NPOESS Preparatory Project Cross-track Infrared Sounder Sensor Characterization Plans and Performance Predictions.

Gail E. Bingham,
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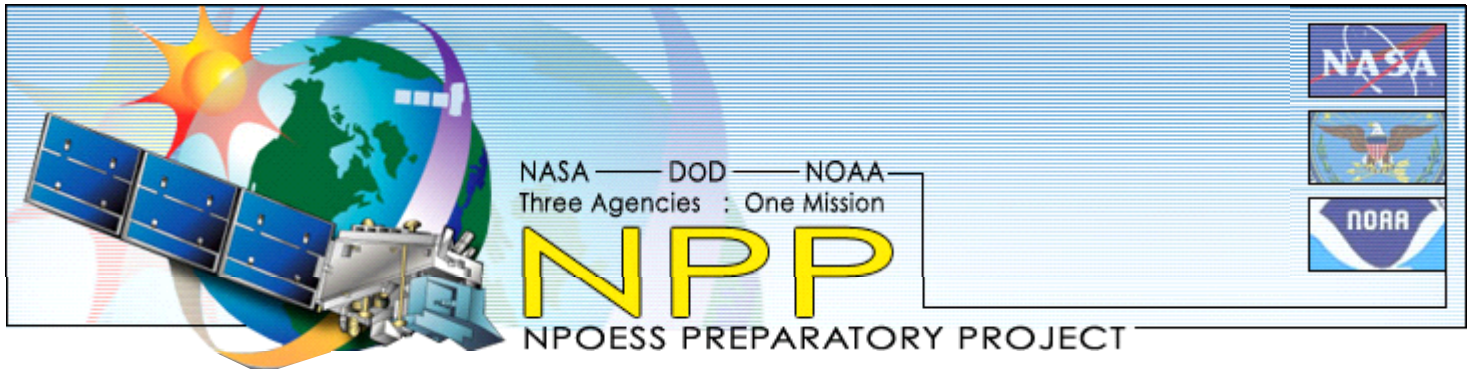
To

Joint Center for Satellite Data Assimilation

December 2, 2008



What is NPP?

The National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) is a joint mission involving the National Aeronautics and Space Administration's (NASA) and the NPOESS Integrated Program Office (IPO).

What is NPOESS?

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is the next generation of U.S. low earth orbiting environmental satellites. The NPOESS will replace both the NOAA Polar-orbiting Operational Environmental Satellite (POES) series spacecraft and the US DOD Defense Meteorological Satellite Program (DMSP) spacecraft series.

What is the NPOESS Integrated Program Office (IPO)?

The NPOESS IPO was established to provide combined agency management of NPOESS. The IPO organizationally resides within the US Department of Commerce, NOAA, NESDIS and is staffed with personnel from the Department of Defense, Department of Commerce, and the National Aeronautics and Space Administration (NASA).

NASA/NPOESS NPP – 24 IORD EDRs

MISSION AREAS

- Atmosphere
- Climate
- Land
- Ocean
- Space Env.
- RDR/SDR Only

NOTES:
1. Precision limited by emissivity knowledge
2. Uncertainty degraded due to sensor limitations
3. No "all weather" capability
4. HCS limitation in cloudy conditions

VIIRS (20)

- Albedo (Surface)
- Cloud Base Height
- Cloud Cover/Layers
- Cloud Effective Part Size
- Cloud Optical Thickness
- Cloud Top Height
- Cloud Top Pressure
- Cloud Top Temperature
- Land Surface Temp[1]
- Surface Type
- Ocean Color/Chlorophyll[2]
- Suspended Matter
- Vegetation Index
- Aerosol Optical Thickness
- Aerosol Particle Size
- Ice Surface Temperature[3]
- ○ Imagery[3]
- Sea Ice Characterization[3]
- Snow Cover/Depth[3]
- ○ Sea Surface Temperature[3]

CrIS/ATMS (3)

- ○ Atm Vert Moist Profile[4]
- ○ Atm Vert Temp Profile[4]
- Pressure (Surface/Profile)[4]

OMPS (1)

- O_3 Total Column (also CrIS)
- O_3 Profile

CERES

- Down LW Radiance (Sfc)
- Down SW Radiance (Sfc)
- Net Solar Radiation (TOA)
- Outgoing LW Rad (TOA)

KEY ○ = EDRs with Key Performance Parameters

EDRs not delivered by NPOESS are not counted in totals

01 October 2008

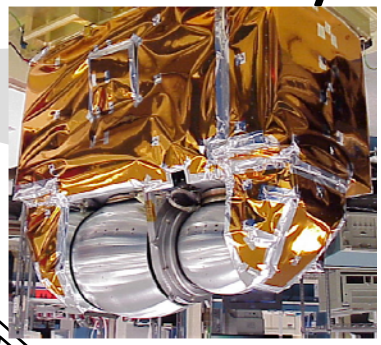
DoD, NOAA, NASA,
Integrated Program Office
M. Haas, F. Eastman
G. Mineart, J. Whitcomb

NPP V16-1

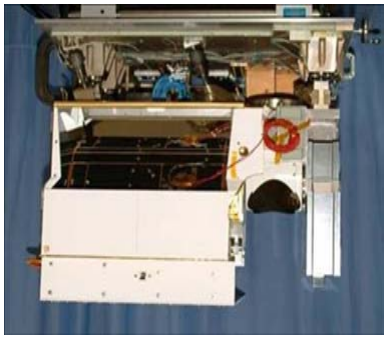
NPP Instruments / Objectives

- Visible / Infrared Imager Radiometer Suite (VIIRS)
  - Replacement for AVHRR/3, OLS, and continuation of most MODIS measurements
  - Carries the majority of the NPOESS Environmental Data Records (22)
- Ozone Mapping and Profiler Suite (OPMPS)
  - Collects total column and vertical profile ozone data
  - continue the daily global data produced by SBUV)/2 and TOMS
- Cloud and Earth Radiant Energy System (CERES)
  - Measures reflected shortwave and Earth emitted radiance in 3 bands
  - three broadband radiometers that scan the earth from limb to limb
- Advanced Technology Microwave Sounder (ATMS)
  - ATMS provides high spatial resolution microwave data to support temperature and humidity sounding generation in cloud covered conditions
  - Combines the current operational microwave sounder elements into a single sensor
- Cross-track Infrared Sounder (CrIS)
  - Provides AIRS resolution and band pass top-of-the-atmosphere radiance for temperature and water vapor profile retrievals
  - Secondary products are total column ozone and pressure profile

ATMS/CrIS

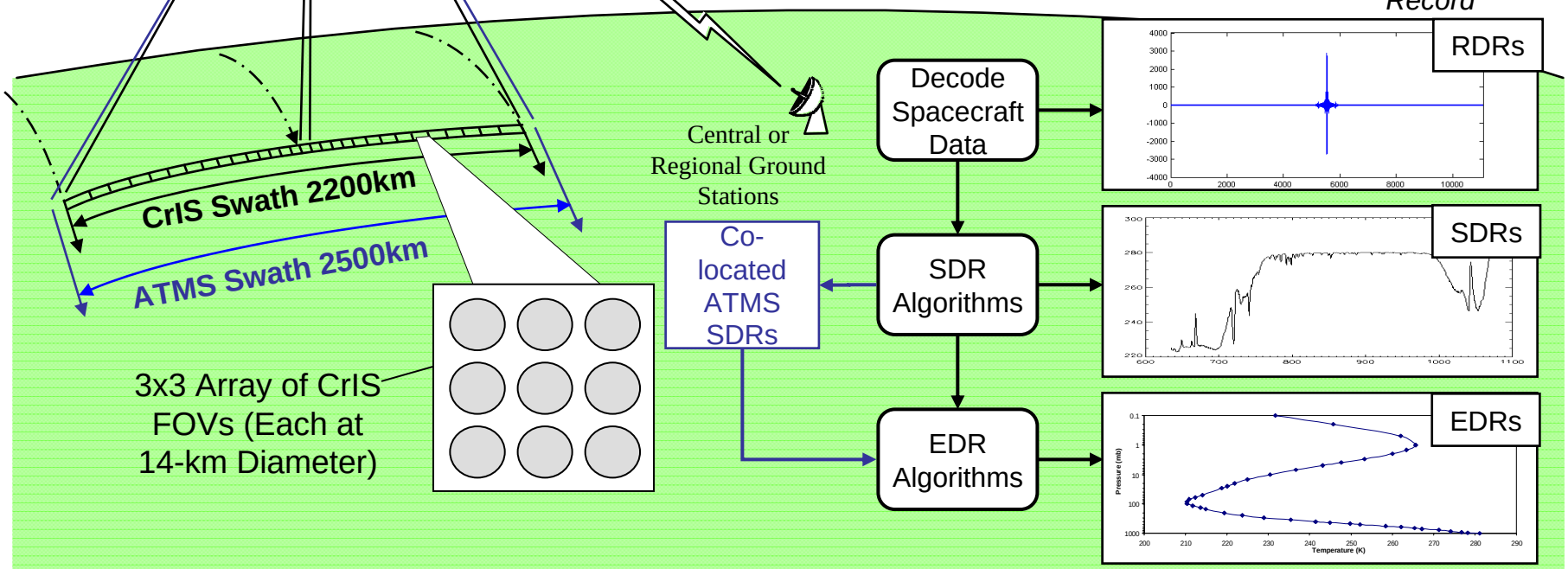


ATMS



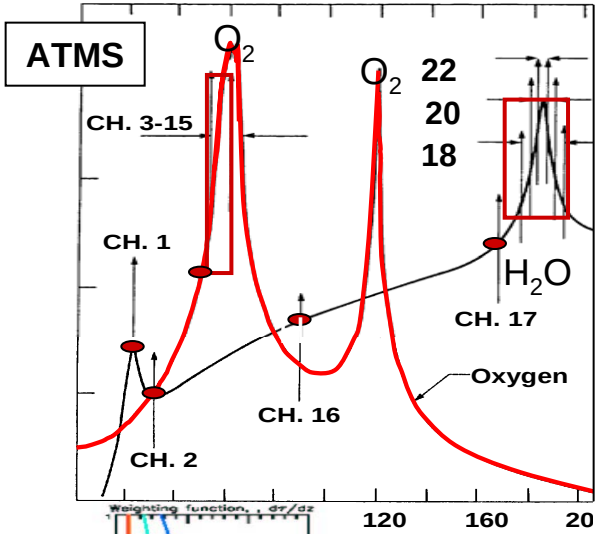
CrIS

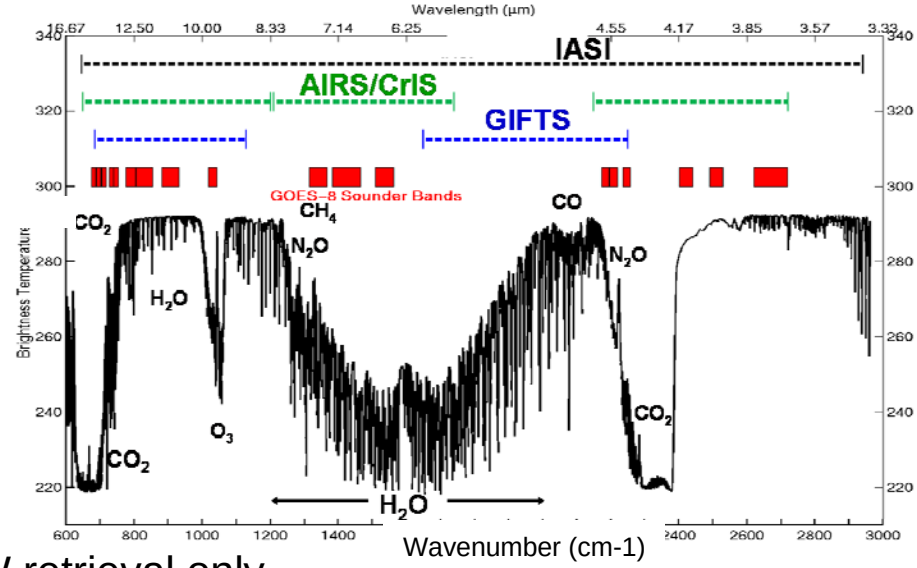
RDR = Raw Data Record
SDR = Sensor Data Record
EDR = Environmental Data Record

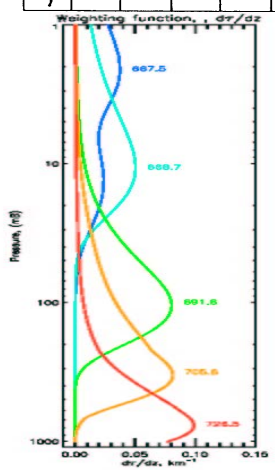


ATMS & CrIS work together to provide soundings in cloudy and clear conditions.

AVTP Retrieval Algorithm Overview





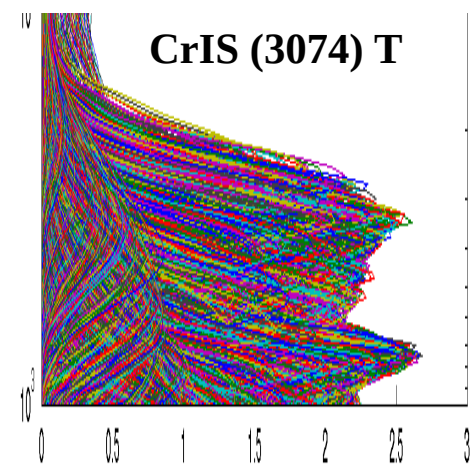


- First guess - MW retrieval only
- Scene classification
- MW used for cloudy solution
- IR and MW maximum likelihood inversion minimizing a cost function

$$(\hat{R}-R)^T S_R^{-1}(\hat{R}-R)+(\hat{X}-X_a)^T S_X^{-1}(\hat{X}-X_a)$$

EDR:

ATMP - Atmospheric Vertical Temperature Profile



MW - weighting functions

MW RT: OSS microwave routine

IR RT: OSS infrared routine

IR TP-weighting functions

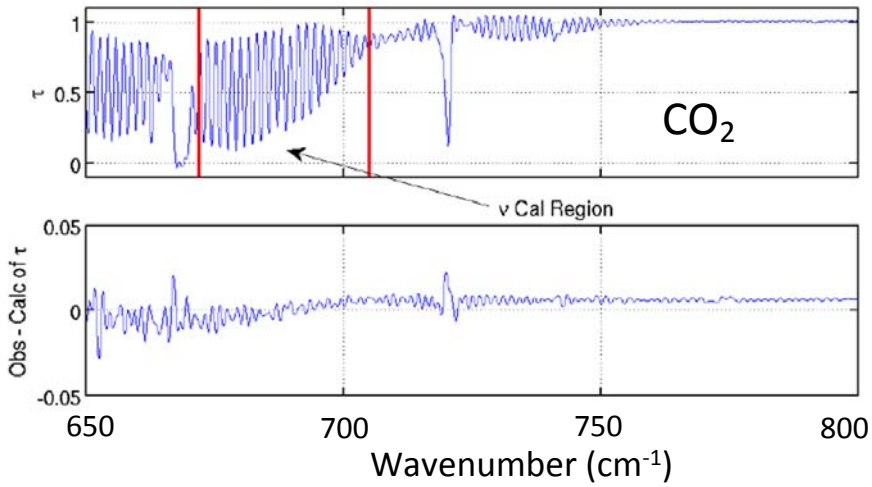
ATMS Instrument Status

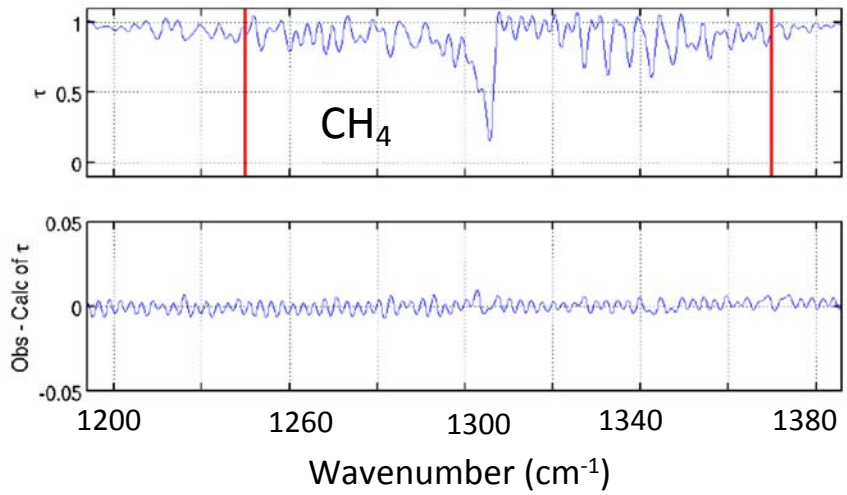
- ATMS FM1 has completed Thermal Vacuum testing and has been delivered to the spacecraft for integration.
- PFM Qual, Environmental and Calibration testing was completed in October 2005
  - Met NEDT requirements for all 22 channels
  - Met calibration accuracy requirements for all 22 channels
  - Met Beamwidth/Efficiency requirements for all channels
  - Nonlinearity waiver has been accepted
  - Temperature-dependent nonlinearity of channel 2
    - On-orbit effect expected to be ~0.1K as cold plate regulated to within 2K
- Watch Items
  - Characterization of sidelobe contamination
  - Potential need for SDR modification to handle temperature-dependent linearity correction

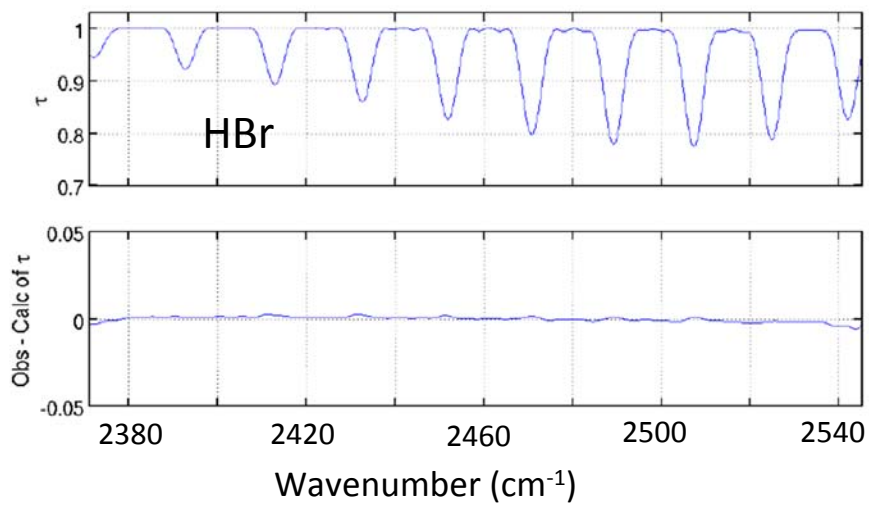
CrIS Instrument Status

- CrIS FM1 is in Thermal Vacuum testing and has successfully completed most tests
  - Vibration& EMI tests (workmanship shake after TV remains)
  - FOV Shape / Coregistration
  - ILS / Spectral Accuracy
  - NEDN
  - Short Term Repeatability
  - Long Term Repeatability
- Radiometric uncertainty and linearity testing on going
- Expected to ship to the spacecraft for integration testing in early December, 2008

CrIS FM1 Spectral Calibration





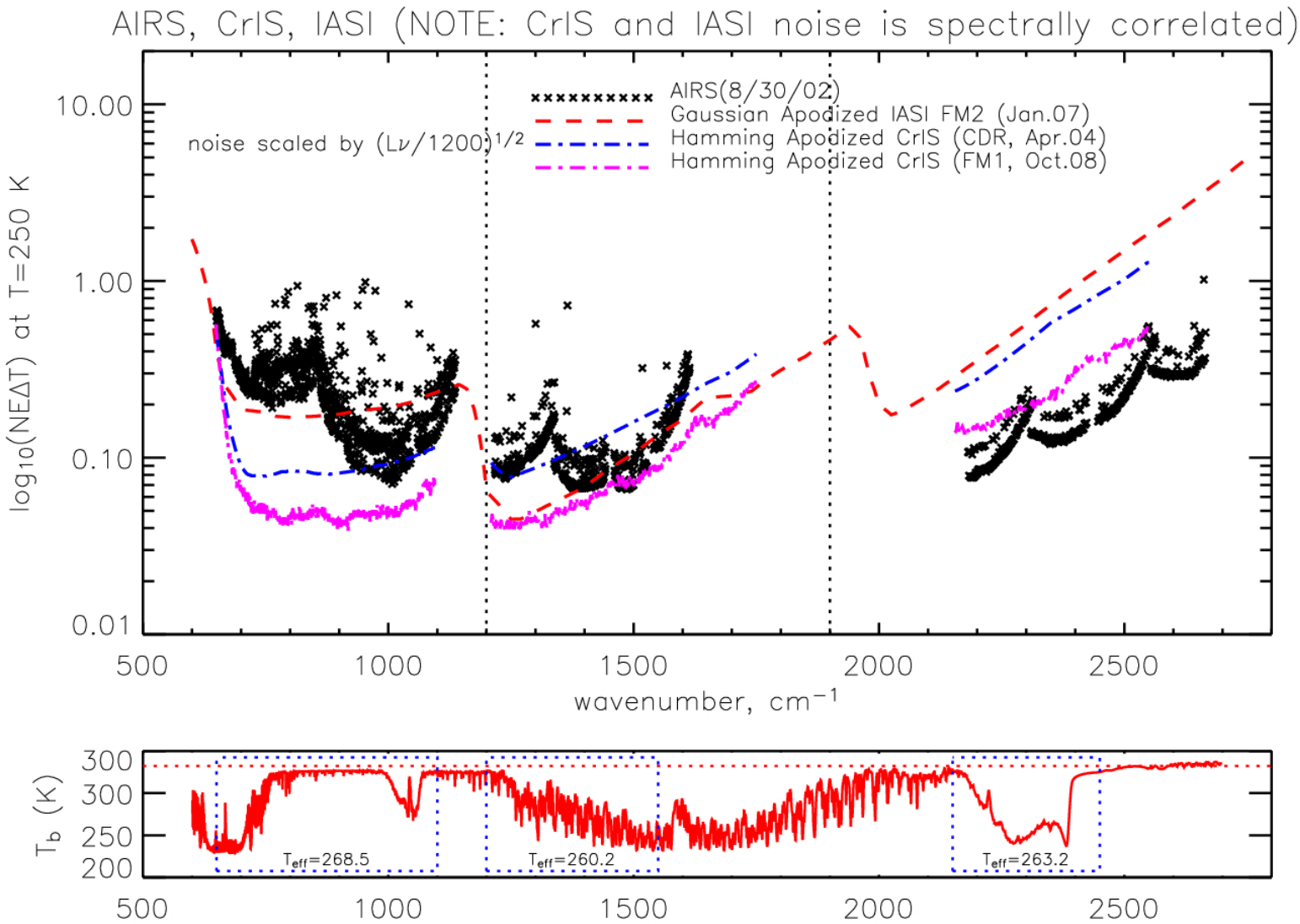


Conclusions

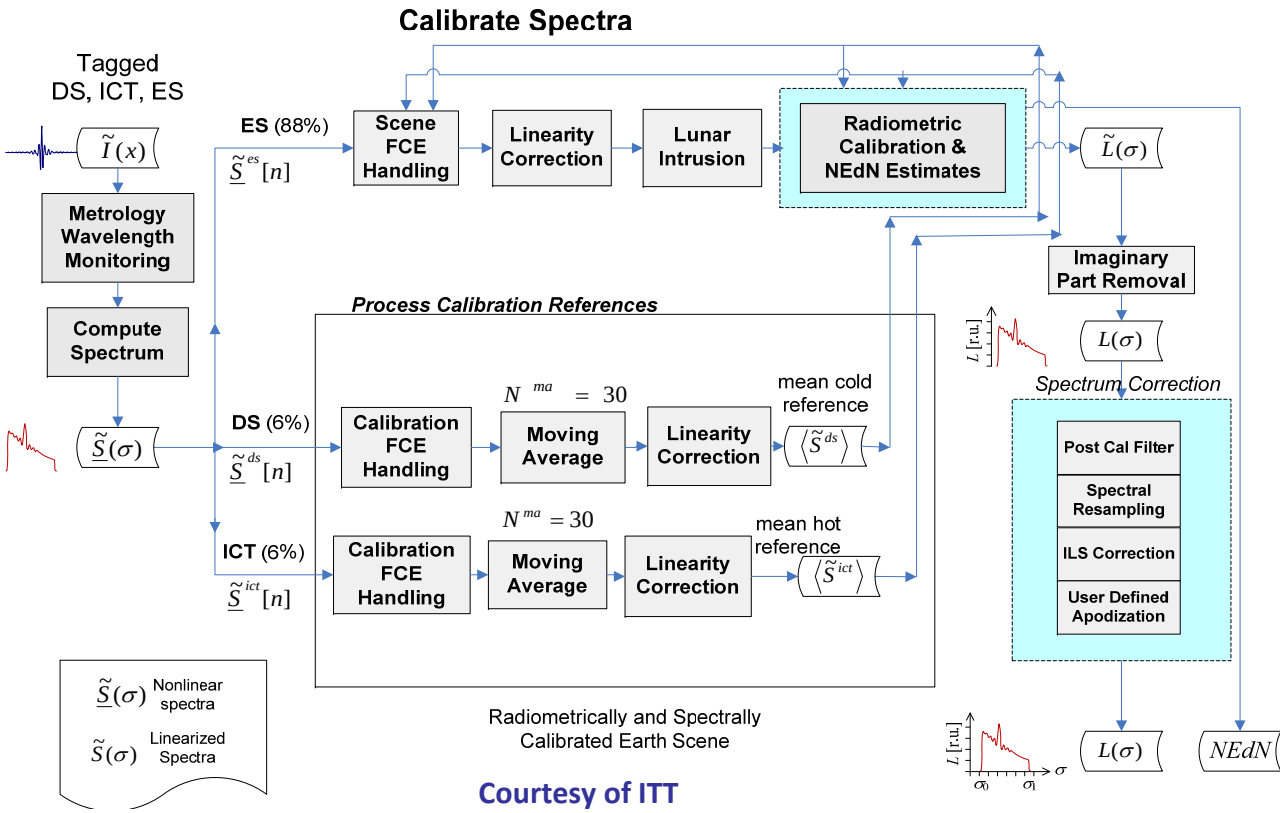
- CrIS frequency calibration using the Neon lamp worked extremely well in TVAC.
- ~ 1ppm accuracy at a single operating temperature with only 2-3 adjustable parameters (x, y, Neon Cal).
- Measured CrIS ILS widths also appear to be extremely accurate, well within specifications.

From: Strow, Motteler and Hannon. *Pre-Launch Spectral Calibration of the CrIS Sensor on NPOESS/NPP*. CALCON 2008. Logan, UT, USA, September 10, 2008.

CrIS NEDT Comparison



CrIS Calibration Processing



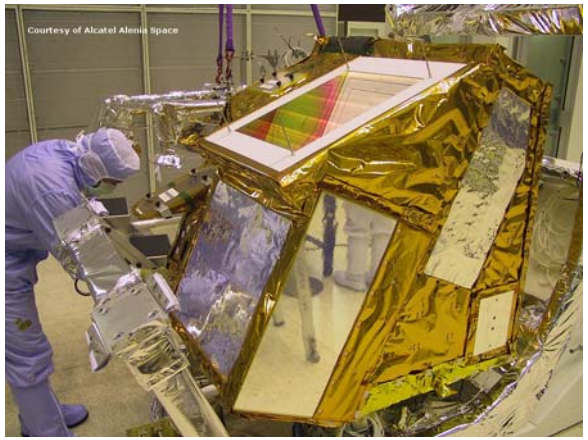
Courtesy of ITT

- CrIS Level 0 to Level 1B processing is provided by the Sensor Data Record (SDR) process
  - SDR algorithm is being developed by ITT in parallel with the sensor
  - Sensor performance processing during T/V is being analyzed using the SDR process software
- Current SDR process is being updated to contain non-linearity correction
  - Current T/V data collections are addressing non-linearity and absolute calibration

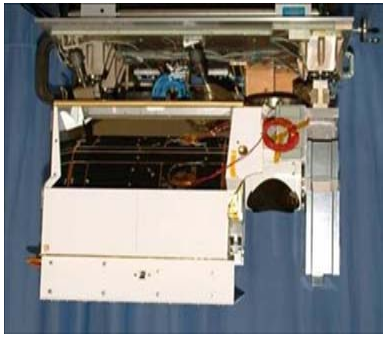
CrIS is the 3rd Hyperspectral Sounder

AIRS

IASI

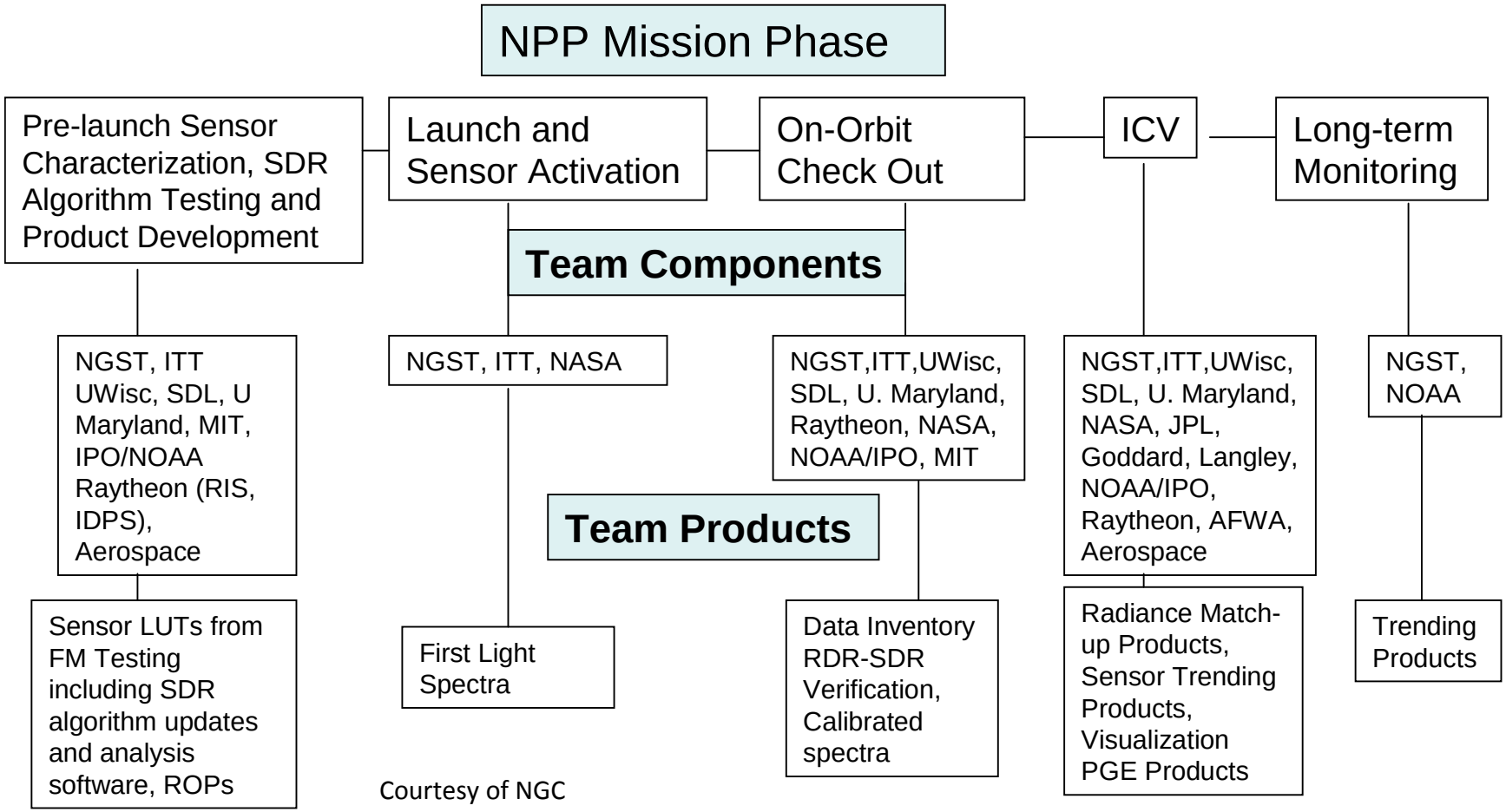


CrIS



CrIS follows two great, well calibrated instruments to orbit
SDR Cal/Val will utilize similar procedures
Co-existence enables direct comparison, and good comparisons from GSCICS
Cal/Val team brings direct AIRS/IASI experience
Hence, today's Cal/Val plan is significantly different than the first one

Cal/Val Process



Courtesy of NGC

NPP CrIS SDR C/V Team

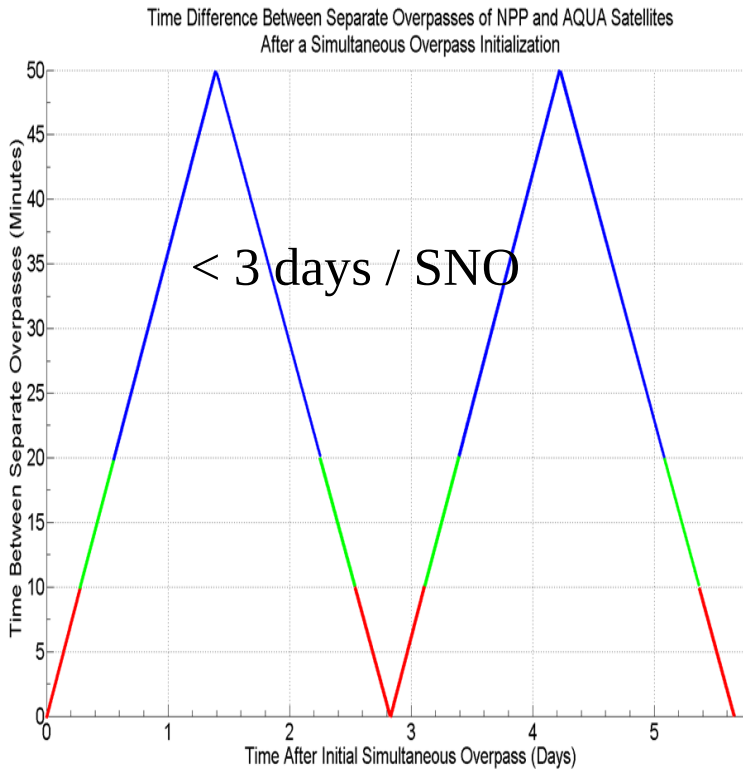
	NGST/Raytheon/ITT	IPO/Govt
Function / Leads	Denise Hagan (NGST)	Gail Bingham (SDL)
Instrument Verification Radiometric Cal SST Comparisons Radiosonde Comparisons Cross-Platform Comparison Model-to-Instrument Geolocation	**Denis Tremblay Chunming Wang Denise Hagan Gene Kratz Giovanni De Amici**	SMEs **Dan Mooney (Lincoln Labs) Hank Revercomb, Dave Tobin and Bob Knuetson (UW SSEC) George Aumann and Tom Pagano (JPL) Larrabee Strow (UMBC) M. Esplin, C. Fish, G. Cantwell, V. Zavyalov, N. Pougatchev (SDL) Chris Barnet (NESDIS/STAR)**
ATMS Interface	**Giovanni De Amici**	**Bill Blackwell (Lincoln Labs) Edward J. Kim (GSFC) Lynn Chidister (SDL)**
Sensor Support	**Joe Predina, Glenn White, Dave.Jordan, Lawrence Suwinski, Ron Glumb, Steve Wells and Nathan Funk (ITT) Farhang Sabet-Peyman,**	**Mark Esplin, Greg Cantwell (SDL)**
SDR Operational Algorithm Change Support SDR ILS Updates	**Denis Tremblay and AM&S (Degui Gu, Xia-Lin Ma) AER (Post-launch POC TBD)**	**Larrabee Strow (UMBC) Dean Ferguson, Mark Greenman (SDL)**

Post Launch Cal/Val Task Summary

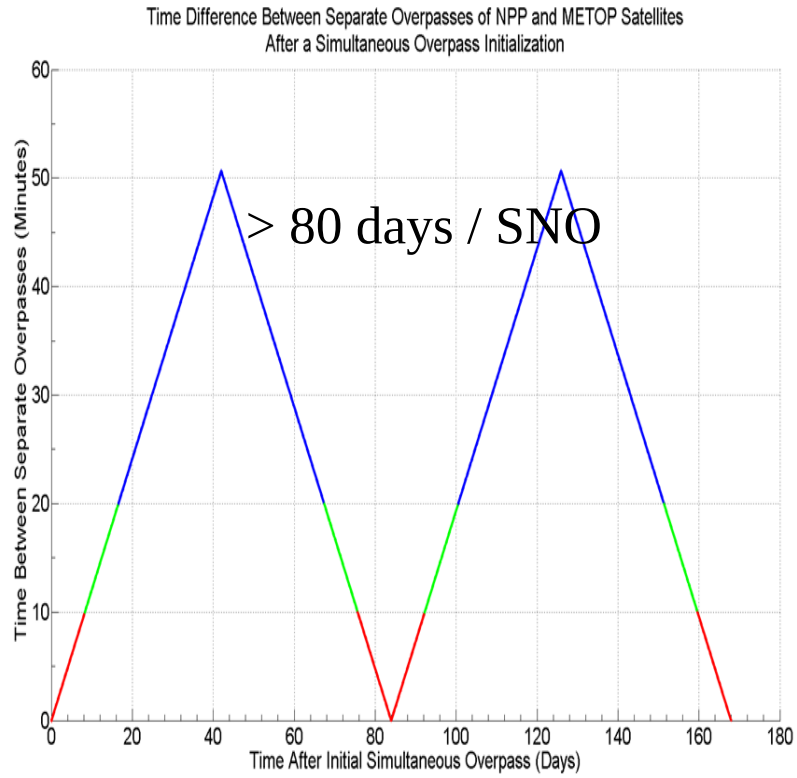
Principal Category	Sub-Category	Task Network ID#(s)	Related Sensor Performance Requirement #s	Cal/Val Phase				Benefit from Air Campaign	Requires Sea &/or Ground Campaign	**Lead / Backup**
				Sensor Activation	Sensor Checkout	SDR Baseline	Long Term Monitoring			
Functional Performance	CrIS Diagnostic Mode	1329, 1330, 905		X	X	X	X	No	No	**ITT / NGC**
	Sensor Checkout Status and Trending	857, 911, 913, 914, 910, 907, 1327, 1569, New Task 1, New Task 2		X	X	X	X	No	No	**ITT / NGC**
	CrIS Activation	1322, 900, 901, 902, 903, 904, 1324, 1325, 1326, 1328, 974		X				No	No	**ITT / NGC**
	CrIS Telemetry Parameters and RDR Status and Trending	1549, 1550, 870, 912, 927		X	X	X	X	No	No	**ITT / NGC**
Radiometric Accuracy	Absolute Radiometric Uncertainty	1552, 870, 871, 935, 936, 1341	SDRP 3481, CSS 4589		X	X	X	Yes	TBD	**SDL / SSEC / NASA**
	Radiometric linearity	867, 870	CSS 835		X	X	X	No	No	**SSEC / ITT**
	Cross Comparisons	1334, 1335, 1339, 1344, 1557, 1553				X	X	Yes	Yes	**NGC / SSEC / STAR / NASA**
	ICT Temperature Stability	864, 975, 1550, 1551, 1552, 1332, 870, 908, New Task		X	X	X	X	No	No	**ITT / NGC SDL / UMBC**
Spectral Accuracy	Laser Wavelength	855, 862, 875, 1333, 1342			X	X	X	No	No	**ITT / UMBC**
	Spectral Calibration	868, 870, 924, 926, 933, 935, 1341	SDRP 7043, 884, 940, 944		X	X	X	Yes	TBD	**ITT / SSEC**
Spatial Performance	Geolocation	925, 934, 929, 1373, 1552	SDRP 3731, 882, 7019, CSS 1762		X	X	X	No	No	**NASA/SDL**
	CrIS FOV Coregistration	869, 871, New Task	SDRP 3695, 3714, CSS 1721, 1736, 1740	X	X	X	X	No	No	**NGC / SDL**

Primary SDR Cal/Val Activities

- Effort is designed to provide primary analysis and independent review
- Unified government and industry team with aircraft and space FTS sensor experience (GIFTS, MSX, NAST-I, S-HIS)
- Plan includes significant use of WMO GSICS and CEOS calibration procedures



AIRS to NPP SNO time delta



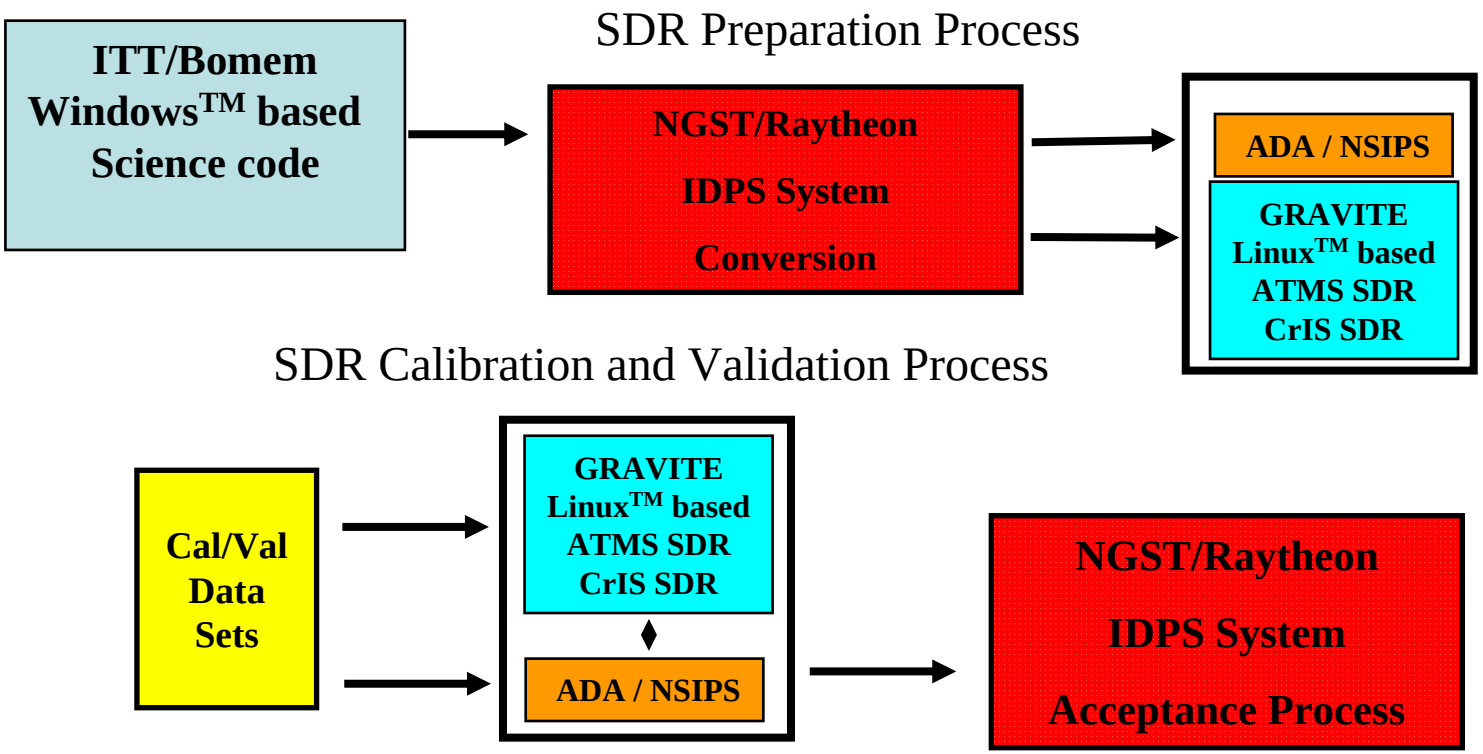
CrIS to IASA SNO time delta

(Exact matches (1 Km, 1 Sec)

SDR Cal/Val Software Strategy

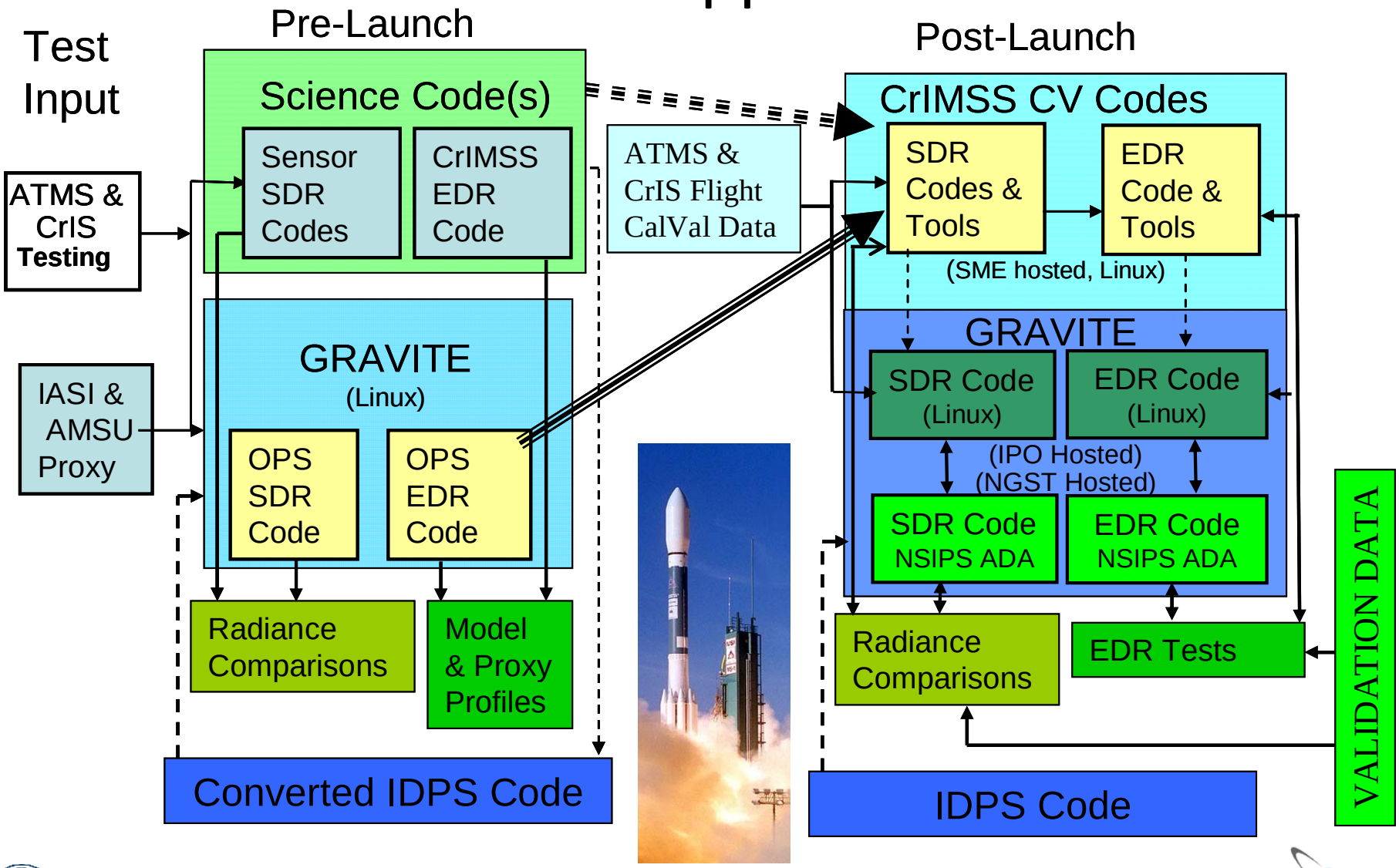
- The IDPS processing system is designed for operational data delivery and is carefully configuration controlled.
- It has no capability for the kind of look and see and try this options required for Cal/Val data analysis.
- Early in the program it was decided to develop two separate, but limited capability systems to handle Cal/Val activities.
- These systems are known as NSIPS and GRAVITE and are physically located in the NOAA NSOF for easy data access.
  - NSIPS is an NGST/Raytheon-managed, off-line copy of the operational process with intermediate product storage access
    - Processes running in the operational environment
  - GRAVITE (Government Resource for Algorithm Verification, Independent Test, and Evaluation – Pronounced "Gravity")
    - IPO-Data Products Division Linux based copy of the IDPS code
    - Linux code available to Cal/Val partners for their "local" processing

CrIS SDR Development System Flow

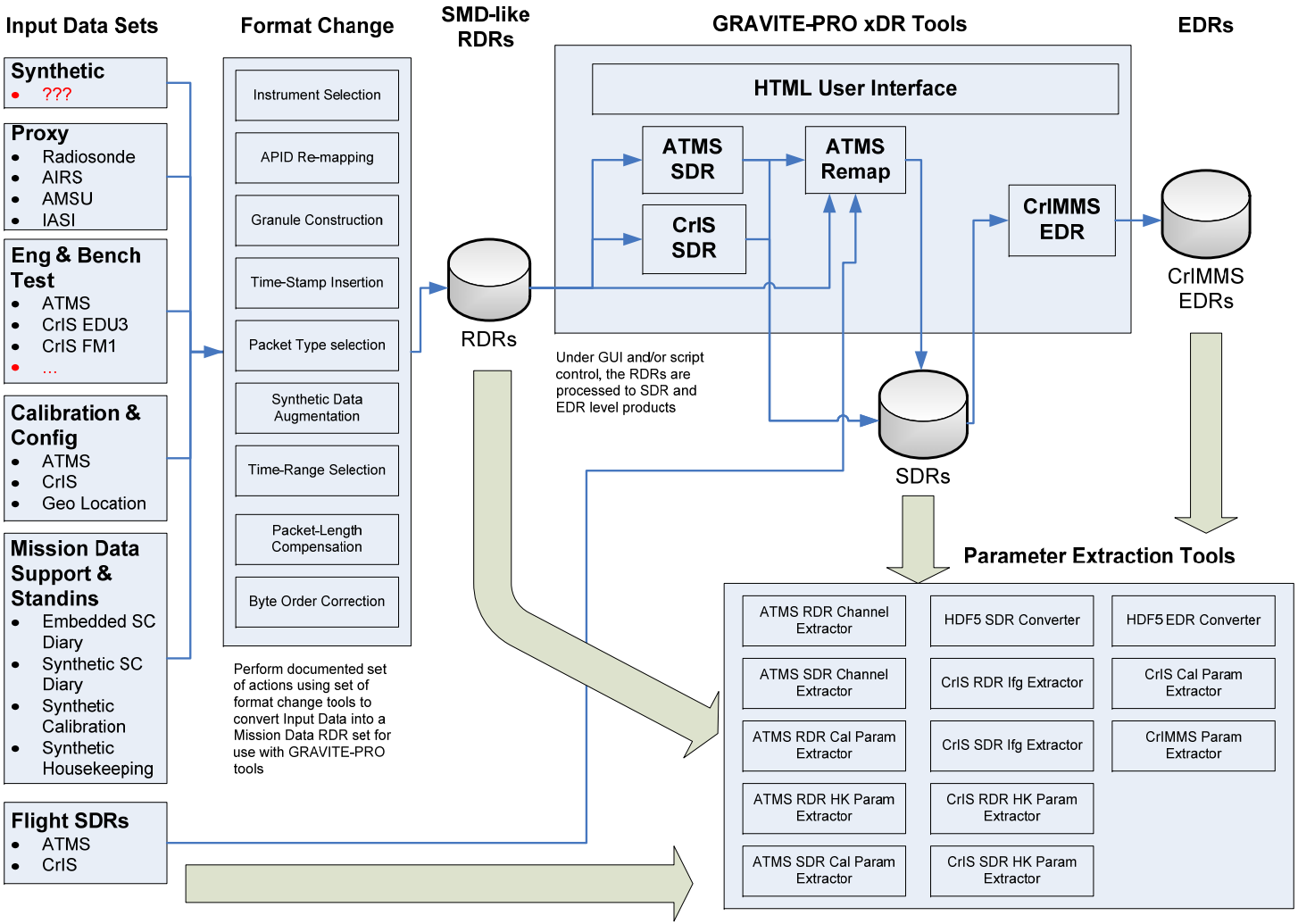


- ITT-developed Science Code is the basis for IDPS development – provides preflight SDR coefficients and instrument performance analysis
- Our effort will validate the science and IDPS codes, before launch, using AIRS/AMSU and IASI/AMSU proxy data

Cal/Val Data Processing Support

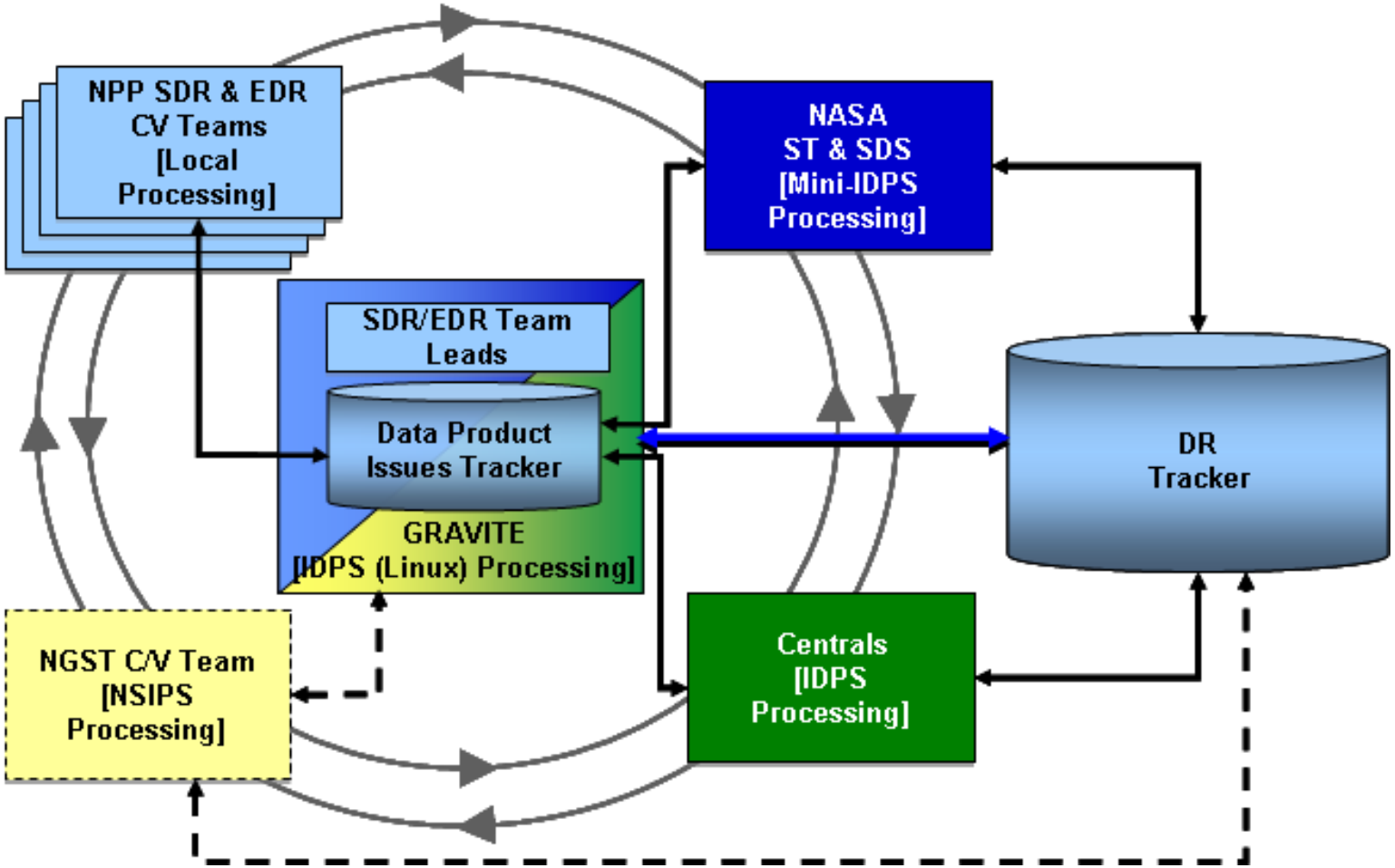


GRAVITE Linux SDR Validation Tool



Sophisticated, flexible package available for team member use

Cal/Val Communications/Coordination



- Team members linked by Internet and teleconferencing links
- External partners attached on a case-by-case basis

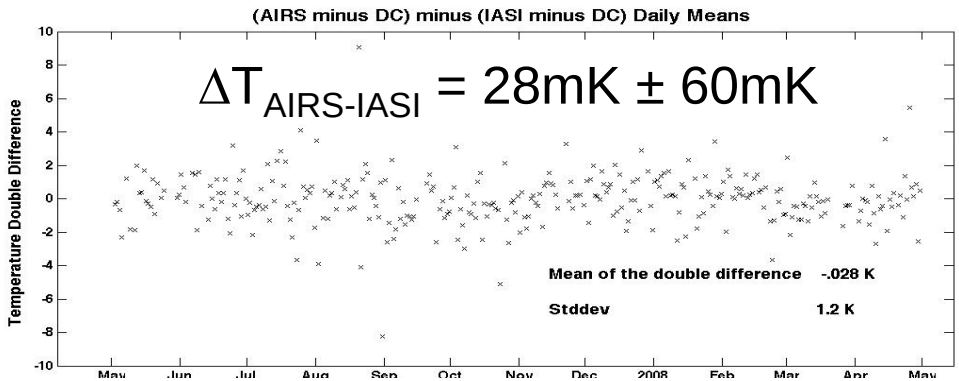
Cal/Val Preflight Exercises

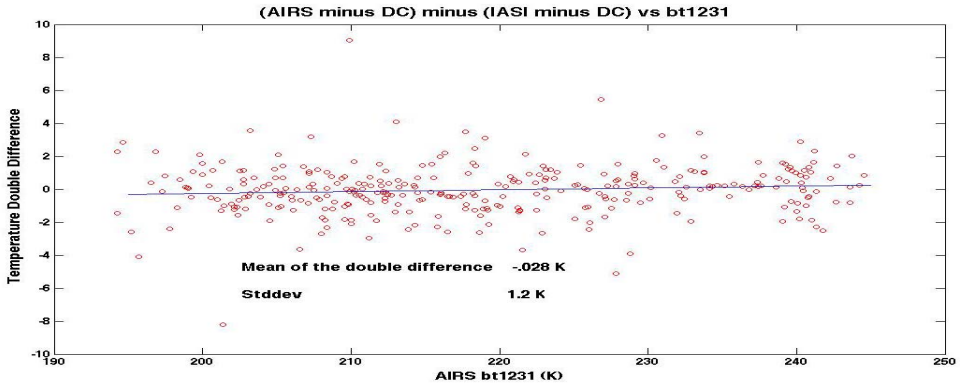
- The data and software interfaces required for Cal/Val effort are complex and cross many boundaries.
- Critical prelaunch steps to implement this plan include:
  - Completion of tool development and validation
  - Definition and EXERCISE of data interfaces and products
  - Specific Cal/Val tasks linked to specific SDR coefficients
  - EXERCISE the Cal/Val data to coefficient update procedure
- Pre-launch Cal/Val exercise plan is under consideration that would use proxy data collection to allow end-to-end verification of SDR performance and the EDR interface.
  - Use real time AIRS & IASI data collection as proxy data source
  - Utilize an aircraft campaign to provide benchmark calibration of existing (heritage) assets.
  - Aircraft requirement may have changed with AIRS/IASI existence and GSICS efforts
  - Verify tools and ancillary data collection, access – utilization

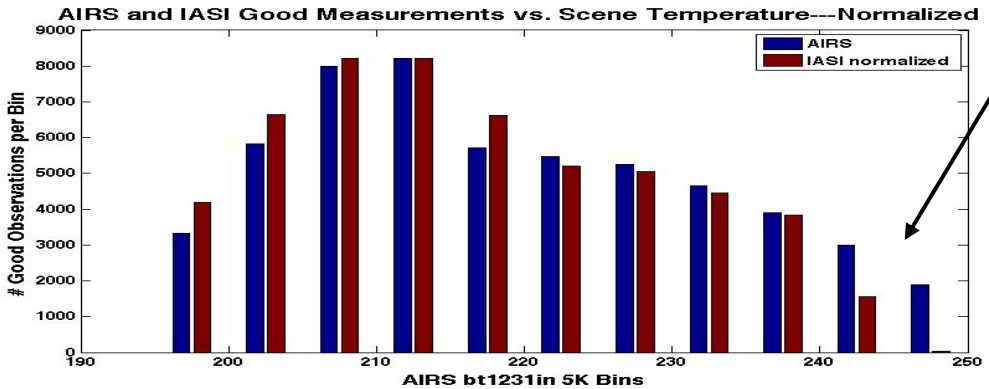
NPP Cal/Val Plan Implementation

- Careful, in-depth coordination of CrIS SDR and CrIMSS EDR planning and development teams is critical to smooth function.
- CrIS/ATMS plans are being carefully coordinated to assure comparable results and timing.
- CrIS/ATMS plans are also being coordinated with the rest of the NPP SDR and EDR plans to provide a single, unified, resourced plan.
- Team leads are shown on the following chart.
- International coordination and cooperation are welcomed.
  - Initial contacts should be via the team leads.
  - Final arrangements made agency to agency.

All-Sky Double Difference (DD) AIRS and IASI Identifies Low Bias and Trend







No Apparent Seasonal Drift over 1 Year
(Clear Conditions)

No Temperature Dependent Biases

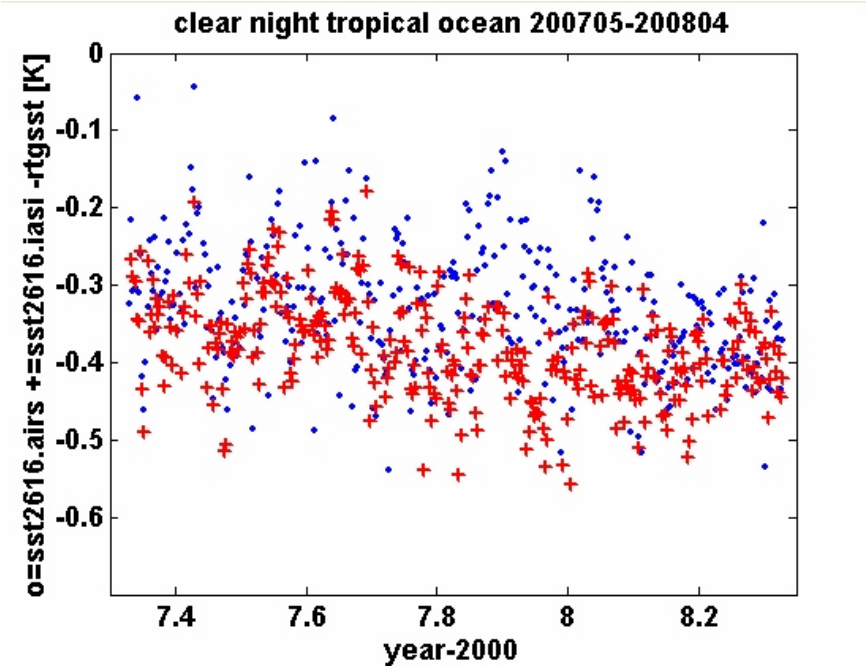
Yield Loss at Mid Temperature Range viewing Dome C

- **>50000 Points Used**
- **Over 1 Year Period**
- **Daily Observations**

From D. Elliott, JPL

IASI-AIRS DD SST Comparisons
Accuracy depends on Atmos. Correction

2616 cm^{-1}, T_{corr} = 0.4K

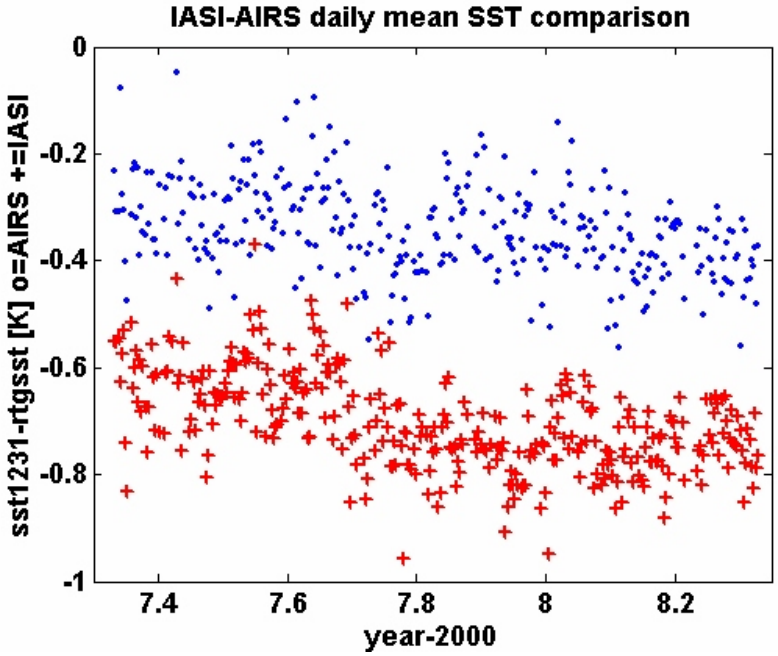


Bias: 45 mK ± 30 mK

Trend is +11 +/- 11 mK/year

AIRS and IASI have a small cold bias due to cloud leak

1231 cm^{-1}, T_{corr} ~ 4K



Bias: 350 mK ± 30 mK

Trend is -52 ± 17 mK/year

The bias difference of 0.35 K is due to a difference in the definition of what is clear

~10,000 Points Per Day

NPP Cal/Val Discipline Leads

- NPP IPO Cal/Val Product Area Discipline Leads and their NGST counterparts
  - ***SDR***
    - VIIRS – Frank DeLuccia (Aerospace) & Lushalan Liao (NGST)
    - CrIS - Gail Bingham (USU/SDL) & Denise Hagan (NGST)
    - OMPS – Scott Janz (NASA/GSFC) & James Done (NGST)
    - ATMS – Ed Kim (NASA/GSFC), Bill Blackwell (MIT/LL) & Giovanni DiAmici (NGST)
  - ***EDR***
    - VIIRS Atmosphere: David Starr (NASA/GSFC) & Mike Plonski (NGST)
    - VIIRS Land: Jeff Privette (NOAA/NESDIS/NCDC) & Alain Sei (NGST)
    - VIIRS Ocean: Bob Arnone (NRL) & Patty Pratt (NGST)
    - VIIRS Imagery/Cloud Mask: Tom Kopp (Aerospace at AFWA) & Mike Plonski (NGST)
    - CrIS/ATMS Sounding: Chris Barnet (NOAA/NESDIS/STAR) & Denise Hagan (NGST)
    - OMPS Ozone: Larry Flynn (NOAA/NESDIS/STAR) & James Done (NGST)

Plan Implementation Summary

- CrIS SDR Cal/Val effort has 4 branches:
  - Thermal Vacuum performance assessment and SDR validation
    - Team wide, biweekly data analysis telecom and result progress reviews
    - Exercise science SDR code with independent TV results
  - Detailed "Task Network" item update and optimization
    - Coefficient identification and CV task link assignment
    - Effort error and resource analysis
  - CV system exercise plan development, budgeting and schedule
    - Coordination and buy-in across agencies and sensors
    - Resource availability verification and schedule development
  - CV personnel interfaces and network development / validation
    - Completion of IDPS to Linux code conversion for GRAVITE
    - GRAVITE operations plan development and user team review
- Careful, in depth coordination of CrIS SDR and CrIMSS EDR planning and development teams is critical to smooth function.