Minutes of the Second Lunar Calibration Workshop - Xi'an 13-16 November 2017

Measurements and Moon observations – 13th November, 2017	
Chair	Xiuqing Scott Hu (CMA)
Minute Taker	S. Wagner (EUMETSAT), M. Takahashi (JMA), F. Yu (NOAA)
Attendance	
Remote attendance	Fred Wu, Matthijs Krijger, Tim Hewison

Agenda Item: 1a – Opening – 09:00 (20 minutes)	
Presenter	Peng Zhang - CMA
Discussion point, conclusions, Actions, Recommendations	
Dr. Zhang opened the meeting with a speech to welcome the participants to the workshop and to emphasize again the interest CMA has in pursuing its effort on lunar calibration and contributing to the international effort in this field.	

Agenda Item: 1b – Welcome – 09:20 (20 minutes)	
Presenter	Wei Zhao - XIOPM
Discussion point, conclusions, Actions, Recommendations	
Dr. Zhao welcomed the participants to the Second Lunar Calibration Workshop, which is hosted by the Xi'an Institute for Optics and Precision Mechanics.	

Agenda Item: 1c – Agenda, announcements – 09:40 (10 minutes)	
Presenter	Sebastien Wagner - EUMETSAT
Discussion point, conclusions, Actions, Recommendations	

Agenda Item: 1d – Achievement from the project "Solar bands calibration technique based on Lunar radiance source" – 09:50 (20 minutes)	
Presenter	Peng Zhang - CMA
Discussion point, conclusions, Actions, Recommendations	
Dr Zhang presented the current activities of CMA and their collaborating institutes on lunar measurements and lunar calibration. CMA is operating a family of 8 satellites for the FY family, of which 5 are operational. They are also working on the joint program Tansat, which is in commissioning test. Real-time calibration on-orbit is a key component of the activities in addition to the (offline) re-calibration to generate fundamental climate data records (FCDR). The instruments operated by CMA cover the whole solar spectrum. For RSBs, since the on-board calibration for RSB experience problems on FY-3C, lunar calibration would become key for MERSI/Tansat.	

Dr. Zhang emphasized the effort done by CMA and collaborating institutes and universities in China since April 2015 on Lunar Calibration. To predict Moon appearance for FY-2G, CMA is using SPICE. Images of FY-2G acquired on Feb 2015 were shown. They are also using SPICE for estimating the geometrical conditions for their ground measurements.

An overview of the measurement experiments performed in 2015 and 2016 was presented (with a description of the instruments and experiments). Ground observations took place at Lingshan, Beijing; Dunhuang, Gansu and Lijiang, Guangxi. An impressive list of data collected on ground and in space (also using data from MODIS) are used for deriving a lunar model.
CIMEL measurement were performed during a couple of days.
400-1000 nm = spectral coverage of the Lunar Spectral Imager. More than 260 channels.
Spectral sampling = 2-10 nm, 0.7 and 0.056 degrees FoV and IFoV size.

CMA is investing a significant effort to develop a lunar calibration model and make it one its main calibration components.
CMA also developed new lunar model based on Selene/SP by incorporating the DEM data.
The lunar model based on the ground measurements is 5-10 % accurate with 2 % uncertainty, by comparing with ROLO.

CMA is intending to acquire more Moon measurements from ground and space. They are working on both lunar irradiance and radiance models

Tom is encouraging CMA and their partners to continue their efforts as it is the way to go.
He is positively impressed by the work performed so far.
Dr. Zhang reaffirmed CMA's wish to share data with the Lunar Calibration Community. Scott mentioned that CMA has already shared some sample data to check the quality of those data.

Agenda Item: 1e – Ground-based Lunar observation and results in Lijiang, China – 10:10 (20 minutes)	
Presenter	Xiuqing Scott Hu - CMA
Discussion point, conclusions, Actions, Recommendations	

Scott recalled that lunar calibration is new to CMA and initiated in 2015.
Lunar observation concepts were developed to acquire the Moon and improvements were made continuously during the development of the project.

A full set of instruments were developed for the measurements (GLIS, LASIS, Hyperspectral instrument, lunar photometer). For the lunar photometer, some results were produced this month. High SNR was achieved for the GLIS instrument.

Almost 20 days of good data out of 3 months of experiments.
MODTRAN is used to perform the atmospheric correction.

Straylight has a large impact on the data quality. Tests were conducted in lab with NIM (National Inst. for Metrology).

Comparison of the measurements with the ROLO and ~~RT2009~~ MT2009 were made. Some small differences are observed between the comparisons with ROLO and ~~RT2009~~MT2009.

In 2017, new measurements were performed in Lijiang (instruments: same LIS, v2 of the Hyperspectral Lunar Photometer, small lidar, automated weather station).
Better instruments for the field campaigns, automatic operation, better data quality control.

CMA is intending to set a long-term automated observation system. They are welcoming international collaboration to make progress on lunar calibration.

Scott Hu concluded his presentation with the following questions to the be discussed:

- Which kind of measurements and observations from ground and space based are needed for lunar model improvement?
- What kind of instruments + specification should be developed?
- How to ensure traceability?
- Work on data quality + data processing common steps and methods.

Tom Stone commented on the discussion topics raised by Scott. In particular, Tom pointed out that the SI traceability is not easy to achieve as the lab calibrators are brighter sources than the Moon. So the community needs to learn how to achieve SI traceability using the Moon as a calibration source.

At the moment, the ROLO and the GIRO has a level of uncertainty than is 5-10% but it can be improved with more measurements.

S. Wagner reminded that instruments operators are encouraged to observe the moon if they have opportunities, also through manoeuvers, as the reference model can be improved.

Marc Bouvet: what about using Langley plots over the night?
Answer: CMA is using MODTRAN to correct for the atmosphere and bring their observations to TOA.

Xi Shao: for the ROLO it took many years of observations to derive a model. What are the expectations from CMA? Scott emphasized that CMA is now investing effort in this activity and this is just a start.
Peng Zhang pointed out the added value of those measurements in terms of spectral resolution of the instruments involved in the field campaigns.
Tom mentioned that the characterization of the phase dependence needs to be done. ROLO/GIRO do not have a spectrally dependent libration correction.
Lawrence pointed out the effort he is conducting with Hugh Kieffer on lunar modelling. He will present some outline later in the meeting.

Commented [TCS1]: I think this is supposed to be MT2009 – the Miller-Turner model that I recommend to not use.

Agenda Item: 1f – Hyperspectral lunar photometer development and measurement – 11:00 (20 minutes)	
Presenter	Yang Luo - CIOMP
Discussion point, conclusions, Actions, Recommendations	

Lijiang: altitude 3100m.

Spectrometer + CCD have the same optical path.
Spectral range = 380-1100nm
Moon tracking by software and GPS

The version 2 of the instrument has much higher performances than version 1.
Active Moon tracking

Yang provided the details of the calibration activities for the instrument.
The uncertainties on the calibration of the instrument were fully assessed.

Among the future development, extending the range to 1100-2500nm.

Tom: about the temperature control, was a temperature dependence observed in the system? If yes, it would need to be removed.
Answer = no temperature dependence was found. The temperature control is done in the instrument.
Jack commented that the change in the temperature would impact the optical system.
However, Tom understands from the design presented here that this should be very limited.

Lawrence: what are the sources of straylight?
Answer: night reflection of the cloud.

Fred asked what kind of spectrometer it is?
Answer: grating

Agenda Item: 1g – Moon Observation with an FTIR Imaging Spectrometer: Recent Progress and Beyond – 11:20 (20 minutes)	
Presenter	Geng Zhang - XIOMP
Discussion point, conclusions, Actions, Recommendations	

Geng presented the difficulties faced when performing the measurements (atmospheric turbidity, irregular movement of the Moon, defective pixels, etc) and the solutions.

Manual pointing to the Moon using a guide telescope

Spatio-temporal rectification work was published in Applied optics.

Future work: increase of the spatial resolution, SNR > 500, use of 2 types of spectrometers to compensate each other (FTIR spectral imager based on Sagnac interferometer and Dispersive spectral imager using Offner principle).

The specification of those instruments were presented with the design of the telescope and the spectrometer.

FTIR Imaging spectrometer (900 – 2500nm), 60 bands, interferogram

Imaging processing challenges: desirable interference direction and orbit moving speed.

Agenda Item: 1i – Lunar spectral irradiance measurement and modelling for absolute calibration of EO optical sensors – 11:40 (10 minutes)	
Presenter	Marc Bouvet - ESA
Discussion point, conclusions, Actions, Recommendations	

Marc presented the scope of the project.and its objectives.
The project targets a sub-2% absolute accuracy.
Project started in September 2017. The project is foreseen to last 21 months.
At Kick-Off + 6 months: lunar data collection will start in Spain (Izana Observatory 2401m and Pico Teide at 3555m).

NPL + Univ of Valladolid + VITO are involved.
Instrumentation: CIMEL CE318 (9 bands)
Polarisation sensitivity will be part of the characterisation in lab, with temperature dependence, irradiance responsivity, non-linearities, etc.

334 Langleys plots in 3 years are already available from existing conventional CIMEL. But there is no polarisation capabilities on those. The project starting now will cover this need.

One of the objectives is to build a database of data quality controlled observations that will be then used for deriving a model similarly to the ROLO (data fitting).
Langley plots will be derived through the night to estimate the atmospheric corrections.

Tom mentioned that once those measurements are validated, they would be a valuable contribution to the GLOD (GSICS Lunar Observation Dataset). He also discussed the criticality of understanding what are the levels of non-linearities as those photometers are designed to look at the sun and not the moon. So the photometers need to be well

characterised at the level of moon signal.
Marc mentioned that those aspects have been covered within the context of the RADCALNET activities. But more work would indeed need to be done to go further down in the level of brightness.

Lin Chen asked about the channel customisation. Is it possible for the manufacturer to customise them?
Marc: it is possible but it increases significantly the cost of the instruments.

Lin also asked about the location of the site(s) and in particular if it is also an AERONET site (or if there is one nearby)?
Answer: yes. It is in the Canary Islands (Pico Teide)
Tom pointed to the high suitability of the site for those measurements (AOD < 0.01).

Scott asked how many days can be expected from the site. Marc: 50% of the time the Langley plots can be produced during night.

Comparisons will be done using satellite measurements from Proba-V, Pleiades, and GLOD data; The GIRO will be used for comparison with the model derived from this activity.

Agenda Item: 1j – General discussion – 11:40 (20 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	

Seb mentioned the high added value measurement campaigns could represent for the GLOD. Data quality needs to be careful checked but it would be highly appreciated if new measurement datasets could be provided to the GLOD.

Tom emphasized again the high value of the efforts currently on-going.
Lawrence asked about the possibility to have the ROLO dataset in the GLOD. Tom answered that the dataset needs to be presented in a way that it can be used by the scientific community. The current situation prevents that. **However, Tom mentioned that he got funding from NASA to make the ROLO dataset in a format that people can use for analysis (including the star observations). The final data will be reflectance and radiance.** The project shall start within 6 months. It will last 3 years.

Regarding the GIRO/GLOD agreement, KMA/JMA/USGS submitted the policy agreement to get the GIRO source code.

NASA (Jack): working on it.

ESA and JAXA are in the process.

Agenda Item: 1k – Moon prediction, registration and navigation for FY satellites – 13:30 (20 minutes)

Presenter	Lei Yang - CMA
Discussion point, conclusions, Actions, Recommendations	

Launch FY-4A = Dec 17, 2016
First image = Feb 20, 2017

They make use of the fire channel to look at the moon.

FY-4A/AGRI sees the Moon ==> the data are registered and compensated for image motion.
Tom + Peng: for the registration, as the Moon is moving relative to the stars, landmarks on the moon surface

Lunar prediction for FY-4A AGRI and GIIRS, and FY-3

FY-4A AGRI and GIIRS operationally observes the Moon since Feb 2017.

Agenda Item: 1l – GOME-2 lunar measurements – 13:50 (20 minutes)	
Presenter	Matthijs Krijger - Earth Space Solutions
Discussion point, conclusions, Actions, Recommendations	

Matthijs explained how GOME-2 aboard the Metop satellites are acquiring the Moon.

A very stable reflectance spectrum was derived.
However, some issues came out while processing the data:

- Degradation,
- Straylight contamination (it will impact the relative accuracy)
- Problems with the pointing

Results from the GOME-2 analysis were compared with the ESS-GIRO model (the model Matthijs and Ralp Snel have derived to match the GIRO).

GOME-2 has a very small range of librations and phase angles.
Those data could be combined with SCIAMACHY to improve the ROLO/GIRO model.

The ROLO/GIRO can be extrapolated down to 300nm but not below.

Tom asked about the Response Versus Scan. Matthijs confirmed that the RVS is accounted. However there is no validation for GOME-2 A and B. The on-ground calibration of GOME2-C was extended to try to cover this need.

Xi Shao asked about the low levels of reflectance in the low end of the spectrum. Tom mentioned that it has also to do with the solar spectrum features and the band pass.

GOME-2 lunar irradiance:

- Straylight exists. Source unknown. Will impact irradiance value
- Wavelength dependent reflectance/irradiance variation
- Show instrument degradation

Agenda Item: 1n – General discussion – 14:10 (30 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	
Skipped due to time constraints	

Agenda Item: 1o – Status of the CLARREO and ARCSTONE projects – 15:10 (20 minutes)	
Presenter	Tom Stone - USGS
Discussion point, conclusions, Actions, Recommendations	

First, Tom Stone introduced CLARREO Pathfinder mission, which is a demonstration on orbit, with high accuracy, SI-Traceable calibration, and inter-calibration capability. The Pathfinder Reflected Solar (RS) instrument is planned to be mounted on the ISS. This is not the final goal, but a critical step on the way to the full CLARREO mission.

Two scanning modes for lunar views - along-slit and across-slit scans. The latter for lunar inter-calibration with other instruments in addition to contribute to the database of high-accuracy measurements. Potential Moon view opportunities are simulated for 1-year flight using currently available information such as ISS inclination angle (51.6 deg.): 3502 points, which correspond to view opportunities with > 4 minutes duration (>80% have < 10 minutes duration). Substantial coverage could be achieved in 1 year.

ARCSTONE mission: the goal is to deliver lunar spectral reflectance data with a uncertainty level sufficient to establish lunar spectral reflectance as SI-traceable absolute calibration standard. Planned to be on a Cubesat (ideally 6U spacecraft). Orbit at 500-600 km, sun-synchronous.

The instrument collects data every 12 hours within 10 minutes to achieve combined uncertainties < 0.5% (k=1), spectral range 350-2500 nm.

Key technologies: use of the same optical path for sun and Moon using integration time to reduce solar signal and spatial dispersion. There are 6 orders of magnitude difference between the Moon and the Sun brightness.The integration time can resolve 3 orders of magnitude. The sun and the moon are the same size in the FOV.
The goal is 3-year observation.

Funding - CLARREO Path Finder: SRR Jul 2017, awaiting direction from NASA on future funding, ARCSTONE: funding from NASA ESTO for EDU instrument development. Mission design and operations supported by NASA Langley.

CLARREO pathfinder: planned to be launched in early 2021. 1 year of mission + 1 year of science data. Current funding for mission risk reduction activities, next ~6 months. Awaiting direction from NASA (and US Congress) on future funding.

Q: How to use CLARREO Path Finder observation data on ISS? Inclination of 51 deg. is fairly good for inter-calibration purpose with other instruments. It is a precessing orbit, so many opportunities for simultaneous nadir observations with LEO satellites.

The threshold value for the spectral range = [380-900nm]. Goal = [350-2500nm]

Agenda Item: 1p – Characterization , calibration and traceability for Lunar observation instruments – 15:30 (20 minutes)	
Presenter	Benyong Yang - AIOFM
Discussion point, conclusions, Actions, Recommendations	

Benyong Yang pointed the importance of comparing field calibration and laboratory calibration.
A novel method using lunar Langley plot was presented. It includes a correction in time of the phase based on lunar irradiance model. This is done using the post time phase-correction lunar irradiance as relative stability reference. Advantage is effective atmospheric correction.

Wavelength range = ~ [400-1000nm]

Lab calibration - Moon simulator has been developed using a tunable laser-illuminated integrating sphere. The scale trace from cryogenic radiometer by trap detector was also proposed.

Scott: When 3 proposed methods have different results - then how to evaluate? Best one? Irradiance calibration system would be the best, but there are some limitations, so Langley plot would be preferable.

Tom: do they have results from the laboratory measurements of the irradiance simulating the moon (trap detector)? - Not yet. Tom says that the approach adopted by AIOFM (trap detector) is the right way to do the SI traceability if the laser source can simulate the Moon in the lab.

Absolute calibration: radiative transport model with atmosphere correction using Langley_plot method

Agenda Item: 1q – Lunar observation plan based on SI-traceable demonstration instrument development – 15:50 (20 minutes)	
Presenter	Feng Jiang - STIP
Discussion point, conclusions, Actions, Recommendations	

SI-traceable demonstration of lunar observation instrument. Proposal: altitude 410 km, inclination angle of 50 deg.

Imaging spectrometer: the moon vertically move to the slit. 1 obs / month.

Trap detector has several sources of uncertainties like spatial non-uniformity, instability, repeatability, polarization, linearity. Expected combined uncertainty was calculated.

Pre-flight calibration of standard radiometer: polarization sensitivity for zigzag blazed grating - depolarizer is considered.

Uncertainty of VNIR spectrometer is estimated up to ~1.24%

Jack: any plan for using attenuator (neutral density filter) for on-orbit calibration? When the attenuation is put into space, the attenuation could change in time. No solution, but need to monitor. Attenuation change could be wavelength dependent, similar to solar diffuser.

Jack: did they consider a change when in flight for the attenuator? How would they monitor? If the instrument look directly at the sun, the temperature will be much larger. It would affect the transmittance.

SI-traceability

1. To solar irradiance. Concerns about the solar attenuator degradation. One option is to use the Moon as reference
2. SI-traceable lab measurement.

Tom: Need to demonstrate the data to show the SI-traceability

Q: relative accuracy of ROLO model? A: as good as <1%, phase angle and wavelength dependent.

Agenda Item: 1r – General discussion – 16:10 (30 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	

Methods for the SI-traceability. A way forward was proposed by Benyong Yang (AIOFM).

Institutes are encouraged to pursue their efforts. Cryogenic radiometer measurements, the use of the trap detector dataset to characterise the instrument shall be demonstrated. It could be done from the ground, taking a radiometer to look at the moon. Lijian would be a good site.

In the course of the night, the phase angle varies little. So for those measurements the relative accuracy of the ROLO/GIRO is much below 1%. However, the absolute accuracy is also critical.

Aerosol retrieval at night, 2 sources of uncertainties: the instrument and the model itself. These uncertainties cannot be separated in the aerosol retrievals – need independent assessments.

Doing a radiance calibration requires to address some specific difficulties. Tom would still be in favour of using irradiance calibration instead.
The ROLO has some residual dependencies on the phase but the level of those dependencies is hard to estimate as there is not standard.

Can SCIAMACHY measurements be helpful? The problem would be the varying oversampling... It should be checked.

Agenda Item: 1s – Dataset cataloging – 16:40 (20 minutes)	
Presenter	Fangfang Yu - NOAA
Discussion point, conclusions, Actions, Recommendations	

New lunar observation dataset on orbit/ground. The goal is for the irradiance model and new applications such as MTF. Feedbacks were gathered for ABI, AHI, MI, FY-2/VISSR, SGLI, ASTER, MERBE, MHS and ground observation at NIST. Data already in the GLOD (as defined by the first Joint GSICS/IVOS Lunar Calibration Workshop) are already covered.

She introduced data survey contents - calibration method, data accessibility, lunar observations, computation of the lunar irradiance etc. This contains future plans. ABI was shown as an example.

Application to MW instruments - MHS. Observation at narrow phase angle range (> 90 deg) for given local equator crossing time of satellite.
Model (Mo and Kigawa 2007) of TB of Moon gives max value at full moon, independent of frequency.

Discussion on data sharing in GLOD:
Scott commented that CMA is willing to share example observation at ground. FY-4/AGRI, GIIRS - data processing is under-testing.

Sebastien raised one concern of data volume of GLOD with an evolution of the lunar

observation dataset. We also need to keep in mind the purpose/applicability of GLOD, e.g. inter-band calibration, inter-calibration. Extending GLOD is welcome, but IR and MW might be a little bit different from the purpose of GLOD/GIRO because initial purpose was to improve GIRO/ROLO - good time for thinking about the purpose.
 	
New data survey:
 	
9 new types of measurements received before the meeting
- New high-quality satellite based lunar observations
- Extension from satellite to ground
- Multiple spectral to hyperspectral
- VNIR to MW
- New uses
    o MTF
    o Radiance model

Agenda Item: 1t – Evolution of the GLOD – 17:00 (10 minutes)	
Presenter	Sebastien Wagner - EUMETSAT
Discussion point, conclusions, Actions, Recommendations	
Seb reported the current status of the GLOD. The GLOD was first envisaged to be a reference dataset for lunar calibration using GIRO. In 2014 before the 1st lunar calibration workshop, each satellite operator was asked to provide the irradiance data (at least), and possibly the imagettes, to the GLOD. He briefly listed all the lunar observation datasets currently in the GLOD. Sebastien plans to ask CNES to provide more PLEIADES data (currently 20 images are shared), which would be very useful for the lunar calibration community. SCIAMACHY is not yet in GLOD, but to be agreed between EUMETSAT and ESA. MSG-4/SEVIRI dedicated lunar observation data during its commissioning are not yet a part of GLOD but will be. The GIRO benchmark dataset is also intended to be part of the GLOD (to be presented in Day-2). GLI data - no SRF was provided - need to be checked with JAXA (or JMA). VIIRS - v2.1.0 images by NASA, 19 images by NOAA Discussions: How to handle updates of GLOD? Do we want to change the scope of GLOD? Currently, it is a static dataset whose aim is to improve the lunar calibration reference and verification/validation/comparisons for new developments. However, it would be potentially applicable to inter-calibration. So the GLOD	

could potentially provide a instrument database for intercalibration.

Fangfang: does each data provider need to provide all the lunar observation dataset? Answer: no need. Representative samples (e.g. data covering whole possible lunar phase angles) were initially requested.

Sebastien pointed out that the lunar observation data are not included in GLOD until each data provider signs the GIRO/GLOD license agreement.

Marc Bouvet asked if the lunar observation data provided to GLOD are publically available? Not for all the cases. Any plans to encourage each agency to make the data available in public? It would be expected to be discussed at the level of CGMS or CEOS/WGCV. Scott proposed to make a recommendation to CGMS/CEOS to consider the open-data policy.

The license agreement for joint mission was also discussed. The situation is dependent on the cases, so each data provider was asked to look for the way to solve the issue.

LCWS.2017.1t.1: EUMETSAT to contact the participants to get updates on the lunar data for the GLOD.

LCWS.2017.1t.2: CMA to send the data survey form for FY-4A and Chinese MOST ground measurements to NOAA (Point of contact: Fangfang Yu).

LCWS.2017.1t.3: CMA to consider a similar plan to ESA to schedule ground measurements in the future (e.g. instruments, calibration, sites, measurement strategy).

GLOD:

EUMETSAT: it is the agency representative who should sign the agreement. The agreement can be agency specific to meet the agency's data public accessible policy.

Q: with more observations of the Moon, could the GLOD be large enough to host the data? A: Imagette is not required. In this case, the dataset is very small.

Q: what is typical lunar observation data? A: data to cover the phase angle range. The more the better.

Q: Can we make the data policy at higher level management? A: Good suggestion.

Agenda Item: 1u – General discussion – 17:10 (30 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	
Done at the agenda#1t.	

Minutes of the Second Lunar Calibration Workshop - Xi'an 13-16 November 2017

Using the ROLO/GIRO – 14th November, 2017	
Chair	Tom Stone (USGS)
Minute Taker	M. Takahashi (JMA), S. Wagner (EUMETSAT), Fangfang Yu (NOAA),
Attendance	
Remote attendance	Truman Wilson, Hongda Chen, Amit Angal, Fred Wu, Yoshihiko Okamura, Yusuke Yogo

Agenda Item: 2a – ROLO and data preparation – 08:30 (10 minutes)	
Presenter	Tom Stone - USGS
Discussion point, conclusions, Actions, Recommendations	

The objectives of the session are:

- Look at methods for measuring lunar irradiance from images.
- To identify potential sources of error, cover all aspects of lunar irradiance obs from images
- Comparisons of observed lunar irradiance to model outputs; individually, for each sensor, collectively, to identify common characteristics that may indicate potential errors in the lunar model
- New developments toward advancing lunar models for a calibration reference.

Equation for computation of the lunar irradiance is pretty simple, but each component would have significant impacts on the irradiance.

Oversampling factor shall account for non-uniform spatial sampling due to the rotation of the moon and the relative moon motion during the scan for instance, or caused by rotating or accelarating scan mechanisms.

Radiance: which data level is used? What calibration coefficients? What is the level of dark signal? What about extraneous signals such as ghost, stray light, electronic crosstalk and so on?

Pixel IFOV: possibile dependence on detector position in the focal plane array.

Moon pixel selection: method for eliminating cosmic hits
The purpose of the session is also to look into other requirements such as observation time, spacecraft position, finding the moon in a data archive

Second part of this session: Lunar model development - current status of ROLO and future development at USGS
validation vs. ROLO - GIRO benchmark (in development)
New models from recent lunar observations

Agenda Item: 2b – Lunar data preparation for MODIS – 08:40 (15 minutes)	
Presenter	Truman Wilson - NASA
Discussion point, conclusions, Actions, Recommendations	

MODIS sees the Moon in the space-view port FOV.
Irradiance is calculated by integration of all imagette pixels, with background corrected to zero.

Moon location predicted to perform maneuver.

Level-1a as raw digital counts; background subtraction and temperature corrections are applied.

Oversampling by using satellite altitude, moon-MODIS distance and so on> It changes in time (from event to event) but the difference is not large. It is defined as the ratio between the pixel size projected on the moon and the distance that the moon moves in the track direction.
Pixel IFOV determined by dividing the GIFOV by the nominal latitude (P=Rmm/(705*Nsf)).
screening for distance between moon the earth limb
Remaining oscillations after correction are due to libration.

Issues with MODIS Aqua and Terra with straylight and x-talk for SWIR (5-7, 26), MWIR (20-25) and 27-30

Tom: is the pixel size projected the foot print on the moon? Does the size of the moon in the image match the expected size in the IFOV?
Truman: yes

Agenda Item: 2c – Lunar data preparation for VIIRS – 08:55 (15 minutes)	
Presenter	Hongda Chen - NASA
Discussion point, conclusions, Actions, Recommendations	

Moon and Solar Diffuser are viewed at the same AOI (60.2 deg) for RTA HAM
the Moon diameter is ~10 pixels, imagette are about 16x16 pixels.
L1A image is used, processing adapted from MODIS.
Data are converted from 14 to 12 bits.

No artifacts in VIIRS RSB/DNB such as a cross-talk

Lunar calibration scheduling tool is developed for VIIRS based of SPICE package.

Oversampling factor estimated from ephemeris of SNPP and Moon at the center time of calibration (varies from 1.0-2.5).
IFOV : same computation as that for MODIS.
VIIRS and the Earth limb is more than 100 pixels away from the Moon.
Dark signal level: for RSB, it is a mean of pixel away from the Moon (5 pixels away the lunar images on both sides). For DNB, it is based on BB offset trending (time of the lunar calibration is used)

Each year: about 8 to 9 events.

LCWS.2017.2c.1: NASA and NOAA to compare their results on lunar calibration (calculation and trending) and report at 2018 GSICS Annual Meeting.

Tom: VIIRS lunar time series can provide constraint on the libration for modeling because the instrument is very good. He complimented the work done at NASA on VIIRS data. Those data are of high quality and highly valuable to the community.

Sean: NOAA has two teams in calculating the lunar F-factor. Consistent results.

LCWS.2017.2c.2: NASA and NOAA to compare their lunar f-factor and to report at the next GSICS annual meeting (NASA VCST, NOAA Ocean Colour and NOAA SDR).

Agenda Item: 2d – Using lunar calibration for MODIS/VIIRS – 09:10 (20 minutes)	
Presenter	Jack Xiong - NASA
Discussion point, conclusions, Actions, Recommendations	

Regularly scheduled lunar observations: Terra 178, Aqua 153, VIIRS 51 as of 2017-10-31
The lunar data are used for:

- Radiometric calibration
- Band-to-Band Registration and MTF
- Inter-sensor-calibration,
- Inter-band, inter-detector calibration
- Optical leak and crosstalk characterization.

MODIS: Solar Diffuser at AOI (angle of incidence) of 50.2 deg, lunar obs at AOI of 11.2 deg. on-orbit change in MODIS RSB Response Versus Scan which is applied to L1B
VIIRS: SDSM monitoring is not enough (0.4-0.93 micron). Small but noticeable differences between SD and lunar responses
Future:

- MODIS to improve RVS characterization and calibration transfer from SD to lunar obs for long term trending
- VIIRS to improve SD degradation monitoring for all RSB wavelengths from VIS to SWIR

The RSV changes are not linear. Two points are not enough to characterise it.
VIIRS SD degrades much faster than MODIS SD.

The microstructure present in the painting of the SD causes Rayleigh scattering in the short wave (in particular in the UV). Surface roughness change (hypothesis) due to 1/lambda^4 wavelength dependence of degradation. Due to surface degradation under UV influence. Confirmed by lab measurements and electron microscopy.

MODIS: RSB responses are wavelength, AOI, and mirror-side dependent. RVS response degrades.

VIIRS: discrepancy between solar calibration and lunar calibration. Can be observed at short-wave channels. Because SD degrades faster than detectors.

Q: is the diffuser degradation a function of exposure time?

A: Cleanliness is an important contributor, but is not everything

Comment from Jack: lunar band-to-band inter-calibration can only partially remove the libration effect, as libration is wavelength dependent
Comment from Lawrence: solar diffuser on EO-1 is white paint; rapid degradation was observed, but it stabilized over time

Agenda Item: 2e – Lunar data preparation for ASTER – 09:30 (15 minutes)	
Presenter	Toru Kouyama - AIST
Discussion point, conclusions, Actions, Recommendations	

ASTER is actually made of 3 instruments (VNIR/SWIR/TIR).
ASTER VNIR: Stereo-images using two observing ports. Narrow swath makes it difficult to catch the Moon using regular observation.
Two Moon acquisitions are now available after a successful second pitch manoeuver on 2017-08-05 (first one was performed on 2003-04-14). The phase angles are respectively -27.7 and -20.3 degrees.
High resolution achieved on the Moon.
The oversampling factor is ~4.6.

The Moon image represents 450 pixels and 2100 pixels for cross and along track direction performed in ~5 sec. ASTER team is using SPICE/TLE for estimating the geometry. The L1R (calibrated data) is used, irradiance is measured from integrating all image pixels. Different dark signal offsets are observed below/above the Moon. After the dark signal reduction, a noisy pattern still exists. Ellipse fitting the Moon limb is also used. SWIR and TIR have crosstalk and straylight, but no issue in VNIR. Sensor degradation from 2003 to 2017 using SELENE/SP model 3.0, 5.2, 5.7 % Bands 1, 2 and 3N shows good agreement with vicarious calibration results. Discussions on the possible cause to the horizontal background striping: one possible reason is the 8-bit truncation. Jack Xiong mentioned that it is foreseen to perform a third pitch maneuver with the Terra spacecraft. NASA will contact JAXA at the end of Terra mission.

Agenda Item: 2f – Lunar data preparation for MERSI/Tansat – 9:45 (15 minutes)	
Presenter	Ronghua Wu
Discussion point, conclusions, Actions, Recommendations	
MERSI: phase angle ~50 deg (11 observations between 2013 and 2014). Moon masking based on DN. Results of band-to-band irradiance temporal behaviour were shown. Irradiance of Band 3 is smaller than Band 2 and 4. Bands 2,3,4 are polarization band with the same wavelength. Some bands degrade strongly over time (several percent per year, with a maximum of 14% per year for Band8). Comparison with GIRO shows decent agreement, but wavelength dependence. TanSat/CAPI: Integrating sphere used, so no polarisation effects on radiometry Complex computation of lunar irradiance due to a polarization Two lunar images per orbit. One lunar acquisition lasts about 10 minutes. Measurements were performed 5 times in 2017. A manoeuver is done to look at the Moon in the shadow of the Earth. A lunar image is about 32 by 1200 pixels.	

LCWS.2017.2f.1: CMA to investigate further the calculation of the irradiance for MERSI as the irradiance signal seems to vary too much.

Big difference between CAPI and GIRO irradiance, with CAPI much smaller than GIRO. No strong degradation in time is observed.

Comment: phase angles that are too close to opposition phase (0.0deg) shall not be used as the models have large uncertainties for phase less than 2deg.

For CAPI, Tom recommends to estimate the oversampling with another method than the one currently in place for Tansat/CAPI as the moon is not perfectly round. One could consider the spacecraft altitude information to calculate the OF like MODIS.
A: difficult for FY-3C

LCWS.2017.2f.2: CMA to investigate alternative method for estimating the oversampling for Tansat/CAPI.

FY-3C observes the Moon like MODIS; TanSat uses pitch maneuver like ASTER.

Jack: to consider use delta-DN in the calibration algorithm for the TanSat. They are now using delta radiance.

Agenda Item: 2g – Lunar data preparation for ProbaV – 10:00 (15 minutes)	
Presenter	Stefan Adriaensen - VITO
Discussion point, conclusions, Actions, Recommendations	
No thermal control. Proba-V calibration based on vicarious technique using deserts, DCC and lunar. A manoeuver is done twice per month for lunar observation at phase angle of ~7 deg. It takes 2.6 seconds for the moon observation. Each band has different viewing angle. L1A data are used. For the irradiance calculation, lunar masking is used (geometrical computation or thresholding). Dark current calibrated using night ocean scenes every month. Background radiance in the lunar image is close to 0 (~0.6%). Along-track size is number of lines in the Moon image – Stefan recognizes that this does not account for Moon image orientation Moon masking works well. No imagettes in the GLOD, but planned in the future. Proba-V calibration: traceable to Aqua/MODIS The oscillations observed in the data might be related to the libration (in particular the longitude)	

SWIR processing still requires full review.

5% is consistent with MODIS offset, due to vicarious calibration

Q: Threshold to mask the moon: why 5% of the maximum radiance?

A: 5% is empirically selected.

Q: how often is calibration updated?

A: monthly

Q: consistent oscillation among the bands? Is it correlated with librations?

A: correlation with librations was not tested.

Tom recommended to consider plotting the time-series of libration parameters.

Agenda Item: 2h – Lunar data preparation for GCOM-C – 10:55 (15 minutes)	
Presenter	Yoshihiko Okamura - JAXA
Discussion point, conclusions, Actions, Recommendations	

GCOM-C is planned to be launched in December 2017.

SGLI-VNIR is a pushbroom radiometer (380 to 868 nm) using Solar Diffuser and LED for on-board calibration.
For the IR, whiskbroom radiometer, 1.05, 1.38, 1.63, 2.21 mu, + 10+12 mu TIR
Lunar calibration planned once per month over 5 year mission
Foreseen use of lunar imagery:

- Radiometry
- Stray light (MTF, crosstalk)
- Dark signal for VNIR, SWIR and TIR
- Polarisation for VNIR

Lunar observations are obtained using maneuvers. They are planned to take place every 29.5 days during the 5 years of the mission, with a phase angle of about 7 degrees with a margin of +/- 3 degrees.

L1A are processed. Offset will be determined using deep space obs before/after the lunar image.
Rotate around pitch axis for lunar observation with high stability rate (0.15° /sec). Oversampling factor derived by precise attitude control rate.

Details of radiometric calibration is to be considered. SGLI lunar calibration results would be released 1 year after the launch.

Tom Stone commented that 2 polarization channels could provide very good information to the lunar calibration community.

Marc Bouvet: any recommendation regarding the fixed phase angle for future missions?
Tom commented that 7 degrees is a general recommendation, but not a requirement.
Seb commented that MODIS/VIIRS uses efficiently large phase angle. Impact on the design has to be considered when deciding observation conditions for the phase.

LCWS.2017.2h.1: JAXA to share SGLI lunar observation data, particularly polarization bands with the lunar calibration community.

LCWS.2017.2h.2: JAXA to report on GCOM-C lunar observation data (in particular on the polarised measurements) either at a GSICS annual meeting or a lunar calibration meeting.

Agenda Item: 2i – General discussion – 14:10 (30 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	
Skipped.	

Agenda Item: 2j – Lunar data preparation for FY-2 – 11:10 (15 minutes)	
Presenter	Lin Chen - CMA
Discussion point, conclusions, Actions, Recommendations	

The first of the FY-2 geostationary satellites was launched in 1997. FY-2G was launched in 2017 (F and G are part of the third sub-series, for which the straylight has been improved). For the VIS band, there is no on-board calibration. It relies on vicarious methods such as DCC, Gobi desert, deep space.

Quadratic calibration equation using the relationship between DN vs. voltage as detector response is not linear.
VIS data are quantized on 6 bits.

Moon images can be acquired in two different ways:
- Specific manoeuvre: it means lunar phase angle and measurement time can be selected (sub-area scan with 5 minutes measurement instead of 25 min for full disk)
- normal free observation, when the moon is crossing the field of regard.

IR band is used for the Moon extraction from the data archive.

Oversampling factor changes in time (1.27-1.33) for different pixels

Average of 10 pixels along the border of imagette is used for the deep space signal
1.96 and 1.72 % degradation/ year for lunar and DCC caliration

Tom: computing the oversampling by using the moon size from the image size has an inherent error due to the illumination condition. He recommends to use the sampling and scan rate.

If the calibration equation is quadratic, the way the offset is addressed may lead to some error. It should be studied.

LCWS.2017.2j.1: CMA to investigate the impact of the offset cause by the quadratic calibration equation on the lunar calibration results.

Q: is IR image used for masking the Moon?

A: no, only for finding images in the archive.

CMA will provide the FY-2F to GLOD once approved by CMA management.

Agenda Item: 2k – Lunar data preparation for SEVIRI – 11:25 (15 minutes)	
Presenter	Sebastien Wagner - EUMETSAT
Discussion point, conclusions, Actions, Recommendations	

All Meteosat satellites are so far spinning satellites.

Moon observations are extracted from the L1.0 raw data since the operational image processing keeps only the Earth pixels in Level 1.5. This extraction is done automatically with a time delay of ~15 days.
Offline processing is planned for MVIRI prior to Meteosat-7. For MVIRI, no radiance data is used (the calibration is done on the GIRO irradiance scale to monitor the instrument).
Jitter could cause the problem in extracting the Moon. In such a case, the jitter is corrected before the extraction.
GIRO-scale calibration slope is used at EUMETSAT as well as irradiance difference between SEVIRI/MVIRI and GIRO.

Moon masking is based on DC threshold (masking).
Oversampling factor is assumed to be 1, but it is still open question.
Less than 1.6 secs for one swath (3 detectors in the low resolution channels, 9 in HRV)
Uncertainty evaluation is to be done in future.

Seb recalled the phase angle dependence in NIR1.6 that is observed also with AHI (~10-12%).

SEVIRI channels behave as expected as required for all platforms: 0.5% degradation per years for Meteosat-1 and -2. For Meteosat-10, the degradation reaches ~15 per year, which is still well within specifications.

For Meteosat-7 a non-linear degradation trend is observed. But the SRF (broadband) and its degradation should be revisited. It is an on-going activities in EUMETSAT Climate Group and it will be eventually applied to lunar calibration.

Tom asked about the offline processing of Meteosat-7. It is planned and will be performed by the EUMETSAT Climate Group.

LCWS.2017.2k.1: Agencies operating geostationary instruments to work together to investigate the possible non-linearity impact on the phase angle dependence of the ratio between measured irradiance and the modeled irradiance.

Agenda Item: 2l – Lunar data preparation for COMS – 11:40 (15 minutes)	
Presenter	Tae-Hyeong Oh
Discussion point, conclusions, Actions, Recommendations	

Lunar acquisitions can be made in two different modes:

- Specific lunar observation local area (KMA uses 6-month period to schedule the phase angle)
- Occasional availability in the FOV (full-disk mode)

Processing L0 to L1A in IMPS for lunar observation (IM image processing)
Imagette size: 560x330 pixels (cropped from 2080x1200 L1A lunar data).
The oversampling factor is estimated to be 28/16 = 1.75.

Sensitivity test of the moon imagette area and DC thresholds was done to identify the Moon pixels. The deep space counts are very stable.
Comparisons were made between the COMS MI observations (146 MI lunar observations from April 2011 to Sept 2017) and the GIRO.

Degradation reaches 1.35 and 1.24 % per year respectively for lunar and DCC methods.

A residual phase dependence of ~2% is observed when looking at the inter-annual time series.

LCWS.2017.2l.1: Agencies operating geostationary instruments to check the semi-annual phase angle patterns as observed in COMS data.

Agenda Item: 2m – Lunar data preparation for AHI – 11:55 (15 minutes)	
Presenter	Masaya Takahashi - JMA
Discussion point, conclusions, Actions, Recommendations	

10 march 2017: Himawari-9 put into in-orbit stand-by as back up of Himawari-8 (instrument is switched off and checked every 2 weeks).

26167 obs in 20 months.

The 3.9 band does not saturated over the moon. It means that those images can be used for instance for MTF.

N-S oversampling = N-S IFOV / N-S sampling distance; no E-W oversampling
Both oversampling and pixel IFOV are assumed constant. Information used is as provided by the vendor.

In Band 1-3 (0.47, 051, and 0,64), an out-of-field effect (ghost) is observed. There is coherent noise (of a magnitude of 1-3 counts)
This occur only in the bands with silicon detectors. This effect is not observed on ABI and AMI.
The question of the non-linearities on AHI needs also to be further investigated.

JMA is planning to share between 500-1000 lunar observations.

Masaya showed the irradiance as a function of the phase angle for all channels. A clear dependence is visible in the 1.6 and 2.3 micron. Also seen in SCIAMACHY data (comment by Ralph). However, the dependence reported in the shorter wavelength is going in the other direction and is not seen with SEVIRI. ABI results would be needed for the investigations.

LCWS.2017.2m.1: NOAA and JMA to consider revisit the oversampling factor calculation.

Discussion:
Recalling discussion started with COMS, phase angle dependency could be investigated by plotting the ratio between the observed irradiance and the model irradiance.

Agenda Item: 2n – Lunar data preparation for ABI – 12:10 (15 minutes)

Presenter	Fangfang Yu - NOAA
Discussion point, conclusions, Actions, Recommendations	

Meso scan mode 3 is used.
Moon chasing can be between 10min and 1 hour. Moon chasing is mainly conducted during PLT/PLPT periods, for characterizing RVS.

L1Alpha format. Data are calibrated but not navigated
For trending, Moon are acquired 2-4 times per month.
For ABI, the integration factor is 9 whereas it is 10 for AHI.

Harris (vendor) proposed to calculate E-W oversampling using distance of two observation samples (see ABI terminology).
Two methods (a theoretical method and an empirical one) for calculating the oversampling factor were tested and compared. The difference between the two methods is within 1.30%.

The position of the activated pixels on the focal plane causes some geometrical shift.

ABI terminology:

- A sample = Level 1A
- A pixel = Level 1B

The results shown for the consistency of the theoretical and the empirical estimation of the oversampling factor were obtained for a 10 deg phase. For higher phases the level of uncertainties is much higher.

With ABI, the time of sample acquisition is available. It was a lesson learnt from the previous GOES.

Agenda Item: 2o – General discussion – 12:25 (30 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	

The question of the oversampling is a recurrent issue for all the GEO satellites.

Oversampling factor: computing the oversampling by using the moon size from the image size has an inherent error due to the illumination condition. Instead one should use the sampling rate.

LCWS.2017.2o.1: agencies to investigate further their calculation of the oversampling factors and to make use of the operational scan rate and corresponding time when available.

Lesson learned from GOES Imager is to be able to retrieve the time for each sample.

Phase angle dependent irradiance ratio: the DC offset may cause the phase angle dependent irradiance ratio.

LCWS.2017.2o.1: all the agencies to examine the impact of dark count on the phase angle dependency.

Agenda Item: 2p – SCIAMACHY lunar measurements and radiometric accuracy – 13:45 (25 minutes)	
Presenter	Ralph Snel
Discussion point, conclusions, Actions, Recommendations	
SCIAMACHY - data provided by ESA. The analysis and the further processing of those data were done within the framework of a external study commissioned by EUMETSAT. Spectrometer of 8192 wavelength split in 8-channels Spectrum acquisition takes ~1 second; Moon crosses the slit in ~4 seconds Polarization measurements are also performed. Dirty scan mirror is supposed to result in degradation (contamination changes in reflectivity), and this was modeled. Wavelength dependent irradiance difference between SCIA and GIRO was shown. SCIA phase angle dependence in 1.6 micron shows good agreement with SEVIRI . **LCWS.2017.2p.1: S. Wagner (EUMETSAT) to clarify with ESA the possibility of sharing SCIAMACHY lunar observation data (as processed for EUMETSAT) within the lunar calibration community.** ROLO/GIRO agreement < 2%, phase angle dependent (GIRO?) Call for work update - Phase angle dependence - Extension to shorter wavelength - what about a model to describe the light polarization by the Moon?	

Agenda Item: 2q – General Discussion – 14:10 (20 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	

Minutes of the Second Lunar Calibration Workshop - Xi'an 13-16 November 2017

Lunar Model Development – 14th November, 2017	
Chair	Tom Stone (USGS)
Minute Taker	
Attendance	
Remote attendance	

Agenda Item: 3a – Current status of the ROLO and future developments – 14:30 (15 minutes)	
Presenter	Tom Stone - USGS
Discussion point, conclusions, Actions, Recommendations	

Tom gave an overview of the ROLO. The observation dataset was built over 8 years. It represents about 110,000 images acquired by the two telescopes, of which 65000 data were used for the ROLO model development.

ROLO is typically used for relative calibrations, such as monitoring sensor changes with time. SeaWiFS achieved 0.13% stability for water-leaving radiances.

Current limitation of using the ROLO for absolute calibration due to 5-10% current absolute scale uncertainty of the ROLO.
Potentially lunar calibration can provide an absolute calibration reference with uncertainty of ≤1% (k=2).

Tom got funding (including USGS-EROS) to perform the refinements (including on the ROLO dataset) needed to improve the current ROLO model. The NASA project will kick-off in Q1 or Q2 2018 (within 6 months after green light for funding).

As part of the enhancement of the ROLO model, the ROLO data reduction system will be revised and the ROLO dataset will be reprocessed.
The image processing to retrieve the lunar irradiance from the telescope observations is similar to space-based imagers and requires correcting for atmospheric transmission of the observations using extinction measurements from star observations.

Still needs to refine the algorithm for moon irradiance measurements from images including SWIR camera characterizations. Stellar irradiance algorithm has be updated already and applied for absolute scale, including Vega. In fact, far more stellar measurements were acquired by ROLO than moon measurements. The stellar extinction analysis was also done using multi-variate Langley fits (USGS funding).

The next step is to refine/develop a new empirical formulation of the ROLO model: utilization of knowledge gained from current and past lunar calibration accomplishments such as VIIRS time series of libration dependency effect, wide phase angle coverage data (GEOs, PLEIADES). NPP VIIRS clearly shows a dependence effect. Those data could be used as constrains on the fitting procedure to derive the new model. Other instruments shall demonstrate that the data are fully validated.

Seb: could the polarization of the moonlight be considered in the planning reprocessing? Can be done in parallel - different model is used for taking the polarization into account.

Tom emphasized the fact that many terms of the current model are not band dependent.

Goal:

- Absolute accuracy (<1%) is technically achievable, but may be limited by atm corr.
- New high-accuracy measurements to characterize the Moon needed to advance an absolute lunar calibration reference. Tentative requirements for new dataset in CGMS working paper CGMS-44 GSICS-WP-02 (2016). The new measurements should include above-atmosphere measurement component. To reach full potential for accuracy, must consider polarization aspects.

Agenda Item: 3b – GIRO benchmark – 14:45 (15 minutes)	
Presenter	Sebastien Wagner - EUMETSAT
Discussion point, conclusions, Actions, Recommendations	

Main purposes of the benchmark which uses synthetic dataset:

- Assessing GIRO performances w.r.t ROLO - verification and validation of new developments, uncertainty assessment
- Uncertainty assessment and traceability to GIRO for local implementations
- Possibility to perform a similar assessment for newly developed models w.r.t. GIRO

Parameters to vary

- 18-year cycle with a 6-hour resolution
- Satellite position: Earth center, GEO orbit
- SRFs: narrow + medium + large SRFs w/ spectral resolution of 1 nm (foreseen to go down to 0.1 nm)

GIRO output of the benchmark is planned to be part of the GLOD.
Simulated geometries are for the period 2000-2017. Actual geometries for Meteosat-7, -8, -9 and -10 were overplotted over the simulated cases to show the geometrical coverage. Geometrics at the Earth centre does not cover the whole selenographic lon/lat of the real satellite observation. It means the specific satellite cases outside the range of geometries covered by the ROLO/GIRO are to be considered with attention.

SRFs are generated using 4th order Chebyshev filter with a pass band ripple.

Typical widths for the SRFs are 10, 30, 300nm with 2.5 nm or 10nm spectral shift over 350-1200nm and 1200-2350nm respectively.
Case reduction idea is to subsample in selenographic space, then for each subdomain, regular sampling of phase angles is taken.

Next step:

- Finalizing the traceability of the GIRO to ROLO
- Refine the cases by the next GSICS annual meeting
- Prepare a paper to serve a reference for the giro in 2018.

Tom: location in space - libration range at the earth centre is close to the ROLO dataset.
Seb: For uncertainty assessment, GEO position would be useful.
[0,0.0] is good to firstly adopt.
Tom: Precision of ROLO also needs to be considered – it is limited.

Marc: why don't you use GLOD for the benchmarking?
Seb: at present, not enough data in GLOD. The benchmark covers more extensive set.
Two cases would be tested - control cases and real observation cases.

Regarding inserting the benchmark in the GLOD, the following approach is envisaged:

- Code will be stored, output is also stored as a reference, input is not stored and stays on the shape of a template
- Computing time is a limiting factor. We should rethink the amount of tests.
- ROLO model precision has its limits
- Previous test (LCW1) was limited to MSG warm channels (VIS0.6, VIS0.8, NIR1.6, HRV).

LCWS.2017.2p.1: EUMETSAT/USGS to report at the next GSICS annual meeting on the traceability of the GIRO to the ROLO using the benchmark.

Tom: we can focus on (0,0,0) position first to see the libration range/phase angle range. The purpose is to compare the behaves of GIRO and ROLO.

Agenda Item: 3c – Comparison of the Lunar Model Using the Hyper-spectral imager observations – 15:00 (20 minutes)	
Presenter	Yang Wang – CIOMP
Discussion point, conclusions, Actions, Recommendations	

Yang presented the work he did in comparing the GIRO lunar model with hyperspectral imager measurements.
Oversampling by two methods: ellipse fitting, along-track image size. Oversampling is 0.75

to 1.45.

Questions comments:

- Is an extension of the spectrum to 2400 nm planned? Yes, within the next 2 years.
- The Miller-Turner 2009 model does not account for opposition, wax/waning and libration as it was defined for a specific purpose and scope. For all those reasons, the model is not suited for comparisons.
- The oversampling factor calculation should be done using the scanning rate.

Difference between the observed hyperspectral observations and the GIRO are about 7-12%, dependent on wavelength, as well as phase angle.

Q: plan to continue the observation campaign? A: yes, one year.

Agenda Item: 3d – A novel hyperspectral lunar irradiance model based on ROLO and mean equigonal albedo – 15:20 (20 minutes)	
Presenter	Lu Zhang - CMA
Discussion point, conclusions, Actions, Recommendations	
Lu presented the developments CMA is doing on a hyperspectral lunar irradiance model. The equigonal means are deduced from C.Pieters catalog. The ratio between Highlands and Maria changes with phase angle. Phase curve is fitted with cubic polynomial. The model does not account for libration. Comment: cubic fit should be checked against actual measurements, not the extracted values from the ROLO model.	

Agenda Item: 3d – General discussion – 15:40 (20 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	
Scott Hu announced the successful launch of FY-3D on Wednesday morning. It carries MERSI and microwave sounder and imager instruments.	

Lunar Model Development– 15th November, 2017	
Chair	Tom Stone (USGS)/Sebastien Wagner (EUMETSAT)
Minute Taker	
Attendance	
Remote attendance	

Agenda Item: 3f – SELENE – 8:30 (20 minutes)	
Presenter	Toru Koyama - AIST
Discussion point, conclusions, Actions, Recommendations	

SELENE mission: lunar orbiter; polar orbit, non-Sun sync, it means the lunar surface is observed with different illumination angles. Japanese name is "Kaguya", after a Moon princess in Japanese fairy tale.

The SP (Spectral Profiler) sensor acquires observation with a swath of 500 m. The SP instrument performance showed to be very stable (comparison were made over 4 Apollo sites). The comparison over those sites require a photometric correction to account for the emission angles.
A multi-band imager is also available onboard SELENE (swath ~19km).

The SELENE reflectance map is now 0.5x0.5 degree resolution on the moon surface. Toru published the reflectance model in 2016 (PSS, 2016). The model covers the range 512-1650nm, with a 6-8 nm spectral resolution.

The reflectance model was used to simulate an ASTER Moon image acquired in 2003. Image registration need to be carefully taken into account.

Comparison were made betwen the model and the observations from SELENE. Further comparisons between the ROLO and SELENE model showed a good agreement. However some phase dependence is observed. Some correction is done using the ROLO model. To assess the accuracy, other sensor data were used like Hayabusa-2 (Suzuki et al. Icarus, 2017). The adjustment done to the model using the ROLO improved the comparison between the SP model and the observations. However, at high emission angle and high latitude regions, the accuracy of the radiance model is not good. As a result, only emission angle < 45 should only be used.

The map of the SP model has not been distributed from the archive. However, it has been shared with NOAA, JMA and JAXA. But it can be made available after contacting the PI.

Fangfang: SP stability < 1%. Is it the spectral or radiometric stability?
Toru: it is the radiometric stability.

Question: Is a BRDF model used? Answer: observations are done in nadir only, but photometric models are used for correction.

Question: Which sensor is used in the 900 to 1000 nm overlap region? Answer: Up to 950 nm the VIS detector is used.

Question: which solar irradiance model was used? Could differences between SP model and ROLO be caused by solar irradiance models? Answer: the observed differences are larger than the solar model differences.

Question (Scott): can the model be shared for comparison with ground-based measurements? Answer: basically: yes, contact by e-mail for details.

Agenda Item: 3g – New Lunar model establishment based SELENE/SP observation with incorporated into lunar DEM data – 8:50 (20 minutes)	
Presenter	Lu Zhang - CMA
Discussion point, conclusions, Actions, Recommendations	

Various lunar models exist, derived from ground-based observations, from Earth orbit, and from Lunar orbit.
Moon data from lunar orbiters:

- Lunar orbiters: Moon Mineralogy Mapper (M3) on Chandrayaan-1,
- Interference Imaging Spectrometer (IIM) on Chang'E-1 (mission is over)
- Spectral Profiler on SELENE

Only the latter has full lunar coverage

DSK subsystem of SPICE can be used to recalculate illumination geometry from shape information.
Data is screened on incidence angle, phase angle, and emission angle, and noise.
The VIS band was used to classify regions on the moon: Mare, Middle and Highland
The model has 1 * 1 degree resolution, corresponding to 900 km^2 near the equator. At high latitude the lunar data (562 x 400 m^2) are not good enough.

Question: does SP really cover the entire moon, seen the small footprint? Answer: More than 2000 or 3000 orbits used for the model, so with interpolation this should be enough, though interpolation may introduce some uncertainty

Agenda Item: 3h – A New Lunar Radiometric Model and Its Irradiance Based on China's Lunar Orbiter and in situ Data – 9:10 (20 minutes)	
Presenter	Yunzhao Wu - CAS
Discussion point, conclusions, Actions, Recommendations	

History of Moon's absolute photometry: since 1939 many observations. Currently widely used model is the ROLO model.
Orbiting instruments: SELENE SP, LROC WAC, Chang'E-1 IIM, M3 Chandrayaan-1.

Chinese mission: Chang'E-3 "Yutu" rover did in-situ measurements, using a calibrated reference diffuser. Wavelength coverage from 450 to 2400 nm. Four measurements were made, with different geometries.

Chang'E-1 IIM model was used employing the moon split up in 4 classes with 4 phase functions. A new flat fielding algorithm was used. Previous models showed boundaries between adjacent orbit's measurements, the new model is seamless, demonstrating better relative accuracy. Reflectance comparison: many models and lunar calibration sites are compared, scatter is in the order of several tens of percent Chang'E-3 site is proposed as new standard calibration site, consisting of young homogeneous material. Comment Tom: in-situ measurements are a great achievement. He complimented our Chinese colleagues for the accomplishment of the mission and performing spectral measurements of the reflectance directly on the Moon ground. Question (Jack): The relative accuracy is with respect to the on-board diffuser. What is the absolute accuracy of the reference diffuser? Answer: 1.5% for the BRDF, assuming no change since on-ground calibration. The diffuser is stored in a protected cover and only briefly exposed to the sun. Time since launch is 2 months, total use is 40 minutes of sun exposure. The diffuser is Spectralon-like material. Question (Lawrence): can the propellant use during landing have affected the diffuser? No effect is expected since the diffuser was closed inside the rover. Question (Sean): many reflectance measurements, showing large differences – which one to believe? All lunar orbiters experience problem in maintaining calibration from ground to orbit. The absolute calibration is not achieved.

Agenda Item: 3i – Progress on the development of a radiance model for ABI – 9:30 (20 minutes)	
Presenter	Fred Wu / Xi Shao / Fangfang Yu – NOAA
Discussion point, conclusions, Actions, Recommendations	
The moon reflectance and irradiance is very stable, but complicated to estimate due to phase- and libration dependence. An alternative is to work with lunar radiance. One difficulty to resolve is the determination of the lunar and deep space pixels. When using ellipse fitting, the irregular shape of the observed moon was an issue. Measured irradiances show unexpected behaviour, pixels can not always uniquely be assigned to moon or background. For a radiance model, the image-to-image registration is key. 15 sites + 1 landing site were used for the navigation and registration (both dark and bright).	

One year of AHI data was provided by JMA to NOAA (June 2015 - May 2016). SPICE was used for the lunar geometry. The radiance model was developed using those AHI data. There is a strong relationship between the radiance and the phase angle. The assumed oversampling rate is not as stable as previously assumed. When looking at lunar radiance, challenges move to BRDF characterisation, image registration, extraction of the region of interest. Many high quality lunar radiance observations exist. Selene Spectral Profiler and Digital elevation model were combined to identify 16 calibration sites. Sites are large enough to be insensitive to image registration issues, and cover a representative selection of lunar features. An automated region identification method was developed and applied to GOES-12 lunar observations The BRDF model of each region was determined. Strong Solar Zenith Angle dependence, very little satellite zenith angle dependence. Remaining phase angle dependence is also large, and varies from site to site. Sites near selenographic longitude = 0 degree should be used to develop the radiance model

Agenda Item: 3j – Discussion – 9:50 (30 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	

Inter-calibration and inter-band calibration – 15th November, 2017	
Chair	Sebastien Wagner (EUMETSAT)
Minute Taker	Ralph Snel (ESS), Masaya Takahashi (JMA)
Attendance	
Remote attendance	

Agenda Item: 4a – Inter-calibration scheme using the Moon and current issues + old results using MODIS as a reference – 10:40 (20 minutes)	
Presenter	Sebastien Wagner - EUMETSAT
Discussion point, conclusions, Actions, Recommendations	
The Moon is used through the GIRO model for inter-calibration of multiple instruments There is no need for coincident time of observation or field of regard. This dependence is	

covered by the GIRO model. Past, recent and future instruments can be tied together. Spectral band adjustment factors take into account different spectral bands of the instruments to be compared. Inter-band calibration indicates a difference of ~2% between VIS0.6 and VIS0.8 on Meteosat-9, consistent with other findings. In principle interband calibration is possible, provided that: ● GIRO dependencies are negligible (wavelength dependence). This can be circumvented by limiting to similar spectral bands in the comparison ● Phase angle dependence is small The other agencies are encouraged to test this scheme with their own data. Seb presented also some results on inter-band calibration using the data as available in the GLOD. Based on Sentinel 3 ideas of using the Moon. Relative and absolute radiometric calibration can be checked, in particular for instruments without on-board calibration possibilities. Lunar reflectance spectrum is smooth with only shallow features, and is out-of-atmosphere spectrum. Tested on PARASOL, MODIS/VIIRS comparison. More work is required on current results. The method is powerful and all kinds of comparisons can be made for monitoring the instruments. However, interaction with instrument teams is needed to define reference band(s) for each instrument.

Agenda Item: 4b – Moving from MODIS to VIIRS as a new reference for inter-calibration – 11:00 (20 minutes)	
Presenter	Jack Xiong – NASA
Discussion point, conclusions, Actions, Recommendations	
VIIRS should be used as a new reference. One point is about what data should be used (NASA SIPS, NOAA IDPS , etc.). Looking at the current methods for inter-cal (DCC + Moon), VIIRS is more suitable than MODIS (MODIS saturates in some bands over DCCs, experiences crosstalk in some bands in the SWIR that makes it unusable for lunar inter-calibration). Jack mentioned CNES work; Seb recommended an action on CNES to present lunar work to GSICS. **LCWS.2017.4b.1: CNES to report on the current status of their work on lunar calibration, in particular on the corrections using Pleiades, at the next GSICS annual**	

meeting.

Question: there are many VIIRS calibrations, which one to use? For inter-calibration reference, stability is important. Calibration for ocean colour emphasizes stability.

CLARREO or THRUTH missions may become a reference instrument in the future.

Comment (Seb): one strength of having the Moon inter-calibration method additionally to the DCC method is to extend the dynamic range coverage.

Agenda Item: 4c – Inter-calibration of AHI with MODIS – 11:20 (20 minutes)	
Presenter	Masaya Takahashi - JMA
Discussion point, conclusions, Actions, Recommendations	
In the current status, the algorithm does not account for the SBAF adjustment. There are still some open issues with the calculation of the oversampling GOES-12 sees a similar phase dependence in Band 3 (0.64 micron) as seen by AHI. SCIAMACHY seems to see it. But it is a point of discussion Future plan: VIIRS, and intercalibration with GEO imagers Also possible inter-calibration of GEO-ring	

Agenda Item: 4d – Alternative approaches for cross comparisons between instruments – 11:40 (20 minutes)	
Presenter	Jack Xiong – NASA
Discussion point, conclusions, Actions, Recommendations	
In Jack's talk, #year_D (slide 8) = deep space. #year_R = Moon The lunar model can help to allow comparisons of different calibration measurements with systematic differences. Jack raised a list of points for discussion: ● Traceability + uncertainties ● Calibration coefficients + data collections: multiple calibration results (and teams) make comparisons tricky. In particular, Jack mentioned that there are many calibrations for VIIRS. What data to use? ● Detector IFOV: IFOV specified or measured? Lessons learned and improved calibration insight over time. ● Lunar model ● Impact of sensor performances + characteristics ● Others...	

LCWS.2017.4d.1: NOAA/NASA to interact on calibration dataset and report back at the next GSICS annual meeting to provide advice on what to use for inter-calibration

Jack also provided an insight on the work by NIST, Gene Eplee and himself on SI traceable TOA lunar irradiance.
They used Pleiades data as part of their work. The dataset seems to be different from what CNES in the previous LCWS.

Measurements are available from a spectrometer covering 380 to 1040 nm @ 3 nm, + irradiance standards.
Uncertainty budget included.
Documented in NIST technical report.
Combined with SeaWiFS measurement, comparison with ROLO model, using SeaWiFS as transfer instrument.
Short wavelength deviate, libration angle effects?
Pleiades also included for phase angle correction (better phase angle coverage, instead of 6.6 degrees)
Considering all corrections combined, the uncertainty varies from 1.52% at 400 nm to well below 1% at longer wavelengths
Goal: use ROLO as SI traceable reference

Question (Seb): does CNES use the same phase angle correction?
Answer: no

Dataset provided to NIST is a CNES dataset

Question: MODIS/VIIRS cross-comparison results may depend on user (Gene).
Answer: that depends on "which VIIRS" is used. Traceability!
Seb: VIIRS calibration experts should provide a recommendation on the "best" calibration version to use
Remark: Be careful with "Circular calibration" using the moon, M1 to M4 in a certain team uses the moon.

Agenda Item: 4e – Inter-calibration using the Moon to bridge instruments with different relative spectral responses(RSRs) in reflective solar bands(RSB) – 12:00 (20 minutes)	
Presenter	Lu Zhang – CMA
Discussion point, conclusions, Actions, Recommendations	
Apollo sample spectrum fitted to measurements from instruments A and B, both normalized using lunar model results. Inter-calibration parameters found by difference of ratios.	

Agenda Item: 4f – Inter-band calibration with PROBA-V – 13:20 (20 minutes)

Presenter	Stefan Adriaensen - VITO
Discussion point, conclusions, Actions, Recommendations	
DCCs are used for inter-band stability and calibration on PROBA-V GIRO used as comparison. GIRO is not run operationally, but compares well to DCC and show that PROBA-V is within requirements.	

Agenda Item: 4g – Discussion – 13:40 (30 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	
For comparing instruments, the over-sampling factor and the IFOV need to be addressed when looking at inter-band using the moon.	

Alternative uses of lunar measurements – 15th November, 2017	
Chair	Jack Xiong (NASA)
Minute Taker	
Attendance	
Remote attendance	

Agenda Item: 5a – Introduction to the session – 14:10 (10 minutes)	
Presenter	Fred Wu - NOAA
Discussion point, conclusions, Actions, Recommendations	

Agenda Item: 5b – MTF of ABI, AHI, FY-2, MI, and SEVIRI – 14:20 (30 minutes)	
Presenter	Xi Shao - NOAA
Discussion point, conclusions, Actions, Recommendations	
Lunar image is a nearly ideal and widely available target for the evaluation of the spatial quality. NOAA project (with GSICS) used 6 GEO instruments: ABI, AHI, GOES-15 Imager, COMS MI, SEVIRI and FY-2G Imager. Fermi function based parametric method for edge location to sub-pixel accuracy to derive	

fitting function of edge spread function.

Validation at 0.9 Nyquist would be recommended.

Edge spread function directly measured. From ESF, the PSF and the MTF are successively calculated.

Seb: C. Ledez applied his algorithm for MTF evaluation to Meteosat-9 SEVIRI lunar observations, but also to ABI and AHI.

Comment (Tom): is MTF recommendation a GSICS task or more something for industry?
Comment Marc: Synthetic / simulated images were used to test MTF algorithms. Seb: This is something that could be done for the Moon as well.
Comment: Other teams have used bridges for MTF measurements, they had problems with the moon. Seb: this is not something that would work for GEO, with resolutions coarser than 250 m.

Seb commented on the need to involve the CEOS WGCV IVOS group as they do extensive work on MTF post-launch characterisation.

Agenda Item: 5c – MTF evaluation of Meteosat-9 SEVIRI using Lunar observations + results on the ABI + AHIMTF evaluation of Meteosat-9 SEVIRI using Lunar observations + results on the ABI + AHI – 14:50 (15 minutes)	
Presenter	Claude Ledez / Sebastien Wagner - EUMETSAT
Discussion point, conclusions, Actions, Recommendations	

Seb presented the main lines of the method developed by C. Ledez at EUMETSAT.
Many issues with using lunar observations:

- alignment with sampling direction(s)
- alignment of edge profiles with each other
- truncation, to avoid lunar terrain features
- selection of regions of interest, w.r.t. round image

Several questions/comments were presented at the end of the talk:

- MTF curves more useful if provided up to x2 Nyquist to identify possible aliasing
- Can we agree about a frequency range to estimate the MTF? ([0, Nyquist] or [0, 2xNyquist])
- What about using a consistent sampling for the MTF?
- What about agencies sharing the details of their algorithms for estimating MTF post-launch?
- Do we target a GSICS-recommended approach? What are the next steps for this MTF exercise?

● Exchange with JMA on the data processing è for the exercise, GIRO imagettes (="processed" data) were used ● Exchange with NOAA on ABI data processing (in particular stretching)?

Agenda Item: 5d – MTF evaluation of AHI using lunar observations – 15:05 (15 minutes)	
Presenter	Ryuichiro Nakayama / Masaya Takahashi - JMA
Discussion point, conclusions, Actions, Recommendations	

Agenda Item: 5e – MTF evaluation of FY-2 – 15:20 (15 minutes)	
Presenter	Lin Chen - CMA
Discussion point, conclusions, Actions, Recommendations	
Lin performed an analysis on the impact on MTF of SNR, selection of the Region(s) Of Interest, the impact of atmosphere, etc. Very interesting analysis. More work needed in particular to check the ROIs.	

Agenda Item: 5f –MTF evaluation of MERSI using lunar observations – 15:35 (15 minutes)	
Presenter	Min Min - CMA
Discussion point, conclusions, Actions, Recommendations	

Agenda Item: 5g – MTF evaluation of Proba-V – 15:50 (15 minutes)	
Presenter	Stefan Adriaensen - VITO
Discussion point, conclusions, Actions, Recommendations	

Agenda Item: 5h – Discussion – 16:05 (45 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	
Different instrument have different terminologies (L1B, L1A, L1Alpha, etc.) How many samples shall we assemble to derive the oversampled Edge Spread Function? **LCWS.2017.5h.1: Points of Contact to coordinate and provide details about the algorithm implemented in their agency (see Seb's presentation on MTF, slide 30, point 4).**	

EUMETSAT and ESA mentioned IVOS activities on MTF.

LCWS.2017.5h.2: JMA and NOAA to interact on the oversampling and MTF.

Agenda Item: 5i – GOCI-II MTF – 16:50 (20 minutes)	
Presenter	Seongick Cho - KIOST
Discussion point, conclusions, Actions, Recommendations	

GOCI mission will be extended by 2 years.

N-S FoR is +/- ~11deg, whereas E-W FoR is +/- ~8.6 deg.
Several priorities exist for moon obs, ~25 obs is planned in 2019.
GOCI-II lunar calibration module was verified using COMS/MI lunar observation data.
GUI software for MTF calculation is prepared.

Tom and Sebastien highly recommended KIOST to use GIRO for the purpose of the lunar calibration. If individual implementation of the ROLO model is used, the model should be properly validated.

Agenda Item: 5j – Lunar Observation Activities with a Small Satellite and a Planetary Exploration Satellite – 17:10 (20 minutes)	
Presenter	Toru Koyama - AIST
Discussion point, conclusions, Actions, Recommendations	

Toru presented lunar observation activities using small satellites and planetary exploration satellites.
Hodoyoshi-1: launch in 2014
For this satellite community, radiometric calibration is not a concern. However, Toru advised to look at the moon every month. So they did. First results were shown on the calibration using the moon.

Hayabusa-2: using the SP model corrected with the ROLO allowed a good match of the observation from this planetary mission.

Agenda Item: 5k – OLI – 17:30 (20 minutes)	
Presenter	Lawrence Ong - NASA
Discussion point, conclusions, Actions, Recommendations	

OLI and TIR performances are 2-3 and 8-10 times better than specified in the requirements.

For lunar calibration, they perform a pitch manoeuvre in 2 successive orbits to capture the

Moon in all 14 focal plane arrays (slide 11). Slide 12: time series of sensor response: the oscillations cannot be attributed only to temperature in the SWIR The OLI raster acquisitions of the moon reveal straylight. The straylight source was characterised using ray tracing and a linear model was derived to correct the data. The SLIM Lunar Irradiance Model is under development between Lawrence and Hugh Kieffer ==> ROLO data is only one dataset among the others. So a database is being built to derive SLIM. For the moment, only Hyperion, MODIS, VIIRS and OLI are used. Lawrence invited groups who want to contribute to this effort with their dataset to contact him. Comment (Seb): the new modeling effort is working the problem backwards – building a calibration reference based on measurements that are supposed to be calibrated by the reference. Discussion: this might be OK, if each instrument dataset is assigned an uncertainty. But the instrument teams must be honest about the actual uncertainty of their lunar irradiance measurements. Comparisons against ROLO show differences between instruments that are larger than the uncertainties specified by the teams. The lunar model is typically cited as the cause, but the model relative uncertainty is smaller than the differences seen, especially for similar phase angles. Comment (Tom): Hugh has in the past wanted to collect measurements from all instruments that have viewed the Moon and settle on a scale for the lunar irradiance. But that is a different activity than Hugh's current modeling work, which takes each instrument's measurements as truth.

Alternative uses of lunar measurements – 16th November, 2017	
Chair	Jack Xiong (NASA)
Minute Taker	
Attendance	
Remote attendance	

Agenda Item: 5k – MODIS PC bands optical leak characterisation using lunar observations – 09:00 (20 minutes)	
Presenter	Jack Xiong - NASA
Discussion point, conclusions, Actions, Recommendations	

Jack presented the correction that is applied to the MODIS data to correct optical leak. Lunar data were used to analyse the problem. The problem was found on Terra, Aqua was build after lesson learnt from Terra.

PC bands: photo conductive, 11-14.4 micron wavelength, MCT detectors.
Optical leak identified during on-ground characterisation.
2D spatial/spectral scan revealed the optical leak.
Spectral leak detected, and spatial leak detected.
Bands 32-36 respond to some degree to light in band 31 as well.
Non-linear response also affected by cross-talk, used for characterisation of cross-talk as function of temperature.

Scanning over the moon creates response in each band sequentially, crosstalk thus shows up in other bands with a time shift.
Results in ghosting in images, correction quality can be checked visually at high contrast scenes, ghosting present or not?

Question: what is the root cause of the cross-talk? Is it because of proximity of the detectors?
A: The key reason is bouncing of the light within the focal plane after it got in through a specific band. Spectral filters separate the bands, but a gap combined with a reflection allows light to enter other bands.

Agenda Item: 5l – Electronic x-talk characterisation using lunar observations for MODIS and VIIRS – 09:20 (20 minutes)	
Presenter	Truman Wilson - NASA
Discussion point, conclusions, Actions, Recommendations	

The small size of the moon makes it a good target for electronic cross-talk characterisation.

Electronic x-talk will appear in striping in between detectors in some thermal infrared bands.
A linear algorithm is used to correct for that effect, even though there might be some non-linearities.
More results are presented in T. Wilson et al. Remote Sensing 2017, 9 (6).
The linear correction shows to be very efficient.

Implemented in Collection 6.1

Validation: Brightness temperature drift over the ocean is greatly reduced; great lakes print-through in atmospheric bands is removed.

Ralph: the correction for both electronic and optical is similar. How can we separate electronic from optical?
Electronic normally leads to negative values. Optical x-talk is usually positive. In the case of

MODIS it was identified pre-launch. It is constant over the time of the mission. In-flight it is very difficult to separate the two sources of x-talk. However, the correction works irrespectively of optical or electronic origin.
Question: Why the time dependence?
Answer: related to radiation damage, typically while passing the SAA. Also annealing effects when the detectors heat-up to ambient temperatures.

Question: are all bands contaminated and will that complicate the characterisation? Answer: Yes, and iterative correction has been investigated but doesn't significantly improve the final result. Impact of crosstalk (2nd order effect) is a negligible effect since the crosstalk is small (~5%).

Agenda Item: 5m –Ghost effects/ X-talk characterisation using Moon observations from ABI– 09:40 (20 minutes)	
Presenter	Fangfang Yu - NOAA
Discussion point, conclusions, Actions, Recommendations	

In Band04, blooming effect (halo) around the moon. Image enhancement shows patterns that need to be worked out. Noise is in specification but it may have an impact.

NOAA performs north-south scan of the Moon.
NS-scans reveal xtalk in band 6 in GOES-16 ABI.

Test when building the focal plane: ROAC shall be performed to identify potential x-talk.

In flight it is difficult to identify the reasons for the x-talk (separation between optical/electronic and light reflection, out-of-band, etc.)

Discussion of various terms regarding xtalk: subsystem level detector testing (without optics) can reveal electronic xtalk while ruling out optical xtalk.

Investigations are ongoing, more results expected.

Agenda Item: 5o – Lunar calibration consideration for FY-3 Microwave instruments – 10:50 (20 minutes)	
Presenter	Songyan Gu - CMA
Discussion point, conclusions, Actions, Recommendations	

Use of "lunar glint" in deep space view for interchannel calibration (e.g. MWHS 118 GHz) is planned.

The Moon shows as a clear signal in the MW data. It can be used for calibration purposes.

Chang'E-1 orbits the Moon and has produced microwave maps of the moon. Some MW imagery of the moon with MICM were shown.

By choose a reference band, calibration could be transferred to other bands using the Moon.

Future work: use the Moon for radiometric calibration and to monitor the lifetime stability of the MWHS and also evaluate the pointing accuracy of some bands.

Fred: FOV (footprint)? A: same as ATMS.

Agenda Item: 5p –Discussion – 11:10 (60 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	

Conclusion and way forward – 16th November, 2017	
Chair	Sebastien Wagner (EUMETSAT)
Minute Taker	
Attendance	
Remote attendance	

Agenda Item: 6a – Discussion - Establishing new requirements on the ROLO/GIRO application – 13:10 (20 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	

GLOD:
Policy: data provision needs to be approved by the corresponding agency or group, not just by the contact person.

Static or living database? Preference is living database, but this needs commitment from the agencies, and effort to keep the database up-to-date.

Scott: China will provide FY-3 and some ground-based data for GLOD.

Agreement: GIRO/GLOD should only be used for the missions included in GIRO/GLOD.

In next release of GLOD: only include the data of agencies who have signed already.

Benchmark: will be included in next distribution
Benchmark dataset will be large and may take some time. Possible reduction could be to have a lower wavelength resolution since the lunar reflectance spectrum is smooth.

Data provided to GLOD should have explicit permission of the data owner to be included.

Data preparation:
Method for lunar analysis: do not use the apparent size of the moon to determine IFOV or oversampling factor. Use operational parameters instead.

LCWS.2017.6a.1: in the preparation of the data for the GIRO and in particular the calculation of the oversampling factor, it is recommended to use the operational parameters from the instrument instead of the apparent size of the Moon.

LCWS.2017.6a.2: the Lunar Calibration Community is invited to contribute to the development of a polarisation model for the Moon light. This model would complement the ROLO/GIRO and could be a separate model.

EUMETSAT envisages to revisit the GIRO internal mechanism that model the reddening of the Moon light with the phase.

LCWS.2017.6a.3: CMA is encouraged to report on lunar model development based on the new ground-based lunar observations.

Agenda Item: 6b – Discussion – Establishing new requirements on lunar measurements-13:30 (20 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	

CMA has new ground-based measurements. More lunar observation campaigns will take place. CMA asked for some support with the validation of their data. After quality assessment CMA is willing to share those data.

CMA invites collaboration to improve the ground-based and space-borne lunar measurements. Covering both instrumentation and model development.
Tom: improve in particular the traceability to national standards

LCWS.2017.6b.1: ESA is invited to present the status of their initiative with the CIMEL

lunar photometers in a future meeting (possibly at the next GSICS annual meeting or at a web meeting).

Apollo return samples: Tom states that the samples could be made available if someone could do the measurements. The idea is to measure the BSDF (bi-directional scattering distribution function)

Agenda Item: 6c – Discussion - Next steps for inter-calibration – 13:50 (20 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	

CMA: there is need for better inter-band calibration in particular for the water vapour bands using the moon.

Seb recalled the difficulties to be overcome in order to inter-calibrate instruments using the Moon as a transfer. However, some ideas were discussed (inter-calibration between GEOs, or subsampling of moon imagery for similar phases for instance) and could be tested.

LCWS.2017.6c.1: agencies are invited to report on their progress on inter-calibration and/or inter-band calibration at the next GSICS annual meeting.

Agenda Item: 6d– Discussion - Next steps for alternative methods (radiance models/MTF/other irradiance models) – 14:10 (20 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	

SELENE-based radiance model. Lunar satellites have their own radiometric issues. Once these are resolved the potential is great.

LCWS.2017.6d.1: NOAA is invited to report on their progress on their radiance model development at the next GSICS annual meeting or at a lunar calibration web meeting.

MTF:

LCWS.2017.6d.2: NOAA to circulate a questionnaire to the agencies POC for MTF in order to collect information about the algorithms in place to estimate the MTF using the Moon.

LCWS.2017.6d.3: NOAA to liaise with IVOS regarding MTF estimation (contacts: Francoise Viallefont - Francoise.Viallefont - AT - onera.fr , or Dennis Helder - Dennis.Helder - AT - sdstate.edu).

LCWS.2017.6d.4: agencies participating to the MTF activity to communicate to NOAA (Xi Shao / Fangfang Yu) the details of the Point Of Contact for their MTF algorithm.

Agenda Item: 6e– General discussion – 14:30 (20 minutes)	
Presenter	All
Discussion point, conclusions, Actions, Recommendations	
Next iterations: ● GSICS Research and Data Working Group meeting - Shanghai March 2018 ● Next lunar calibration meeting about 2 years from now. Format for the workshop: 4 days, extend to 5 days? Coverage of topics was right.	

Agenda Item: 6f– Review of recommendations/actions – 14:50 (20 minutes)	
Presenter	Sebastien Wagner - EUMETSAT
Discussion point, conclusions, Actions, Recommendations	
Done offline	

Agenda Item: 6g— 15:10 (20 minutes)	
Presenter	Xiuqing Hu / local host
Discussion point, conclusions, Actions, Recommendations	
Scott closed the meeting and took the opportunity to thank all the participants for attending the meeting and sharing their work and expertise. XIOPM representative also thanked all the participants and invited the community to continue with their effort in the field of lunar calibration.	

Agenda Item: 6h– Summary and future activities at CMA in collaboration with the Chinese Academy of Science – 15:10 (30 minutes)	
Presenter	Peng Zhang – CMA
Discussion point, conclusions, Actions, Recommendations	
Cancelled	