/m <sup>2</sup> -sr	>100 w/m <sup>2</sup> -sr	All Levels
Accuracy Requirements	0.8 w/m <sup>2</sup> -sr	1.0 %	0.8 w/m <sup>2</sup> -sr	0.5 %	0.3 w/m <sup>2</sup> -sr
SOW Stability Requirements		< 0.14%/yr		< 0.1%/yr	
Climate Stability Goals		< 0.6 w/m <sup>2</sup> /dec < 0.03 %/yr		< 0.2 w/m <sup>2</sup> /dec < 0.02%/yr	

- Requirements for CERES are more stringent than ERBE's by a factor of 2
- Requirements per Ohring et. al. are more stringent than CERES by a factor of 3-5

***Calibrate, Calibrate, Calibrate....***



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# Why is CERES Climate Quality Calibration so difficult?

**A question of time scales, experience and balancing accuracy with providing data products to the community.**

- **Calibrated Radiances have been released on ~6 month centers**
- **6 months is just a blink of an eye when analyzing long term trends...**

**Same time scale as phenomena which influence instrument response**

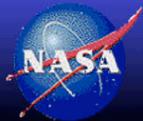
- **Beta Angle**
- **Earth Sun Distance**
- **Orbital shifts/maintenance/maneuvers**
- **Instrument Operational modes (I.e RAPS vs. Xtrack)**

**Design weaknesses and failures in onboard calibration hardware**

- **full spectral range of observations not covered by cal subsystems (PFM-FM6)**

**Complicates separation of instrument 'artifacts' from natural variability.**

**Edition3 reprocessing of the first 10 years of radiances allows a more rigorous identification and separation of instrument artifacts and climate signals.**



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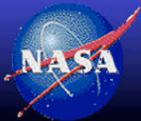


# Enabling Climate Data Record Continuity

## CERES Flight Schedule

Spacecraft	Instruments	Launch	Science Initiation	Collected Data (Months)
TRMM	PFM	11/97	1/98	9
Terra	FM1, FM2	12/99	3/00	133 +
Aqua	FM3, FM4	5/02	6/02	106 +
<i>NPP</i>	<i>FM5</i>	<i>9/11</i>	-	-
<i>JPSS - 1</i>	<i>FM6</i>	<i>2016 (TBR)</i>	-	-
<i>JPSS - 2</i>	<i>ERBS</i>	<i>2020 (TBR)</i>	-	-

**40 + Instrument Years of Data**



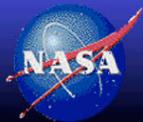
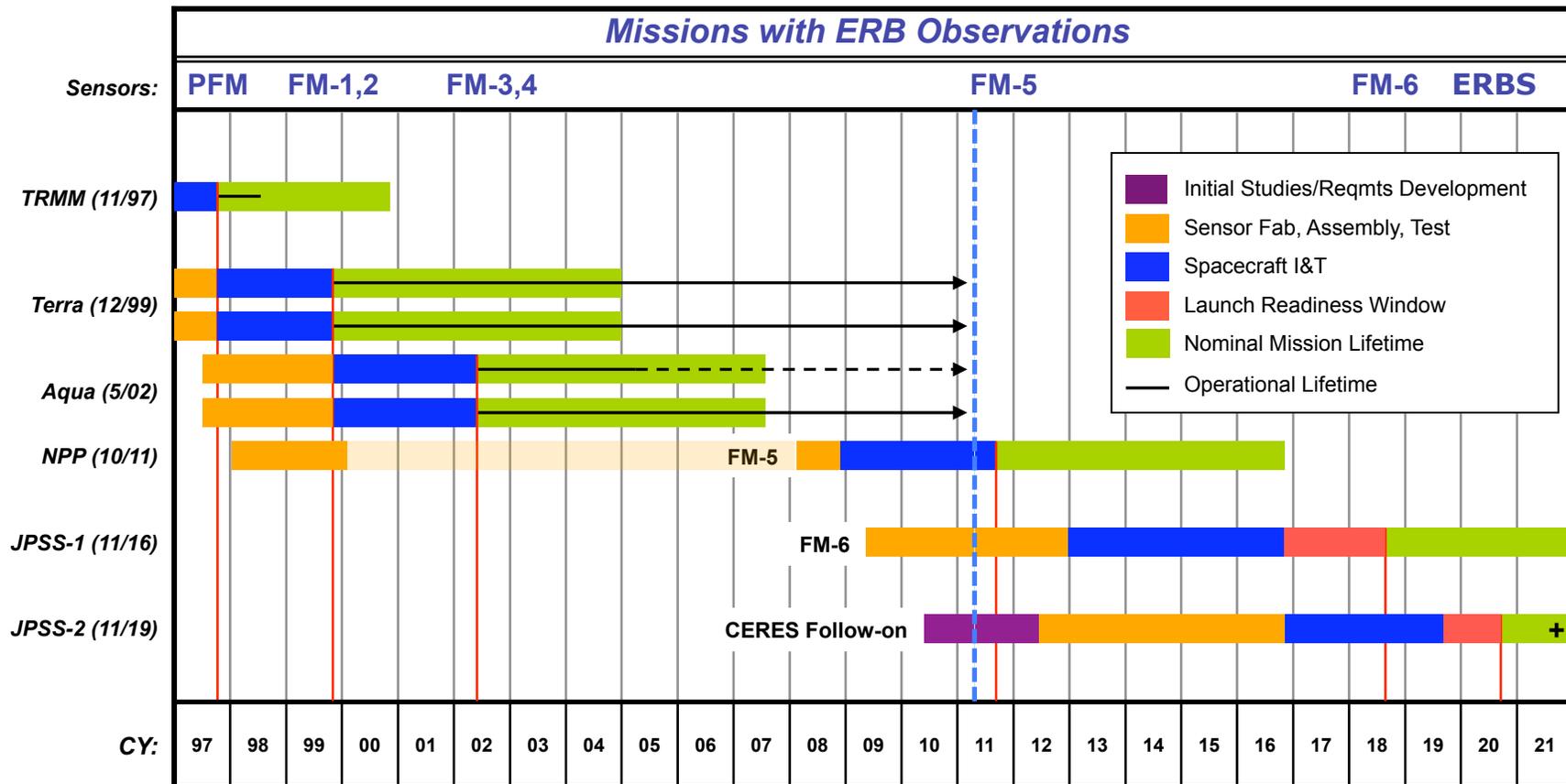
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# Enabling Climate Data Record Continuity

CERES

## CERES Flight Schedule



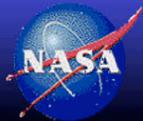
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# Enabling Climate Data Record Continuity

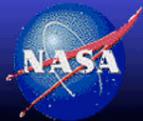
## Agency Roles and Responsibilities

Mission	Instruments	Responsible Agency (\$\$ in budget)		Implementation	
		<i>Hardware</i>	<i>Science, Data Processing</i>	<i>Hardware</i>	<i>Science, Data Processing</i>
EOS	PFM-FM4	NASA	NASA	NASA Procurement	NASA Science Team
NPP	FM5	NASA/ <b>NOAA</b>	NASA	NASA Procurement	NASA Science Team
JPSS-1	FM6	<b>NOAA</b>	<b>NOAA</b>	NASA Procurement	<b>TBR</b>
JPSS-2	CERES follow-on	<b>NOAA</b>	<b>NOAA</b>	NASA Procurement	<b>TBR</b>





# EOS Status



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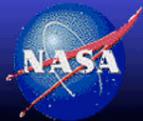


# CERES/EOS Operational History

With the exception of the SW channel on the CERES/Aqua FM-4 Instrument, the CERES Terra/Aqua instruments are functioning nominally...

Spacecraft	Instruments	Launch	Science Initiation	Collected Data (Months)
TRMM	PFM	11/97	1/98	9
Terra	FM1, FM2	12/99	3/00	133 +
Aqua	FM3, FM4	5/02	6/02	106 +
<i>NPP</i>	<i>FM5</i>	<i>10/11</i>	-	-
<i>JPSS - 1</i>	<i>FM6</i>	<i>2018</i>	-	-
<i>JPSS - 2</i>	<i>ERBS</i>		-	-

**40 + Instrument Years of Data**



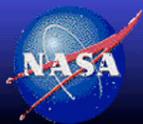
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# Terra/Aqua Instrument and ERBE-Like Availability

Spacecraft	Product	Version	Available	Months Processed
TRMM	BDS	Edition1	Yes	1/98 - 8/98 , 3/00
	ERBE-Like	Edition1	Yes	1/98 - 8/98 , 3/00
		Edition2	Yes	1/98 - 8/98 , 3/00
Terra	BDS	Edition1CV	Yes	2/00 - present
		Edition2	Yes	2/00 – 6/10
		Edition3	Yes	2/00 – 11/10
	ERBE-like	Edition1CV	Yes	3/00 - present
		Edition2	Yes	2/00 – 6/10
		Edition3	ASDC Testing	3/00 – 11/10
Aqua	BDS	Edition1CV	Yes	6/02 - present
		Edition2	Yes	6/02 – 6/10
		Edition3	Yes	2/00 – 11/10
	ERBE-like	Edition1CV	Yes	7/02 - present
		Edition2	Yes	7/02 – 6/10
		Edition3	ASDC Testing	7/02 – 11/10

Note: Red cells indicate datasets that are no longer in production.



# Cal/Val Protocol Overviews

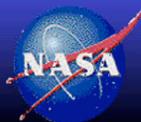
**Edition1\_CV - Static Algorithms and coefficients - baseline product used in cal/val protocol**

**Edition2 - Utilizes temporally varying coefficients to correct for traceable radiometric drift. All spectral changes are broadband and 'gray'.  
*(EOS Ed2 Production ended with 6/2010)***

**Edition3 - Accounts for temporally varying spectral artifacts in the SW and LW measurements.**

**User Applied Revisions - Advance capabilities to the users prior to the release of the next Edition.**

**Edition3 products lag Edition1 by a minimum of 6-12 months**



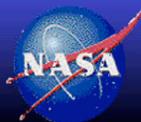
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# CERES Calibration Input Parameters

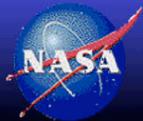
## Coefficients updated in Cal/Val Protocols Traceability Matrix

Category	Parameter	Edition1	Edition2	Edition3
Radiometry	Gain	Static	Piecewise linear ~ 6 month intervals	Continuous, based upon ICS
	Spectral Response	Static	Gray Changes	Wavelength Dependent Changes
	Scan Dependent Offsets	Ground	Ground	Terra - DSCAL Aqua - TBD
	2 <sup>nd</sup> Time Constant	Ground	Ground	Flight
	Thermal Correction	Common Correction	Common Correction	Instrument Specific
	IBB PRT Coefficients	Static	Static	Static
Pointing	Alignment	Static	Static	Static
	Gimbal Offsets	Static	Static	Static
	Time Response	Static	Static	Static





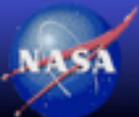
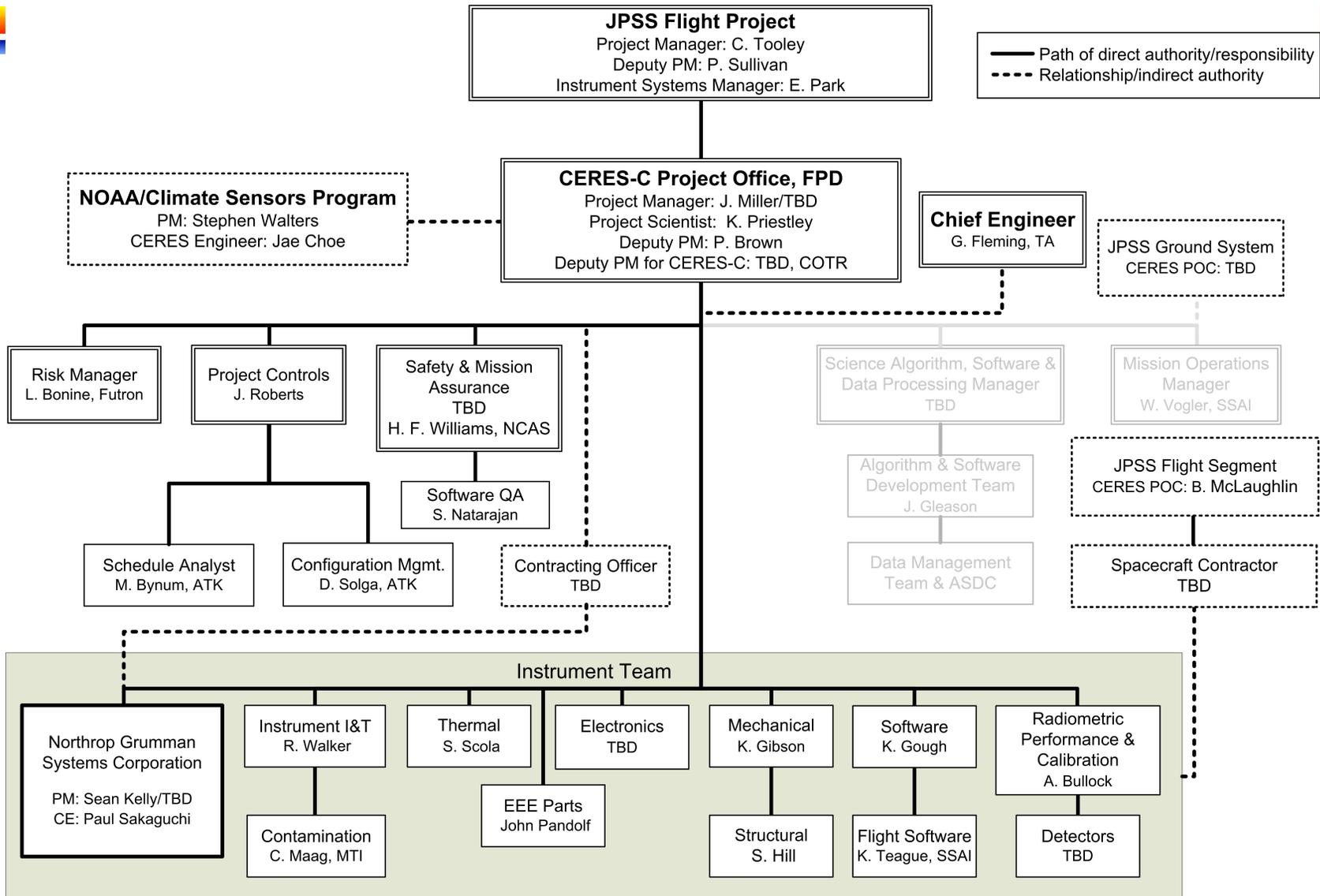
# FM-5 on NPP Status



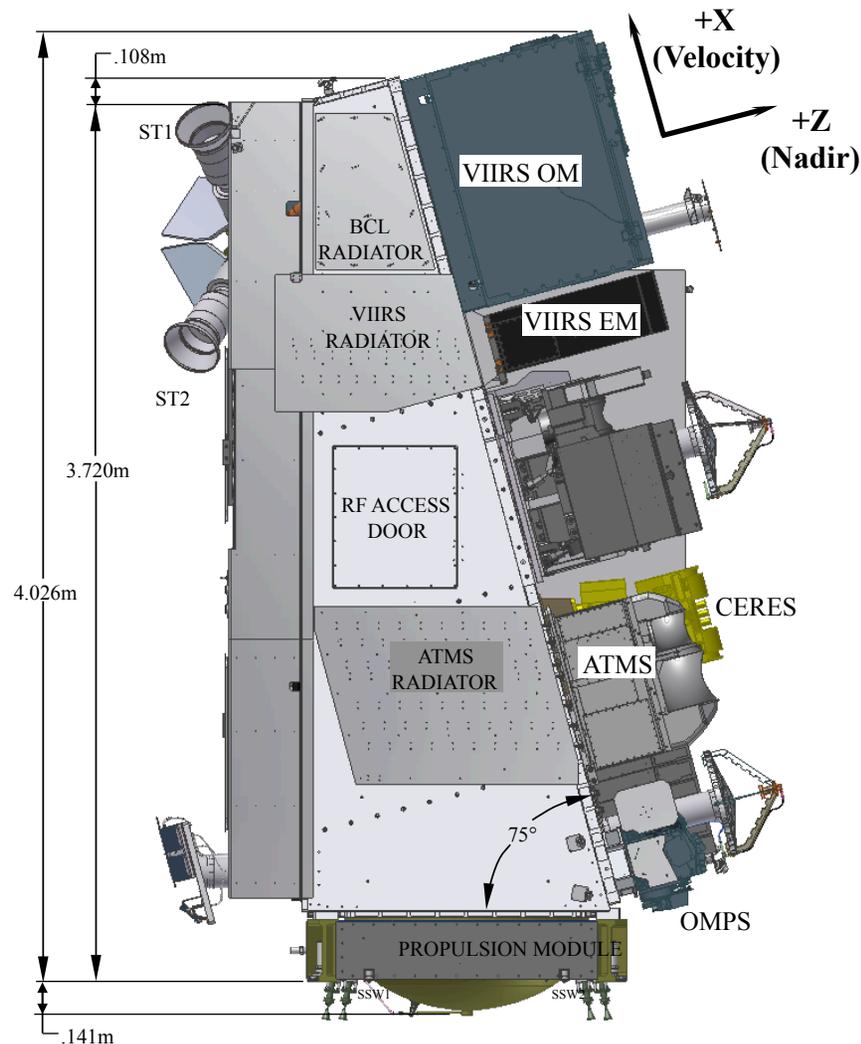
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# CERES Flight Project Organization

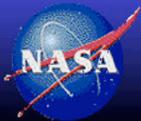


# CERES Compatibility with NPP Spacecraft



## Observatory Information

- Launch Readiness October, 2011
- Location - Vandenberg AFB
- Launch Vehicle - Delta II
- Altitude - 824 Km
  - CERES FOV increases to ~ 24Km
- Inclination - Sun-Synch, 98.7-deg
- Crossing Time - 1:30pm, Ascending
- Payload -
  - CERES
  - VIIRS
  - OMPS
  - CRIS
  - ATMS

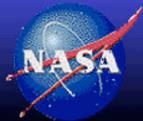


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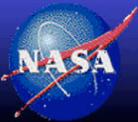
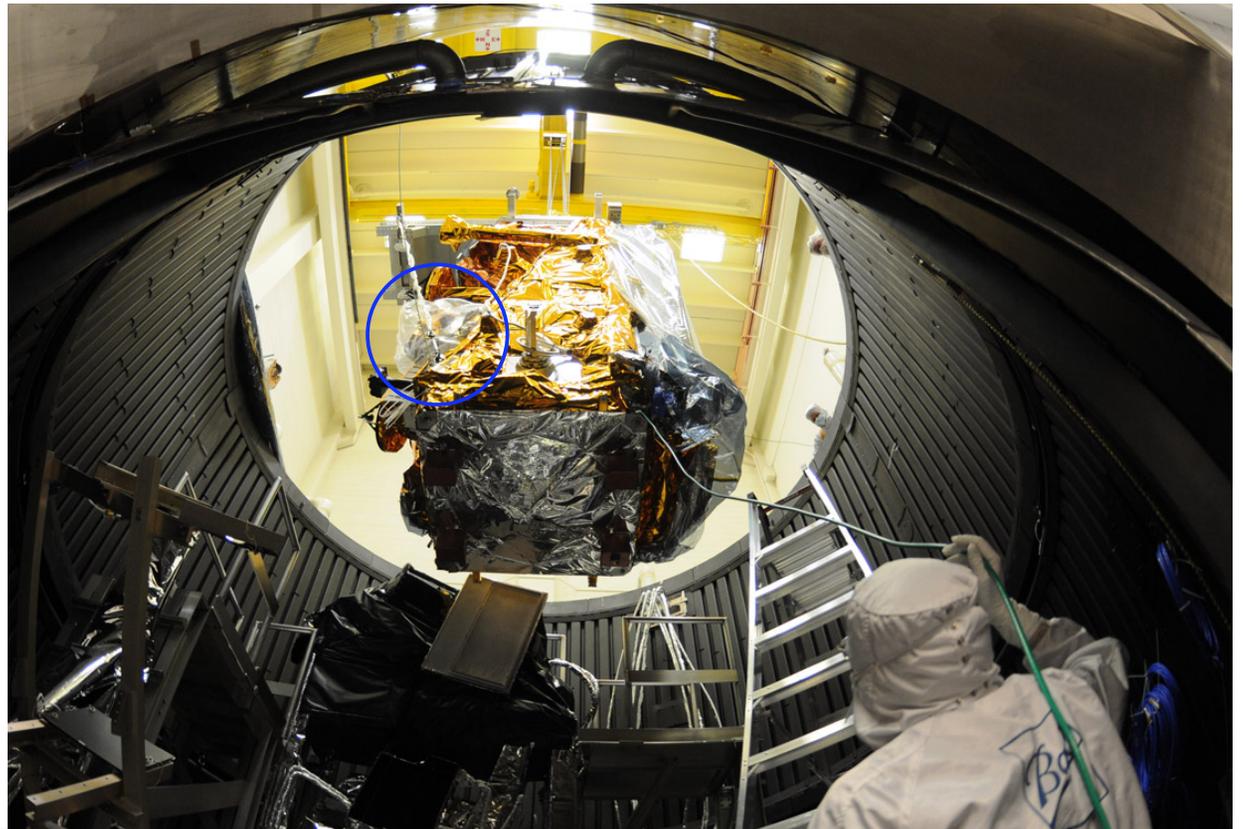


# CERES FM5 Hardware Status & Near-Term Activities

- **Fabrication, Assembly and Test Program is complete**
  - Ground Calibration was most extensive to date in the CERES Program
- **System Acceptance Review 10/30 at NGST**
- **Shipped to BATC on 11/2/09**
- **Mechanical/Electrical Integration to NPP spacecraft completed 11/11/08**
- ***Observatory Pre-environmental Test Readiness Review 9/20-21/10***
- ***Spacecraft Environmental Campaign 11/10-4/11***
- ***Operational Readiness Review 6/20-24/11***
- ***Satellite Pre-Ship Review 8/2/11***
- ***Mission Readiness Review (L-75) 9/6/11***
- ***Flight Readiness Review (L-4) 10/21/11***
- ***Launch Readiness Review (L-1) 10/24/11***
- ***NPP 'Official' Launch Readiness Date is currently October 25, 2011***
  - *Initial NPP launch date was mid-2006*



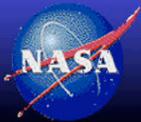
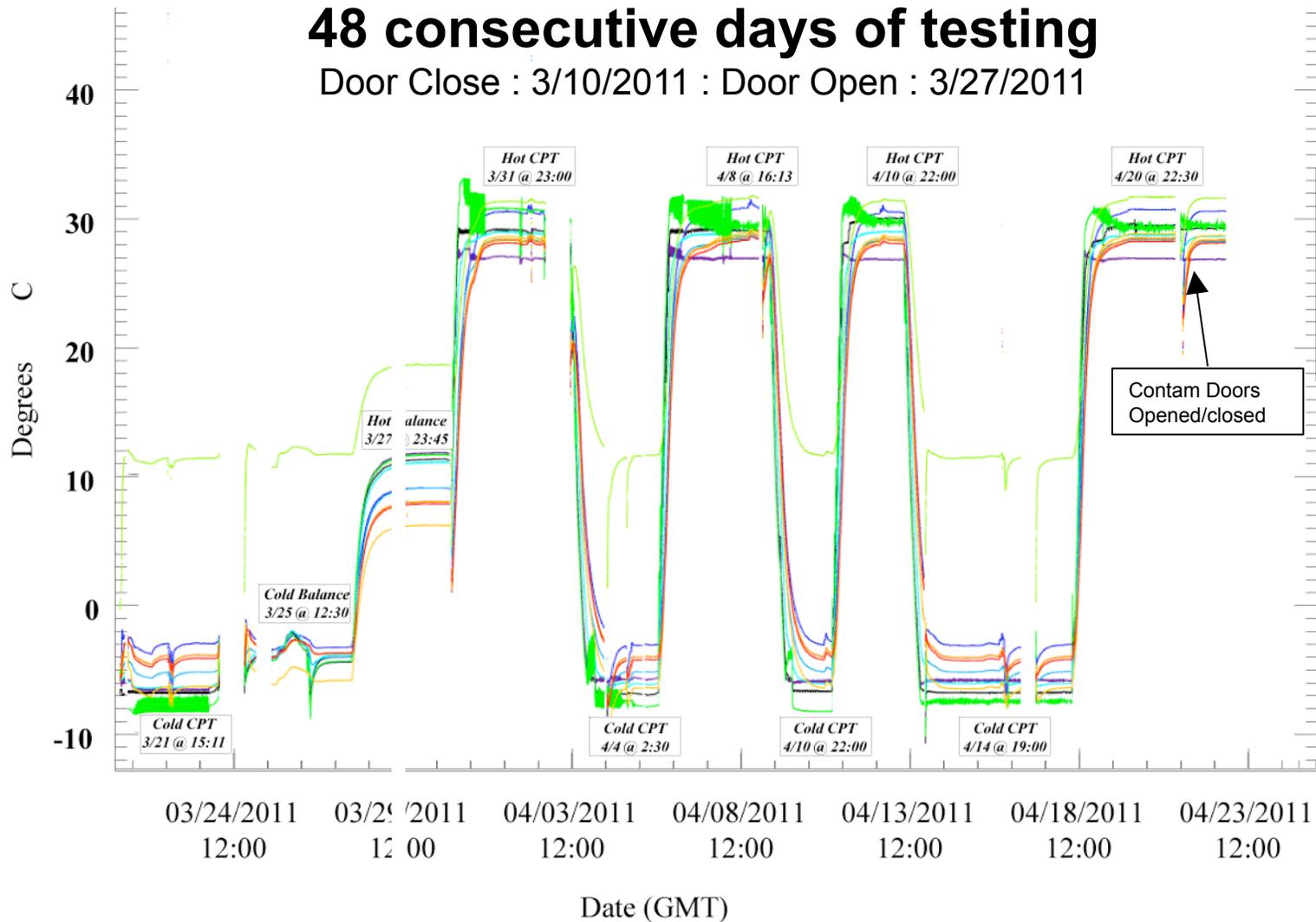
# Observatory TVAC Testing Complete



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# CERES FM-5 on NPP TVAC Timeline

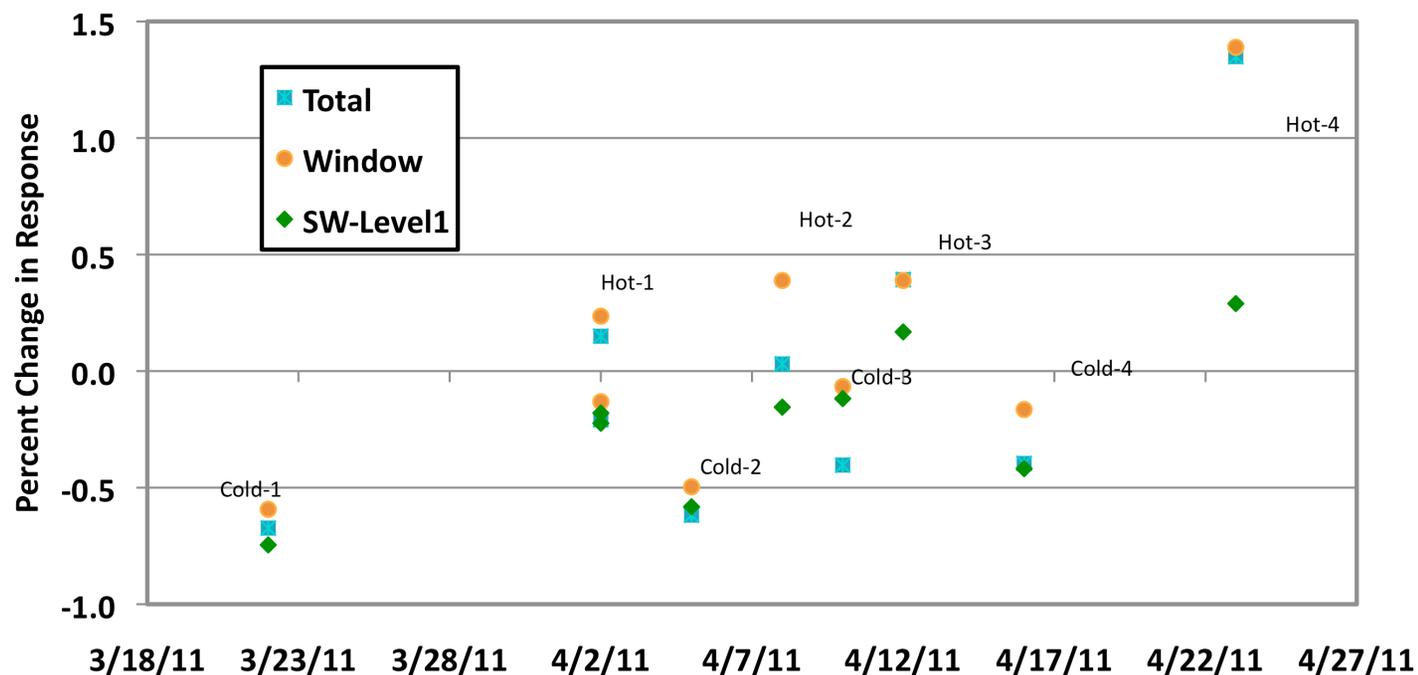


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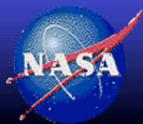


# FM-5 TVAC Internal Cal Results

CERES FM5 NPP Thermal VAC Calibration Trends  
(Comparison with Instrument-level Calibration)



***CERES is the only instrument with no outstanding instrument or science related TAWSs.***

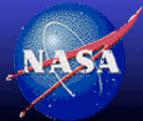


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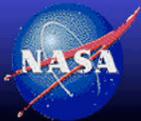
# NPP Path to Launch – Ground System Prep

- Update NPP RDR Preprocessor software to fix issues discovered during NCT 3 Part II.
  - Delivery to CERES CM May 6 (L-5 months).
- Update NPP Instrument Main Processor software to fix issues discovered during TVAC and NCT 3 Part II.
  - Delivery to CERES CM May 13 (L-5 months).
- Provide updated instrument parameters, gains, spectral response functions, etc. (Scan dependent offsets set to zero, Second Time Constant correction turned off)
  - Delivery to CERES CM July 25 (L-3 months).
- Flight Verification of NPP RDR Preprocessor/Instrument Main Processor during NCT 4 (7/5-18/11).
  - Delivery any final updates CERES CM 2 weeks after NCT 4 (L-3 months).



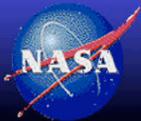
# Post-Launch Data Product Strategy

- First 6 months after launch (Edition1\_CV)
  - Analyze in-flight data to determine any changes to Instrument parameters, gains, spectral response functions, scan dependent offsets, etc.
- 1 year after launch (Edition2)
  - Delivery to CERES CM, ground based scan dependent offsets, turn-on second time constant calculations with values determined after launch, update gains if necessary with in-flight values (if large changes seen in-flight vs ground).
- 2 to 3 years after launch (Edition3)
  - Determine if any gain and spectral response function trends have occurred during the mission. Delivery to CERES CM updated gains (including ground to flight shifts) and spectral response functions, deep space cal determined scan dependent offsets, etc.

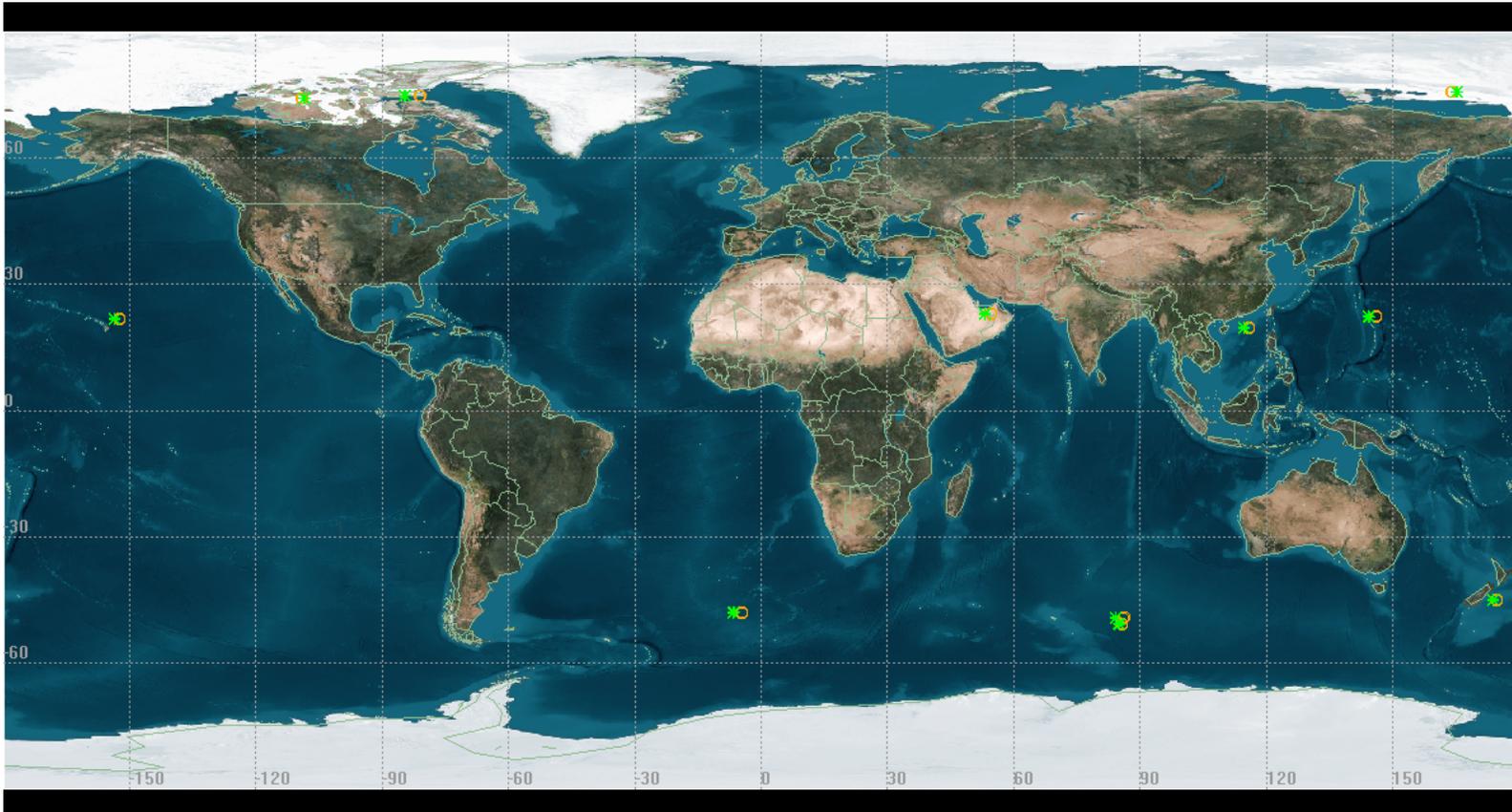


# Aqua/Terra and NPP Intercomparison Opportunities

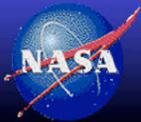
- **Primary comparison - Aqua and NPP:**
  - Ascending 1330 orbits, inclination angles differ by about  $0.5^\circ$ 
    - Simultaneous (within 6.6s)
      - » Groundtrack difference for lat < 0.25 deg; lon < 2 deg
      - » Each opportunity lasting 1 minute
    - Matched sites (within 0.25deg)
      - » Time differential < 5 min.
      - » Groundtrack difference for lat < 0.25 deg.; lon < 0.25 deg
      - » Varying duration of each opportunity from 1 to 5 minutes
- **Secondary comparison - Terra and NPP:**
  - Descending 0930 and Ascending 1330 orbits
    - Matched sites (within 0.25deg)
      - » Time differential < 5 min.
      - » Groundtrack difference for lat < 1.0 deg.; lon < 1.0 deg
      - » Duration of each opportunity ~20 seconds



# Aqua and NPP : Simultaneous Matches



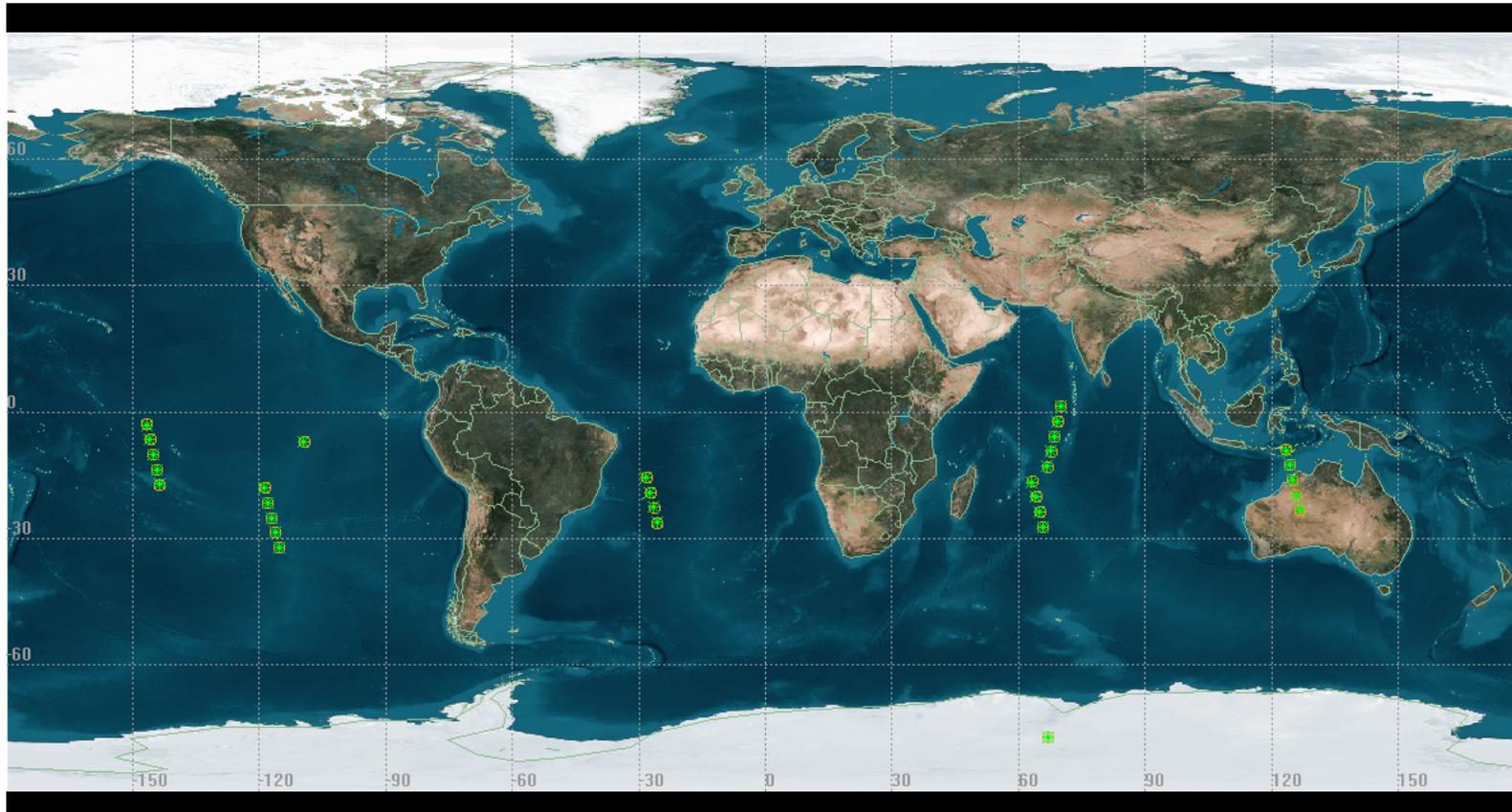
11 day-night opportunities within 27 days; about 64 hours apart



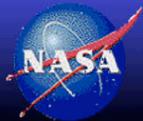
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# Aqua and NPP : Matched Sites



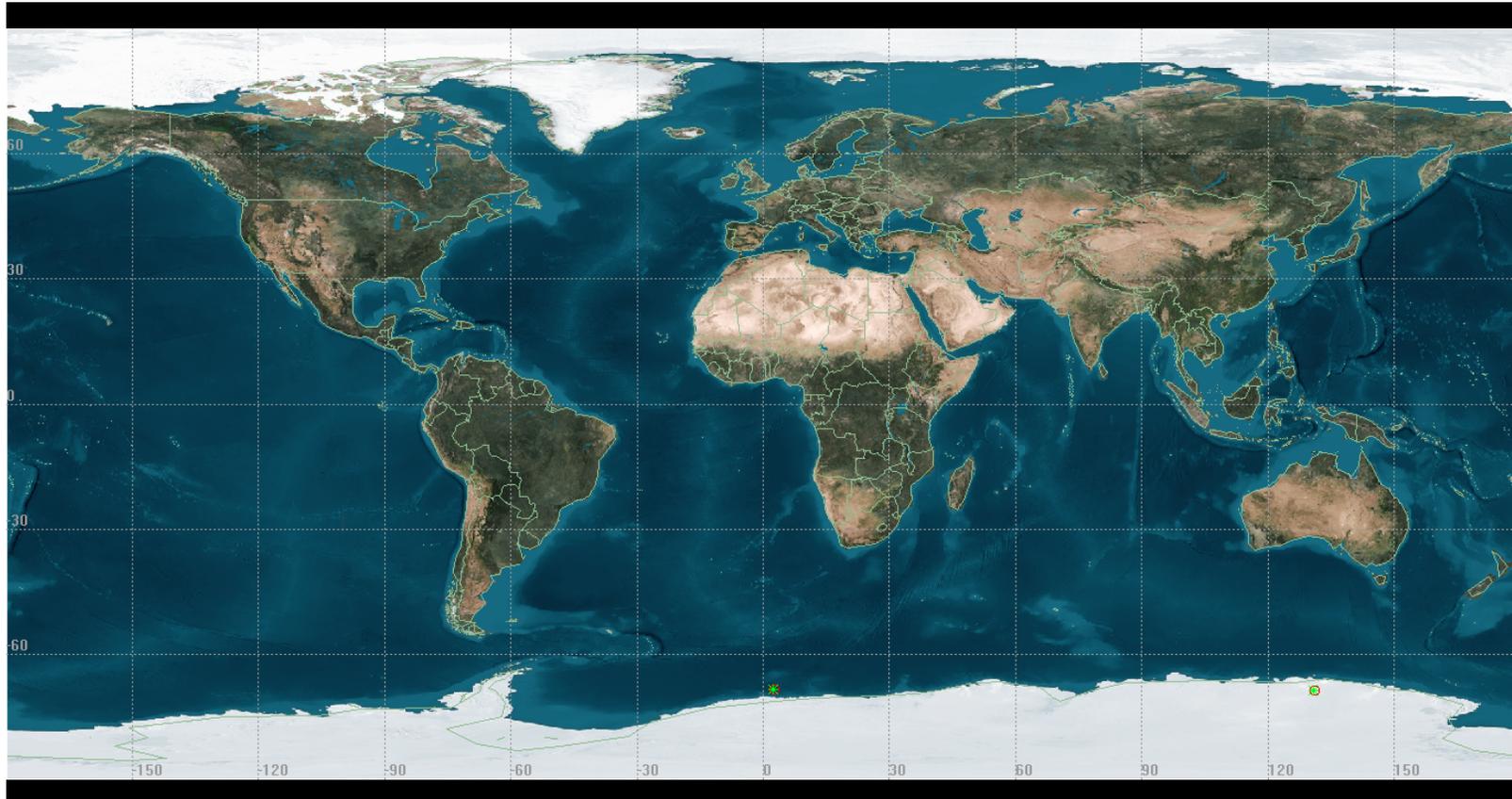
8 day-night opportunities within 27 days



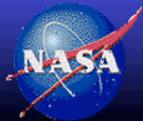
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# Terra and NPP : Matched Sites



2 night opportunities within 27 days



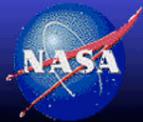
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# Summary

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## NPP Mission Video

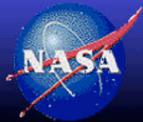


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# FM-6 on JPSS-1 Status

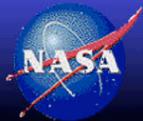


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# CERES FM6 Status & Near-Term Activities

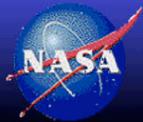
- Project received ~\$5M for FM6 in CY08
- Allowed for enhanced study phase only, start 11/08
- Long Lead item procurements authorized 3/09
- Contract negotiations completed 4/23/09
- Key Milestone Dates (Preliminary)
  - Authority To Proceed – 5/1/09
  - Systems Readiness Review – 9/22/09
  - Delta Preliminary Design Review – January 2010
  - *Delta Critical Design Review – September 28, 2010*
  - *All major subassemblies delivered to NG, currently in sensor I&T*
  - *Ground Calibration Campaign – Spring 2012*
  - *Delivery – Summer/Fall 2012*
  - *Launch Readiness Date of Jan, 2015 (TBR)*
  - *Launch Date of Oct. 2016 (TBR)*



# Summary

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## NPP Mission Video

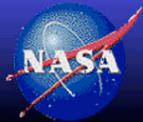


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# BACK-UP SLIDES

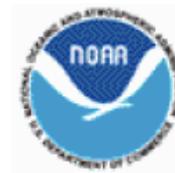


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# Achieving Satellite Instrument Calibration for Climate Change (ASIC<sup>3</sup>)



Report of a Workshop Organized by

National Oceanic and Atmospheric Administration  
National Institute of Standards and Technology  
National Aeronautics and Space Administration  
National Polar-orbiting Operational Environmental Satellite System-  
Integrated Program Office  
Space Dynamics Laboratory of Utah State University

At the National Conference Center, Lansdowne, VA, May 16-18, 2006

Edited by George Ohring

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Stephen Ungar	Bruce Wielicki	David Winker
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June 2007



DRAFT



# ASIC<sup>3</sup> (2006) Workshop Recommendations

- Partially ***redundant on-board calibrations*** to improve knowledge of instrument stability. Improvements are needed in broadband MAM or diffuser designs to meet the new climate stability requirements.
- More ***careful attention be paid to potential contamination of optical surfaces*** for climate instruments during ground testing, as well as improving the technologies for measuring and correcting any potential contamination.
- Flight of the CERES FM-5 instrument use only the crosstrack scan mode to avoid in-orbit contamination of the SW channel optics. ***We also recommend that future calibration observatories in space be designed to explicitly account for expected in-orbit contamination***, even if its level is small.
- ***Future broadband instruments should examine the potential for 0.3 to 0.5  $\mu\text{m}$  sources*** such as small nonlinear optics lasers to explicitly monitor throughput below 0.5  $\mu\text{m}$ . This issue appears to exist for all instruments measuring solar radiation with wavelengths below 0.5  $\mu\text{m}$  and should be accounted for in calibration system design.

