# Introduction

In the recent years, space and meteorological agencies operating Earth Observing satellites have shown an increasing interest in lunar calibration for monitoring the temporal stability of their instruments. Both GSICS and CEOS IVOS recommend lunar calibration as a calibration and inter-calibration method for VIS/NIR bands that should be implemented for instruments that have the capability to sense the Moon. The current reference model for lunar calibration (the so-called ROLO model) has been developed and is being maintained by the United States Geological Survey (USGS). A few agencies have implemented their own version of this model. However, experience has shown that there could be differences between some of these independent implementations and the official USGS version of the ROLO model.

During the last GSICS Research and Data Working Group annual meeting in Darmstadt (24-28 March 2014), the GSICS community, together with the CEOS-IVOS chairman (Nigel Fox, from NPL) recommended to harmonize the version of the ROLO model that is used for lunar calibration of VIS/NIR satellite instruments by more and more operators. Indeed, in the context of instrument inter-calibration, the use of the same transfer reference should be ensured.

EUMETSAT offered to host a lunar calibration workshop to initiate an activity to share knowledge on lunar calibration and to promote the use of a common reference across participating groups. This workshop is organized by EUMETSAT, USGS, CNES and NASA. EUMETSAT proposed to use its current implementation of the ROLO model as a baseline for an official GSICS implementation of the USGS ROLO model. EUMETSAT's implementation has been verified, with good agreement, against the USGS implementation. This has been achieved by close interactions with Tom Stone from USGS.

USGS will keep the leadership on the improvement of the ROLO model. EUMETSAT would then implement these enhancements once they are made publically available via peer reviewed papers. CNES is collaborating with USGS to help improving the reference lunar model by using data derived from the Pleiades observations. And NASA will provide data for the current GSICS agreed reference instrument (Aqua MODIS) in order to transfer the MODIS calibration to the target instruments.

# SCOPE of the workshop

## Objectives

The main objectives of the workshop are:

1. To work across agencies / operators with a common and validated implementation of the USGS ROLO model. For that, a reference GSICS implementation of the model has to be considered. This reference model, based on the EUMETSAT ROLO Implementation, will be available primarily to GSICS and CEOS IVOS member organisations, but also to any other groups working with lunar observations from Earth Observing satellites.
2. To share knowledge and expertise on lunar calibration.
3. Generate for the first time a reference dataset that could be used for validation / comparisons later on.

This workshop would be the first step for providing the international community with a referenced and traceable version of the USGS ROLO model. Such a model, called GSICS Implementation of the ROLO model (GIRO), will be usable to transfer the calibration between different instruments and to generate inter-calibration products - even from different eras, supporting the generation of Fundamental Climate Data Records. The GIRO does not include any pre-processing routine for extracting lunar observations from the satellite imagery. The preparation of the input data is left to the responsibility of each and every agency and participant to the workshop.

The implementation of the ROLO model within GIRO would be updated and maintained at EUMETSAT using the latest publically available developments on lunar calibration as done by USGS. Binary files and source code would be distributed under the auspices of GSICS, using the EUMETSAT GSICS server and the EUMETSAT configuration control environment. The GIRO would be fully validated through coordination with Tom Stone at USGS before it becomes the official GSICS recommended lunar calibration reference. The goal is to provide the international community with access to a unified version of the ROLO model.

One of the key benefits of the workshop is to generate for the first time a reference dataset comparing observations from a range of satellite instruments using a common lunar irradiance model. This will be used to identify shortcomings in the existing model and develop and validate future improvements.

## Expected time frame

The workshop is expected to take place preferably in December 2014 or as an alternative in January 2015. This will allow the participants to have sufficient time to perform further analysis on their datasets if necessary after the workshop and before the next GSICS Research and Data Working Group annual meeting (foreseen in March 2015).

The workshop is foreseen to last 4 days.

## Organisers

The workshop will be organised at EUMETSAT by:

* Sébastien Wagner (RSP/INRC)
* Andrea Danz (RSP secretary)

Other scientific and organisational support will be provided by:

1. CNES:
   1. Sophie Lachérade
   2. Bertrand Fougnie
2. USGS:
   1. Tom Stone
3. NASA:
   1. Xiaoxiong (Jack) Xiong

## Requirements to attend the workshop

We are defining some pre-requisites for participation in the workshop to force participants to actively prepare for the workshop and avoid the need for them to do major re-processing to run the GIRO model. If it becomes evident that a team cannot process their data at the workshop, then a sample of MSG data will be made available to them.

The workshop attendees are therefore asked to provide:

1. Processed lunar image data. This can be a few example images or the entire dataset acquired by an instrument. The team should bring imagettes containing the Moon to show to the workshop participants. These sample images are for demonstration purpose and will be proposed on the common test dataset only upon agreement.
2. The lunar irradiance measurements derived from the imagettes, following a procedure presented below and for a minimum set of illumination and acquisition conditions. These measurements will be put together on a common test dataset (hereafter called the lunar calibration reference dataset) and shared between participants.
3. The normalised spectral response functions (SRF) for the instrument sensors.
4. A PowerPoint presentation that explains in detail the image processing that was used to derive the lunar irradiance measurements. Each team will be required to present their processing methods to the group. The required elements of the presentation are:
   1. An explanation of the conversion from digital counts to radiance, including which calibration coefficients were used, any corrections for detector artefacts and non-linearity, and the method used for evaluating and subtracting the image background level.
   2. Explanations of how the pixel IFOV (solid angle) and image oversampling have been handled.
   3. Explanations of the processes for selecting the image pixels on the lunar disk and summing the pixel radiance values to irradiance.
   4. List recommendation and difficulties experienced by every participant.

## Expected attendees

All operators of Earth Observing satellites with Moon viewing capabilities are expected to participate to the workshop. We expect members of GSIC and CEOS IVOS to participate but also other groups from the Ocean Colour community for instance.

Participants will be requested to have a good knowledge of the image processing that is specifically applied for their instrument(s). They must identify contact points in the image processing teams within their agency in order to be able to contact them during the workshop, if necessary.

# Sketch of the Workshop agenda

The workshop would last four days. Each day would include one hour of open discussion and exchange between the participants on the top of the identified topics to be addressed and that are shortly presented n the following sections.

## Day 1

* Introduction to the workshop: goals, expectations, practicalities.
* General presentation(s) on lunar calibration: description of the reference, uncertainties, current limitations, common identified pitfalls when analysis the data.
* Description of the lunar calibration system as provided to the attendees.
* Establishing a lunar calibration reference data set for the calibration community.
* Recommendations on how to estimate the observed irradiance from the available imagery.
* Beyond the workshop: a framework for using a common referenced and traceable calibration and inter-calibration reference.
* Starting presentations by each group on their datasets. Presentations will address separately GEO and LEO platforms as these two types of orbits raise specific issues.

## Day 2

Continuation of the presentations by each group about:

* Their data sets (accurate description of the lunar observation extraction and image processing done to provide the input to the GIRO, in particular the observed irradiance). It should show at least image of the Moon in order to appreciate the image resolution and potential issues with the image processing.
* Preliminary results obtained without support in preparation of the workshop.

## Day 3

* Discussion on the results presented by each group to identify potential deficiencies in the data preparation and in the use of the GIRO.
* Sensitivity analysis to be performed on the data brought by each participant (practical work performed on the TCE).

## Day 4

* Guidance and recommendations on:
  + How to prepare the data.
  + How to look at the results.
* Wrap-up and way forward.

# workshop preparatory work

In order to optimise the workshop outcome, the attendees would need to do preparatory work before the meeting:

* Preparation of their data sets according to the requirements to be established by the organisers.
* Processing of these data sets with the GIRO.

USGS, EUMETSAT, CNES and NASA agreed on providing for the workshop a first version of a reference implementation of the ROLO model for distribution on the shape of a binary executable, to prevent modifications to the source code that would destroy the consistency of the version.

The binary executable would need to be built at/by EUMETSAT. This also means the distributed binary would be platform-specific (e.g. Linux x86\_64).

It is envisioned that documentation will be provided to participants. This documentation will include a full description of the data format for the GIRO input and output. Each participant to the workshop would be responsible of preparing the input data to inject into the GIRO model.