National Physical Laboratory

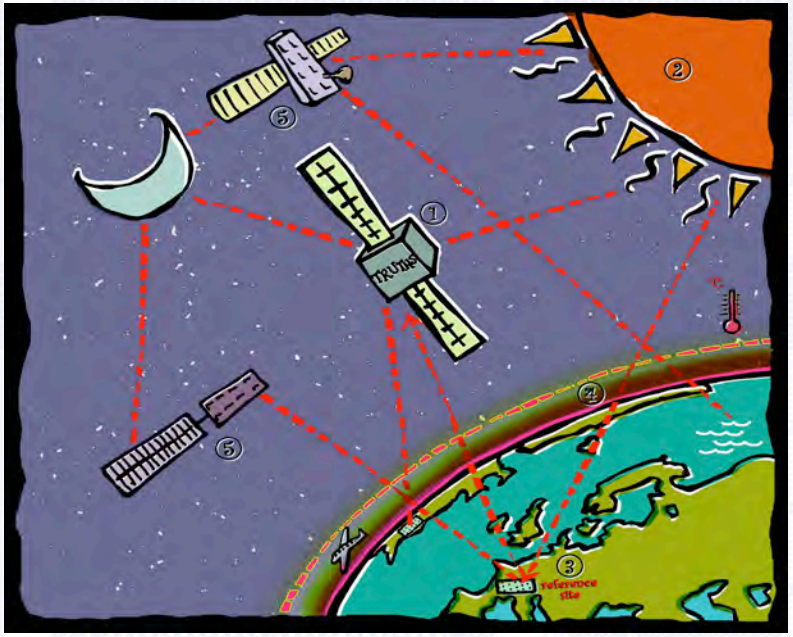
Benchmark missions to meet the needs of climate and land surface imager constellation (update)

Dr Nigel Fox

Optical Technologies and Scientific Computing Team

Quality of Life Division

Nigel.Fox@npl.co.uk



Climate action A5 (responding to GCOS)

2006/07
CEOS will plan by 2011 to make absolute, spectrally resolved measurements of radiance emitted and reflected by the Earth to space for information on variations in both climate forcings and responses.

- 2002: NPL led a team (largely from CEOS IVOS) submitting a proposal TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio-Studies) to open ESA call:
  - Benchmark mission to provide SI traceable measurements of incoming solar irradiances (total and spectrally resolved and reflected spectral radiances (0.01 to ~ 0.3% respectively)
  - Transferring its in-flight calibration accuracy to other sensors via calibrating a set of ground targets and the moon

"To the best of the reviewers' knowledge, there is presently no strong need for absolutely accurate Earth spectral radiances since other errors dominate the radiometric error budgets of planned missions."

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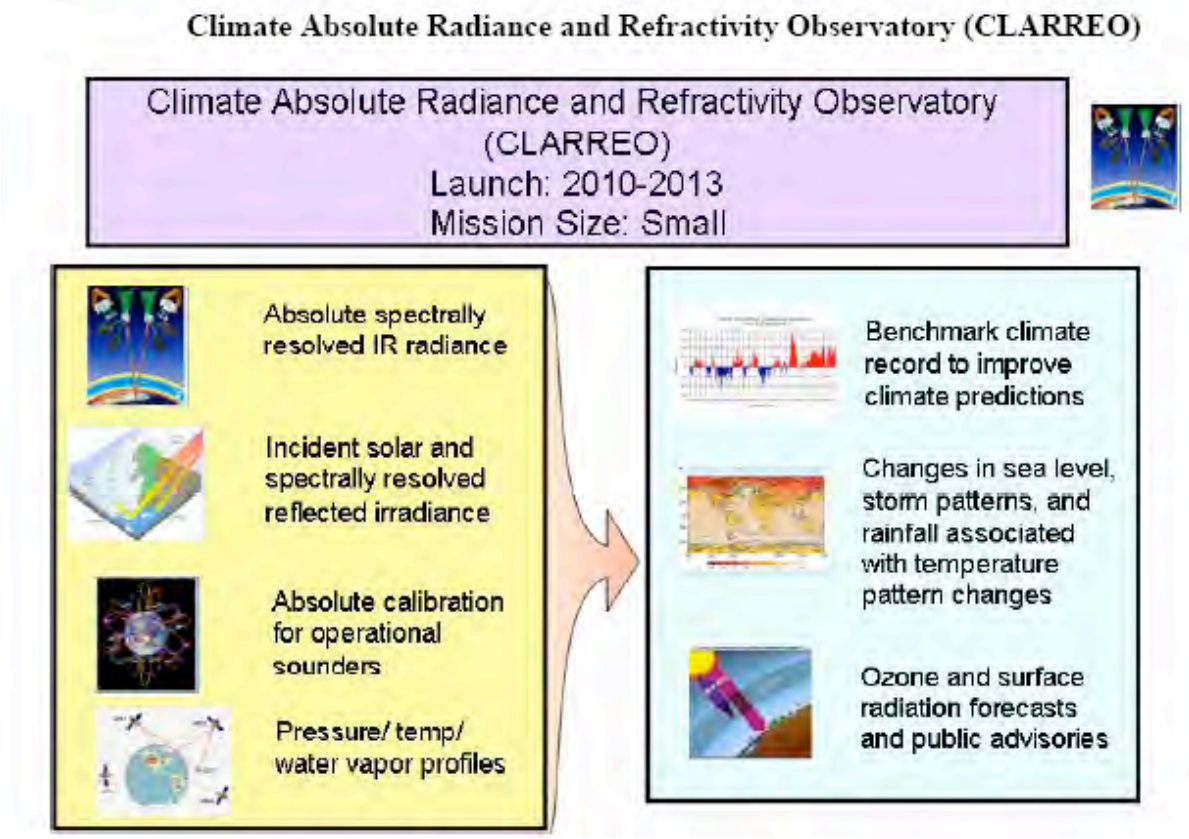
NRC decadal survey 2007



- One of four missions under consideration by NASA
- Traceability to SI in orbit is key *avoids high risk strategy needing data overlaps and instrument degradation*
- Operationally can provide calibrations to other dedicated EO missions
- Workshop July 2007 to detail requirements and options
  - Ideally 3 satellites (2 for IR, 1 solar reflective)
  - International collaboration to implement
  - TRUTHS baselined to provide solution for solar band

Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond http://www.nap.edu/catalog/11820.html

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http://map.nasa.gov/clarreo_materials.html

Requirements

Climate Need:

	Accuracy/stability (over 10 yrs)
– Total solar Irradiance	<0.02 %
– Solar spectral Irradiance	<0.1 %
– Earth reflected spectral radiance (380-2400 nm)	<0.5 %
- Emitted (brightness temp) to ~100 μm	0.1 K

Environmental monitoring …. Reliability, indisputable, sensitivity, detectability

- LSI constellation <~1%

Only reliable (low risk) solution is to establish robust traceability to international agreed standards "SI units" in common with other terrestrial applications but must have traceability "in flight"

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Status of CLARREO & TRUTHS

CLARREO

- Baseline concept is for IR to be global sampling,
  solar reflective to be targeted sampling and cross-calibration
- Mission development studies managed by Dave Young NASA Langley
  - Mission optimisation: spectral, orbits, intercomparison strategy, sampling
  - Concept development: FTIR, blackbodies, (concentrating on IR domain)

TRUTHS

- Baseline concept exists
- Primary standard (cryogenic radiometer) under design/engineering model build (NPL (UK) and WRC (CH) (testing in 2009/10)
- Promoting concept (seeking resource to optimise and launch)

  BNSC have indicated interest in seeking ways to support!

  Timely- new UK space strategy development of implementation plan

Between Projects

- Informal links

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IR development

To support climate and other research, including proposed CLimate Absolute Radiance and Refractivity Observatory (CLARREO) mission:

Realization/ validation of the IR spectral radiance scale for near-ambient radiation sources in laboratory conditions:

Scale realization and AIRI/FTS internal comparisons (accomplished in 2007).

Validation via comparison with other NMI's including PTB (Germany), NPL (UK) and NRC (Canada) is in progress (to be f inalized and reported in 2008).

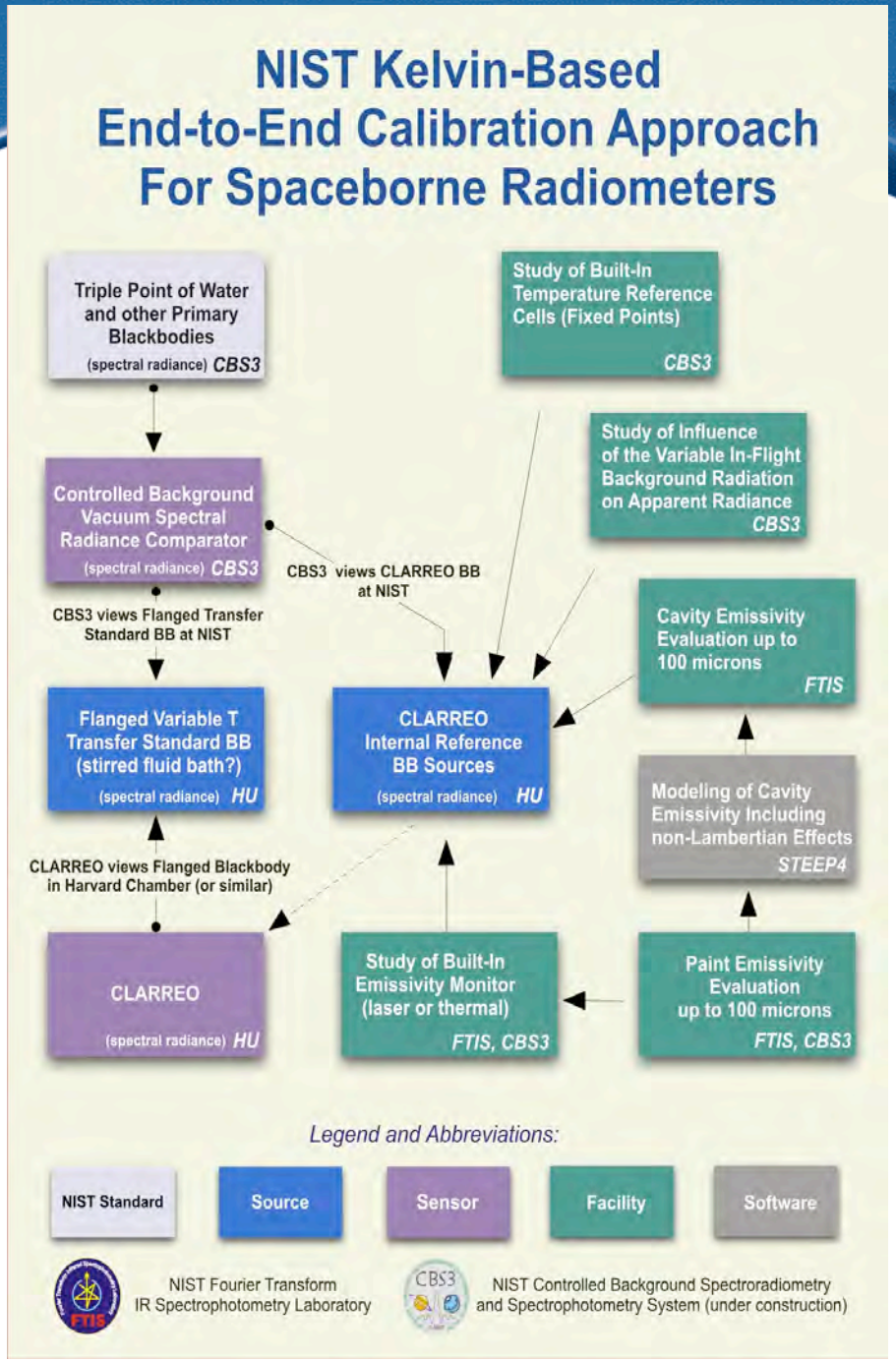
Support pre-flight calibration of space radiometric instruments:

Design of the vacuum spectral radiance comparator

In 2008 we are planning to finalize the design and proceed with CBS3 construction.

Support of in-flight monitoring to maintain and validate traceability of spaceborne instrumentation.

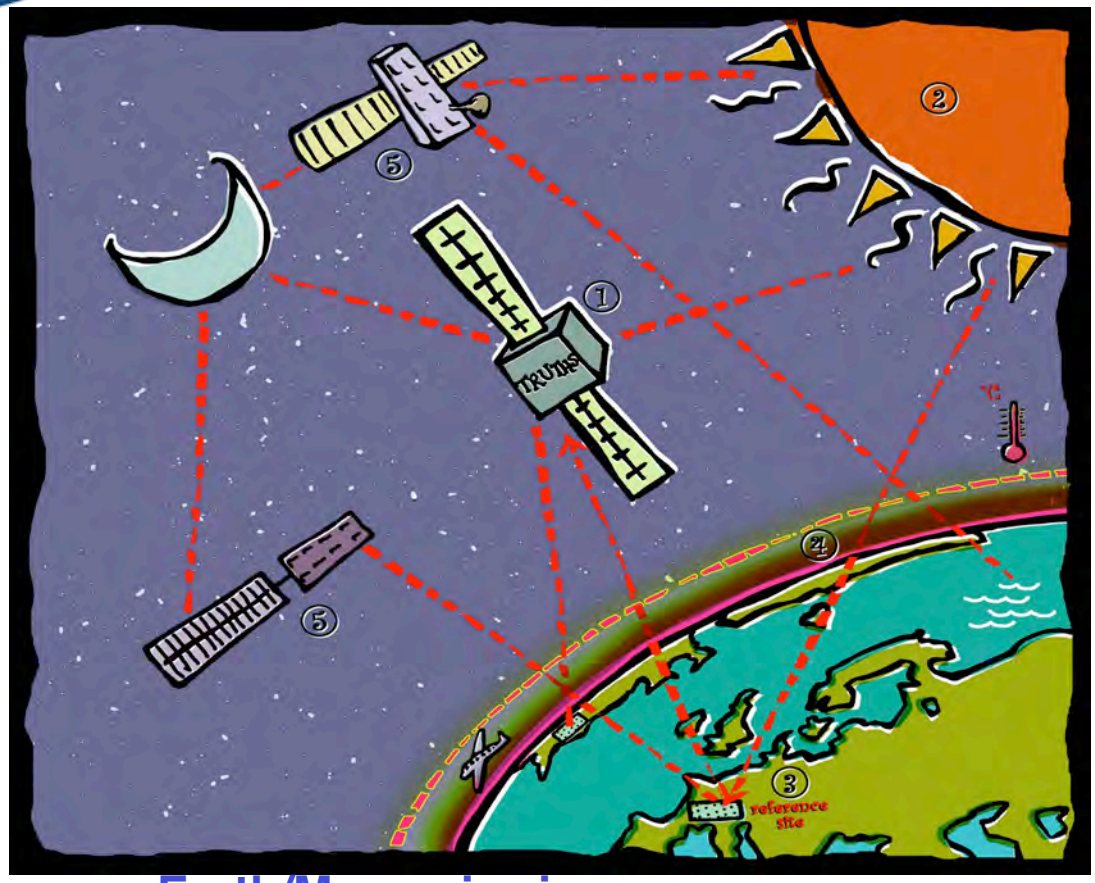
Cooperation with the School of Engineering and Applied Sciences (Harvard University) and Space Science and Engineering Center (University of Wisconsin-Madison) aimed at development of self-calibrating spaceborne blackbody - a demonstration study is planned for accomplished in 2008.



TRUTHS: Traceable Radiometry Underpinning Terrestrial- and Helio- Studies

Satellite based mission to:

- **make SI traceable high accuracy measurements of solar radiation incident on, and reflected from, the Earth**
- **transfer its unprecedented calibration accuracy to other satellite-based EO instruments through the calibration of reference targets such as the Sun, Moon and the Earth's deserts**
- **Supporting measurements of land processes, ocean colour, Earth radiation budget, atmospheric chemistry and aerosol distribution**



Earth/Moon viewing

baseline

- **Wide spectrum (380 to 2500 nm)**
- **Spatial resolution ~ 25 m (multi-angle)**
- **Spectral radiance uncertainty <0.5% (using novel in-flight calibration system)**

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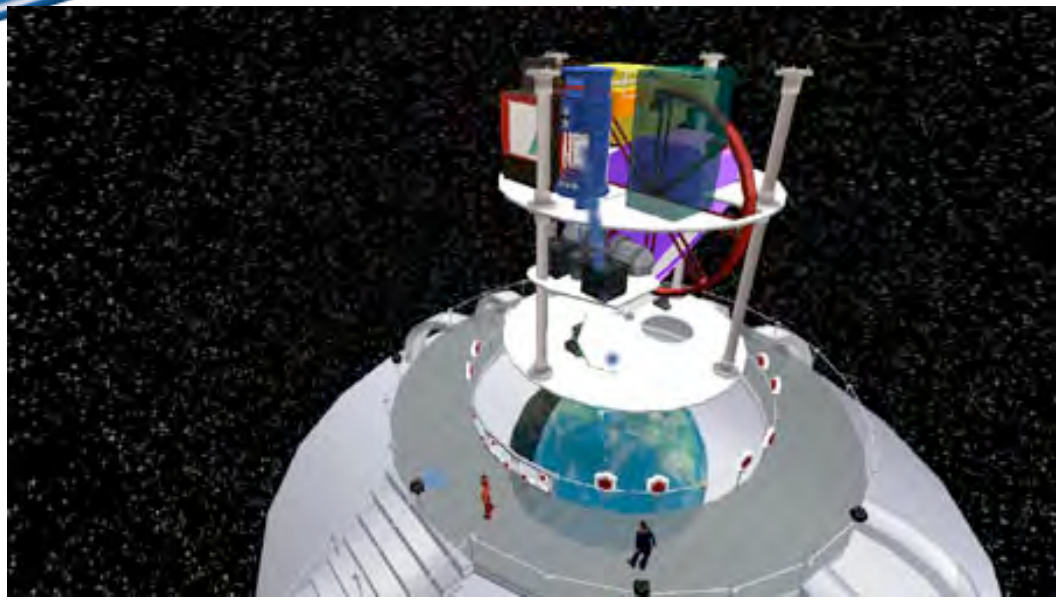
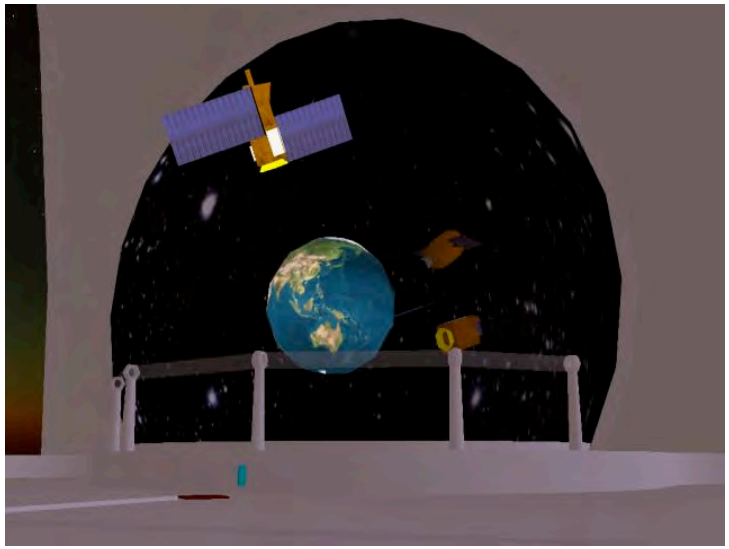
Working model in “second life”





TRUTHS mission and calibration concept is demonstrated in the virtual world “Second life”

http://slurl.com/secondlife/NASA CoLab/244/110/23

&

http://slurl.com/secondlife/SciLands/105/143/29

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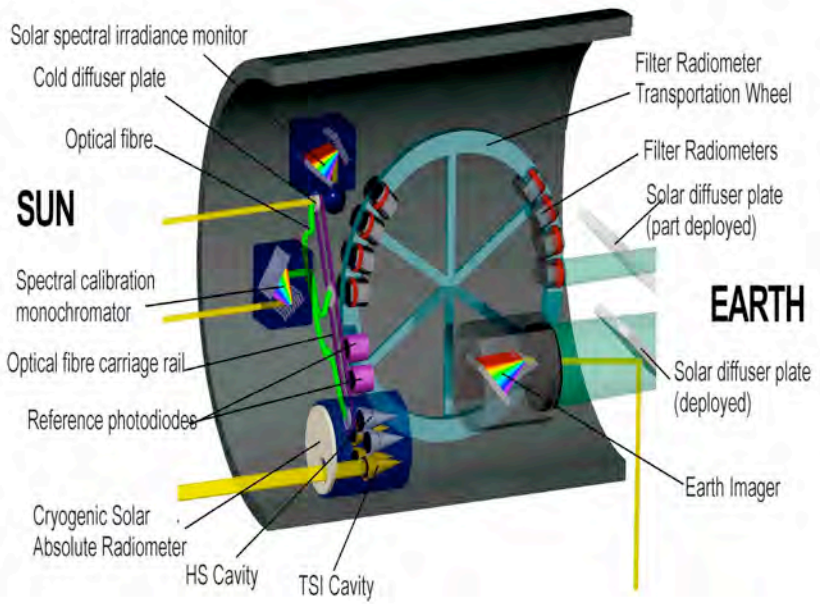
TRUTHS Traceability



Calibration drift, spectral and gain, removed by performing calibrations in space directly against a primary standard using terrestrial methodologies adapted for space.

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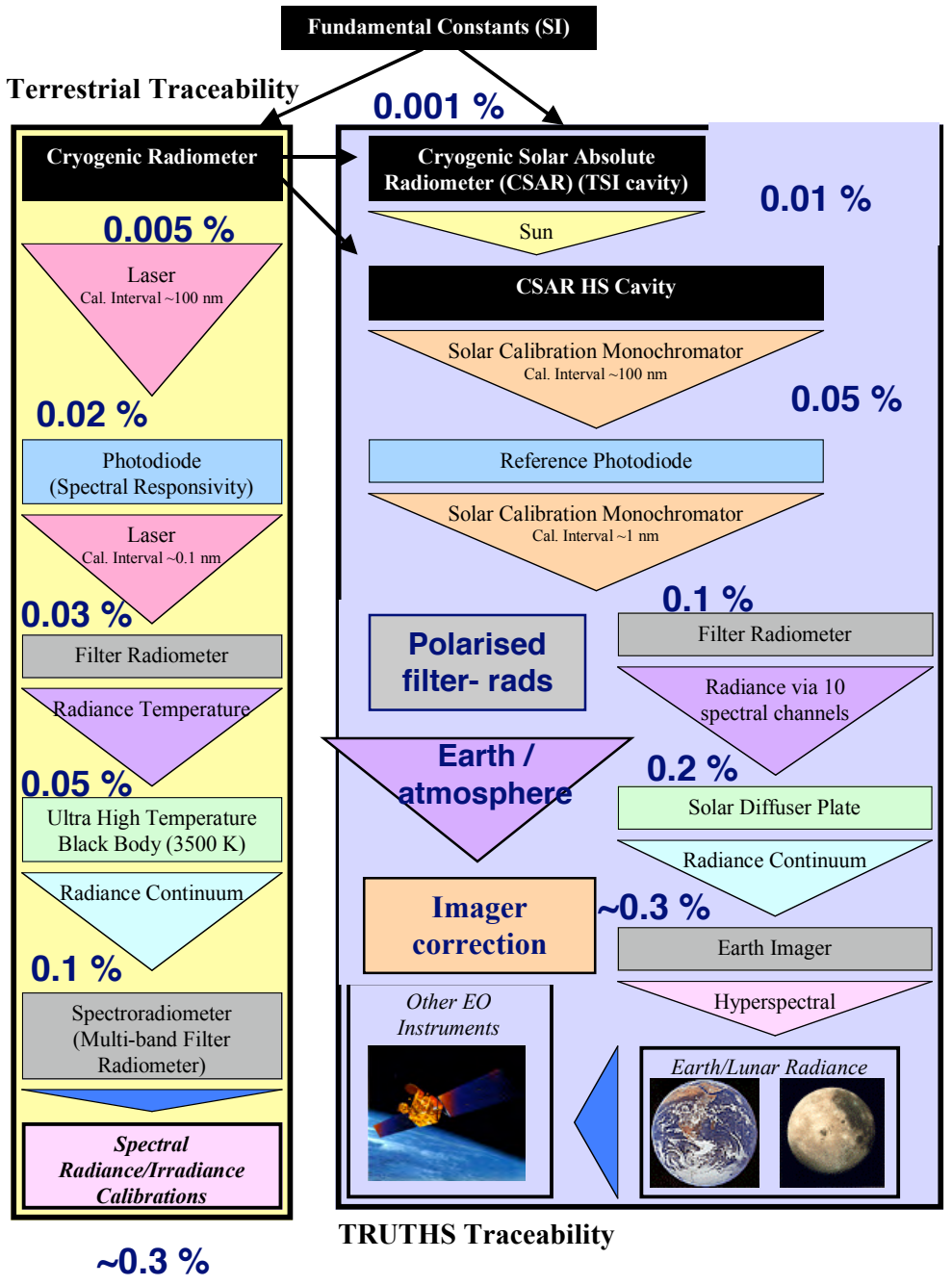
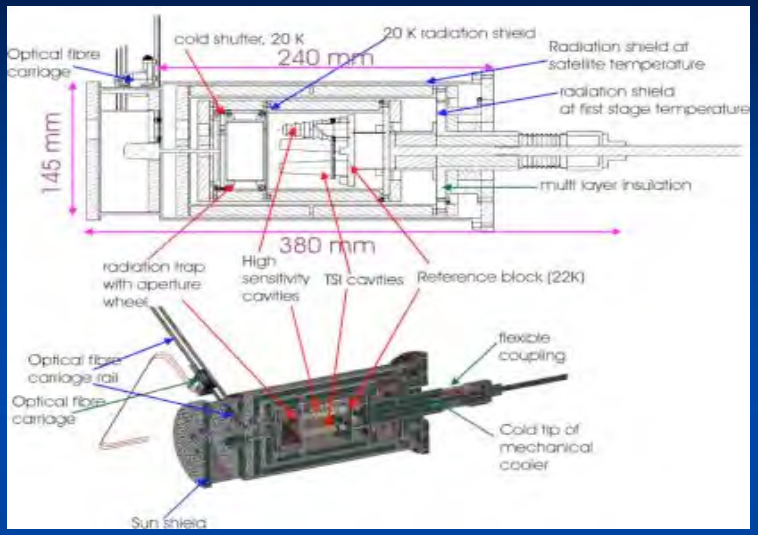


Primary standard (CSAR)

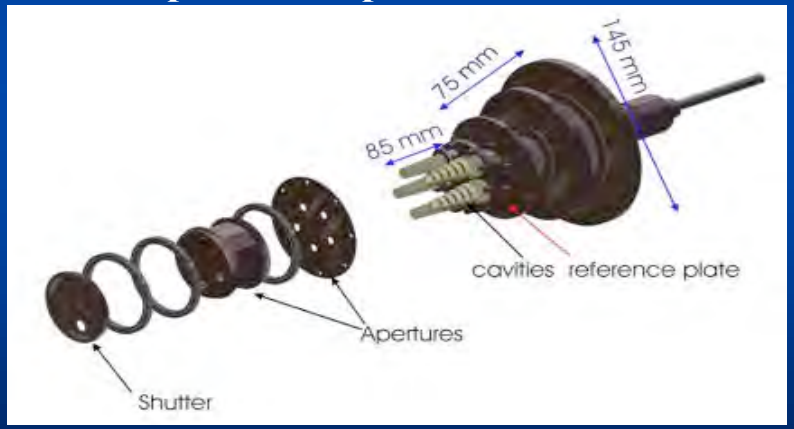
Cryogenic Solar Absolute Radiometer



Use of electrical substitution makes traceability to SI through convenient electrical units – optical interface via black cavity absorber, coated with 'NPL super-black' Solar weighted absorbtance >0.99998.

CSAR cooling from Astrium 20 K cooler

3 cavities for TSI – t ~ 15 s
- operating range 10 mW to 100 nW
2 cavities for spectral response – t ~ 0.5 s
- operating range 0.1 mW to 10 nW
3 off 5 mm precision apertures + 2 off 0.5 mm



Under development

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Geophysical parameters measured by TRUTHS (baseline)

Measurand	Spectral resolution nm	Spatial resolution m	Accuracy %
Total Solar Irradiance	Total	-	0.01
Solar Spectral Irradiance	200 – 2500 (0.5 - 1)	-	0.1
Lunar Spectral Irradiance and Radiance	380 – 2500 (10)	-	<0.5
Earth Spectral Radiance (Polarised and Non-pol) *multi-angle*	380 – 2500 (10 nominal)	~ 25 (TBD) (20 x 20 km) *for optimisation*	<0.3
via filter rads *for Aerosols / E Rad Budget*	TBD	20 km (TBD)	<0.3

Observing conditions (near polar 700 km)

Solar viewing - ~ 10 mins per orbit

Earth viewing ~ 10 sites (20 * 20 km) at 5 angles per orbit

-Pointing accuracy – 0.5 km (knowledge ~ 10 m)

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Transfer of calibration to global EO missions

- **Establishment of reference data for Sun and Moon.**
- **In-orbit Comparison of solar viewing instruments e.g SORCE.**
  - **Link to VIRGO of SOHO.**
- **Establishment of network of Earth based Reference test sites.**
  - **E.g Railroad Valley, Libyan Desert, Antarctica etc**
    Sites to be characterised by field studies
  - **Instrumented with remotely controllable/readable monitors**
  - **Calibration coefficients updated regularly by TRUTHS satellite**
  - **Data accessible over WWW to allow reprocessing to suit individual satellite footprints and spectral characteristics**
  - **Improve accuracy of all sensors but particularly those with no on-board e.g. MSG, DCM … reference for NPOESS etc minimising DATA GAPS!**

- **Simultaneous Nadir Overpass (SNO) with other sensors**
  - **additional use of Geo-stationary as monitors and transfer instruments**
- **Archived data reprocessable to improve historical reference.**
  - **Many in-flight sensors have the resolution, dynamic range and stability to allow update of calibration and viewed same desert targets.**
- **Targeted Science:** Surface BRDF, Carbon cycle, atmosphere, coastal zones ….

Summary

TRUTHS "International Standards laboratory in space" removes uncertainty due to storage, launch and degradation and its mission provides this benefit, together with SI traceability, to all other EO optical sensors in the solar spectral domain.

component of " international calibration constellation" / CLARREO / Land constellation

- **Set of SI traceable reference targets: Sun, Moon, network of ground sites**
- **Utilises terrestrially implemented techniques and technology**
  - **In-flight calibration concept applicable to other missions**
- **Order of magnitude improvement in measurement accuracy**
- **Baseline for detection of climate change – reduce need for overlapping data sets**
- **Quality Assure data used by 'decision makers' and improve synergy between sensors**
  - **Tools to underpin GMES and GEOSS initiative**
- **Improved algorithms to allow quantitative measurement of bio-physical products**
- **Provide data to improve understanding of natural solar induced variation on climate and compare with anthropogenic effects.**

The step change reduction in uncertainty and spin-off benefits is analogous to that obtained in NMIs when cryogenic radiometers were introduced in1980s

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Fox et al Adv in Space Physics **32** p2253 (2003)

Way forward

- Establish international collaboration based on
  - climate requirements
  - Land Surface imager constellation
- Design study to optimise operational and detailed instrument requirements (baseline costing)
  - IR (NASA supported)
  - TRUTHS (BNSC/ESA ?)
  - CEOS SIT (project) ~£50 to 100k (6 months)
- Establish priority need and consequential funding proposal as “CEOS mission”.

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CEOS recommendation

WGCV requirement:
To facilitate the identification of an optimum collaboration for implementation, requires a detailed design/optimisation review of the TRUTHS mission concept. This would result in a full set of instrument specifications optimised for functionality, accuracy and ability to establish traceability in-flight. Such a study would also consider the operational aspects of such a mission e.g. how best to transfer its calibrated spectral radiance values to other sensors with a particular emphasis on the mission ground-segment.

Recommendation:
CEOS agencies endorse the concept of establishing a "CEOS calibration mission" through a collaborative international partnership to address the specific needs of Climate Action A5 and the future ongoing calibration needs of GEOSS. As a first step towards such a mission, resource is requested to support a small design study, focused on the TRUTHS concept to establish a "straw-man" as a basis for international collaboration.

WGCV follow up Action:
CEOS WGCV IVOS sub-group to provide support to the study and ensure coordination with the broader CLARREO mission. Following the completion of the report the IVOS sub-group will identify potential collaboration opportunities between members based on the reports findings.