Specification for a modular lunar spectral irradiance software system pre-LCW4 draft

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1 Overview

The ROLO lunar spectral irradiance model, in use for nearly two decades, was written in IDL, a proprietary language. To allow broad use, it was converted to C, an open language, and named GIRO (GSICS implementation of ROLO). However, at that time there was no other lunar model suitable for use in lunar calibration, and the architecture of GIRO has little consideration of incorporating other lunar models.

Now, other models are becoming available and some appear to be significant improvements to GIRO. There is a general desire within the lunar calibration community for a new lunar spectral irradiance model system which can incorporate various models of lunar reflectance with a minimum effort and which will be available to everyone. Also, this software system should anticipate expected developments, such as models treating polarization.

The concept of an architectural framework to accomplish this was suggested at the GSICS annual meeting 2023 Feb, and there have been several discussions within the VIS/NIR subgroup about the path forward. By vote 2028 July11 the name 'Lunar Spectral Irradiance Calibration System, LSICS. pronounced L6 (el-six). was chosen for this software system. An early need is a formal specification LSICS and of the files (or datasets) that interface between the several software modules that comprise it..

This document is an initial draft of that specification.

1.1 Draft terminology

All numerical values are TBD.

'L6' is shorthand for this software system.

"shall" means a requirement

"should" means a recommendation

"may" means the item is optional

"DataGroup" is a term for sets of information that are commonly produced or needed togetherInstrument-related files are identified by a single letter, typically in a single file.

In this draft, the font INDICATES a Better Word is desirable.

The wavelength unit for VIS/NIR (solar reflectance) is nanometers.

"alpha-character" is a single ASCII alpha-numeric character or underscore or dash. Abbreviated AC.

'band' is synonymous with 'channel'.

"bands" refers only to bands with the majority of their spectral response between 300 nm and 2500 nm
Note: Wavelengths longer than about 2500nm are subject to DETECTABLE thermal emission.
Areas at the peak lunar surface temperatures (405K) reach 10% of nominal solar reflectance (albedo 0.2) near 2330 nm. Whole-disk thermal radiation is near 92C at small phase [Matthews,2008] which reaches 1% near 2250nm and 10% near 2620nm.

An "observation" is defined as near-simultaneous measurements by a group of bands.

1.2 Reference documents

1. Hugh H. Kieffer, Multiple-instrument-based spectral irradiance of the Moon
   Journal of Applied Remote Sensing (JARS). Vol. 16, Issue 3
   https://doi.org/10.1117/1.JRS.16.038502
2. Tom Stone and Hugh Kieffer: GSICS Annual Meeting: 2023 March 02:
   Discussion on Implementing a New GSICS Lunar Model

http://gsics.atmos.umd.edu/pub/Development/Gsicsannualmeeting2023/7v_GSICS_2023_TStone_Lunar_model_discussion_Intro.pdf

3. High Level Description of the GIRO Application and Definition of the Input/Output Formats.
EUMETSAT Document EUM/TSS/TEN/14/753739, 24 February 2015
http://gsics.atmos.umd.edu/pub/Development/LunarWorkArea/GSICS_ROLO_HighLevDescript_IODefinition.pdf

2 Top level requirements

Given a set of 1 to N observations of lunar irradiance by an instrument with 1 to M bands in the solar reflectance wavelength region, the L6 system will produce the expected lunar spectral irradiance for those conditions.

In may be necessary to impose limits on N or M or NM

; e.g., 1000, 250 and 50,000 , respectively.

All files will be netCDF.

All routines will be coded in Python.

The L6 software system shall consist of several modules, to be applied in succession; the concept is described in Ref_2.

The interfaces between modules shall consist of fully-defined sets of information here called "DataGroups". Each DataGroup is defined in a Table in the Appendix. A DataGroup may be a file or structure or group of arrays and scalars. The DataGroup input to the first L6 module and that output by the last L6 module shall be files. The total information may be grouped in ways different than organized here, but all that is listed in Required categories (2nd column in tables) shall be in the final set of DataGroups.

It is critical that the definition of the minimum contents all DataGroups be complete. The current tables are based upon the definitions for GIRO (Ref. 3), consideration of a new model system (Ref. 1 and Ref. 2) and anticipation of availability of polarization measurements. **The tables in the Appendix should be considered TBD pending discussion and approval by the GSICS community.**

2.1 Standard Wavelengths

The L6 system may utilize a "Standard Wavelength Set" (SWS), a fixed set of wavelength points used for combining solar, Lunar and Instrument spectra. If used, the SWS shall be positive increasing monotonic and cover at least the 300nm to 2400 nm range. A point spacing of about $\lambda/\Delta\lambda = 1000$ is recommended.

An SWS should be defined in a manner that different Moon Modules (§5.3) may redefine the point set.

3 Input package

Data submission to the L6 system for calibration is called a "Team package", containing the information described in this section. The data may be contained in separate files, as listed in the first three subsections, or combined in other ways, TBD. Units shall be specified for all numerical values.

A Team package shall contain the information listed in Tables 3, 4 and 5. For only "rsr", the units may be as chosen by the Team.

3.1 Spectral response

The system-level relative spectral response (RSR, including detector responsivity and all optics) is required for each band. It shall be at the image level; e.g., averaged over individaul detector elements and averaged over any multiple focal-plane arrays, as in OLI. It should be provided for the configuration of normal science observations and, if different, the configuration of normal lunar observations.

The RSR for one band consists of a set of wavelength and response pairs, in monotonic wavelength order.

- A representative value of wavelength uncertainty (fractional or in wavelength units) should be provided.
- Two representative values of response uncertainty, fractional and absolute (MINIMUM ACCURACY), should be provided.

The spectral response will generally be treated as constant over an instrument mission.

If changes are known, full sets of RSR's should be supplied along with the time period for which each applies.

These data should be contained in a band wavelength and response file, Table 3.

3.2 Time and view-point

The "Effective time" of a band observation is the instance by which 1/2 of total flux for the Lunar disk has been integrated.

For framing systems, this is the middle of the exposure time.

For scanning imaging systems, this is when the geometric center of the Moon is captured.

"Effective time" shall be specified to a resolution and accuracy to support geometry calculations, i.e., to an accuracy of 0.01 degrees or better; see next paragraph.

Effective time should be specified in ISO-6801 in UTC. Any other time system used must include a well-defined relation to UTC. Discontinuous time systems such as "UNIX" time (computer time) shall not be used.

A representative value for the uncertainty in 'effective time' for the instrument should be stated.

Observations are "near-simultaneous" if acquired in a time span during which the photometric angles change by no more than 0.01 degrees. This is about 10 seconds for LEO, 20 sec for GEO, and 150 sec for surface observatories.

If the range of effective times for all bands of an instrument exceeds this time span, bands should be grouped into subsets that satisfy this time span, and each subset treated as a separate observation.

"Sensing duration" is the time required to measure the radiance across the lunar geometric disk for one band, or to integrate the irradiance.

A representative value of 'Sensing duration' for the instrument, or for each band, should be stated.

The instrument location at the 'effective time' shall be given as Cartesian coordinates in km in the ICRF or J2000 Reference Frame centered on the Earth center-of-mass (as used in the JPL ephemeris) or some other ECI system different by less than 0.4 km (1 ppm of lunar distance).

A representative value of uncertainty in location for the instrument (offset distance) should be stated.
Alternate. If the instrument is in a fixed geographic location. That single location should be specified in WGS-80 (or later) coordinates; Degrees East, degrees North, elevation above the geoid in meters.

The above data should be contained in a 'time and view-point' file, Table 4

3.3 Measured irradiance

The MEASURED lunar spectral irradiance for each band for each observations shall be submitted in SI units. Note: micro-Watts m^{-2} nm^{-1} is convenient as values are on the order of 1.

Uncertainty of each measurement shall be supplied in the same units.

These data should be contained in an 'irradiance' file, Table 5

A major question is if Tables 4 and 5 should be combined.

4 Naming and formats

In order for data to flow smoothly through the L6 modules, some consistency in file naming is required.

NOTE: All *file* naming conventions are TBD, pending review and consensus by the GSICS community. Those here are based on the practicality of working with many instruments. This section must be replaced by the final agreements.

For DataGroups that cover the same set of observations, the order of observations and the order of bands shall be the same in all DataGroups.

Attribute and variable names shall conform to the specifications of Tables 3 to 9.

Every variable shall have associated with it:
long_name: describing the variable
fill_value: identifying values which are invalid or not specified
Every numerical variable shall have associated with it:
units: relating the values to SI units. Standard powers-of-1000 multipliers, such as milli, m or nano, n are

allowed.

———-

The first part of a 'Team Package' file names shall identify the instrument and should have a (brief) section that provides uniqueness for multiple submissions for an instrument. Here, this part of the name is called the "stem"

The last part of L6 file names before the extension (.nc), called the "file-type", shall be consistent for each file-type and should correspond in a recognizable way to the DataGroup name. It is suggested that an underscore preceed the file-type.

The 'stem' for all output files shall correspond to the Team Package stem.

A fill value of -999 is adequate for most numeric or character variables. An exception is 'satpos', requiring a magnitude of at least 50,000 for GEO. However, lunar calibration has been done from Mars, so the magnitude should be at least 4.1e8 km.

5 Modules

All modules reading files from Teams should initially check that the file contents and formats are proper for the L6 system.

5.1 Input Spectral

Notes:

1. It may be possible to define a lunar spectral irradiance system that uses only the band RSR's as submitted by the Teams, not requiring spectral resampling or the concept of 'effective wavelength'. In such a case, most of this section is not needed.
2. At a minimum, this module needs only to read the instrument RSR's. Because RSR's are commonly constant over the life of an instrument, processing of these data in preparation for the Spectral Irradiance Module (§5.5) is described here and need be done only once for an instrument. However, RSR processing could be moved to the Spectral Irradiance Module.

This module accesses the W DataGroup (Table 6) and resamples the instrument RSR's for each band onto a "Standard Wavelength Set (SWS) " This process should be rigorous-weight-preserving, ensuring that the fraction of the RSR assigned to each individual SWS point domain, defined as the wavelength region between the adjacent midpoints between SWS points, is the same in the input and output.

The output is two arrays as specified in Table 6.
1) 'resampled wavelength', representing each band on the SWS points.
2) 'effective wavelength', computing for each band at least':
The effectivewavelength for the reference spectra
The mean in-band spectral irradiance.

Note: The reference solar spectral irradiance and the reference lunar spectral reflectance both need to be resampled by the same algorithm onto the SWS points.

The effective wavelength for lunar light is defined by the reference solar spectral irradiance $S_0(\lambda)$, the reference lunar disk spectral reflectance $R_0(\lambda)$ (currently based on laboratory measurements of returned Apollo samples) and system-level relative spectral response for band j, $T_j(\lambda)$

$$\lambda_{e_j} = \frac{\int_{\lambda_1}^{\lambda_2} \lambda \cdot S_0(\lambda) R_0(\lambda) T_j(\lambda) d\lambda}{\int_{\lambda_1}^{\lambda_2} S_0(\lambda) R_0(\lambda) T_j(\lambda) d\lambda} \quad (1)$$

Once all spectra are resampled as specified above, this integral is easily computed as

$$\lambda_{e_j} = \frac{\sum_{l=1}^{L} \lambda_l \cdot S_{0_l} R_{0_l} T_{jl} \Delta\lambda_l}{\sum_{l=1}^{L} S_{0_l} R_{0_l} T_{jl} \Delta\lambda_l}$$

where l are the points of the SWS.

Similarly, the mean in-band spectral irradiance is:

$$Ee_j = \frac{\sum_{l=1}^{L} S_{0_l} R_{0_l} \cdot T_{jl}\Delta\lambda_l}{\sum_{l=1}^{L} \qquad T_{jl}\Delta\lambda_l} \tag{2}$$

5.2 Geometry

This module accesses the Table 4 and the JPL planetary ephemeris for locations of the Sun, Earth and Moon. This module computes for each observation the values in Table 1 at a minimum. For observations from the Earth surface or atmosphere, it may be useful to also compute the zenith angle of the Moon.

For notational convenience the set of angles produced for observation i at time t_i is called P_i.

These data should be output in the Geometry DataGroup, Table 7.

Table 1: Required photometric geometry. The first five angles constitute the Lunar Observation Angle Set (LOAS).

signed phase angle
sub-solar selenographic longitude
sub-solar selenographic latitude
sub-observer (-viewer) selenographic longitude
sub-observer selenographic latitude
Distance between the centers of the Sun and Moon
Distance between the center of the Moon and the viewer,
—— If the lunar model supports polarization ———
Lunar disk bright limb angle, †
Lunar north-pole position axis, †
† measured counterclockwise from celestial North

5.3 Moon Module

This module produces lunar disk-equivalent reflectance (DER) spectra for angles P at each observation time in the P DataGroup.

The wavelength interface between each instrument band for any version of this module and the rest of the L6 system shall be points on the SWS and, optionally, effective wavelengths.

Internal to this module, the representation of wavelength is not constrained. Here, it is called 'wave' and simply represented by 'w'. Several possibilities are listed in Table 2.

$$\mathcal{R}(t,\lambda) \;=\; R_0(\lambda_j) \quad \overbrace{\mathbf{M_{ij}}}^{\text{Lunar Model}} \quad \Longrightarrow \mathbf{R_{ij}} \equiv \mathrm{DER}_{ij} \tag{3}$$

where the subscript j is within the SWS and covers at least the range spanned by all of the instrument bands.

Table 2: Possible wavelength sets

ID	typical M	Description
w1	6:32	At the effective wavelength of each of the lunar model bands.
w2	1:220	At the effective wavelengths of each instrument band in Table 3
w3	∼1500	At the ensemble of SWS wavelengths used by the instrument.
w4	2114	At all of the SWS wavelengths. The number is as used in Ref. 1
w5	∼10000	At the ensemble of all team RSR points in Table 3.
		Largest thus far is 65091

This module will access the data of the P and W DataGroups.

This module should access a 'model definition' file of parameters that define the disk reflectance model. Contents are not specified beyond the 'Standard set' in Table 3, plus a name for the lunar model. However, the model definition file should be structured so that modest revisions can be accomodated without changes to the module code.

The DER spectra shall be output as 'disk reflectance' in DataGroup D.

5.4 Solar Module

This module is optional; it handles variation of the solar spectral irradiance by computing a time and wavelength-dependent multiplier of the reference solar spectral irradiance. It may be replaced by the reference solar spectrum.

The Solar Module typically will access the following reference information:

Reference solar spectrum $S_0(\lambda)$, mean solar spectral irradiance [W m^{-2} nm^{-1}]

Total solar irradiance (TSI) over time $H(t)$, [W m^{-2}], Time resolution of 5 days or smaller.

wavelength sensitivity to TSI variation $f(\lambda)$, factor for solar spectral relative variation to TSI.

This module produces the solar spectral irradiance for each instrument time at the same wavelength set of Table 2 as used for DER.

These data should be output in the DataGroup of Table 8.

Below is an example implimentation based on Ref. 1.

As the TSI varies, the variation of spectral irradiance increases toward shorter wavelengths, represented here by a quadratic fit in log/log space over 290:2412 nm to the ratio f of solar spectral irradiance variation (high-pass filtered) to TSI variation; see Ref_1 §2.3 .

$$f(\lambda) = \exp(-0.338752 - 0.785894 \ln \lambda + 0.202152 \ln^2 \lambda) \tag{4}$$

where λ is in micrometers.

The other required inputs are:
  Time of each observation (in days from 2000 Jan 01 00:00
  Effective wavelength of each band

Solar variation can be computed as

$$S_\odot(t,\lambda) = S_0(\lambda) \left[1 + \underbrace{f(\lambda)\left(\frac{H(t)}{H_0} - 1\right)}_{\mathcal{H}} \right] \implies S_{\odot ij} \tag{5}$$

where $S_\odot(t,\lambda)$ is the solar spectral irradiance and $H(t)$ the total solar irradiance; with subscript 0 being the long-term average. $\mathcal{H}(t,\lambda)$ is the solar variation model. It is applied to the time-independent model irradiances.

5.5 Spectral Irradiance Module

This module produces lunar spectral irradiances at standard distances corresponding to the input observation times and locations, for the instrument spectral bands.

$$E_{\oslash}(\lambda,t) = \overbrace{S_\odot(\lambda,t)}^{\text{Solar Module}} \; \frac{\Omega}{\pi} \; \overbrace{\mathcal{R}(\lambda,t)}^{\text{Lunar Module}} \qquad \text{OR} \qquad S_{\odot ij}\frac{\Omega}{\pi}\mathcal{R}_{ij} \Longrightarrow \mathcal{E}_{ij} \tag{6}$$

Here $S_\odot(\lambda,t)$ is the solar spectral irradiance at 1 Astronomical Unit (au); this may be treated as constant or variable. Ω is the solid angle of the Moon, illuminated or not, at standard distance: 6.41780e-5 steradian.

Depending upon which choice was made in Table 2, some interpolation of $\mathcal{R}_{ij}$ may be required.

The lunar spectral irradiance forecast for an observation is $\mathcal{F}_{ij} = \mathcal{E}_{ij}/D_i$ where $D = d^2U^2$ is the 'distance factor' and d is the distance from the Moon (center) to the viewer ratioed to a standard distance of 384,400 km, near the mean Earth:Moon separation; and U is the Sun:Moon distance in au (1.4959787e8 km).

The calibration ratio is simply the measured spectral irradiance divided by the forecast: $\mathcal{C}_{ij} = E_{obs_{ij}}/\mathcal{F}_{ij}$

A Files

A.1 Abbreviations in the file tables

AC alphanumeric character

C column: Category:
- **e**: essential. Required: for model to run
- **c**: compulsory. Required: for complete identification
- **o**: optional. May be included
- **w**: which. Only if needed to distinguish between similar entities

TYPE column: Word type: Arrays are followed by an indication of dimensionality.
- S: string
- I: integer, generic. I1 is byte, I2 is 16-bit, I4 is 32-bit
- R: real, generic. R1 is 32-bit (single precision), R2 is 64-bit (double precision)

B File and DataGroup definition tables

Table 3: Instrument team, band spectral file contents. **M** is the number of bands, **N** is the number of dates. Leading brackets in the description column contain name used in GIRO, if different than here.

NAME	C	TYPE	———— Attributes ———— Spectral data; DataGroup B
title	c	S	Brief name for what is in this file.
summary	c	S	Summary of file, identifying major contents.
institution	c	S	Name of organization generating this file.
insti_url	o	S	url of the institution.
license	o	S	Any legal limits or disclaimers.
platform	e	S	Name of spacecraft or observatory.
instrument	e	S	Name of instrument. Should not repeat 'platform'.
serial	w	S	Serial number within virtually identical instruments. May be null. See note
acronym	e	S	Short word for platform+instrument. Registered with GSICS to ensure unique.
data_source	c	S	Source of the data, and any version number or date. Comments allowed.
history	c	S	Formatted processing history: [separator], date, software and version, email, source ... See note
id	c	S	File names(s) that institution would normally associate with these data. Commonly ridgedly formatted and long.
model_sys	c	S	Lunar spectral irradiance system being used. E.g., 'ROLO'
reference	o	S	List of materials describing the instrument, observations or processing.
oversamp_stat	c	S	Status of over-sample factor. Valid values are: 'none, 'team', 'calib'. See note
- - -	-	-	- - - End of standard ID set - - - - See note.
num_band	e	I	[chan] Number of bands (or channels) in the VIS/NIR.
——	–	—-	———— Variables ————
band_id	c	S(M)	[channel_name] Name normally associated with the band, each unique. No more than 6 AC
nom_wav	e	I2(M)	[effective_wavelength] Nominal wavelength in nm, each unique.
ifov	o	R1(M)	Spatial resolution at nadir. (M,2) if not close to square.
rsr	e	R1(x,2)	[srf] System-level Relative Spectral Response, bands concatenated. [*,0] is Wavelength or wavenumber, [*,1] is the System-level relative spectral response. See note
nin_band	e	I2(M)	Number of points in each band in 'rsr'.
polar_sens	e	R1(M,2)	If polarized. [*,0] is the fractional polarization sensitivity. [*,1] is the angle of maximum sensitivity, degrees; right-hand around +Z="nadir" from +X="spacecraft forward velocity".

Table 4: Instrument team Lunar Observation file contents, Viewer Time and location

NAME	C	TYPE	———— Attributes ———— Viewer Geometry: DataGroup V
ditto	“	“	The standard set listed in Table 3. 'oversamp_stat' is controlling.
date_type	e	S	Normally 'UTC'. May be double precision of an approved numeric time system.
num_date	e	I2	[date] Number of observation times.
launch	c	S	Launch date, UTC.
sat_pos_ref	c	S	Reference coordinate system for Viewer location (satellite_position). E.g., 'J2000' or 'ITRF'
——	–	—-	———— Variables —————
date	e	S or R2(N)	Observation time of center of the Moons disk, UTC ISO-8601 or double. See note.
sat_pos	e	R1(N,3)	Viewer location (satellite_position). XYZ of Earth-Centered Inertial position. Required unless 'tele_loc' supplied.
tele_loc	e	R1(3)	Telescope location as Longitude E, latitude, elevation. Only if observatory.
obs_qual	m	R1(N)	Relative uncertainty of the irradiance determination of each observation. Median value of 1.
conditions	o	R1(N,C)	Optional. Any number of columns of condition at each observation time.
orientation	e	R1(N,3)	[Only if polarized] Orientation of the instrument relative to the J2000 Reference Frame; 3 angles or a quaternion.

Table 5: Instrument team Lunar Observation file contents, Irradiance

NAME	C	TYPE	———— Attributes ———— Irradiance: DataGroup I
ditto	“	“	The standard set listed in Table 3
——	–	—-	————Variables —————
band_id	c	S(M)	[channel_name] Duplicate of that in W file for insurance.
irr_obs	e	R1(N,M)	Measured lunar spectral irradiance. Units: micro-Watt m^{-2} nm^{-1}. See note
obs_unc	e	R1(N,M)	One-sigma uncertainty of the measurement, same units. Independent of 'obs_qual'.
oversamp_fa	o	R1[N]	Optional. Oversample-factor. Use depends upon 'oversamp_stat'.
modes	w	S[k]	Optional, Names of different modes.
nummod	we	I1[k]	If 'modes' present. Number of observations in each mode, aligned with 'modes'.

Table 6: Lunar Calibration output wavelemgths. 'dup4conv' means: duplicate of an earlier file, for convenience.

NAME	C	TYPE	———— Attributes —————- L6 wavelength: DataGroup W
ditto	“	“	The standard set listed in Table 3.
num_band	e	I	[chan] Number of bands (or channels) in the VIS/NIR.
——	–	—-	———— Variables —————
wavelength_set	c	R1(few)	Parameters that define the Framework Wavelength Set.
band_id	c	S(M)	Name normally associated with the band. dup4conv
rsr_grid	e	R1(x)	Relative Spectral Response, bands concatenated, on the FWS points.
rsr_index	e	I2(M,2)	Indices for 'rsr_grid for each band. 0] is FWS first point, 1] is the number of points.
eff_wave	e	R1(M,x)	Effective wavelength array [band,item]. Each item described.

Table 7: Lunar Calibration photometric geometry files contents. 'dup4conv' means: duplicate of an earlier file, for convenience.

NAME	C	TYPE	———— Attributes —————- Photometric Geometry: DataGroup P
ditto	"	"	The standard set listed in Table 3
num_date	e	I2	[date] Number of observation times. dup4conv
——	–	—-	———— Variables —————
etsec	e	R2(N)	Observation time of center of the Moon's disk, ephemeris time in seconds. See note.
pgeom	e	R1(N,11)	Photometric geometry, distances and celestial angles.
twist	e	R1(N)	[If polarized] Twist of the instrument X-axis relative to the Sun-from-Moon vector (degenerate at zero phase), measured anticlockwise around the disk from the north point of the hour circle through the center of the Moon, degrees.

Table 8: Lunar Calibration intermediate file contents. Moon and Sun

NAME	C	TYPE	———— Attributes —————- Disk-equivalent-reflectance: DataGroup D
ditto	"	"	The standard set listed in Table 3
TSI_name	c	S	Name (and date) of the total solar irradiance model used.
spec_sens	c	S	Name (and date) of the relation used for solar spectral sensitivity.
lunarModel	c	S	Name of the lunar model used.
——	–	—-	————Variables —————
DER	e	R1(N,M)	Disk Equivalent Reflectance for each observation and each band.
sun_spec_irr	o	R1(N,M)	Solar spectral irradiance for each observation and each band.

Table 9: Lunar Calibration output file: Model irradiance [and calibration] contents. 'dup4conv' means: duplicate from an earlier DataGroup, for convenience.

NAME	C	TYPE	———— Attributes —————- Model and Calibration: DataGroup M
ditto	"	"	The standard set listed in Table 3
reference_model	e	S	Name of the reference model and its version .
num_date	e	I2	[date] Number of observation times.
num_band	e	I	[chan] Number of bands (or channels) in the VIS/NIR.
——	–	—-	———— Variables —————
band_id	c	S(M)	Name normally associated with the band. dup4conv
eff_wave	e	R1(M,8)	Effective wavelength array [band,item]. dup4conv
utcd	e	R1(N)	Observation time, center of the Moon's disk, as days from 2000 Jan 01 00:00 UTC
irr_mod	e	R1(N,M)	Model spectral irradiance; micro-Watt m^{-2} nm^{-1}. If polarized, this is the maximum .
irr_pol	e	R1(N,M,2)	[If polarized] 0] is the orientation of the maximum irradiance, measured anticlockwise from the Sun-from-Moon vector (degenerate at zero phase), degrees. 1] is fractional polarization.
calib_ratio	e	R1(N,M)	Calibration ratio: Observed / model irradiance [date,band]. Invalid if no instrument irradiance data.
modes	w	S[k]	Optional, Names of different modes. See note. dup4conv
nin_mode	w	I1[k]	Number of observations in each mode, aligned with 'modes'. dup4conv

C File Table Notes

The following attributes shall agree between DataGroups: 'platform', 'instrument', 'acronym' and 'serial'.

date Lunar observations are commonly initially labeled in UTC, preferably in ISO 8601 format and this time is stored in the _tv files. The GIRO standard for date has been seconds after 1970 Jan 1 00:00, Terrestrial Time, here labeled T7S. In the photometric geometry file, _pg, time is stored as Ephemeris Time in seconds. Time used for display and trends is commonly days from 2000 Jan 01 00:00

history Human-readable history of processing, with at least the first 4 below set of 4+ items in order appended for each process. The item identifiers within brackets below should be included.

1) Entry separator, " [=> ". Omitted before the first entry.
2) Date of running the process as yyyymonddThh:mm
3) [pro~] Process name + '_' + version date as yyyymondd
4) [mail~] Institutional email address of the person who is responsible for this processing. May include additional contact information
5) [src~] Name of [last] primary input file or other source of data.
6) [url~] Optional: URL of a document describing this process.
7) [note~] Optional: Notes: any additional description or comments.

Example: [=> 2023Jun06T03:09 pro slim2pg'2023jun05 mail HHKieffer@gmail.com src /work2/slimnet/S/OLI_tv.nc . This growing attribute replaces 6 GIRO individual fields: 'date_created', 'date_modified', 'creator_name', 'creator_email, 'creator_url, and 'history', which could loose the record of prior processing.

'history' should be restarted whenever the Team inputs change.

irr_obs For lunar spectral irradiance, the system should use micro-Watt m^{-2} nm^{-1}, as do ROLO and SLIM; values are on the order of 1.
Values expressed in GIRO units of W m^{-2} μm^{-1} are smaller by a factor of 1000.

modes To accommodate different operational modes. E.g., different gains, space-port versus nadir port, GEO scan mode, ...

oversamp_fa, oversamp_stat Determination of any oversample-factor ('oversamp_fa', OSF) is done by the instrument team. It is commonly the same for all bands, but may be 2-D:[N,M]. 'oversamp_stat' (OSS) records the OSF status: 'none' if there is none. If OSF is applied before reporting 'irr_obs', then OSS should be 'team'; else it should be 'calib' and the OSF will be applied in the calibration stage. The value 'Yang' may occur for historic observations accompanied by the along-scan apparent size of the Moon; these are converted to oversampling factor in the geometry module.

sat_pos If tele_loc absent, shall have N points of Cartesian Earth-Centered Inertial position as specified in §3.2. If tele_loc supplied, these cartesian positions are optional.

serial Instrument serial number. If not null, shall be inserted in file names for identification.

rsr Concatenation of wavelength and system-level Relative Spectral Response within each band. Bands shall be in the same order as in 'band_id' and 'nom_wav'.

tele_loc Ground-fixed instrument location in WGS-84: degrees E (longitude) and N (latitude), and altitude in meters. Required if 'sat_pos' not supplied. If 'sat_pos' is also present, user can choose which to use.