**THE USGS-NASA PLANETARY GEOLOGIC MAPPING PROGRAM: STATUS, PROCESS, AND FUTURE PLANS.** J.A. Skinner, Jr., C.M. Fortezzo, T.A. Gaither, T.M. Hare, A.E. Huff, and M.A. Hunter, U. S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Drive, Flagstaff, AZ, 86001 (jskinner@usgs.gov).

**Introduction:** Geologic maps are recognized as a framework data product [1] that comprehensively and objectively depict three-dimensional views of rock and sediment bodies as well as geomorphologic and tectonic features that occur at or near the surface of a planetary body [2]. In contrast to terrestrial geologic maps, planetary geologic maps are fundamental research products that typically result from interrogating remote-based orbital datasets and help establish and refine geologic context in parallel with other planetary geoscience disciplines [3]. These maps integrate various investigative results and guide not only future fundamental research but also programmatic decisions such as landing site selection, traverse planning, and data targeting. The USGS and NASA have a >50-year partnership in helping planetary scientists publish geologic maps. However, USGS is also tasked with supporting the broader science community by providing geologic mapping expertise, procedures, and tools to prepare geologic maps, whether published by USGS or not. This includes, but is not limited to, the development and implementation of widely-recognized cartographic standards and guidelines. Here, we summarize the status of NASA-funded USGS geologic map production as well as updates and future plans for the USGS-NASA Planetary Geologic Mapping Program. This is an effort to provide transparency to the process and products so that geologic maps, whether published by USGS or other, can be compiled in a manner that is predictable and cross-compatible.

**Status:** Since 1962, the USGS has published 242 geologic maps of non-terrestrial planetary bodies in the Solar System. These maps cover Mars (n=106), the Moon (75), Venus (34), Ganymede (11), Mercury (9), Io (6), and Callisto (1). Map scales range from very local (1:25K) to global (1:25M). A large number were published as part of a quadrangle-based mapping campaign, especially for the Moon and Mars. As of this writing, the USGS currently lists 45 NASA-funded geologic maps as "In Progress" (including maps for Mercury, Vesta, Triton, Europa, and Enceladus), 6 maps as "In Technical Review", and 1 map as "In Production". In addition to these projects (which focus on creating new maps), the USGS is actively converting all hard-copy, USGS-published planetary geologic maps into GIS format for easier distribution and use. To date, we have converted 56 geologic maps, resulting in a total of 69 maps that are available in GIS format. As of 2012, all USGS-published planetary geologic maps are required to be submitted, reviewed, and published as GIS products (in addition to large-format hard-copy prints).

Investigations with a resultant USGS-published geologic maps are funded from a variety of NASA R&A programs. Typically, body-specific maps are funded through DAPs, where applicable and where guided by a specific hypothesis-driven scientific investigation. NASA SSW feasibly supports geologic maps resulting from comparative planetary studies (and Venus, due to lack of specific DAP). NASA PDART supports geologic map-based investigations, particularly in cases where the geologic context has been established through a preceding investigation (*e.g.*, where a geologic map bridges unmapped regions). In all cases, proposals must thoroughly demonstrate that intended geologic maps are worthwhile community products, especially in instances where areas are being remapped with new data at similar and (or) different scales. Proposers should contact the NASA program office for information regarding relevance of a particular proposal. At this time, USGS cannot support maps that result from projects funded outside of NASA.

**Process:** For NASA-funded investigations that aim to publish a USGS SIM series geologic map, the USGS actively cooperates with and guides geologic mappers from the proposal stage through production. The overarching intent for this close relationship is to help ensure that a project is not only properly-scoped but also prepared in a standard format, is thoroughly reviewed both scientifically and technically, and that review recommendations are appropriately integrated. USGS is annually funded 1.5 FTE (spread across geologists, GIS and data experts, and web developers) to support the entire geologic mapping program and estimates costs based on the number of projects in various stages of completion, as well as community support tasks (*e.g.*, map digitization, standards review, tool development, process guidelines, etc.). Previous experience demonstrates that each map requires ~2 months of direct, project-specific "contact time" between map author and USGS over the life of the project, though this varies significantly per mapping project based on project scope, body of interest, available data, and author experience. An idealized timeline for a USGS geologic map (assuming 3-year funding cycle) is 2 years for map preparation, 6 months for initial review, and 6 months for re-review and acceptance. Once a map is accepted by USGS for publication, the author's role is effectively completed (aside from minimal input regarding layout, proof, scales, etc.). USGS is tracking timelines per map in order to better predict costs and guide project scope. Currently, actual timelines are longer than ideal for almost all mapping projects, perhaps due to modern expectations that geologic mappers are expected be geologists and spatial data experts.

To help direct mapping projects, clarify responsibilities, and ultimately shorten mapping and production timelines, USGS has developed the 2018 version of the Planetary Geologic Mapping Protocol (PGMP, previously the Planetary Geologic Mapping Handbook). The PGMP delineates roles and expectations of participants in the process, the mapping process itself (including criteria for acceptance or rejection for USGS publication), and map package components. These include detailed explanations of author submission as well as technical reviewer guidelines. We specifically note that the PGMP includes Sunset Dates (which limit the length of USGS support) as well as acceptance and rejection criteria. These are not necessarily new requirements, but rather much more explicit description of the roles and responsibilities of process participants. Authors are expected to adhere to the most current PGMP, which will be updated and posted periodically. Aspects related to planetary geologic mapping as a scientific discipline are intentionally deemphasized in the PGMP. As such, reading and citing the PGMP does not constitute mapping proficiency.

**Future Plans:** As a key scientific and technical partner for planetary geologic mapping, the USGS, with input from various community organizations, continuously researches ways to not only improve processes and products but also to ensure that they are modern, reliable, and easily accessible. These efforts aim to maximize the community investment made by funding programs. To this end, and in cooperation with long-term strategic planning by the Mapping and Planetary Spatial Infrastructure Team (MAPSIT) advisory group, the USGS conducted an anonymous, self-selected survey of the planetary science community consisting of 30 questions regarding the preparation and use of planetary geologic maps. This survey was released in March 2017 and was advertised at LPSC and through social media. We obtained 265 total responses (plus additional comments). We are in the process of compiling the survey results, implications, and action items into a white paper for release to the community. Selected responses are listed below.

Respondents identified as "middle" or "early" career professional (56%) working at "university/college" or "federal" institutions (75%) who received funding through "NASA programs" (72%). Respondents indicated that their research *creates* some form of geologic maps "often" or "occasionally" (77%) and that their research uses some form of geologic map "often" (62%). Respondents identified the following geoscience map publication venues as "very important" to their work: "USGS-published maps" (62%) and "peer-reviewed journal maps" (57%). "Control to standard coordinate system" (71%), "objectivity of map unit descriptions" (67%), and "consistent use of preparatory methods" (47%) were the highest selections when asked what geoscience map elements are "very important" to their work. "GIS (vector) format" geologic maps were indicated as a "very important" map format (69%). Respondents indicated that "standardized" (USGS-published) maps were "easy" to locate, access, and use (45%) compared to "non-standardized" (peer-reviewed journal) maps (8%), and "strongly agreed" (77%) that accessing geoscience maps in a single location would be useful. Regarding map scales, respondents indicated that "local" and "local to regional" scale maps are "very relevant". Respondents "strongly agree" (58%) or "somewhat agree" (31%) that targeted mapping campaigns would be useful to the community. When queried about unit, terrain, or feature types that are relevant to their work, respondents indicated that "volcanic", "impact-related", and "stratified" units were "very relevant".

**Conclusions:** Geologic maps are critical data products that assist with, and result from, science investigations. Recent efforts to highlight community needs are clearly instrumental to short- and long-term strategic plans. The community recognizes that standards facilitate the construction of geologic maps that have an expected and recognizable look and feel and promote consistent context, commentary, and use. The community also perceives that GIS formats are the single most valuable format for geoscience map use, though a single access point for locating both digital maps, both standardized and non-standardized, would be exceedingly beneficial. Based on recent survey results, it is clear that GIS formats are simultaneously the most valuable product and the most difficult to prepare. As USGS works toward long-term goals, we continue to provide online resources such as GIS tutorials (now including videos for common technical issues), custom tools, and documented best practices. USGS, as community partner in constructing planetary geologic maps, advocates for continued community investment in the process and product of mapping.

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**References:** [1] OMB Circular No. A-16, (2002). [2] Varnes, D.J. (1974) *USGS Prof. Paper* 837, 48 pp. [3] Skinner, J. A., Jr. (2017) *Plan. Vision 2050*, #8243.