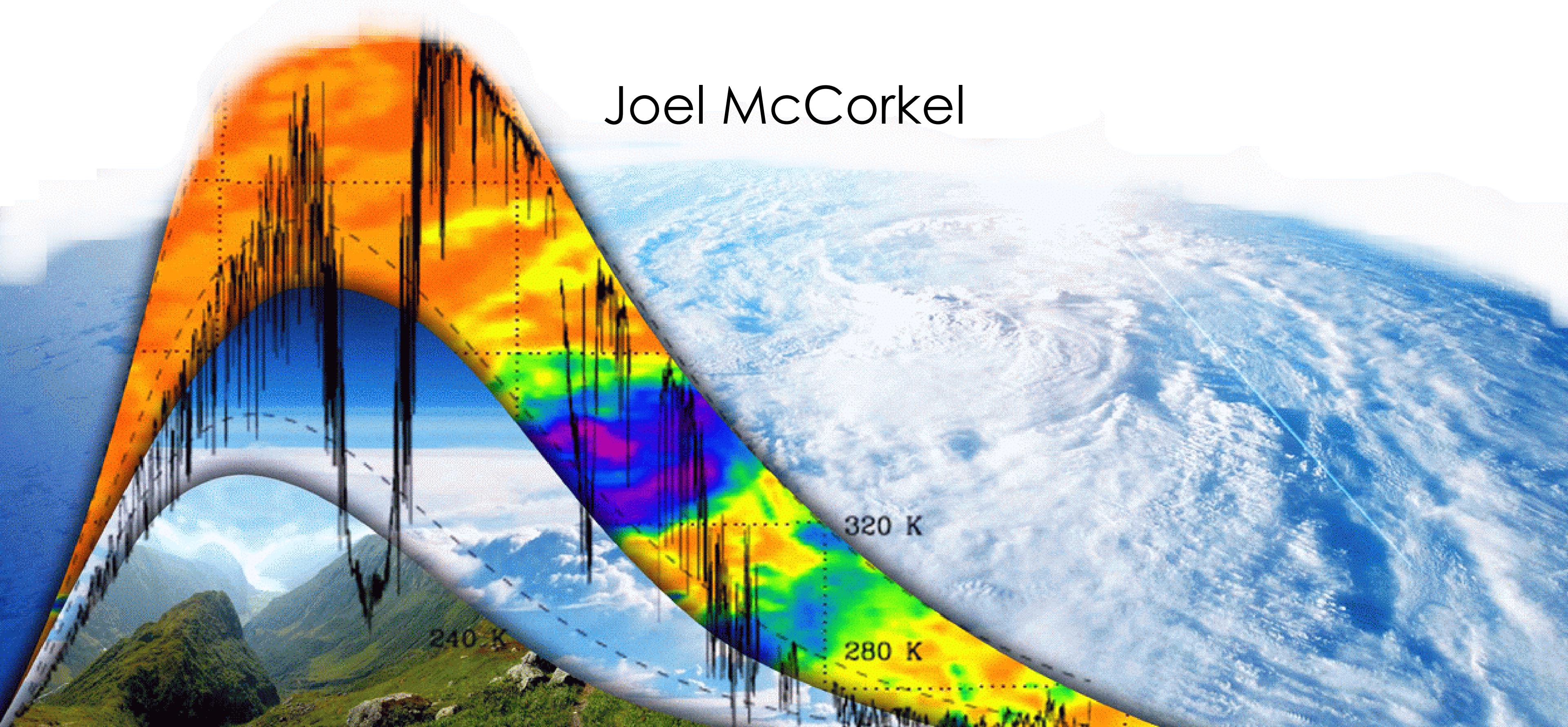
National Aeronautics and Space Administration
Goddard Space Flight Center

Calibration approaches for climate measurements

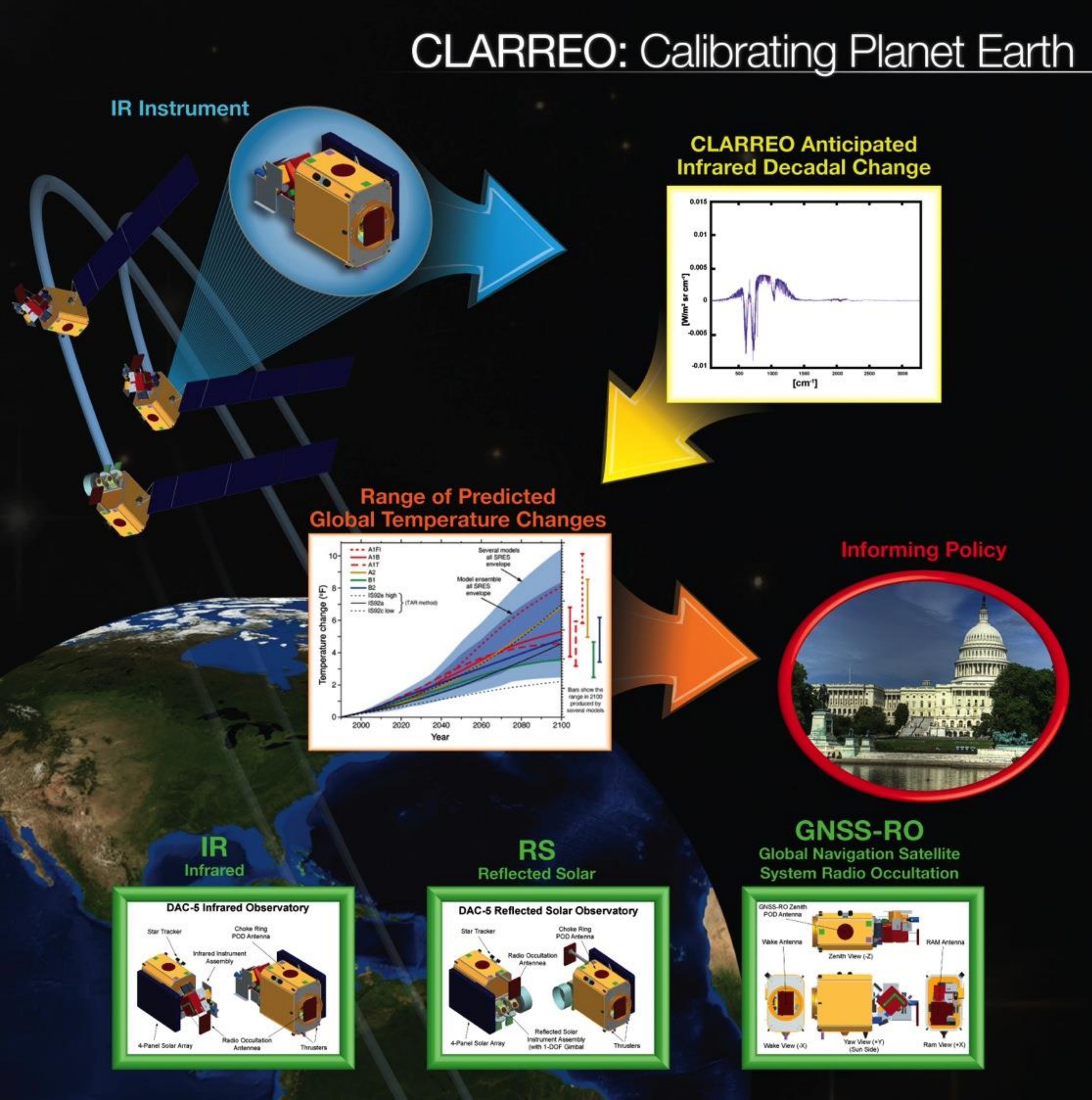
Joel McCorkel



Talk overview

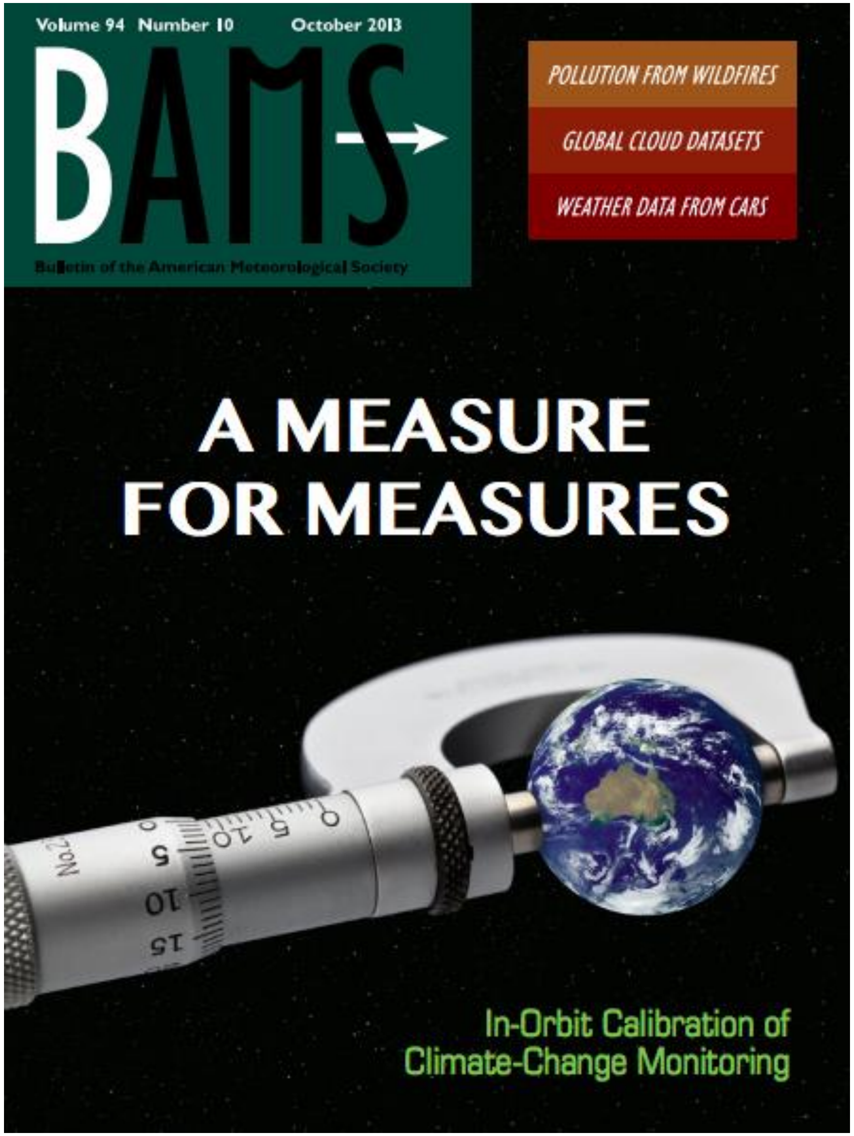
Discussion of complementary laboratory and on-orbit calibration methods for climate measurements

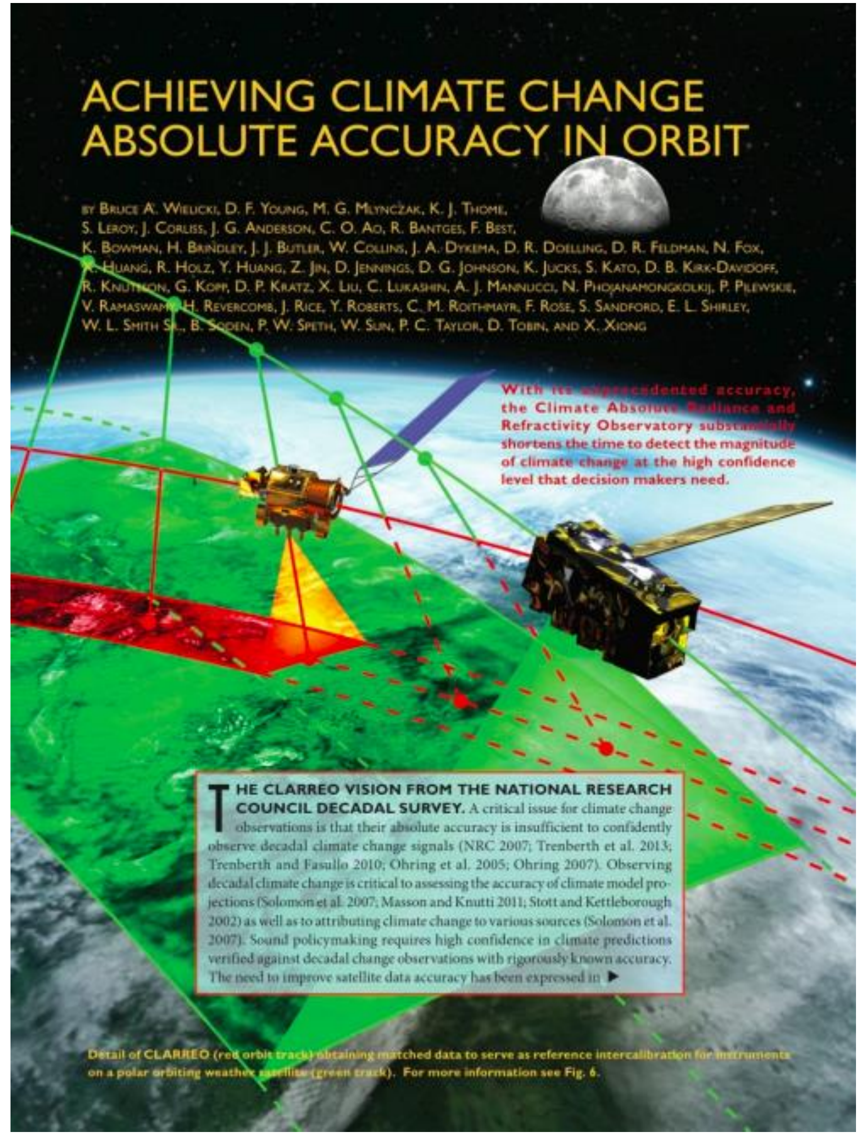
- CLARREO Mission
  - High accuracy calibration requirements
- SI traceability in the laboratory
  - NIST's SIRCUS (detector-based calibration with laser sources)
  - Calibration of G-LiHT, ORCA, SOLARIS (CLARREO), HyPlant, VIIRS
- Model-based sensor inter-calibration
  - Value of imaging spectrometer for site characterization



CLimate
Absolute
Radiance &
REfractivity
Observatory

Calibration for climate observations





ACHIEVING CLIMATE CHANGE ABSOLUTE ACCURACY IN ORBIT

BY BRUCE A. WIELICKI, D. F. YOUNG, M. G. MLYNCZAK, K. J. THOME, S. LEROY, J. CORLISS, J. G. ANDERSON, C. O. AO, R. BANTGES, F. BEST, K. BOWMAN, H. BRINDLEY, J. J. BUTLER, W. COLLINS, J. A. DYKEMA, D. R. DOELLING, D. R. FELDMAN, N. FOX, X. HUANG, R. HOLZ, Y. HUANG, Z. JIN, D. JENNINGS, D. G. JOHNSON, K. JUCKS, S. KATO, D. B. KIRK-DAVIDOFF, R. KNUTESON, G. KOPP, D. P. KRATZ, X. LIU, C. LUKASHIN, A. J. MANNUCCI, N. PHOJANAMONGKOLKIJ, P. PILEWSKIE, V. RAMASWAMY, H. REVERCOMB, J. RICE, Y. ROBERTS, C. M. ROITHMAYR, F. ROSE, S. SANDFORD, E. L. SHIRLEY, W. L. SMITH SR., B. SODEN, P. W. SPETH, W. SUN, P. C. TAYLOR, D. TOBIN, AND X. XIONG

With its unprecedented accuracy, the Climate Absolute Radiance and Refractivity Observatory substantially shortens the time to detect the magnitude of climate change at the high confidence level that decision makers need.

THE CLARREO VISION FROM THE NATIONAL RESEARCH COUNCIL DECADAL SURVEY. A critical issue for climate change observations is that their absolute accuracy is insufficient to confidently observe decadal climate change signals (NRC 2007; Trenberth et al. 2013; Trenberth and Fasullo 2010; Ohring et al. 2005; Ohring 2007). Observing decadal climate change is critical to assessing the accuracy of climate model projections (Solomon et al. 2007; Masson and Knutti 2011; Stott and Kettleborough 2002) as well as to attributing climate change to various sources (Solomon et al. 2007). Sound policymaking requires high confidence in climate predictions verified against decadal change observations with rigorously known accuracy. The need to improve satellite data accuracy has been expressed in ▶

Detail of CLARREO (red orbit track) obtaining matched data to serve as reference intercalibration for instruments on a polar orbiting weather satellite (green track). For more information see Fig. 6.

Value of Information

SpringerLink

Environment Systems and Decisions
Formerly The Environmentalist

10.1007/s10669-013-9451-8

Value of information for climate observing systems

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Published online: 23 July 2013

Abstract

The Interagency Working Group Memo on the social cost of carbon is used to compute the value of information (VOI) of climate observing systems. A generic decision context is posited in which society switches from a business as usual (BAU) emissions path to a reduced emissions path upon achieving sufficient confidence that a trigger variable exceeds a stipulated critical value. Using assessments of natural variability and uncertainty of measuring instruments, it is possible to compute the time at which the required confidence would be reached under the current and under a new observing system, if indeed the critical value is reached. Economic damages (worldwide) from carbon emissions are computed with an integrated assessment model. The more accurate observing system acquires the required confidence earlier and switches sooner to the reduced emissions path, thereby avoiding more damages which would otherwise be incurred by BAU emissions. The difference in expected net present value of averted damages under the two observing systems is the VOI of the new observing system relative to the existing system. As illustration, the VOI for the proposed space-borne CLARREO system relative to current space-borne systems is computed. Depending on details of the decision context, the VOI ranges from 2 to 30 trillion US dollars.

Electronic supplementary material

The online version of this article (doi:10.1007/s10669-013-9451-8) contains supplementary material, which is available to authorized users.

Keywords Value of information – Climate observing system – Social cost of carbon – DICE – CLARREO

Journal of Environment, Systems, and Decisions

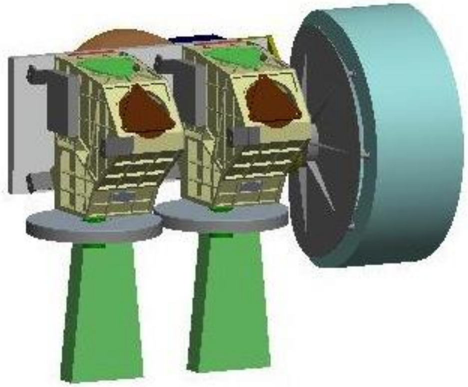
Cooke et al., 2013

Available free and open access online @ http://link.springer.com /article/10.1007%2Fs10669-013-9451-8

2-30T USD

CLARREO reflected solar instrument

Solar/**L**unar for **A**bsolute **R**eflectance **I**maging **S**pectrometer (SOLARIS)

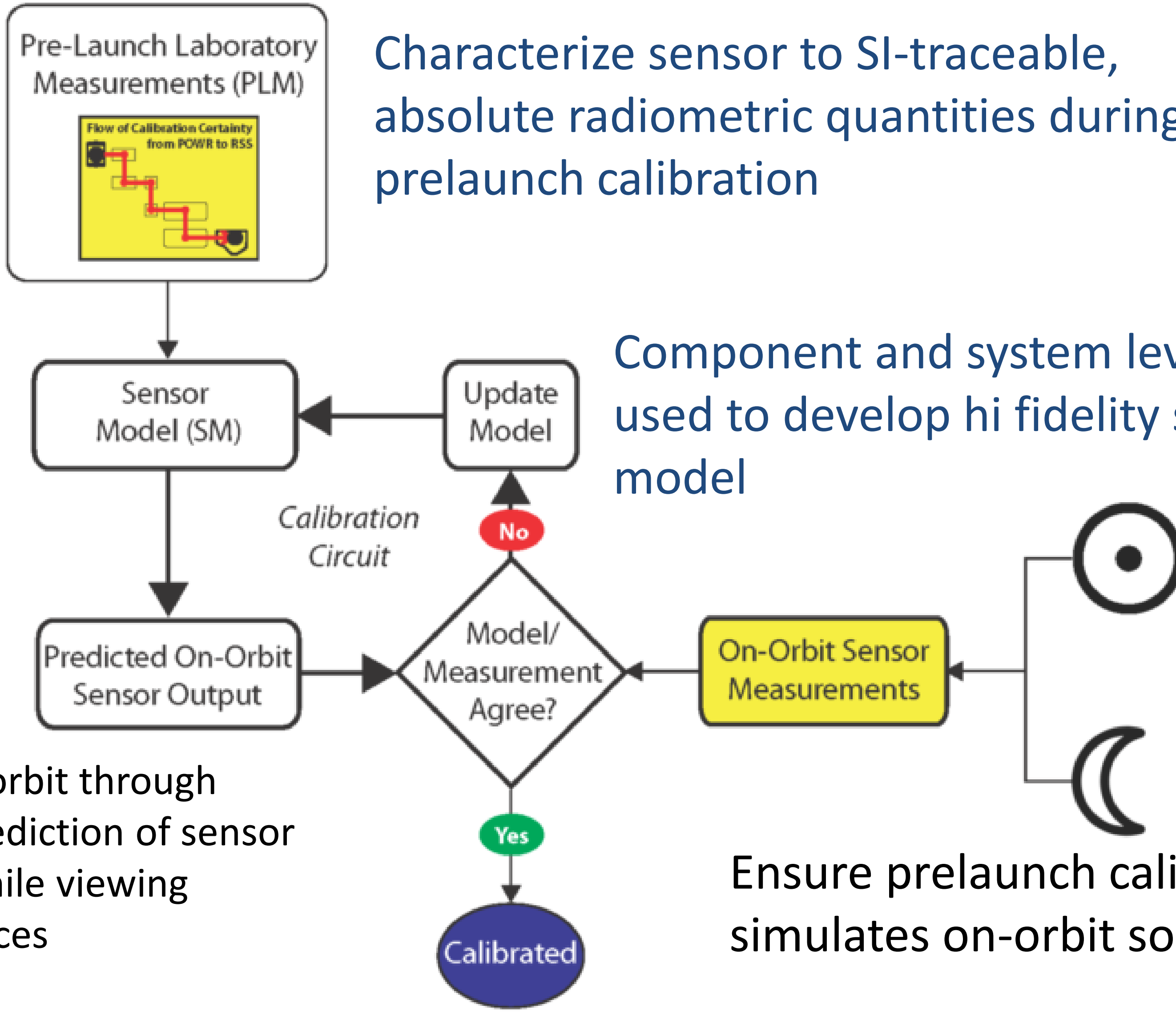


- Spectral range: **320 – 2300 nm**
- Spectral sampling: **≤4 nm**
- Spectral resolution: **8 nm**
- Swath width at nadir from 600 km orbit: **>100 km**
- GIFOV < **0.5 × 0.5 km**
- Spatial resolution per sample:
  - 70% of energy from within a 0.5 km x 0.5 km area
  - ≥ 95% within a 1.0 km x 1.0 km area
- SNR > 33 for λ < 900 nm
- SNR > 25 for λ > 900 nm
- Polarization sensitivity for 100% polarized input:
  - <0.50% (TBD) below 1000 nm and
  - <0.75% (TBD) at other wavelengths
- **Radiometric calibration accuracy: 0.3%** of albedo (integration of reflectance across all wavelengths) and within individual bands

CLARREO calibration approach

Characterize sensor to SI-traceable, absolute radiometric quantities during prelaunch calibration

Component and system level data used to develop hi fidelity sensor model

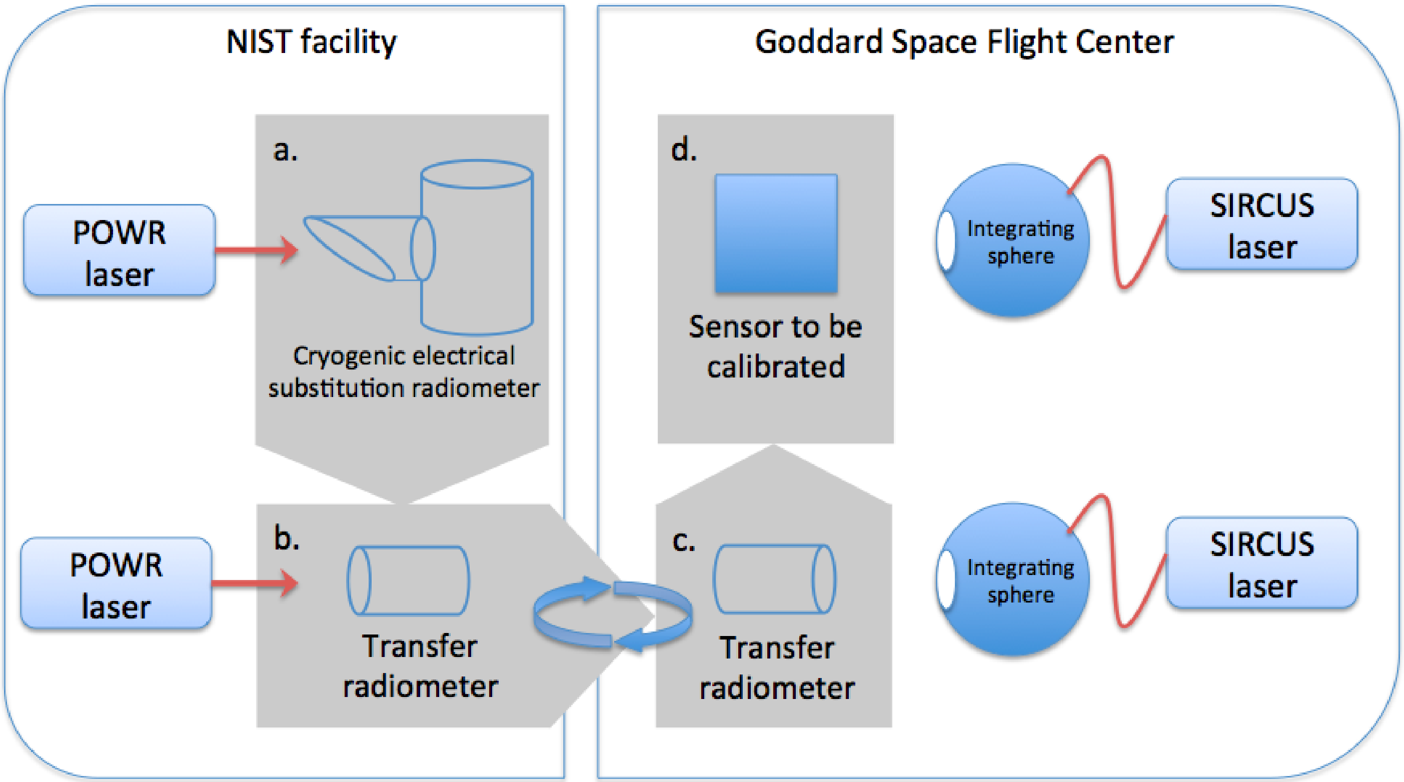


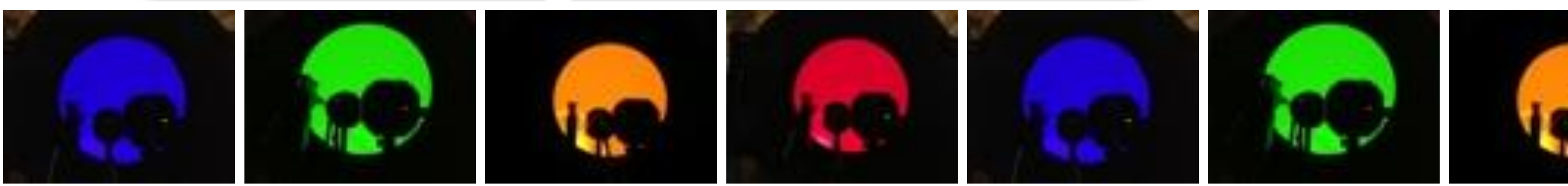
Transfer to orbit through accurate prediction of sensor behavior while viewing known sources

Ensure prelaunch calibration simulates on-orbit sources

Detector-based calibration

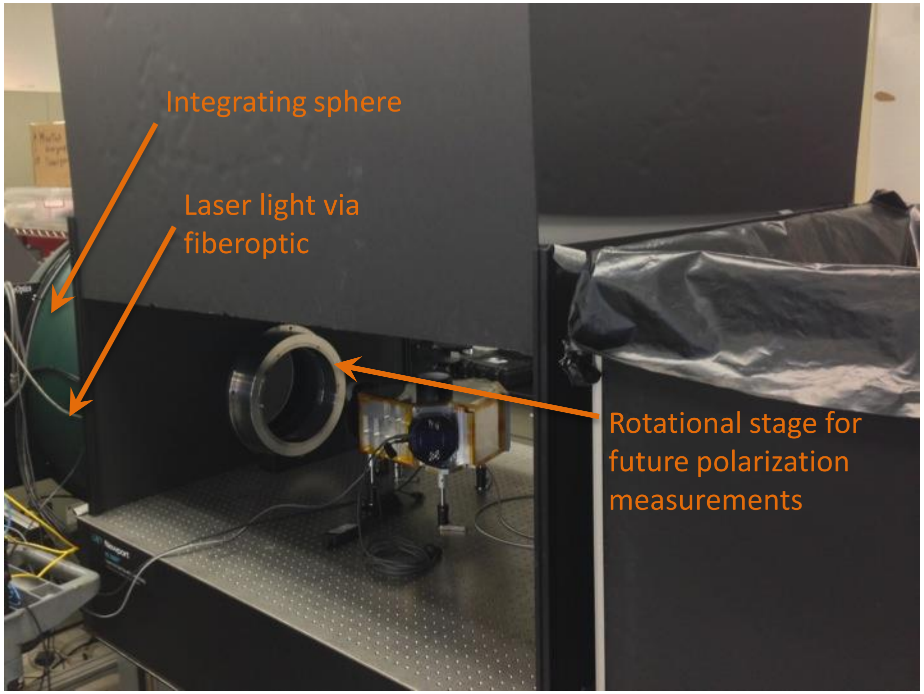
Narrow band sphere output calibrations are achieving 0.09% (k=2)

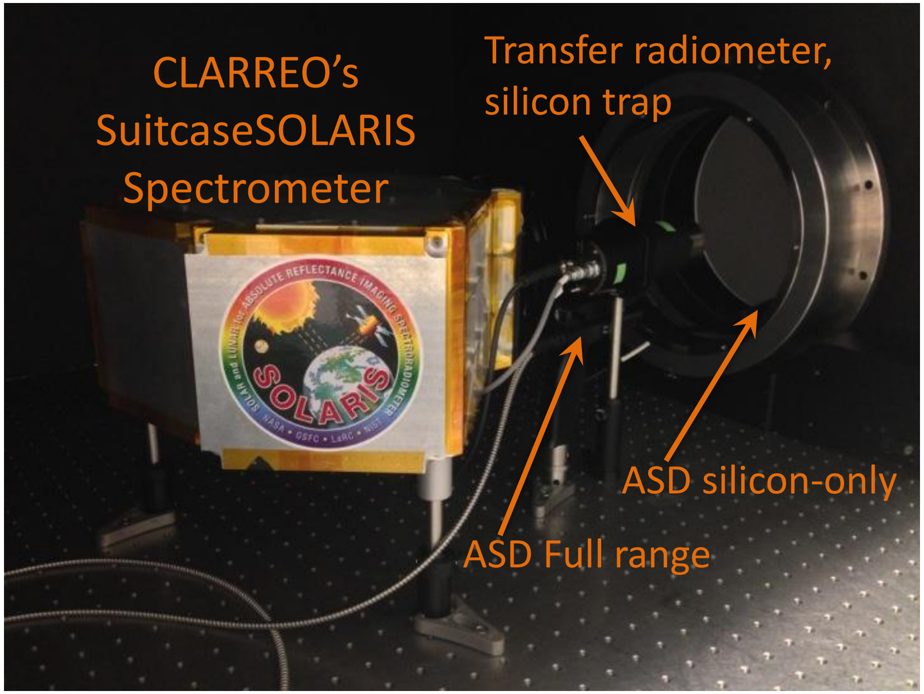




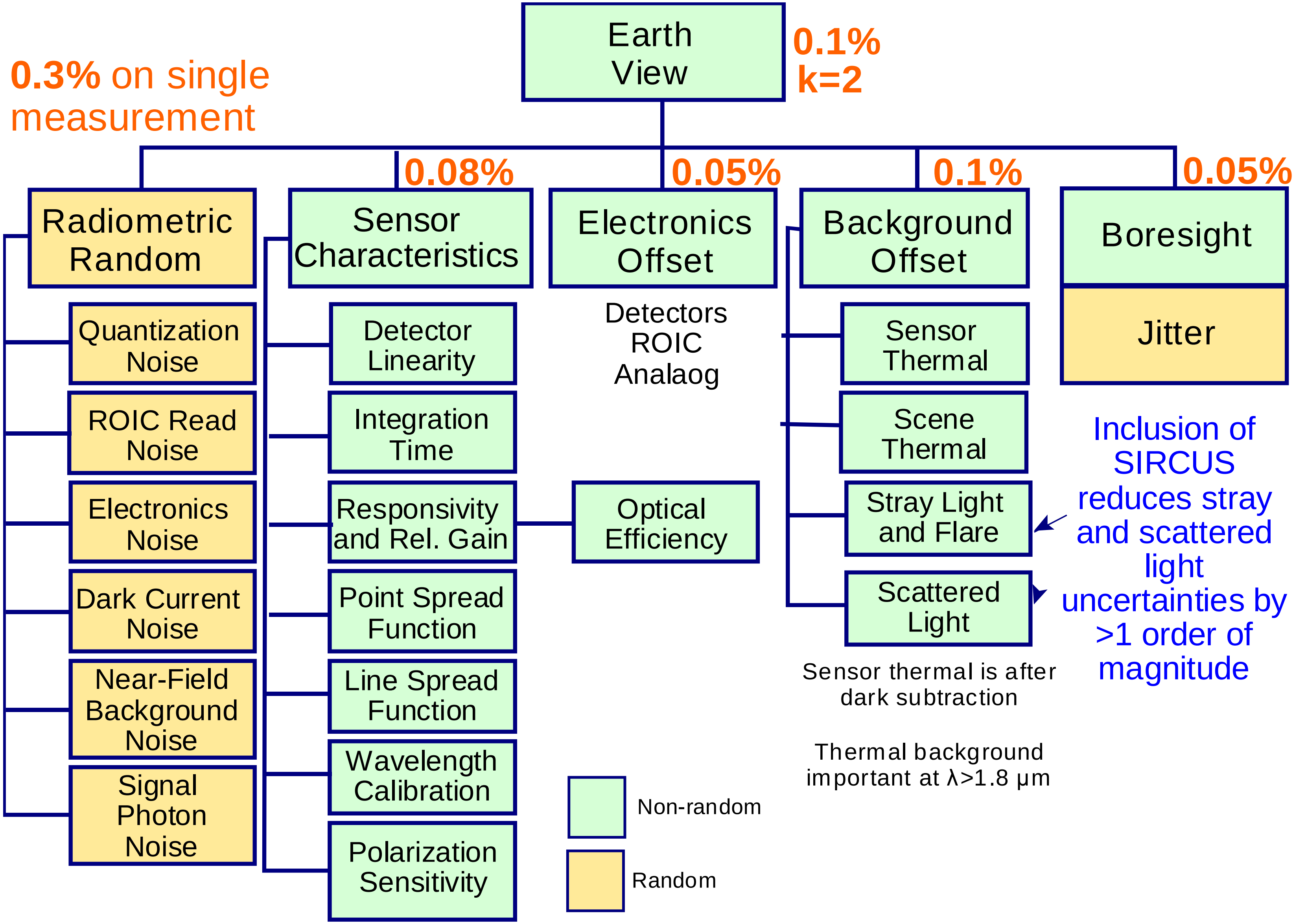
SIRCUS calibration in laboratory

Detector-based calibration with *laser-sphere* source

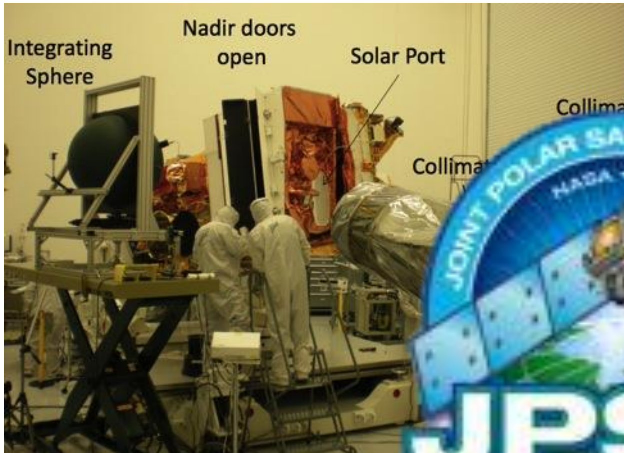


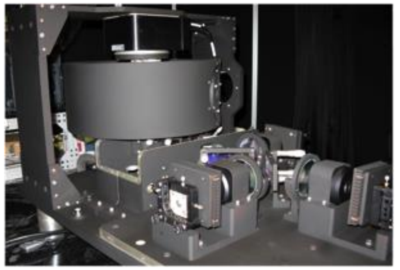


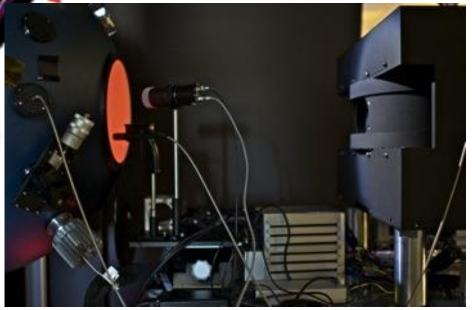
Why SIRCUS calibration?
CLARREO Earth view budget



Current SIRCUS calibration activities

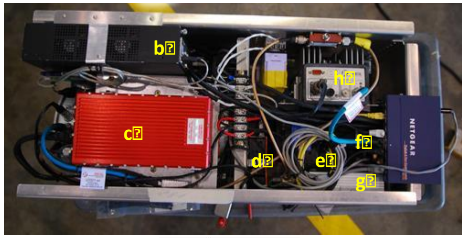




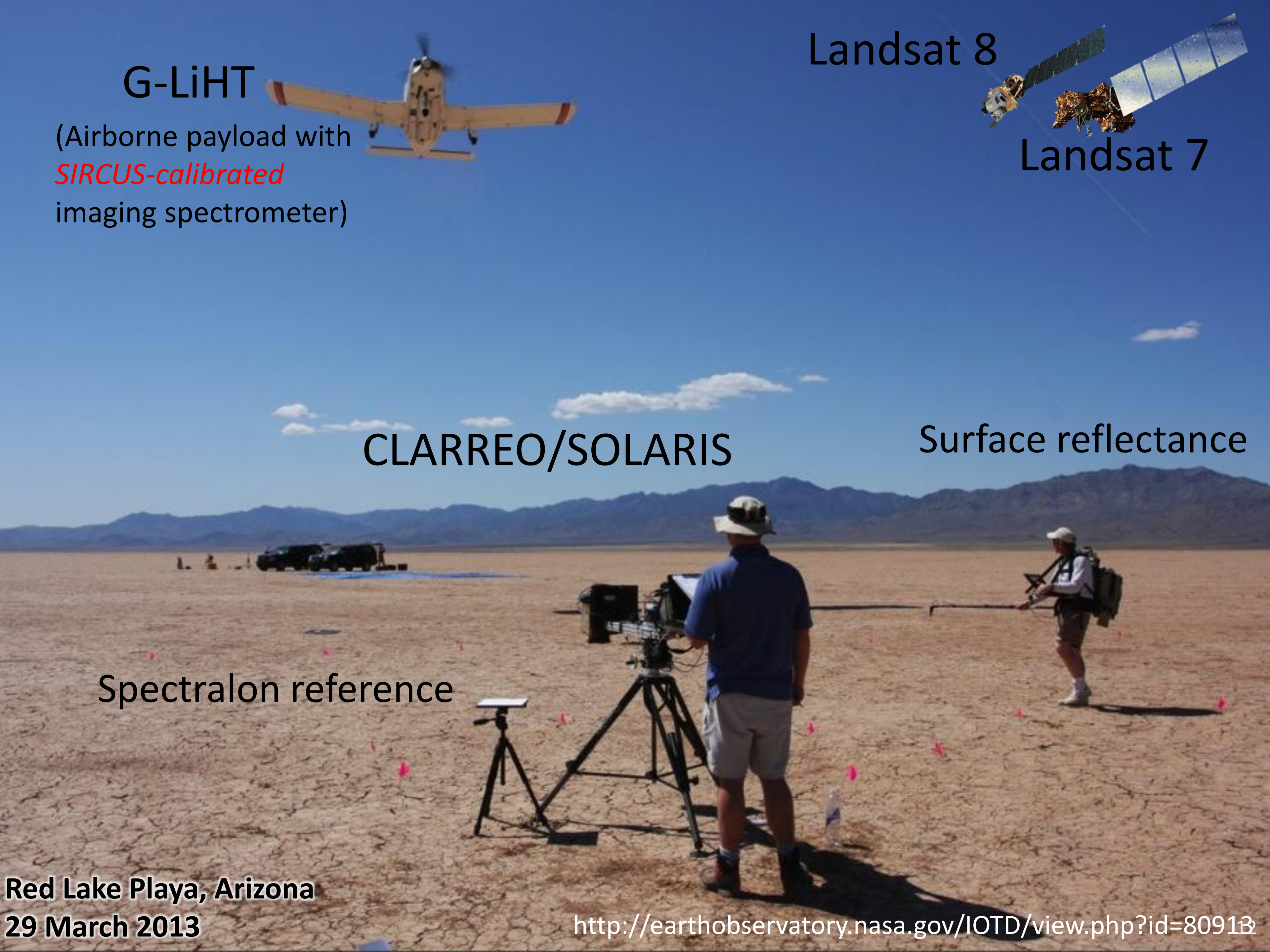


G-LiHT

Goddard's Lidar, Hyperspectral, and Thermal airborne platform

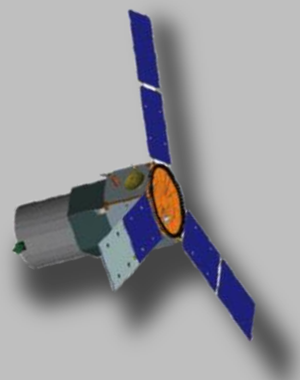


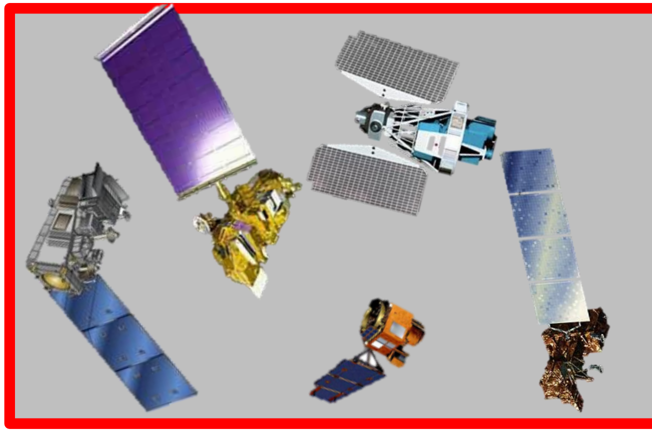
HyPlant

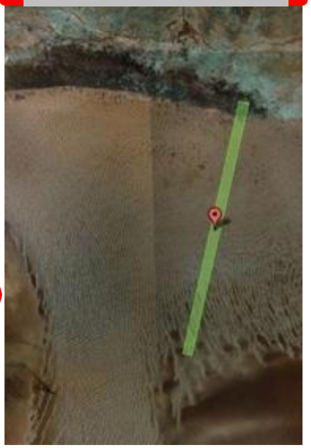

G-LiHT
(Airborne payload with
SIRCUS-calibrated
imaging spectrometer)
Landsat 8
Landsat 7
CLARREO/SOLARIS
Surface reflectance
Spectralon reference
Red Lake Playa, Arizona
29 March 2013
http://earthobservatory.nasa.gov/IOTD/view.php?id=80913

Model-based inter-calibration approach

Traceability from
- Prelaunch
- Onboard
- Sun
- Moon
- Vicarious

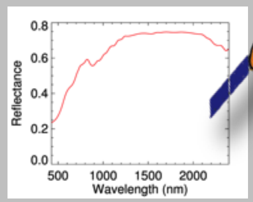


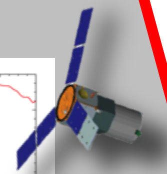




Transfer radiometer + Model supported by array of measurements

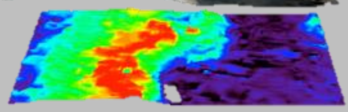
Continuous spectral reflectance measurements





Airborne measurements

SCIAMACHY

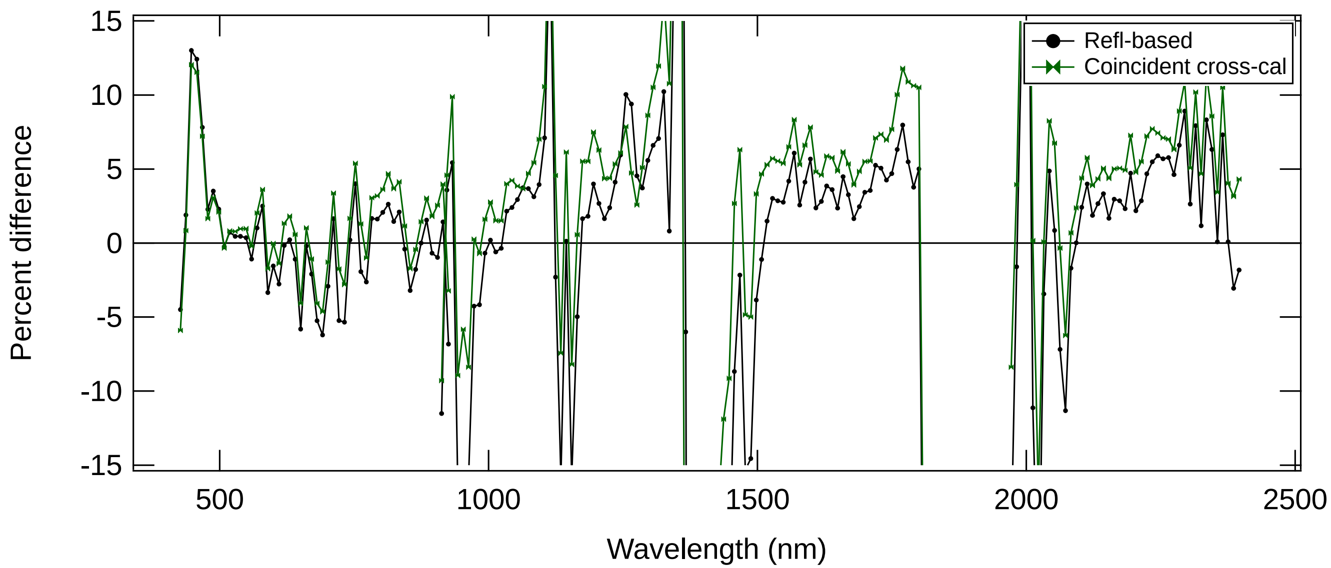


AIRS OMI BRDF Water vapor

Moves away from empirical sensor-to-sensor comparisons

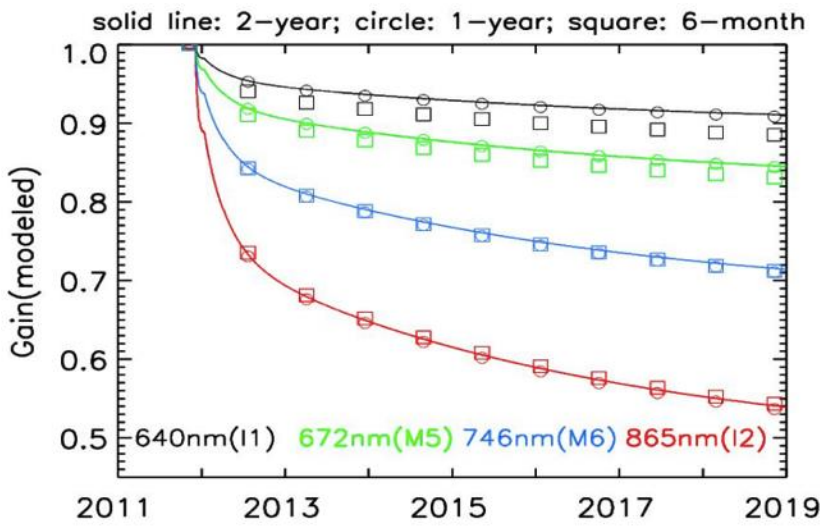
SI-traceable – error budget and uncertainty

On-orbit calibration examples



EO-1 Hyperion radiometric calibration based on

- in situ measurements (black line) and
- inter-calibration with MODIS (green line)



Suomi NPP VIIRS degradation based on model, solar diffuser, solar diffuser monitor, lunar calibration, and model

Xiong et al

Summary

- Detector-based calibration with tunable laser source for high accuracy required by CLARREO
  - Full-field, full-aperture spectral and radiometric sensor characterization
  - SI-traceable (primary optical Watt) with 0.09% k=2 uncertainty
  - Calibration methodology applied to other sensors (ORCA, G-LiHT, NPP & JPSS VIIRS, etc.)

- Imaging spectrometer would advance inter-calibration beyond sensor-to-sensor comparisons to a model-based inter-calibration by providing spectral reflectance factor

- CLARREO and HyspIRI are complementary
  - HypsIRI provides measurements for science questions detailed in other sessions of this symposium
  - CLARREO provides benchmark measurement to better understand climate forcings, responses, and feedbacks
  - CLARREO would increase value of HyspIRI by improving its calibration knowledge