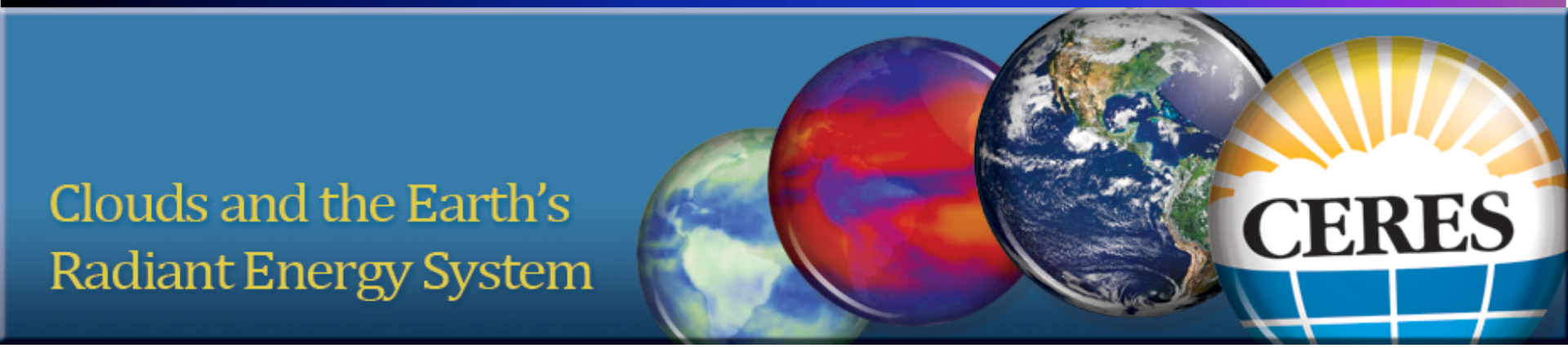
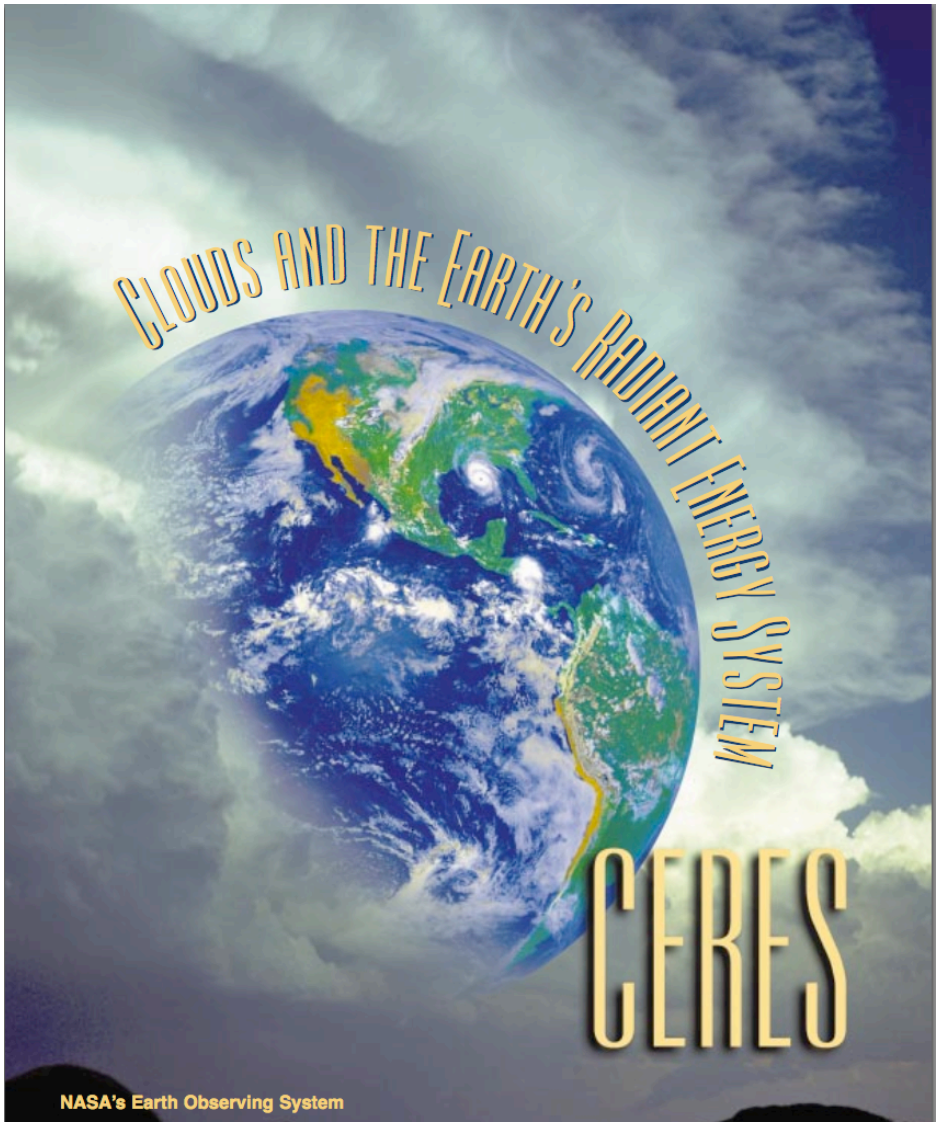


CERES FM6
Calibration Subsystem Performance Issues

Kory Priestley - Project Scientist
Audra Bullock - Chief Engineer

CERES Science Team Meeting
NASA LaRC
May 7, 2013

Discussion Topics



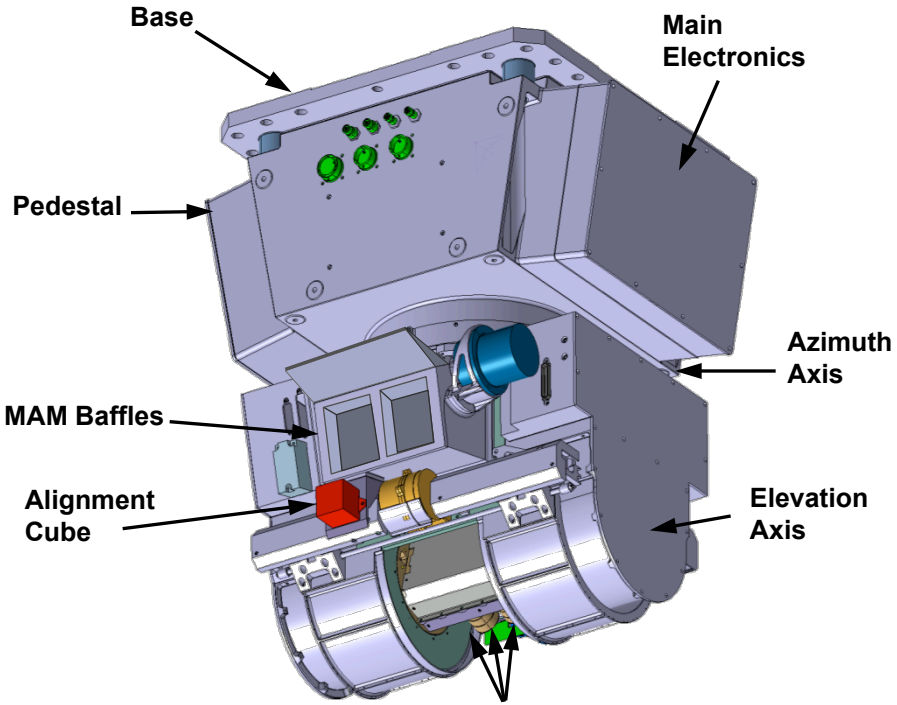
- **CERES Instrument**
  - Description
- **Issues uncovered during FM6 ground calibration (May 2012)**
  - Solar Diffuser non-uniformity
  - SWICS Lamp instability
  - SWICS Reference Detector instability
- **Recovery Status**
- **Programmatics**
  - Schedule/Workplan

CERES Instrument

Clouds and the Earth's Radiant Energy System

- **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**

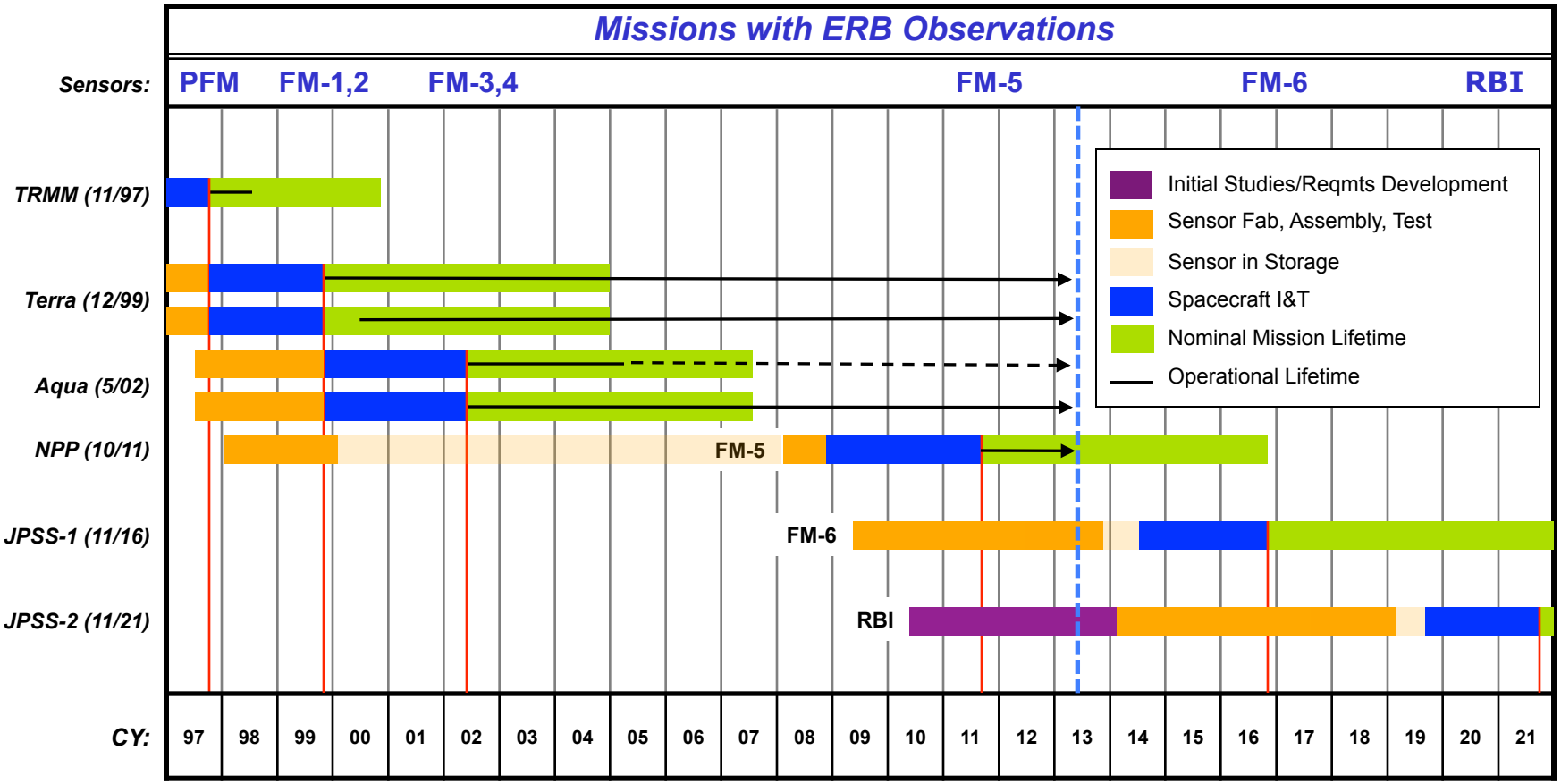
Orbits	705 km altitude, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (PM-1), sun-synchronous, near-polar; 350 km altitude, 35° inclination (TRMM)
Spectral Channels	Solar Reflected Radiation (Shortwave): 0.3 - 5.0 μm Window: 8 - 12 μm , 5 – 40 μm (FM6) Total: 0.3 to > 100 μm
Swath Dimensions	Limb to limb
Angular Sampling	Cross-track scan and 360° azimuth biaxial scan
Spatial Resolution	20 km at nadir (10 km for TRMM, 28 km for NPP)
Mass	45 kg
Duty Cycle	100%
Power	45 W
Data Rate	10 kbps
Size	60 x 60 x 70 cm (deployed)
Design Life	6 years



Enabling Climate Data Record Continuity

Clouds and the Earth's Radiant Energy System

CERES Flight Schedule



CERES FM6 Instrument Performance Issues

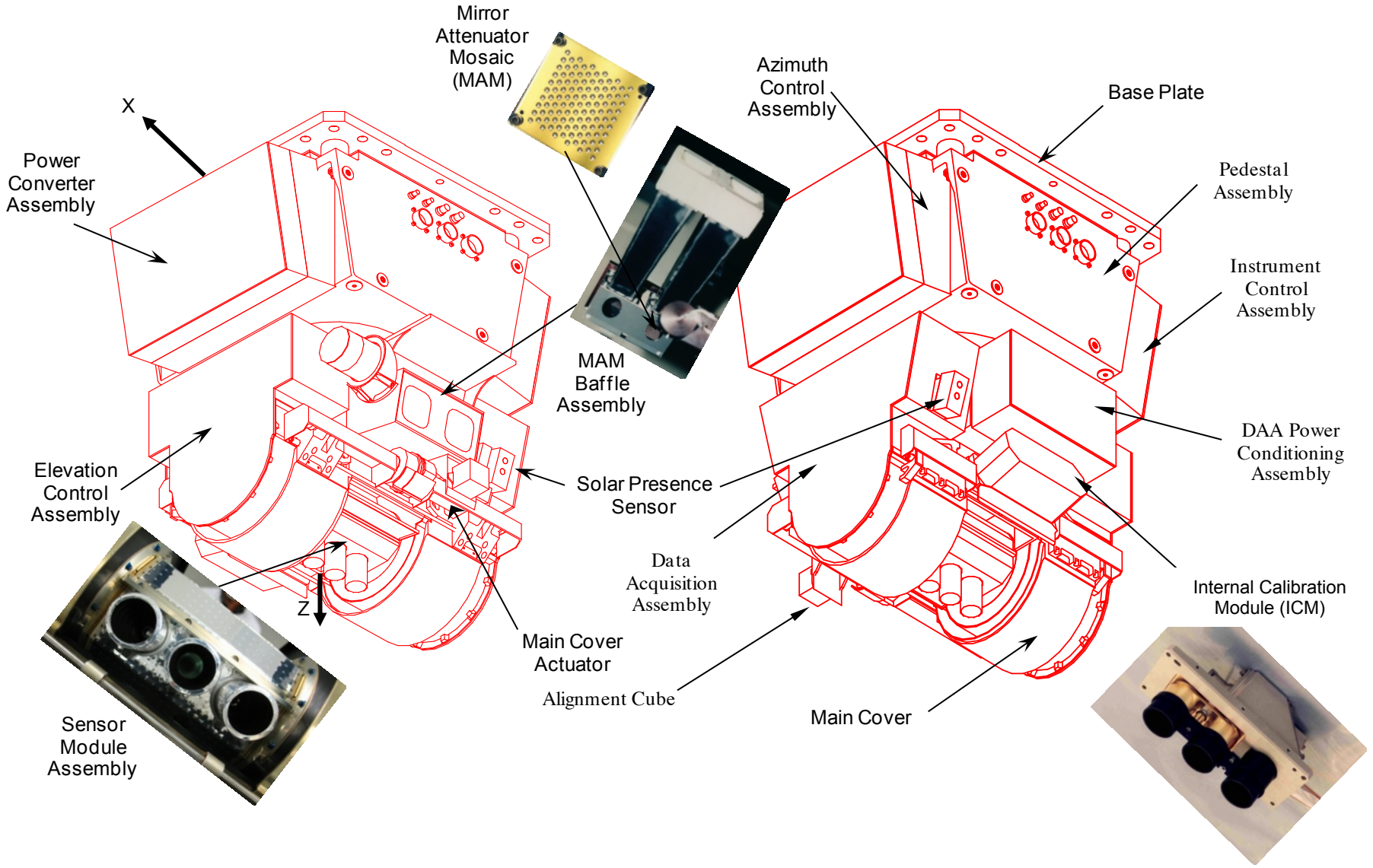
- The CERES FM6 Team continues to pursue resolution of three issues:

  1. Solar Diffuser Mirror Attenuator Mosaic (MAM) scatter non-uniformity
  2. Internal Calibration Module (ICM) lamp brightening
  3. Internal Calibration Module (ICM) reference detector photodiode (PD) response decrease

- In May of 2012, FM6 had completed its baseline calibration with the following open issues:
  - SWICS lamp appears to have increased in brightness throughout the calibration campaign whereas the source monitor photodiode indicated a decrease in source output throughout the calibration campaign
  - Data from MAM scatter testing indicate spatial non-uniformity of >4.5% vs. 1.5% measured at component level.
  - If not resolved, CERES FM-6 will not meet its on-orbit SW channel performance accuracy requirement

CERES Instrument Description

Clouds and the Earth's Radiant Energy System



Performance Resolution Approach

ICM Resolution

- 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 heritage or CERES FM6 parts

MAM Resolution (Complete)

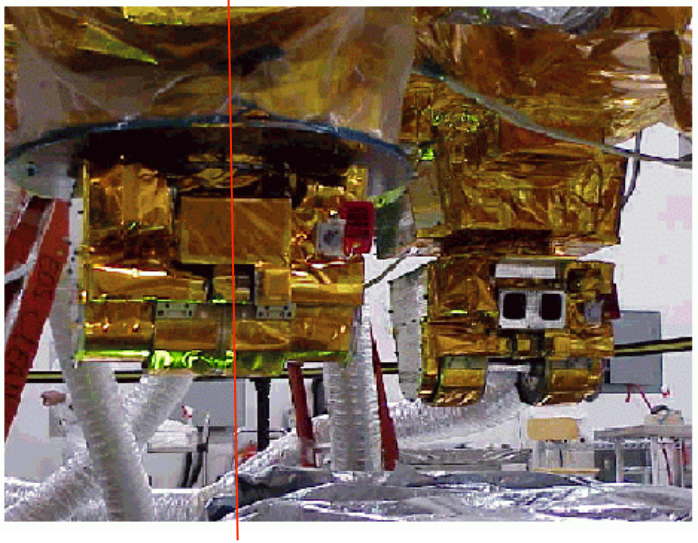
- Isolate Performance Problem
  - Diamond-Turned Tooling marks have been identified as the source of MAM performance issue
- Select replacement flight MAM from CERES heritage MAMs
  - Pe-condition MAM using AO asher from GRC

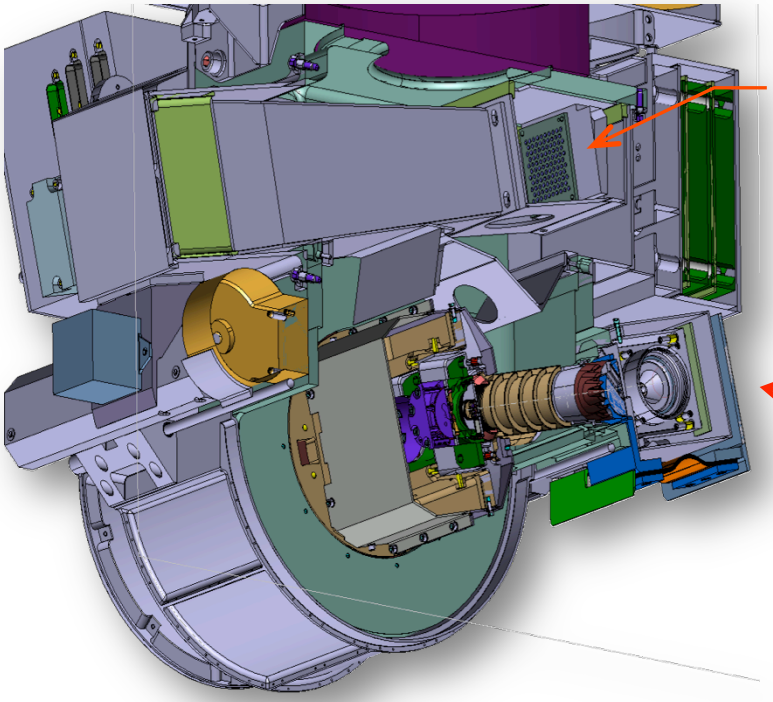
- Verify ICM performance in vacuum
- Verify Instrument Performance
- Conduct SAR/PSRR

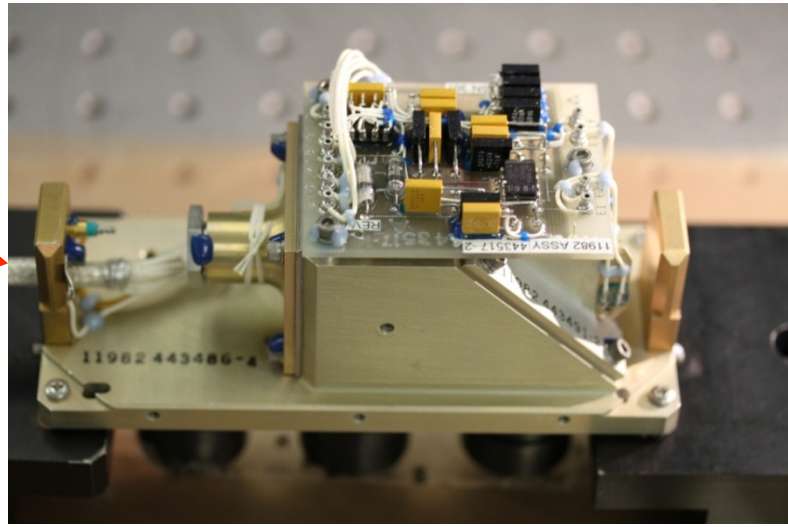
CERES FM6 Instrument Status

Clouds and the Earth's Radiant Energy System

- **CERES FM6 Calibration subsystem issues:**
  1. ***Solar Diffuser Mirror Attenuator Mosaic (MAM) scatter non-uniformity***
  2. Internal Calibration Module (ICM) lamp brightening
  3. Internal Calibration Module (ICM) photodiode reference detector response decrease







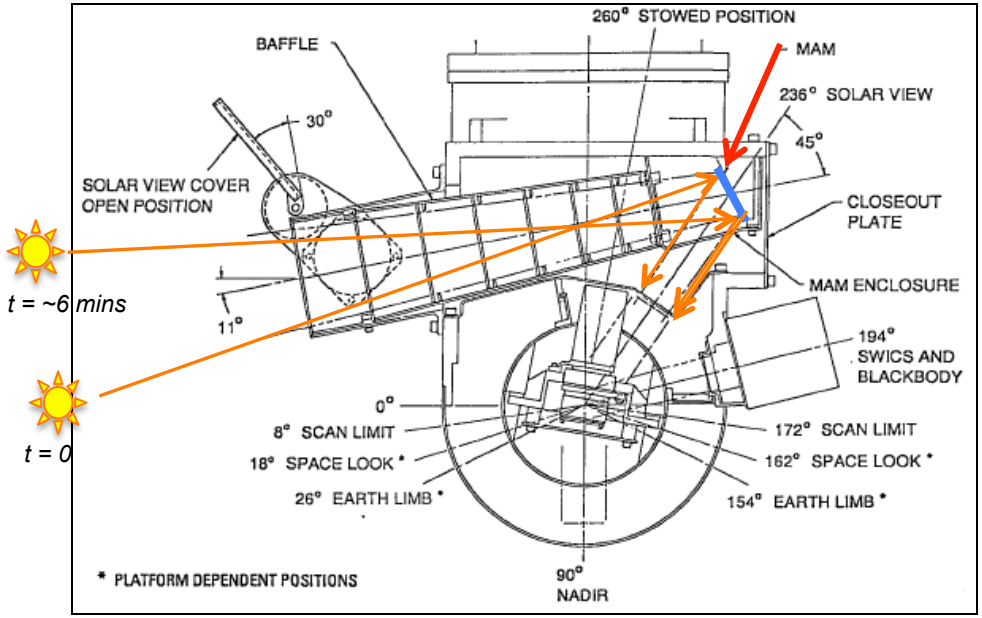
2 MAMs installed in CERES Instrument: SW & Total

CERES FM6 MAM Overview

- Mirror Attenuator Mosaics (MAMs) ***diffuse*** and ***attenuate*** incident solar energy so that the CERES Shortwave and Total Channels are presented with repeatable, on-scale radiance scenes over the range of incident angles experienced during periodic, on-orbit, solar calibrations.
- MAMs fabricated for FM6 are different than prior flight units
  - Substrate is Diamond Turned Aluminum vs. Electroformed Nickel
  - Coatings updated for improved resistance to Atomic Oxygen

MAM Goal
minimize variability in reflected solar energy over all incident angles

- Why did we change Fab process?
  - Diamond turned aluminum substantially easier to fabricate than electroformed nickel and electroform/grinding process has low yield ~25%.

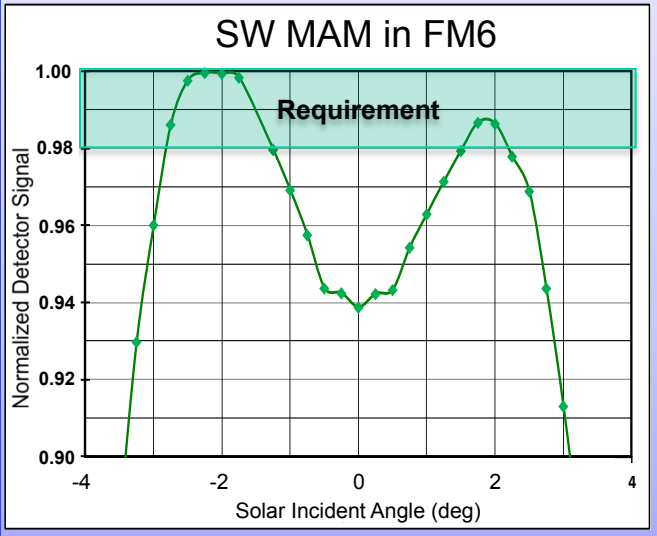


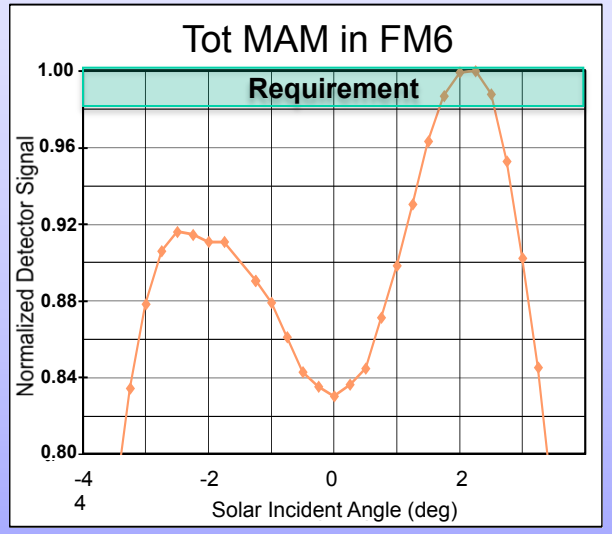
CERES MAM Assembly

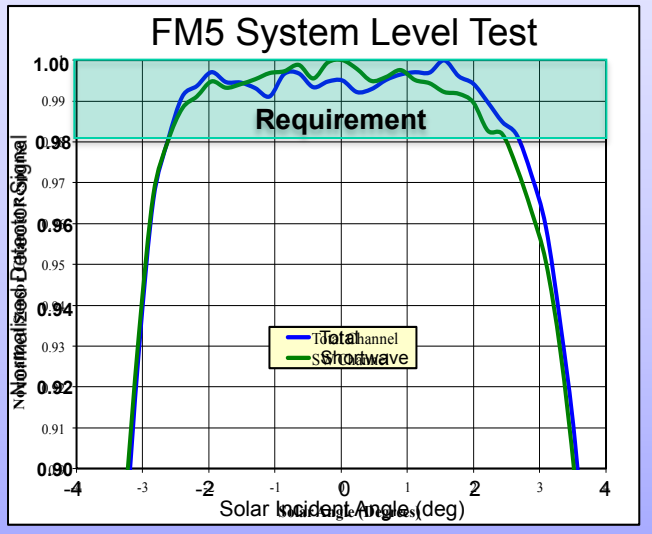
MAM Scatter Uniformity Issue
(Instrument Level Testing)

Clouds and the Earth's Radiant Energy System

Uniformity Requirement ±1% over 4.5° Solar Angle

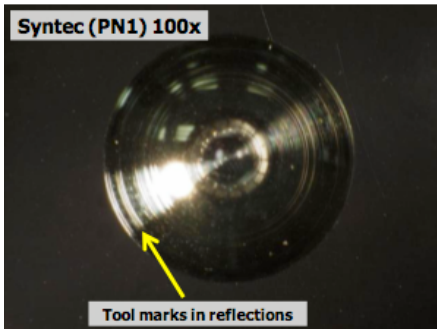


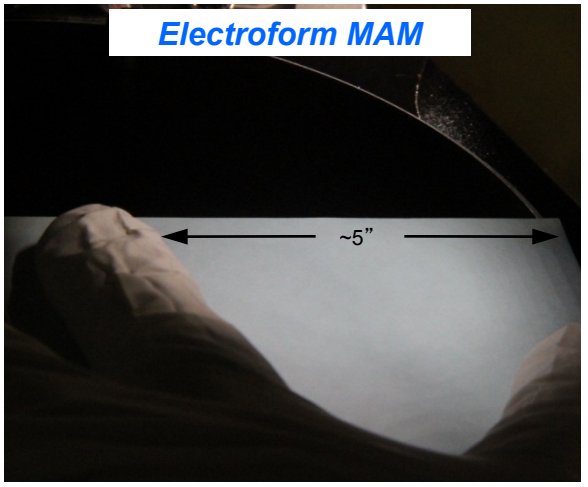




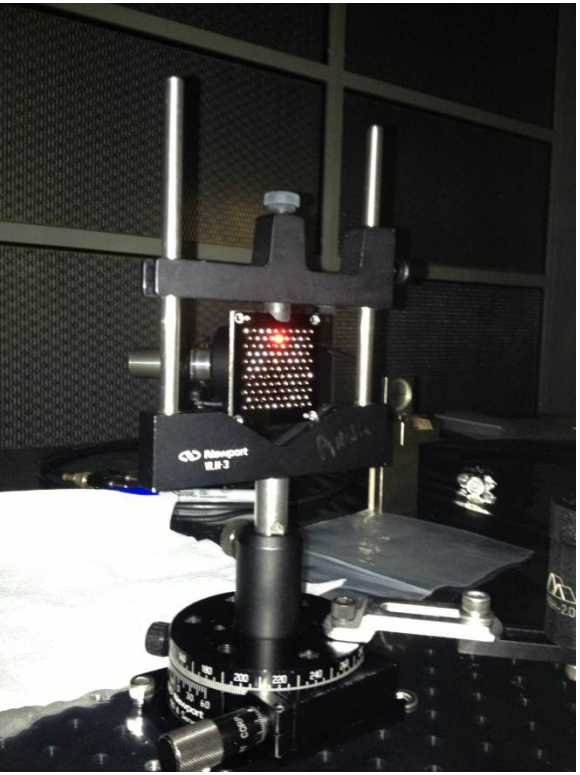
Two contributors identified:

- Solar Simulator non-uniformity
- Diamond-turning resulted in fringed scatter pattern



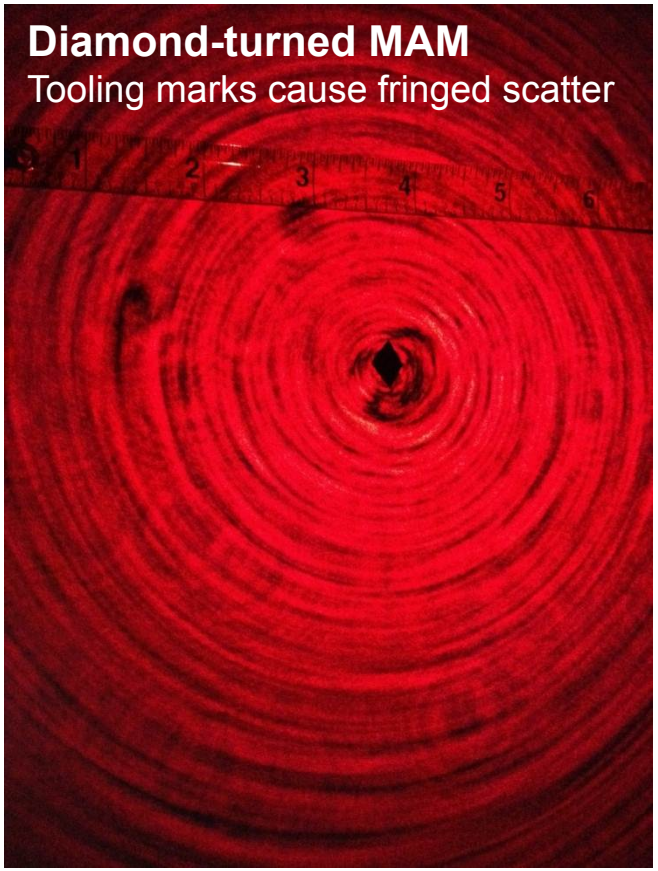


Diamond-turned vs Nickel MAM
Laser Illuminating Single Dimple



Lesson Learned:

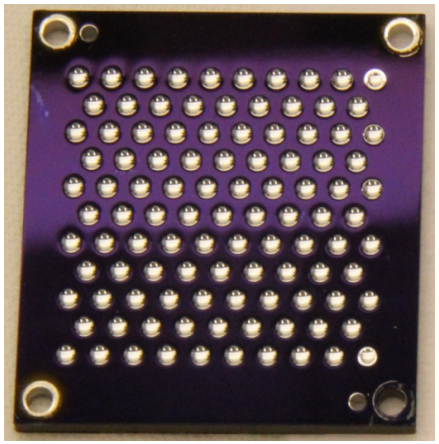
The diamond-turning process is plagued with issues of tooling marks



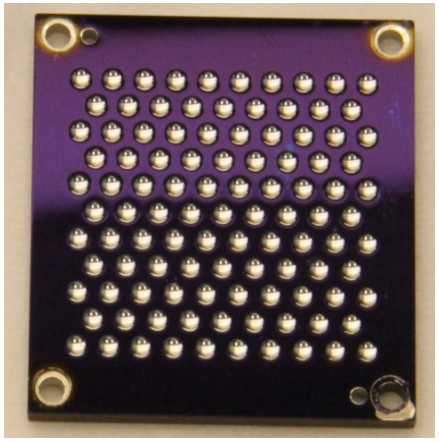
MAM Resolution

- **NG located 2 legacy MAMs of the FM4 vintage**
  - Parts removed from flight status in late 90's for surface blemishes
  - Parts bagged and stored in controlled environment during interim
- **Scatter uniformity meets requirements with margin**
- **AO coating susceptibility corrected**
  - LaRC & NG collaborated with GRC to fully oxidize protective coating *(Complete)*
- **MAMs upscreened and ready for installation 3 weeks ahead of schedule**
  - Coating adhesion testing *(Complete)*
  - Component scatter test post AO exposure *(Complete)*

S/N E1/B3

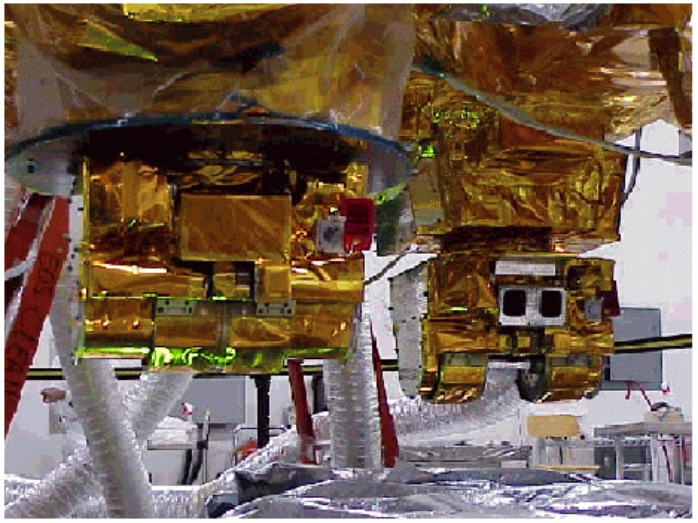


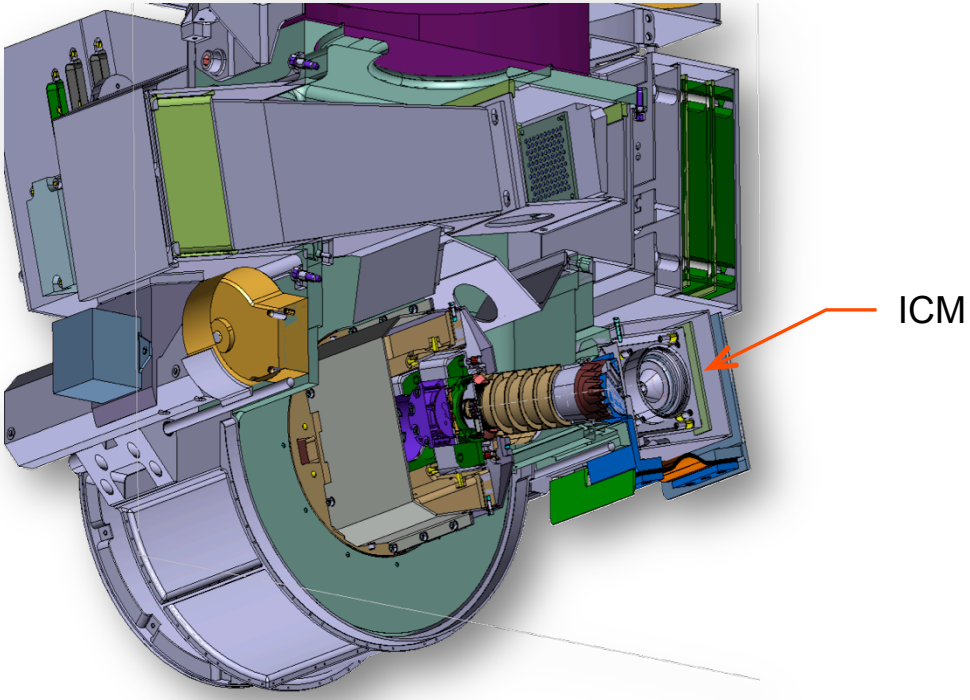
S/N C4

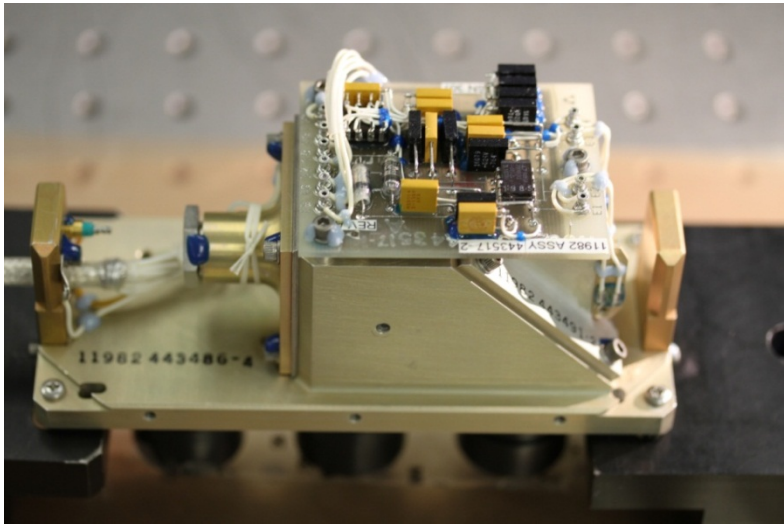


CERES FM6 Instrument Status

- **CERES FM6 Calibration subsystem issues:**
  1. Solar Diffuser Mirror Attenuator Mosaic (MAM) scatter non-uniformity
  2. ***Internal Calibration Module (ICM) lamp brightening***
  3. ***Internal Calibration Module (ICM) photodiode reference detector response decrease***







CERES Internal Calibration Module

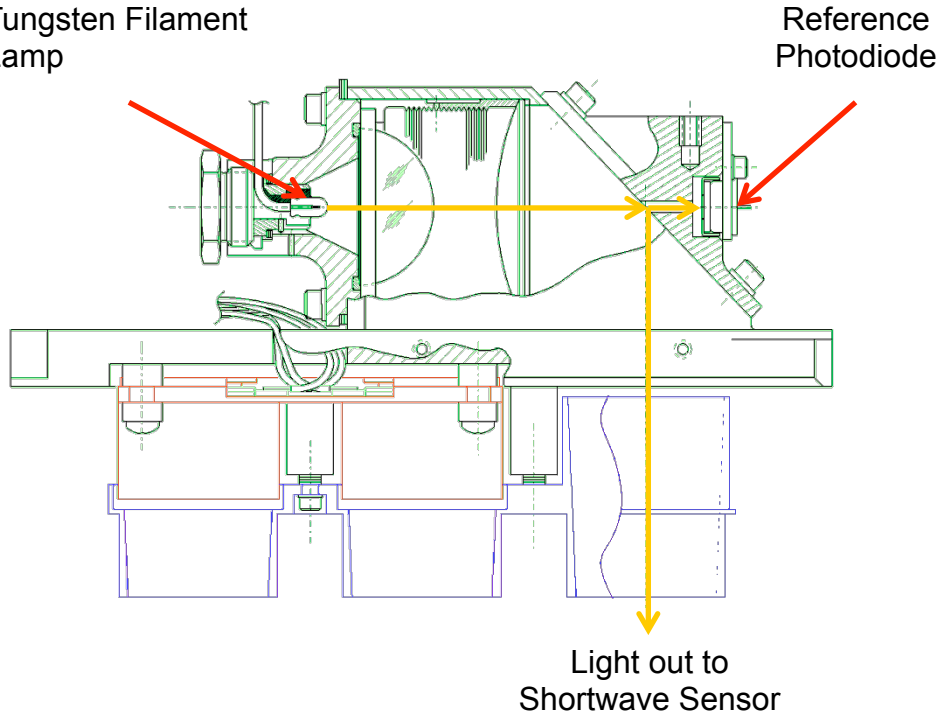
Clouds and the Earth's Radiant Energy System

ICM contains 2 subassemblies

Shortwave Internal Calibration Source (SWICS):
- Lamp and focusing optics
- Reference Detector
- Folding Mirror

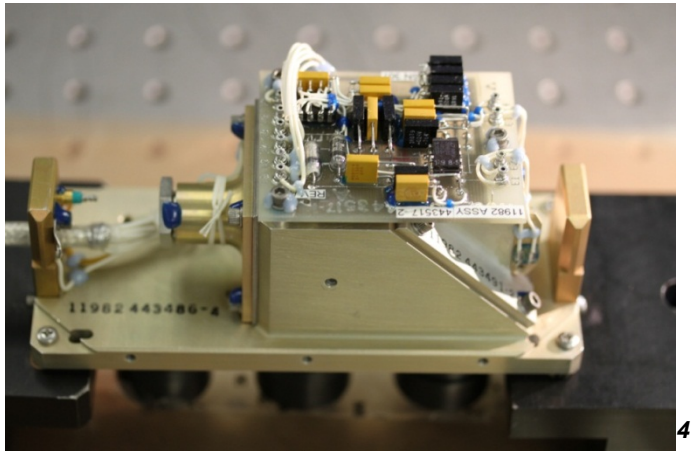
Internal BlackBody (IBB):
- Concentric grooved blackbodies
- Heaters and PRTs

During Calibration we view the SWICS lamp with two independent detectors CERES SW sensor and Reference Photodiode



Instrument vacuum calibration results:

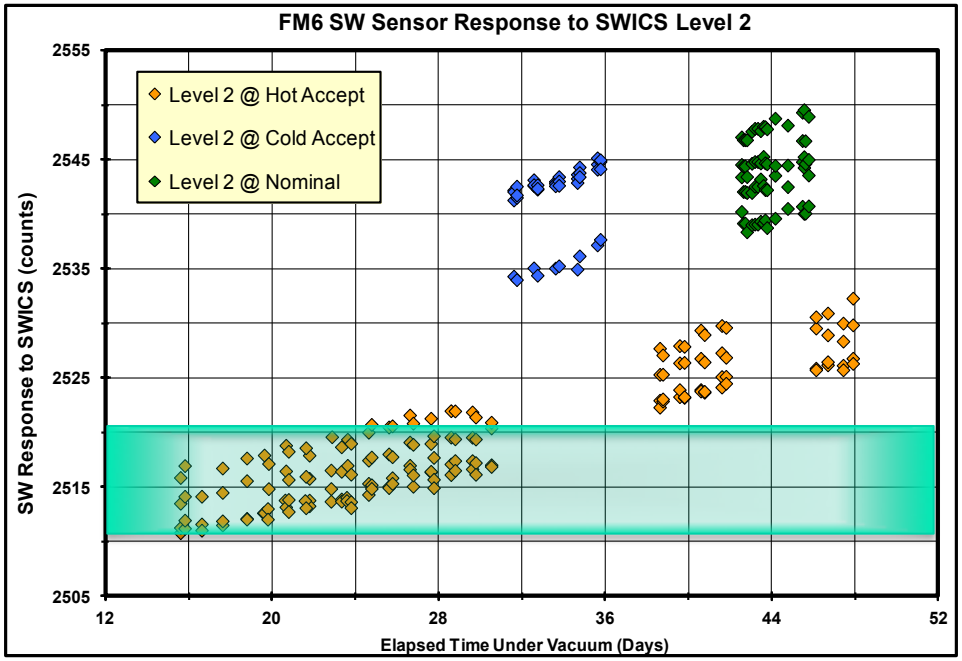
- **Shortwave sensor stability verified independently**
- **Shortwave sensor indicated SWICS brightening**
- **Reference photodiode indicated SWICS dimming**



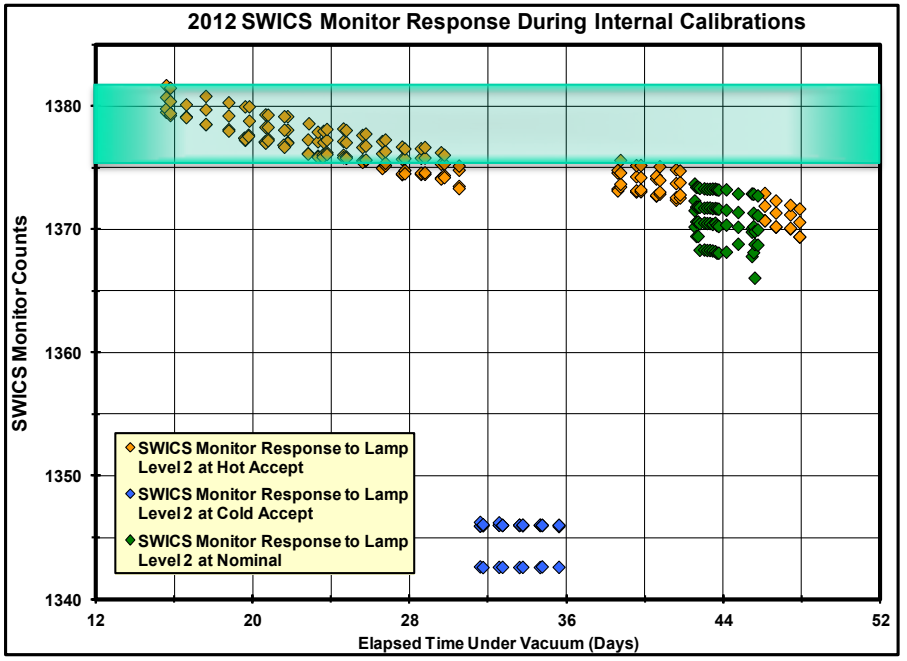
Instability of SWICS Lamp and Photodiode
(Instrument Level Testing)

The trends in the data below should be consistent or preferably flat.

Light Source : SWICS Lamp
Detector : CERES SW Channel
Conclusion : SWICS Lamp appears to be getting brighter



Light Source : SWICS Lamp
Detector : SWICS Photodiode Reference Detector
Conclusion : Photodiode Response Decreasing



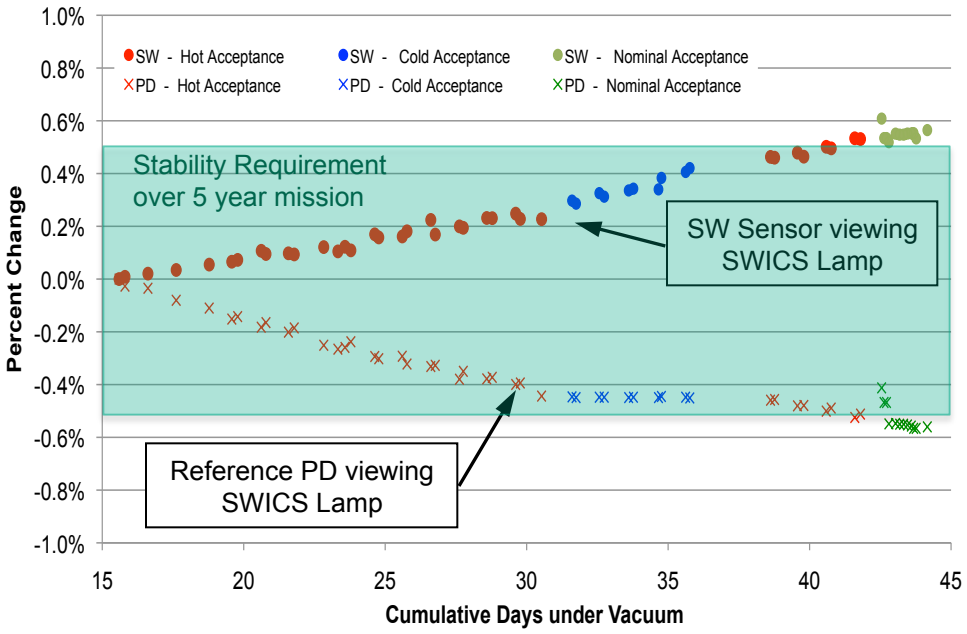
- ICM removed from instrument and tested under vacuum (Oct 2012, Jan 2013)
- Module-level test results ***consistent*** with instrument-level calibration (FM6 Instrument exonerated)
- Shifts with temperature are artifact of sensor and BB heater drive ground bias effect
- PD Data uncorrected for apparent source drift
- PD Response Drift Rate is a function of Instrument Temperature

Instability of SWICS Lamp and Photodiode
(Instrument & Module Level Testing)

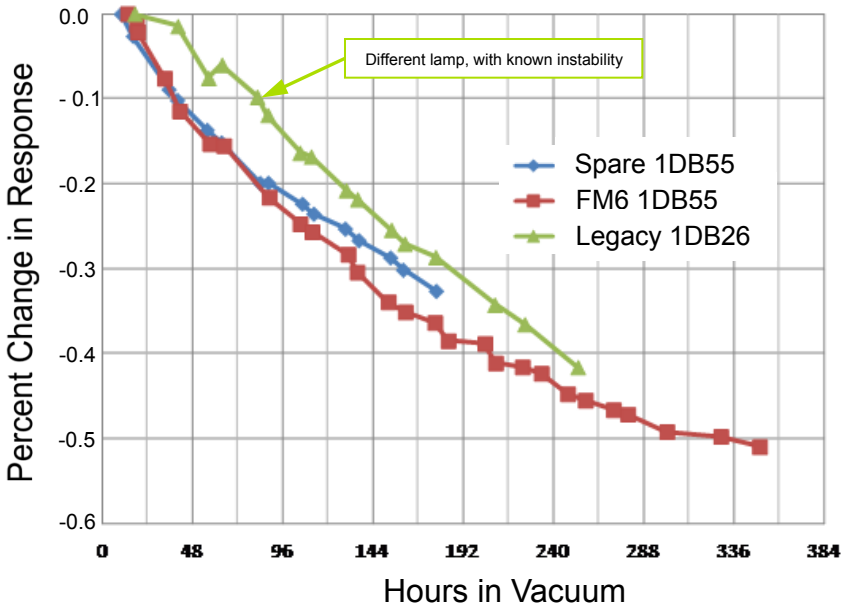
Clouds and the Earth's Radiant Energy System

The trends in the data below should be consistent or preferably flat.

Instrument Level Calibration Test



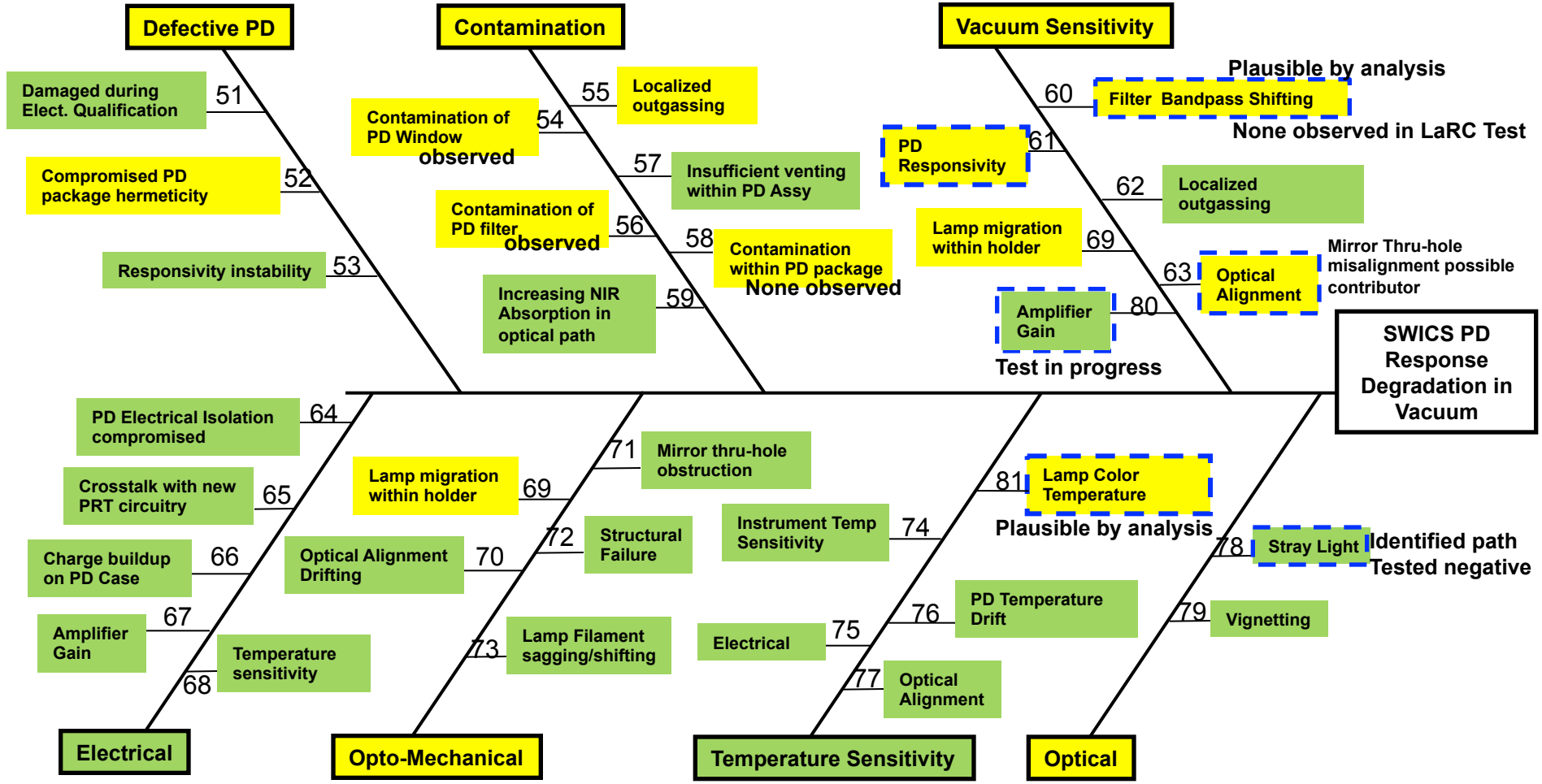
Module Level PD Test



- ICM removed from instrument and tested under vacuum (Oct 2012, Jan 2013)
- Module-level test results ***consistent*** with instrument-level calibration (FM6 Instrument exonerated)
- PD Data uncorrected for apparent source drift
- PD Response Drift Rate is a function of Instrument Temperature

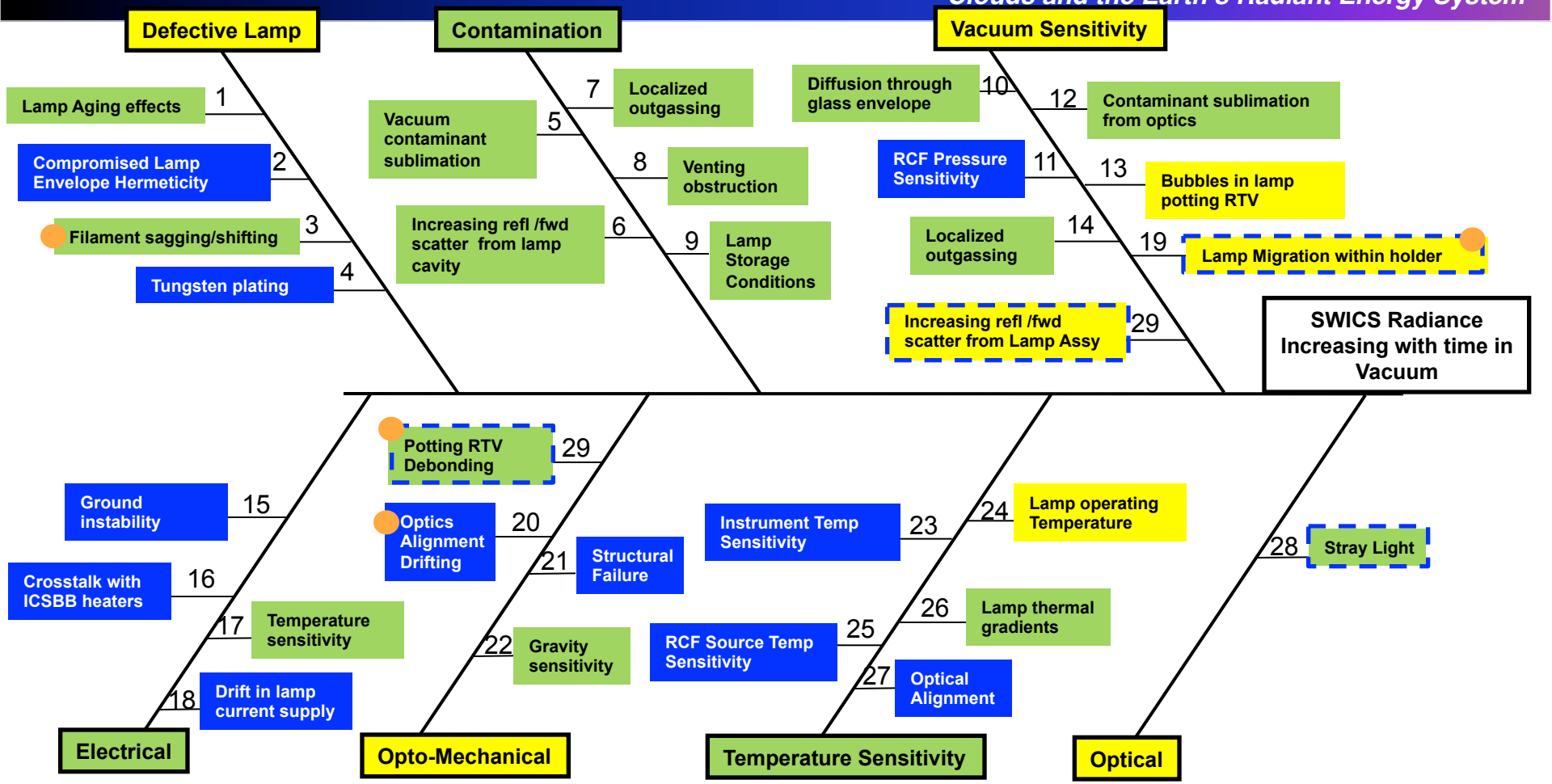
Fishbone Diagram: PD Response Degradation

Clouds and the Earth's Radiant Energy System



Fishbone Diagram: Increasing SWICS Radiance

Clouds and the Earth's Radiant Energy System



Improbable Root Cause | No Supporting Data As Root Cause | Plausible Contributing Root Cause | Probable Root Cause

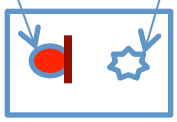
● May also explain apparent PD response degradation

ICM & Breadboard Test Summary

Clouds and the Earth's Radiant Energy System

ICM Baseline Test

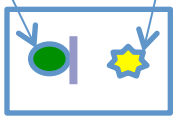
1DB55 FM6 (43) | Lamp FM6 (50)



Repeated Instrument Behavior:
1DB55 Decays
Lamp Brightens
16 day test,
Oct. 8-23, 2012

BB Validation Test

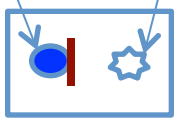
1DB26 Legacy | Lamp Non-flight



1DB26 Decays
Lamp (-/Flat)
Noise on Reference Detector
11 day test,
Jan 11-21, 2013

ICM Test #2

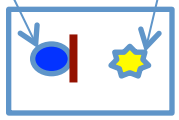
1DB55 New (94) | Lamp FM6 (50)



1DB55 Decays
Lamp (Brightens?)
Noise on Reference Detector
7 day test,
Jan 24-31, 2013

BB Test w. ICM #3

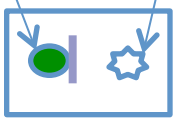
1DB55 New (94) | Lamp Non-flight



1DB55 Decays
Lamp (Brightens?)
Noise on Reference Detector
13 day test,
Feb 7-19, 2013

ICM Test #3

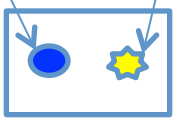
1DB26 Legacy | Lamp FM6 (50)



1DB26 Decays
Lamp (Brightens?)
Noise on Reference Detector
13 day test,
Feb 7-19, 2013

BB Test w. ICM #4

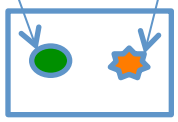
1DB55 New (94) | Lamp Non-flight



Filterless 1DB55 -/*Flat*
Lamp -/*Flat*
Reference Detectors Behaving
12 day test,
Mar 1-12, 2013

ICM Test #4

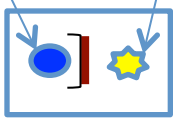
1DB26 Legacy | Lamp New (23)



Filterless 1DB26 Decays
Lamp Brightens
Reference Detectors Behaving
12 day test,
Mar 1-12, 2013

BB Test w. ICM #5

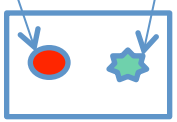
1DB55 New (94) | Lamp Non-flight



Placed Filter 1DB55 Decays
Lamp Flat
Reference Detectors Behaving
7 day test,
Mar 14-20, 2013

ICM Test #5

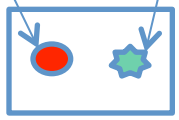
1DB55 FM6 (43) | Lamp New (16)



Filterless 1DB55 Decays
Lamp Brightens
Reference Detectors Behaving
7 day test,
Mar 14-20, 2013

BB Test w. ICM #6

1DB55 FM6 (43) | Lamp New (16)

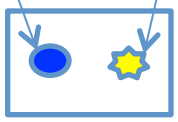


Current Test:
Filterless FM6 1DB55
Spare Flight Lamp

Mar 23-April 3

ICM Test #6

1DB55 New (94) | Lamp Non-flight



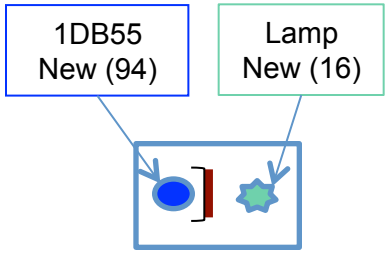
Current Test:
Filterless 1DB55(94)
BB Non-flight Lamp

Mar 23- April 3

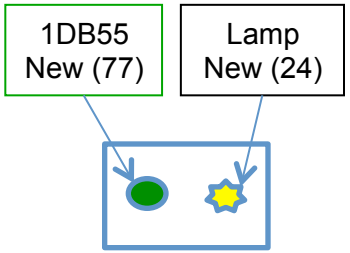
ICM & BB Vacuum Test #7 Results

Clouds and the Earth's Radiant Energy System

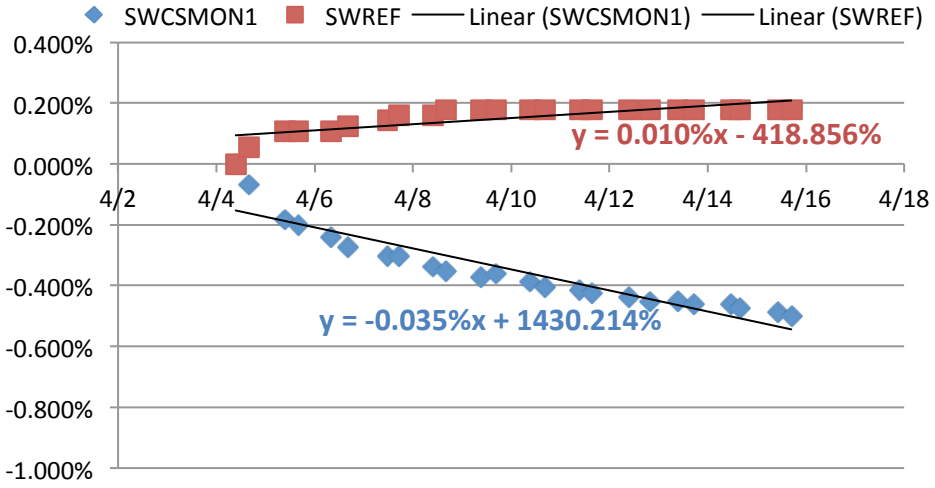
ICM Test #7



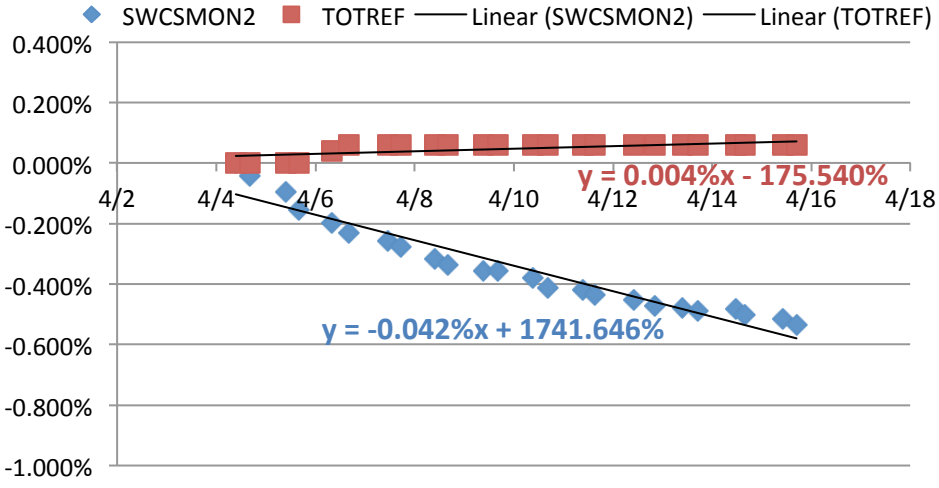
BB Test w. ICM #7



ICM: Flight candidate Lamp SN16, 1DB55 SN94 PD w placed Barr filter, SW Ref

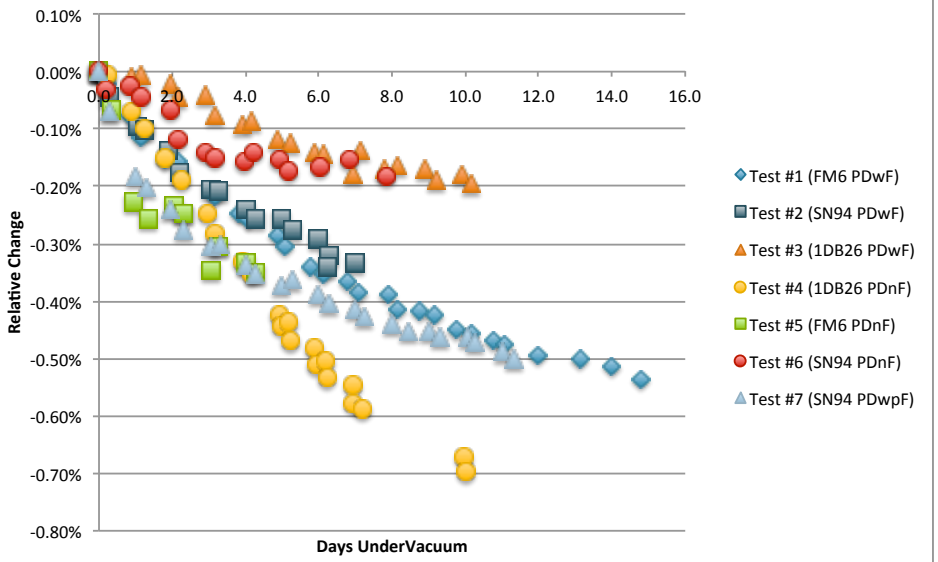


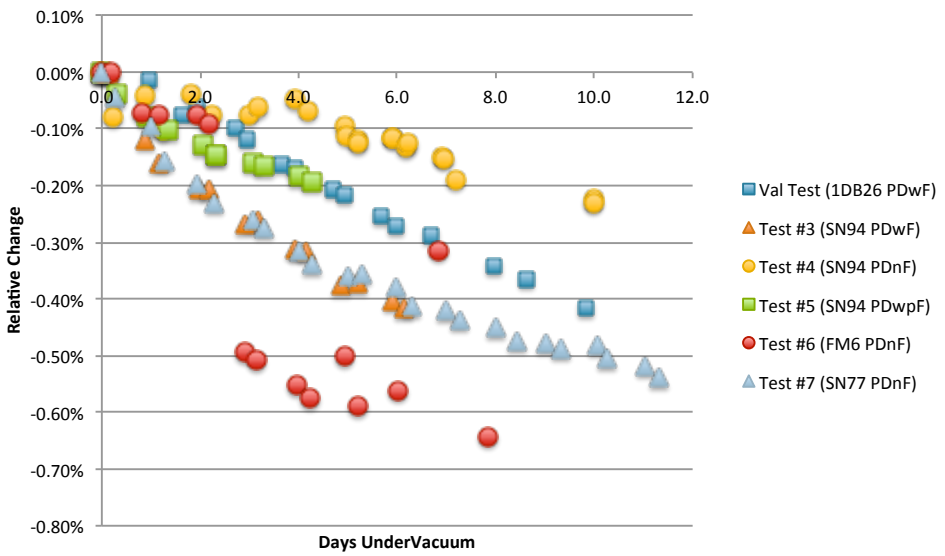
BB: Flight candidate Lamp SN25, 1DB55 SN77 PD w/o filter, TOT Ref



Summary: Lamp SN24 and 1DB55 SN94 w placed filter performed best

FM6 ICM vs. BB#1 ICM: PD Response

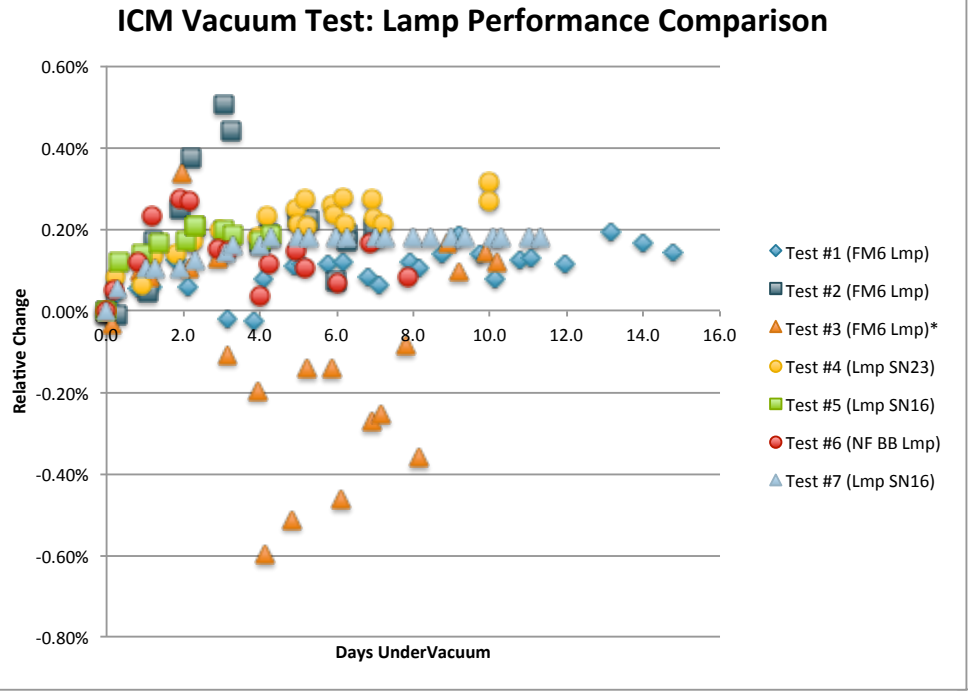


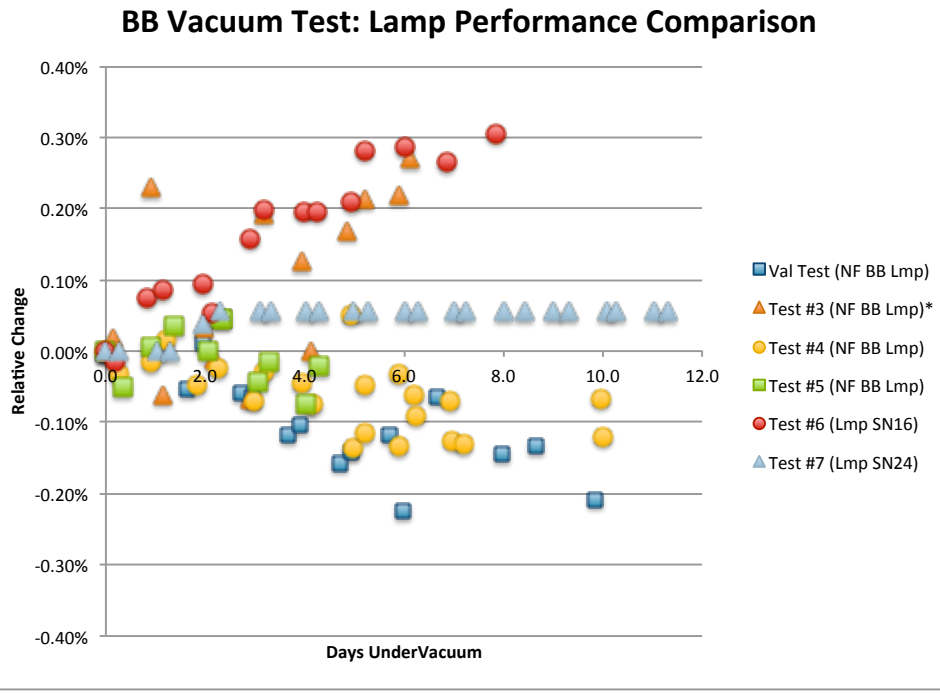


Note- Results uncorrected for measured lamp drift

- **Photodiodes have trended negative in every test configuration**
- **1DB55 PDs tend to exhibit decreasing slope with time in vacuum**
- **1DB55 SN94 remains leading PD candidate**

FM6 ICM vs. BB#1 ICM: Lamps





Results measured with Thermopile reference detectors

- **Data from Test #3 is suspect due to mechanical crosstalk causing dual-off-state level**
- **Non-flight BB lamp is the only one to show a negative trend**
- **Lamps appear to have a vacuum stabilization period in the ICM**

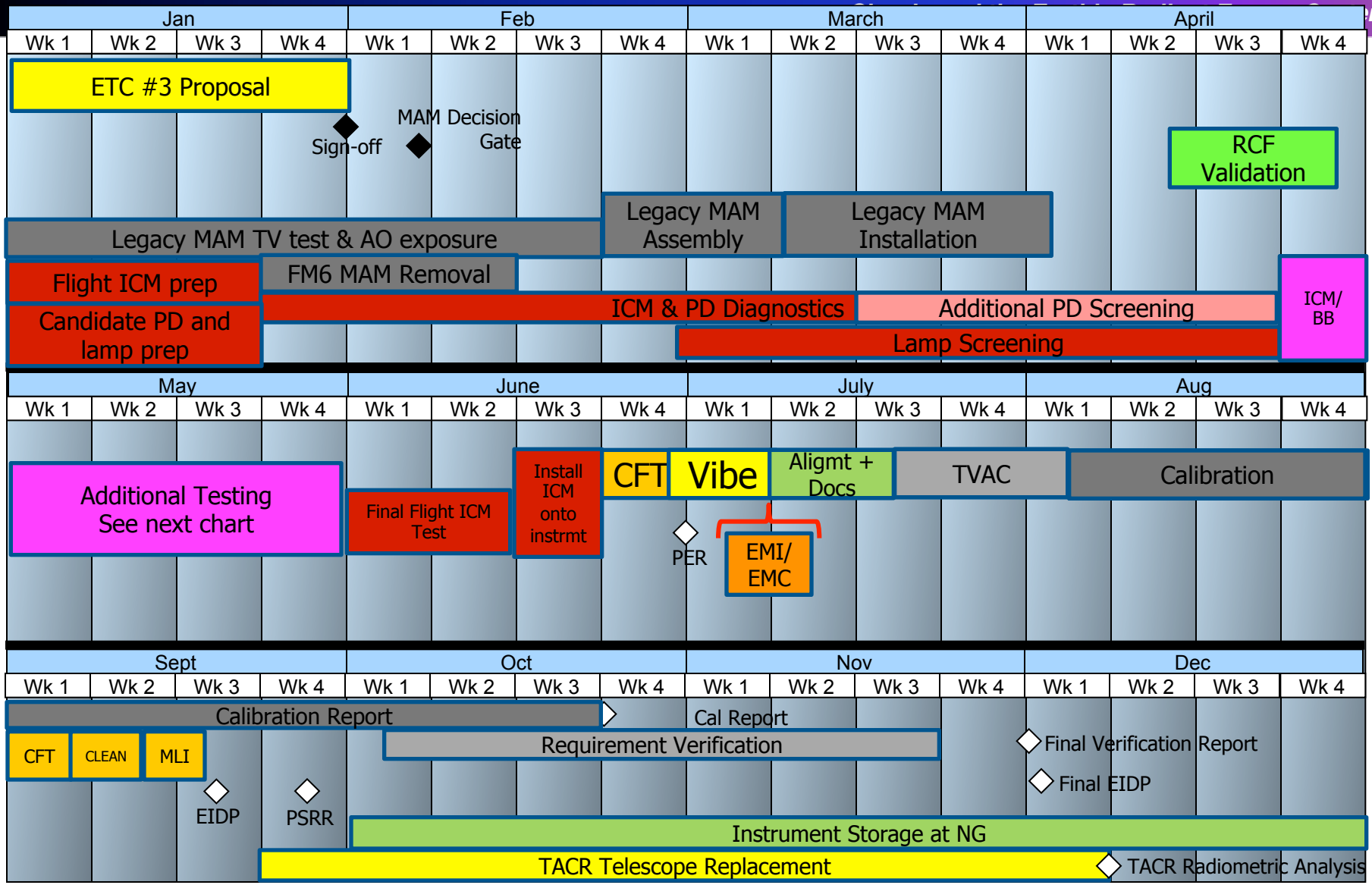
ICM Major Accomplishments since Summer 2012

- **Performed Ambient Instrument-level testing**
  - Testing showed possible air recovery of PD response
  - Testing eliminated gravity effects as root cause for anomaly
- **Module-level ICM Diagnostic Vacuum Performance**
  - Completed 7 vacuum test
    - Isolated problem to the ICM
    - Tested FM6 Lamp and flight candidate lamp assemblies SN 23, 16, & 24
    - Testing of FM6 PD and flight candidate PD assemblies SN 94, 77
  - Discovered and corrected filter assembly issues
    - Reworked filter mounting to shim space between filter and PD window
    - Devised/implemented temporary filter mounting to eliminate epoxy
- **Performed initial stray light test**
  - Remove and replace ICM Cover does not affect PD Signal
- **Exonerated ICM Electronics under vacuum**
- **Performed filter stability assessment**
  - Measured shift does not affect PD Signal

Near Term Path Forward with Photodiode

- **Complete PD sensitivity to lamp de-centering using Breadboard ICM**
- **Prepare test set for ambient thermal sensitivity testing**
- **Configure ICM for Vacuum Test #8**
  - Lamp SN24
  - PD 1DB55 SN94 (assuming uniformity is achieved, test with placed filter)
- **Complete leak test of FM6 PD**
  - NG is working the planning to remove PD from mount for this testing
- **Build-up and vacuum test of non-flight ODC 1DB55 in BB**
- **Build-up TVAC capability for final module test**
- **Resolve PD radiation sensitivity issue**

CERES FM6 Critical Path Schedule



Schedule to Final ICM Test