THE COMMUNITY SENSOR MODEL STANDARD FOR THE PLANETARY DOMAIN.

Trent M. Hare and Randolph L. Kirk, U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ, 86001, (thare@usgs.gov).

Introduction: The U.S. Geological Survey's Astrogeology Science Center (ASC) is a major contributor of software for data processing for NASA missions and research programs. We develop and support the Integrated Software for Imagers and Spectrometers version 3 (ISIS, [1]), a specialized image processing package used to ingest, calibrate, and geospatially control planetary images. The heart of any digital photogrammetric system, including ISIS, is the software used to spatially locate camera data accurately to the ground, known as a camera or sensor model.

Here we present ongoing work ASC is undertaking to better support software interoperability between different photogrammetric applications (including ISIS) by testing and implementing the Community Sensor Model (CSM) standard.

Background: A camera sensor model can be defined as a mathematical description of the relationship between the three-dimensional object (e.g. target's surface) and the associated two-dimensional image plane. As described in [2], the quantities needed to define a sensor model can be divided in two broad categories: interior and exterior. The interior parameters are intrinsic to the sensor design and calibration and typically include focal length, location of the principal point, and lens distortions. For more complicated instruments, the interior parameters may also include wavelength dependencies, gain and pixel summing settings, and (for pushbroom sensors) the timing of line exposures and time delay integration (TDI) settings. The exterior parameters describe the location and orientation of the sensor with respect to the target's reference coordinate system. For planetary applications, this information is typically stored in the form of SPICE (Spacecraft, Planetary ephemeris, Instrument, C-Matrix, and Event) kernels and delivered by the Navigation and Ancillary Information Facility (NAIF, [3]).

Accurate camera models are required for precision georeferencing of image data by geodetic control (bringing images into alignment with one another and with previously determined ground coordinates) and orthorectification (removal of parallax distortions due to topography). In turn these controlled orthoimages are critical for a wide variety of geospatial applications, starting with the production of controlled image mosaics (foundational for many other uses), and leading to the ability to combine and compare different image sets with subpixel precision to produce, for example, digital elevation models from stereo imagery, change detection, and spectral maps. These capabilities are essential for landing site selection and certification, geologic mapping, and rover traverse planning, and facilitate the full range of planetary geoscience research [4]. Currently, the ISIS system provides over fifty camera models supporting NASA and several international agencies (e.g., ESA, JAXA, and ISRO) [1].

The CSM Standard: The Community Sensor Model (CSM) Working Group was established by the U.S. defense and intelligence community with the goal of standardizing camera models for various remote sensor types [5]. The CSM standard, now at version 3.0.2, provides a well-defined application program interface (API) for multiple types of sensors and has been widely adopted by Earth remote sensing software systems. For example, new sensor models using this API will function in a variety of photogrammetric applications such as BAE Systems® Socet GXP photogrammetric suite. Socet GXP is the successor to BAE's Socet Set which has been used in the planetary community for many years and has been critical for mission planning [6]. We are also working toward the incorporation of the CSM standard in near-future versions of ISIS.

As presently defined, the API is tied to a specific Earth coordinate system, making it difficult to use for other bodies. This limitation is being addressed by ASC with help from the CSM working group. Later in 2017, it is planned that version 3.0.3 of the CSM standard will support non-Earth bodies (Figure 1). In technical terms, this is a trivial modification of the standard, but it was recognized as critical to allow ASC to eventually promote its use across planetary NASA missions.

Perceived Benefits: This proposal for using the CSM standard for planetary data sets should provide several benefits for NASA including the following:

- Sensor model infrastructure.
    - Improving flexibility in defining models for future instruments.
    - Decoupling of the target body shape model and map projections.
    - Reducing memory usage.
- A standardized sensor model for the planetary community.
    - Simplifying the addition of new sensor models to ISIS and other software systems for the planetary community.
    - Allowing applications outside of ISIS to easily use the same sensor models, thus leveraging Earth remote sensing capabilities for planetary use.
    - Providing common functionality for all sensor types.
    - Providing a standard template for sensor model definition, ensuring that flight teams deliver a complete description of their instrument's internal geometry and calibration.

It is worth noting that the CSM API does not make the creation of a camera sensor model technically any easier besides serving as a solid framework for others, but once written, it more easily allows interoperability between different photogrammetric applications. And the API has been designed and continuously tested by industry experts and thus the planetary domain will benefit from this more than decade-long effort by the CSM Working Group.

*Progress***:** As stated above, ASC has been working with the CSM Working Group for the past year to implement updates to more easily allow non-Earth targets. We are currently testing the Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) and Lunar Reconnaissance Orbiter Camera (LROC) converted-CSM pushbroom camera model [6] within the BAE Systems® Socet GXP photogrammetric suite. Once we convert the existing pushbroom CSM camera model from version 2 to the latest CSM version 3 standard, we will release the libraries to the planetary community for use in Socet GXP (expected release - fall of 2017). Those who wish to be early testers for Socet GXP can contact Trent Hare (thare@usgs.gov).

This year we have also begun to educate the ISIS programming team on the CSM standard and have already begun testing the API. Currently the team is implementing a MESSENGER Mercury Dual Imaging System (MDIS) CSM framing camera model. We will report on the outcome of our testing as well as provide any documentation and source code that is generated from this exercise. Progress on these activities can be followed by visiting the Astrogeology's GitHub site (http://bit.ly/CSM_wiki). The CSM provides a thorough, provident and modular API design that will be integral part of the ongoing modernization of the ISIS3 software infrastructure.

Conclusion: The CSM standard is the first step in realizing a camera model standard that can be used and shared across NASA's and international planetary missions. This should more easily allow future instrument teams to provide not only cutting edge cameras and sensors but also provide software needed to process the data in a variety of non-mission-specific production environments. Planetary multi-mission packages like ISIS will continue to be necessary for providing capabilities like photometric and bundle-adjustment methods but the CSM standard will make it increasingly easy to exploit other photogrammetric tools as needed for scientific applications like stereo-processing and real-time landing site analysis and in-situ applications.

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References: [1] Sides, S., et al. (2017), *this volume*. [2] National Geospatial-Intelligence Agency, (2011), Frame Sensor Model Metadata Profile Supporting Precise Geopositioning, NGA.SIG.0002_2.1. [3] Acton, C.H. (1996), Ancillary Data Services of NASA's Navigation and Ancillary Information Facility, Planetary and Space Science, Vol. 44, No. 1, 65-70. [4] Archinal, B., et al. (2017) *this volume*. [5] Community Sensor Model Working Group, (2010), Community Sensor Model Technical Requirements Document, v. 3.0, NGA.STND.0017_3. [6] Kirk, R. L., et al. (2008), Ultrahigh resolution topographic mapping of Mars with MRO HiRISE stereo images: Meter-scale slopes of candidate Phoenix landing sites, J. Geophys. Res., 113, E00A24, doi:10.1029/2007JE003000.

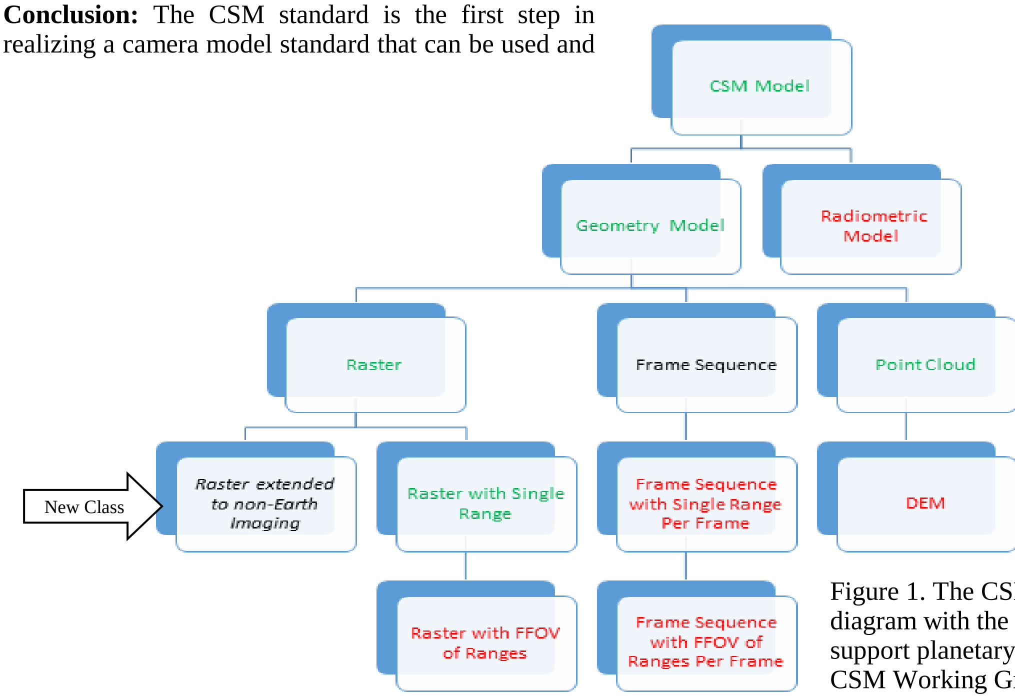

Figure 1. The CSM API hierarchy diagram with the proposed class to support planetary use. Image credit: CSM Working Group.