Outcome of the GSICS/CEOS-IVOS Lunar Calibration Workshop

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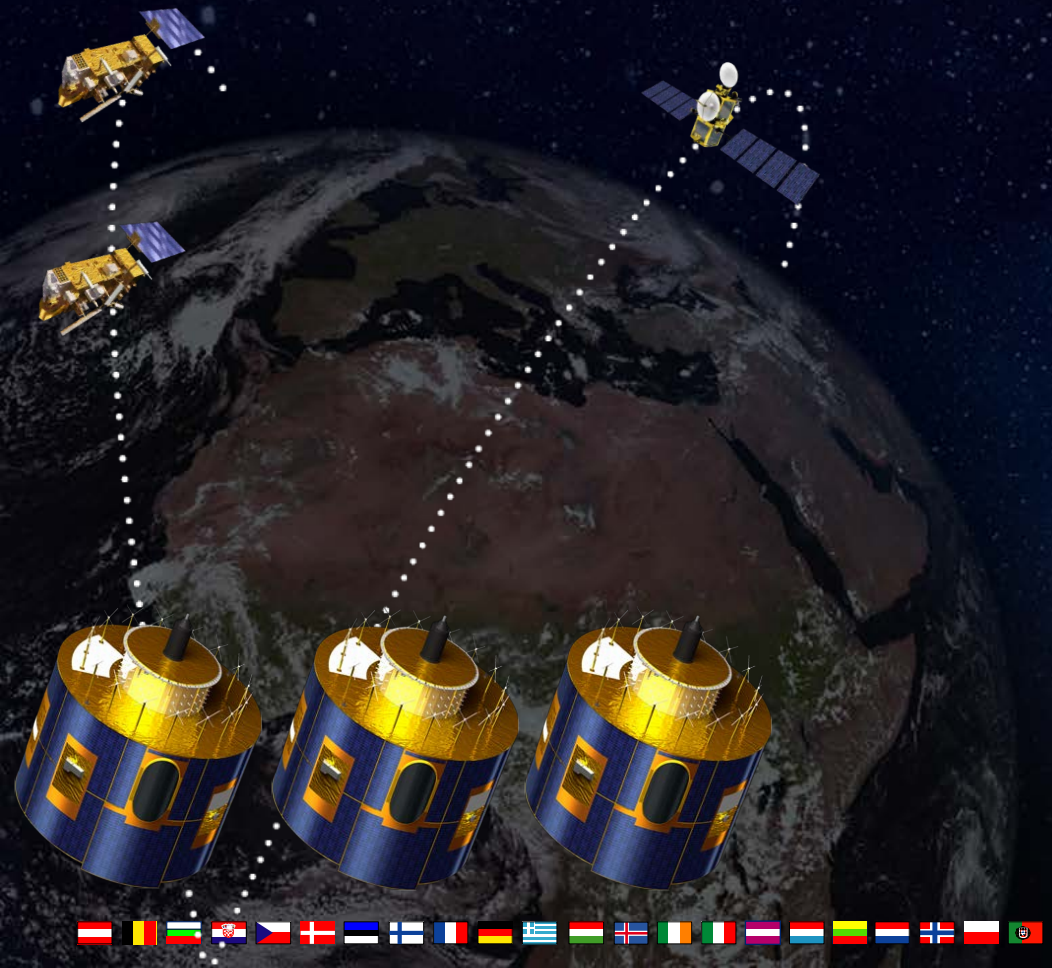


With the support of M. Takahashi – JMA
(1-year visiting scientist at EUMETSAT)

In collaboration with

T. Stone (USGS)
S. Lachérade, B. Fougnie (CNES)
X. Xiong (NASA)

The Lunar Calibration Workshop

Initiative from the GSICS Research Working Group (last annual meeting in March 2014), in collaboration with CEOS/IVOS

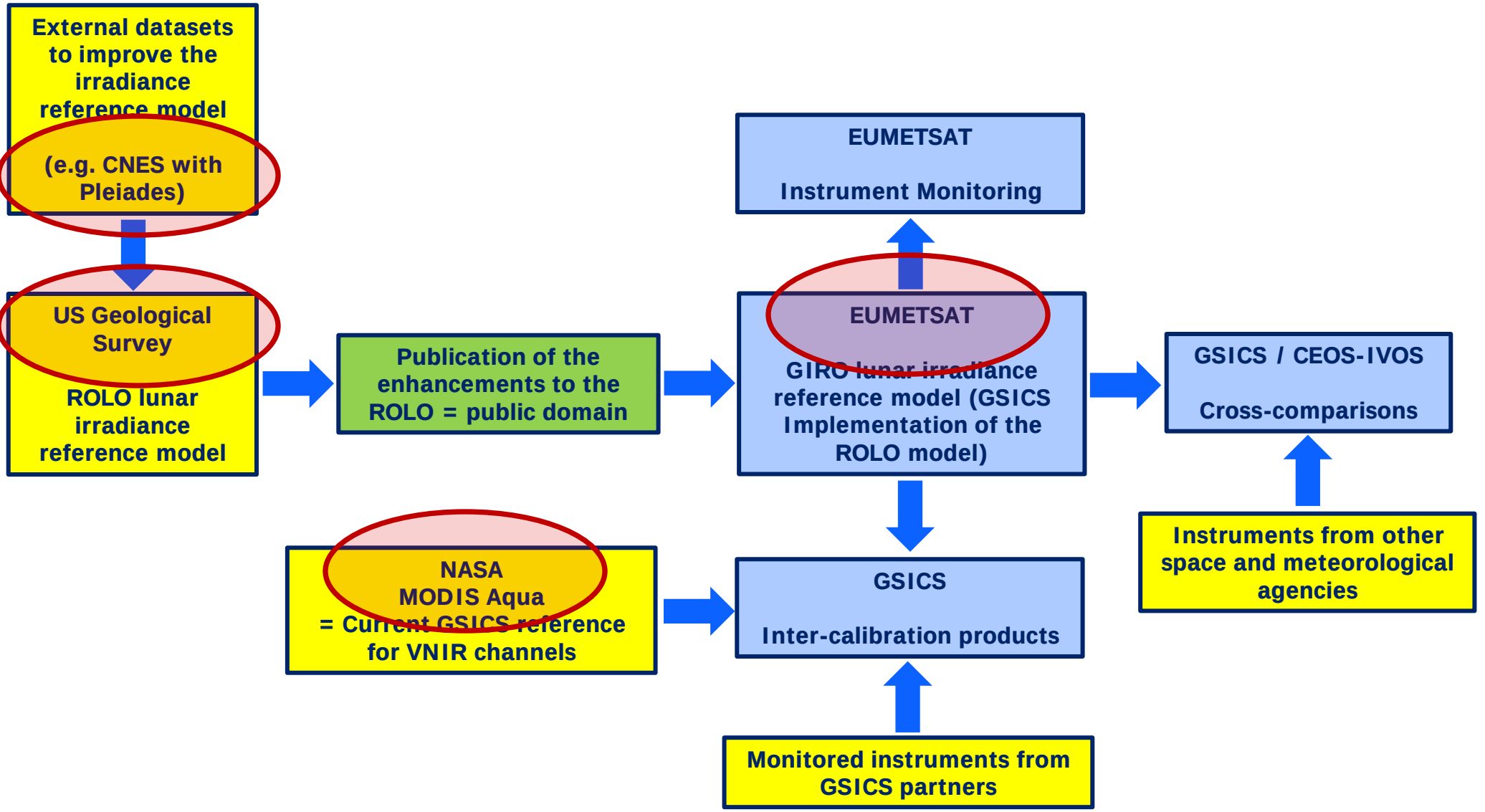
Organisation

EUMETSAT / USGS / CNES / NASA with the support of M. Takahashi (JMA)

Objectives

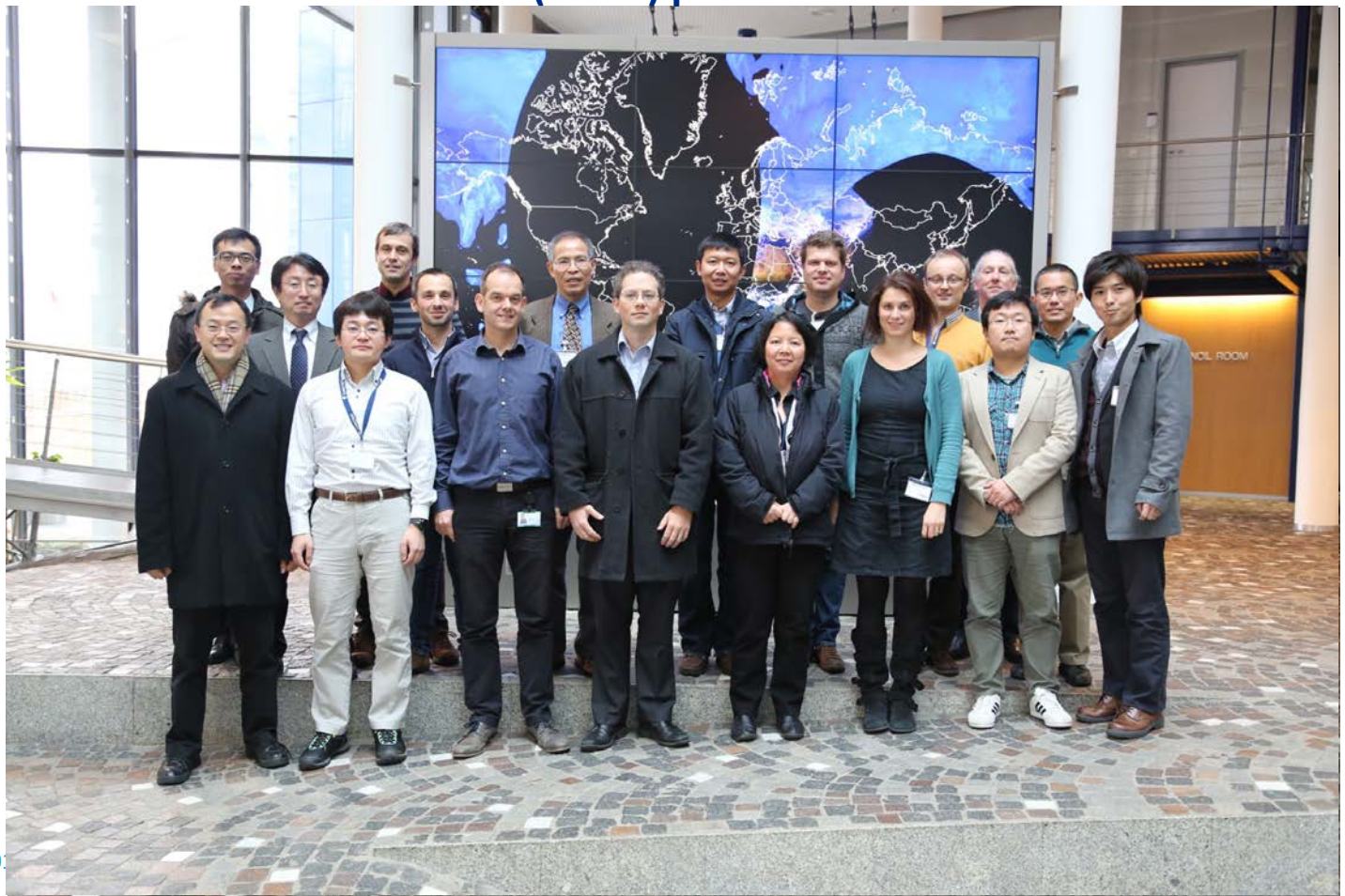
1. **Work across agencies / operators with a common and validated implementation of the USGS ROLO model ➔ one of GSICS' goal = instrument inter-calibration**
2. **To share knowledge and expertise on lunar calibration and to provide guidance on the techniques of lunar calibration.**
3. **First step to provide the international community with validated and traceable version of the USGS ROLO model = GSICS Implementation of the ROLO (GIRO) ➔ Validated against USGS implementation of ROLO v311g**
4. **Generate for the first time a reference dataset that could be used for validation / comparisons later on.**

Lunar Calibration: Definition of a collaborative framework



Outcome from the Lunar Calibration Workshop

- **EUMETSAT HQ, 1-4 December 2014**
- **14 agencies and departments attended the joint GSICS – CEOS/IVOS lunar calibration workshop (including remote attendees through Webex)**
- **Potentially 25 instruments + future and (some) past missions**



From the Lunar Calibration Workshop

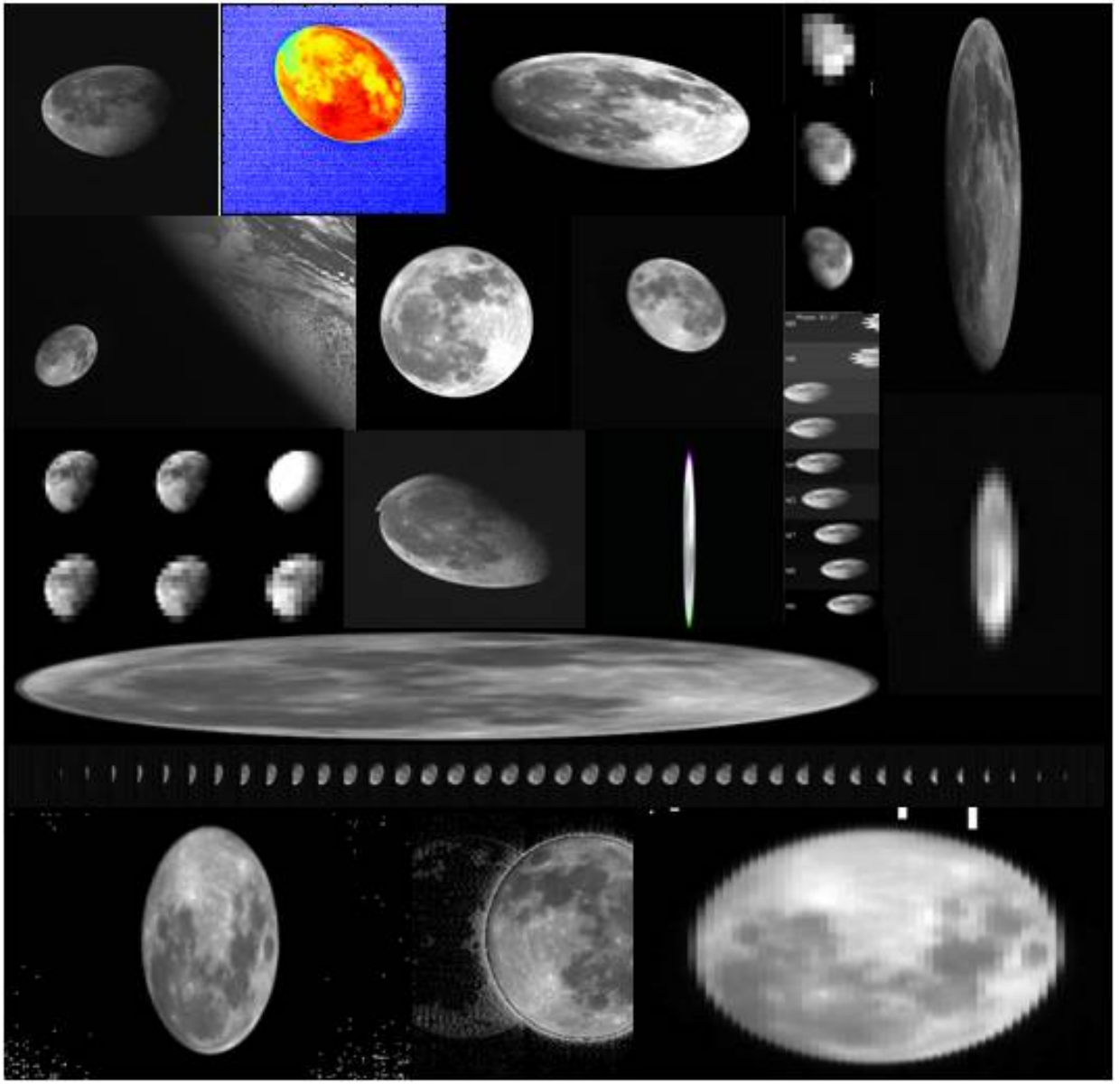
- ✓ Acquisitions from 30 sensors
- ✓ 20 years of acquisitions from 1995 to 2014
  ~ 60% of sensors providing data in the last 2 years – common period
- ✓ For all the reflective spectral domain
  broad or narrow bands
  including a common red band (narrow or broad)
- ✓ Covering the entire lunar phase range
  the full range for GEO (but within GIRO's range of applicability), more limited for LEO

Instruments

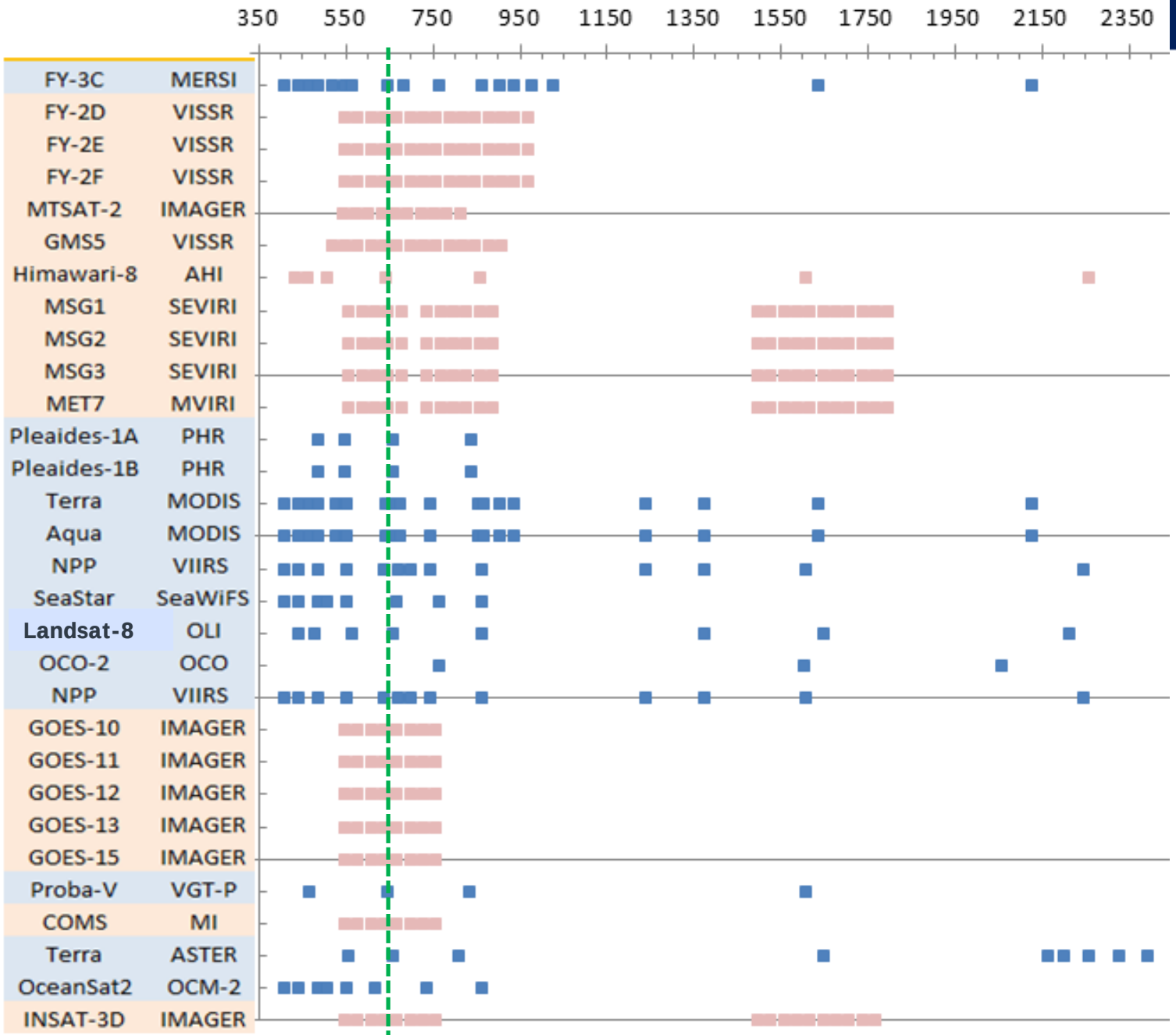
Instruments with lunar observation capabilities, with the minimum number of Moon observations expected to be provided to the Lunar Calibration Dataset (more observations may be available).

Team	*Satellite*	*Sensor*	*G/L*	*Dates*	*Number of obs (GSICSdataset)*	*Phase angle range (°)*
CMA	FY-3C	MERSI	LEO	2013-2014	9	[43 57]
CMA	FY-2D	VISSR	GEO	2007-2014		
CMA	FY-2E	VISSR	GEO	2010-2014		
CMA	FY-2F	VISSR	GEO	2012-2014		
JMA	MTSAT-2	IMAGER	GEO	2010-2013	62	[-138,147]
JMA	GMS5	VISSR	GEO	1995-2003	50	[-94,96]
JMA	Himawari-8	AHI	GEO	2014-	-	
EUMETSAT	MSG1	SEVIRI	GEO	2003-2014	380/43	[-150,152]
EUMETSAT	MSG2	SEVIRI	GEO	2006-2014	312/54	[-147,150]
EUMETSAT	MSG3	SEVIRI	GEO	2013-2014	45/7	[-144,143]
EUMETSAT	MET7	MVIRI	GEO	1998-2014	128	[-147,144]
CNES	Pleiades-1A	PHR	LEO	2012	10	[+/-40]
CNES	Pleiades-1B	PHR	LEO	2013-2014	10	[+/-40]
NASA-MODIS	Terra	MODIS	LEO	2000-2014	136	[54,56]
NASA-MODIS	Aqua	MODIS	LEO	2002-2014	117	[-54,-56]
NASA-VIIRS	NPP	VIIRS	LEO	2012-2014	20	[50,52]
NASA-OBPG	SeaStar	SeaWiFS	LEO	1997-2010	204	(<10 , [27-66])
NASA/USGS	Landsat-8	OLI	LEO	2013-2014	3	[-7]
NASA	OCO-2	OCO	LEO	2014		
NOAA-STAR	NPP	VIIRS	LEO	2011-2014	19	[-52,-50]
NOAA	GOES-10	IMAGER	GEO	1998-2006	33	[-66, 81]
NOAA	GOES-11	IMAGER	GEO	2006-2007	10	[-62, 57]
NOAA	GOES-12	IMAGER	GEO	2003-2010	49	[-83, 66]
NOAA	GOES-13	IMAGER	GEO	2006	11	
NOAA	GOES-15	IMAGER	GEO	2012-2013	28	[-52, 69]
VITO	Proba-V	VGT-P	LEO	2013-2014	25	[-7]
KMA	COMS	MI	GEO	2010-2014	60	
AIST	Terra	ASTER	LEO	1999-2014	1	-27.7
ISRO	OceanSat2	OCM-2	LEO	2009-2014	2	
ISRO	INSAT-3D	IMAGER	GEO	2013-2014	2	

Examples of Moon observations from participating instruments



Spectral coverage



Courtesy B. Fougnie, CNES

LEO (CWL)
GEO (band)

According to OSCAR (WMO)

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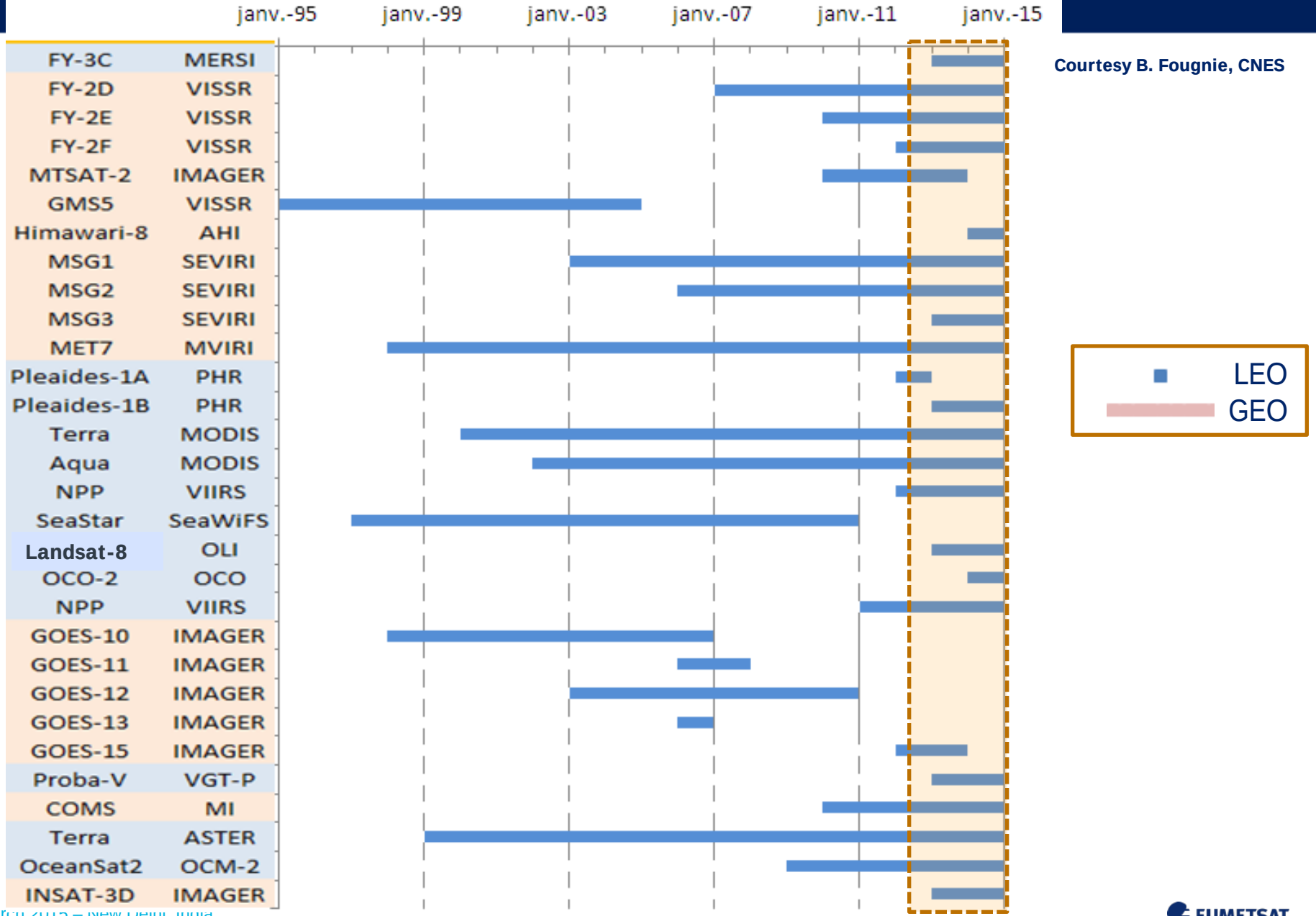
Time series



Courtesy B. Fougnie, CNES

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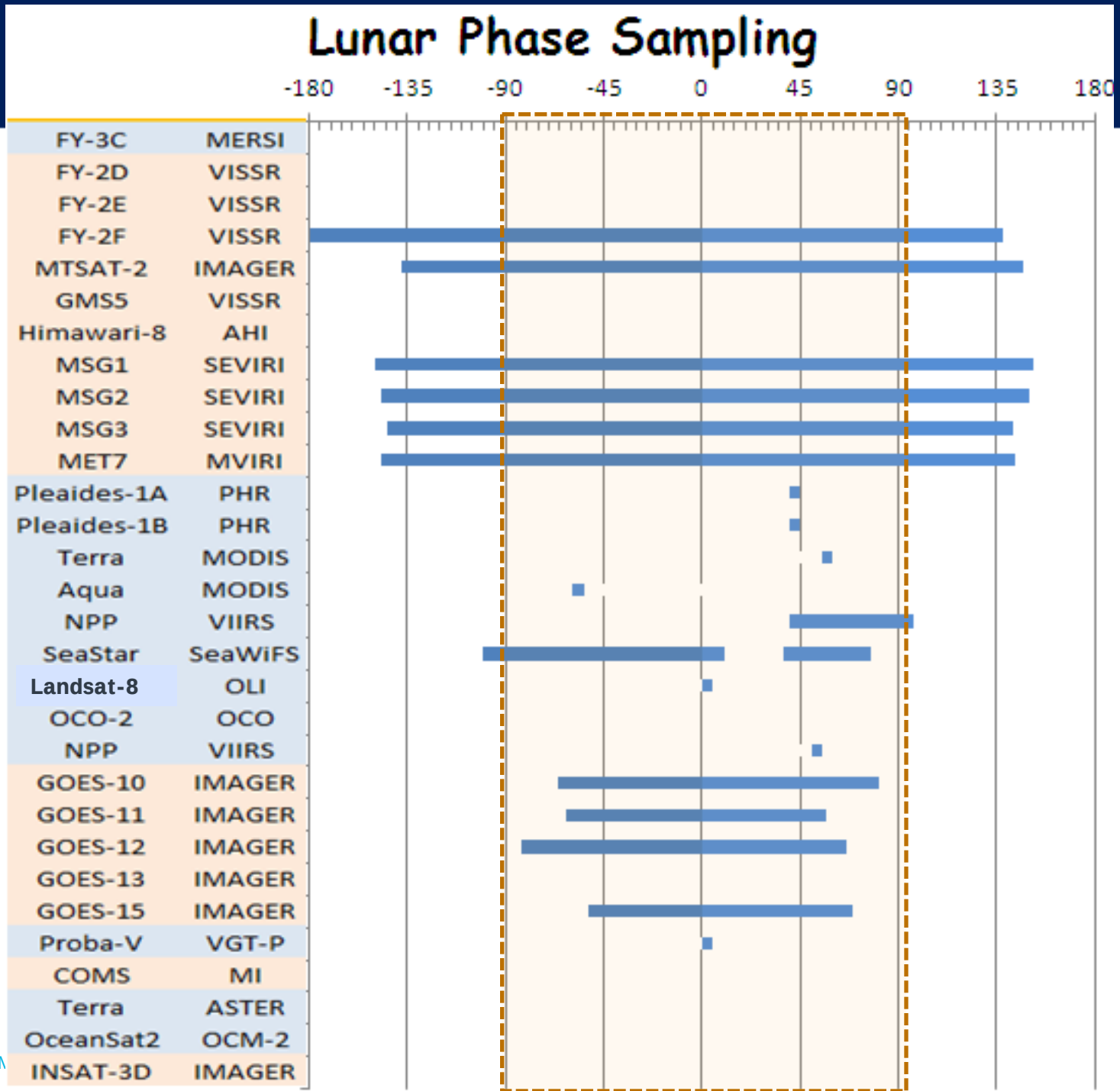
Lunar Phase Sampling



Courtesy B. Fougnie, CNES

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Outcome from the Lunar Calibration Workshop

- All groups prepared input to the GIRO and provided results
- First version of the GSICS lunar observation dataset
- GIRO in agreement with the latest ROLO version over validation test dataset
- A few discrepancies observed when instruments had both GIRO and older ROLO results (in particular beyond 2μm)
  - Most important differences related to the definition of the ROLO version at USGS

    ➔ $ROLO = ROLO_{USGS} + Driver_{USGS}$
    - $ROLO_{USGS}$ = fixed version number (v311g)
    - $Driver_{USGS}$ has changed!

➔ Need for version control to ensure software traceability

- Oversampling factor + dark signal estimation = critical
- Sensitivity analysis + uncertainty budget initiated
- Need for establishing a data policy and a GIRO usage policy

List of actions

Source: https://gsics.nesdis.noaa.gov/wiki/Development/GsicsOperationsPlan

	GLCWS_14.1	NASA and USGS to interact to process the MODIS data with the latest driver to check the agreement with the GIRO. Two methods are tested for the irradiance integration (original MODIS data as provided to USGS initially, and the processing as done for the GIRO). USGS and NASA are invited to report at the next GSICS annual meeting.	18 Mar 2015
	GLCWS_14.2	NASA and NOAA to interact on the VIIRS lunar data to check the result consistency and to compare their oversampling factor estimates.	01 Dec 2015
☑	GLCWS_14.3	EUMETSAT, NASA (VIIRS + Landsat teams) and USGS to interact and investigate the discrepancies observed in the 2.2 microns band.	01 Dec 2015
	GLCWS_14.4	CNES had the possibility to do dedicated Moon acquisitions with PARASOL. CNES is invited to present the results of the analysis at a further meeting (web meeting or GSICS annual meeting).	18 Mar 2015
→	GLCWS_14.5	All participants to provide lunar irradiances from the missing instruments to the common lunar calibration data set.	01 Dec 2015
☑	GLCWS_14.6	EUMETSAT to circulate a draft for a data sharing and GIRO usage policy to the workshop participants. This should include the requirements for newcomers to join the community and get access to the data and the GIRO.	01 Dec 2015
	GLCWS_14.7	GSICS Data Working Group to identify a suitable mechanism for sharing the lunar calibration dataset.	01 Dec 2015
→	GLCWS_14.8	All participants to report any restrictions on the use of their datasets in relation to the proposed data sharing policy.	18 Mar 2015
☑	GLCWS_14.9	Establish a proposal for the way forward on a comparison of instruments with similar SRFs and phase angles. EUMETSAT will circulate a proposal to the Lunar Calibration Workshop participants by mid January.	01 Dec 2015
	GLCWS_14.10	The GSICS Data Working Group is asked to develop a procedure for verifying users' implementation of GIRO.	01 Dec 2015
✘	GLCWS_14.11	EUMETSAT should implement a systematic bias on the irradiance in the GIRO PERT.	18 Mar 2015
☑	GLCWS_14.12	EUMETSAT should implement the proposed formulation for the calculation of the effective wavelength (see the minutes of the Lunar Calibration Workshop).	18 Mar 2015
☑	GLCWS_14.13	EUMETSAT to revisit the change of the SRF shape in order to be more realistic.	18 Mar 2015

Proposal for activities to address inter-calibration using the Moon

In EUMETSAT's proposal, points to be addressed:

A. **Estimating the over-sampling factor**
B. **Drift correction**
C. **Estimating SBAFs from GIRO and verification of the results**
D. **Establishing an absolute scale for lunar calibration**

E. **Medium and long term activities on lunar calibration**

ROLO/GIRO and absolute calibration

- **KNOWN DEFICIENCIES OF THE CURRENT REFERENCE**
  - **SI traceability**
  - **Absolute scale uncertainty (5 – 10 % uncertainty in absolute irradiance scale)**
  - **Residual geometry dependencies**
  - **Multi-band spectral coverage**
- **ESTABLISHING THE REQUIREMENTS**
  - **Defining potential improvements and requirements on user applications**
  - **Independent method to verify that operational visible calibration meets requirements**
  - **Support climate applications and past instruments (e.g. no onboard calibration available)**
- **GOAL**
  - **Getting absolute uncertainties to under ~1%**
  - **Surface stability + predictability of the Moon's brightness = lunar reflectance model valid for all times**
  - **Level of accuracy of 0.5% is achievable**
- **WHAT IS NEEDED?**
  - ➔ **Need for a new lunar measurement program (= many years of observations, to characterize the variations of the lunar brightness with phase and librations)**
  - ➔ **Minimum 3 years to capture the libration dependence within the bounds of its relative effect (ROLO operated for more than 8 years)**
  - ➔ **Traceable high-spectral resolution observations over several years with specific measurements to validate the atmospheric correction.**
- **FUNDING: Currently under investigation (inter-agency [international] collaboration?)**

Conclusions

Conclusions and future work

Conclusions:

- GIRO = endorsed as official publicly available reference model for lunar calibration
- Lunar calibration community supporting the current collaborative framework
- Traceability to the USGS implementation needs to be formalised
- Version 1.0.0 released (issue beyond 2 μm solved!)

Future work:

- Still need to agree about the GIRO usage and GSICS Lunar Observation Dataset policy
- Set-up the infra-structure to distribute the GIRO (exec + sources) + GLOD

  ➔ Support from GDWG
- Expected improvement of the ROLO + publication = end 2015 / early 2016

  ➔ implementation in the GIRO + new release.
- Organisation of another Lunar Calibration Workshop in 2016 (TBD)
- Developing inter-calibration using the Moon as a transfer target within GSICS
- Continuing collaboration between agencies

Thank You!

For more information:

- https://gsics.nesdis.noaa.gov/wiki/Development/LunarCalibrationWorkshop
- https://gsics.nesdis.noaa.gov/wiki/Development/LunarWorkArea

Proposal for a way forward on inter-calibration using the Moon

S. Wagner, T. Hewison

EUMETSAT

Proposal for activities to address inter-calibration using the Moon

In EUMETSAT's proposal, points to be addressed:

A. **Estimating the over-sampling factor**
B. **Drift correction**
C. **Estimation of the SBAFs from GIRO and verification of the results.**
D. **Establishing an absolute scale for lunar calibration**

E. **Medium and long term activities on lunar calibration**

A. Estimating the over-sampling factor

1. Propose a formulation of the over-sampling factors for all imagers while observing the Moon.
2. Derive the over-sampling factors for the current and the past instruments.

Further advice from IVOS on this topic?

B. Drift correction

1. **Using the available information on instrument calibration and drift estimates, the lunar irradiance observed by the instruments in the Lunar Calibration Dataset should be corrected for the instrument drift. A corrected dataset shall be produced.**

➔ **Description of the drift correction:**

Which methods are used?

What are the uncertainties?

Do we need to correct for phase-dependence first?

C. Accounting for spectral differences between instruments

1. Using the Lunar Calibration Dataset, estimate for all instruments and bands available in the dataset the SBAF with respect to Aqua MODIS bands.
2. The generated SBAF must be validated using hyper-spectral observations. Possibly, more hyper-spectral dataset should be used. The current hyper-spectral instruments with lunar capabilities are SCIAMACHY, HYPERION and GOME-2.
3. The results should be compared with equivalent data derived above other targets such as DCCs, ocean targets, etc.

D. Establishing an absolute scale for lunar calibration

1. Analyse the current lunar calibration dataset to investigate the possibility to put the current ROLO/GIRO on an absolute scale using the 0.6.µm observations as a common wavelength
2. Using the current knowledge on the various instruments' inter-band calibration, investigate the possibility to have set the ROLO/GIRO on an absolute scale for other channels.
3. Investigate the uncertainties on the instrument inter-calibration caused by the use of inter-band calibration information.

E. Medium and long term activities on lunar calibration

1. **Investigate the possibility to participate to an international consortium to fund dedicated measurement campaigns.**

Review planned activities in this area:

1. **CMA: Obtained funding for new ground-based observations from CAS**
2. **CNES?**
3. **ESA: interest in contributing but no existing mechanism for such an international funding. Further investigations needed.**
4. **EUMETSAT: no existing mechanism for international funding but possibility still under investigation. Action set on Science Working Group to define users requirements.**
5. **ISRO? IMD?**
6. **JMA: no possibility for funding**
7. **KMA?**
8. **NASA?**
9. **NOAA?**
10. **CEOS/IVOS members: AIST, JAXA, KIOST, VITO?**