



Debrief on Lunar Spectral Irradiance Calibration System (LSICS)

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On behalf of the LSICS Development Team

LSICS: A modular-based framework that can integrate current and future lunar models; an open-source reference for lunar irradiance

Background



- ❖ GIRO (GSICS Implementation of ROLO model) has been used in the GSICS/IVOS communities as the reference for lunar calibration since 2014
 - Issues have been found and confirmed over time
 - Absolute bias (e.g. too dark for some channels), higher uncertainty at wavelengths $> 1 \mu\text{m}$
- ❖ The SLIM model by H. Kieffer published in JARS 2022 exhibits significant improvements to GIRO
 - A new approach to building a lunar irradiance model
- ❖ A modular-based framework to implement a new GSICS lunar calibration system was proposed at the GSICS 2023 Annual Meeting; this was supported by NOAA for development
- ❖ Concept of Lunar Spectral Irradiance Calibration System (LSICS) was formed in July 2023
 - Coded in a public language (e.g. Python), to be open to the public as a reference for lunar calibration
 - SLIM as the first LSICS lunar model to be implemented
- ❖ The precursor LSICS model was presented at LCWS#4 in December 2023
- ❖ Users requested LSICS and the scope of LSICS was endorsed by EP in the 2024 GSICS EP meeting

Project Framework



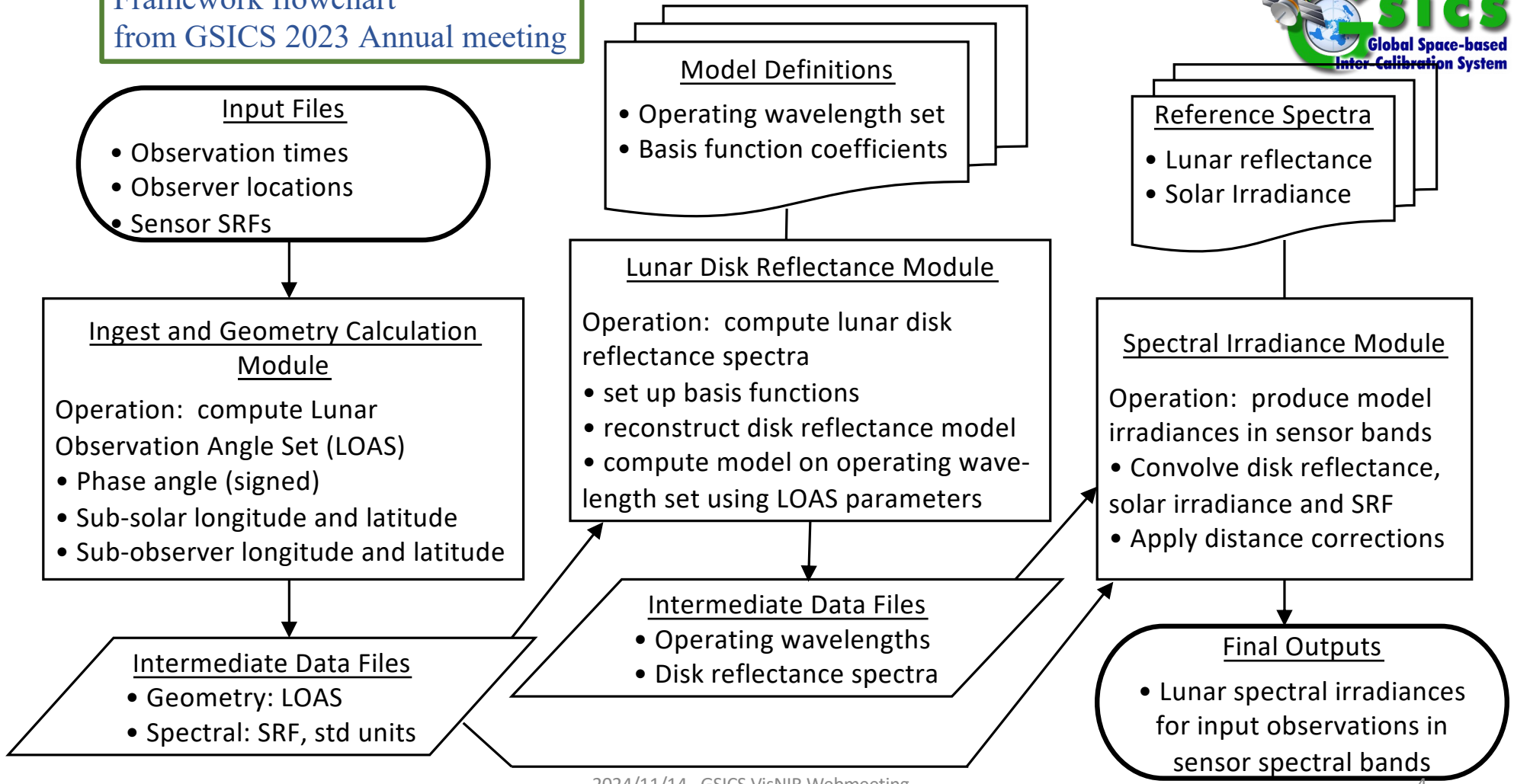
- ❖ LSICS development group
 - T. Stone (USGS) and F. Yu (NOAA affiliate) – co-lead
 - H. Kieffer – Scientific development + prototype provider for the lunar model (SLIM)
 - B. Basnet (NOAA affiliate) – main LSICS programmer
 - M. Krijger (Earth Space Solutions), S. Wagner (EUMETSAT), V. Debaecker (contractor to EUMETSAT), M. Takahashi (JMA, GDWG), and F. Wu (NOAA) – support + reviews

- ❖ Regular progress webmeetings every 2-4 weeks since April 2024, with minutes and decision log

- ❖ Development structure (currently only accessible to the development group)
 - Gitlab repository hosted by EUMETSAT
 - Confluence page hosted by EUMETSAT

- ❖ Specifications for I/O file contents captured by a shared spreadsheet
 - Currently hosted by NOAA

Framework flowchart
from GSICS 2023 Annual meeting



Earlier Efforts toward LSICS



- ❖ H. Kieffer initiated the LSICS I/O files specification as an interface control document in July 2023
 - Evolved from the prototype model - SLIM

- ❖ A precursor LSICS developed by NOAA was presented at LCWS#4 in December 2023
 - Partially modular — while the geometry model was modularized, the lunar model (SLIMpy) was coded in Python but not yet modular with LSICS

- ❖ NOAA showed an experimental LSICS with a modular SLIM model implementation at the GSICS annual meeting in March 2024,
 - SLIM irradiance could be calculated using the DR and spectral irradiance modules
 - Discrepancy between the original SLIM (IDL) and LSICS-SLIM needed to be resolved

Project Status



- ❖ LSICS prototype V0.1 code (python) is largely done
 - LSICS-SLIM results have been validated against the original SLIM model and approved by the developer
 - Ongoing software testing versus users/system requirements

- ❖ Substantial progress made with the I/O and intermediate files specifications
 - Ensure traceability of data processing versions and history
 - Allow interchangeability for different lunar models
 - Allow future integration of lunar polarization models

- ❖ LSICS I/O Filename conventions have been developed and tested
 - Back-compatibility with GIRO
 - Following GSICS naming convention

- ❖ Definition of version tracking is in progress

- ❖ Open points: distribution platform and type of license
 - These issues may defer the release date, which was targeting Q1 2025

Specifications for Input/Output Files



- ❖ Inputs (netCDF format, following LSICS name conventions)
 - Observation files
 - Compatible with existing GIRO files
 - Can be single or multiple observations and files
 - Observation time specified as UTC, preferably ISO 8601 strings. SPICE ephemeris time is optional
 - Only J2000 or ICRF are valid reference frames; all others need to be pre-processed
 - SRF files — separate from observation files
 - Compatible with existing GIRO files
 - Only commonly used SRF units (μm and nm)
 - A user-specified or default fill-value shall be used for invalid/missing data

- ❖ Output files (netCDF format, following LSICS name conventions)
 - Lunar irradiance in units of $\mu\text{W} / \text{m}^2 \text{ nm}$
 - Includes a set of variables and global attributes for tracking processing
 - Shall contain a digital marker, implementation TBD

Some Decisions for Internal Operations



- ❖ SPICE kernels
 - SPICEpy as the SPICE library
 - Ability to auto-update the SPICE kernels
 - Ability to activate light-time corrections in the LSICS SPICE implementation; the default is inactive.

- ❖ TSIS-1 HSRS (currently recommended by GSICS community) is the LSICS standard for solar irradiance spectra. Default resolution is 0.025 nm.

- ❖ LSICS allows external inputs of other solar spectra
 - Back-compatibility; future updates

LSICS Input/Output File Naming Convention (netCDF)



❖ Input files

- Lunar observation: follows [GIRO formats](#), but **supports multiple different observation time data in a file**.

Single obs: W_XX-EUMETSAT-Darmstadt,VISNIR+SUBSET+MOON,MSG3+SEVIRI_C_EUMG_20130101145644_01.nc

Multiple obs: W_XX-EUMETSAT-Darmstadt,VISNIR+SUBSET+MOON,MSG3+SEVIRI_C_EUMG_20130101145644_20140715153303_01.nc
time for 1st obs time for last obs

- Spectral response function: same as [GSICS Convention](#)

❖ Output file

- Similar to GIRO output, but closer to GSICS products (e.g., GEO-LEO-IR) by adding **data type** (BIASM: bias monitoring is one of the application of LSICS output), **algorithm type** (LUNARVNIR), and **reference** (LSICS+SLIMM)

W_XX-EUMETSAT-Darmstadt,SATCAL+BIASM+LUNARVNIR,MSG3+SEVIRI-LSICS+SLIMM_C_EUMG_20130101145644_20140715153303_01.nc

calculated MSG-3/SEVIRI lunar irradiance by SLIMM in the LSICS

c.f., GIRO output: W_XX-EUMETSAT-Darmstadt,SATCAL+ROLOVISNIR, MSG3+SEVIRI_C_EUMG_20130101145644_01.nc

GEO-LEO-IR: W_XX-EUMETSAT-Darmstadt,SATCAL+RAC+GEOLEOIR,MSG3+SEVIRI-MetOpC+IASI_C_EUMG_20190808000000_01.nc