VIPER SCIENCE OPERATIONS: LUNAR DYNAMIC SCIENCE TABLE AND 'TRACKER' TOOL. D.S.S. Lim[1], Z. Mirmalek[1], S. Kobs Nawotniak[2], A. Colaprete[1], D. Lees[1], and VIPER Science Team., [1]NASA Ames Research Center, Moffett Field, CA 94035 (Darlene.lim@nasa.gov), [2]Idaho State University, Pocatello, ID 83029.

Introduction: The NASA VIPER lunar rover mission [1] presents a unique operational paradigm within the history of robotic spaceflight. The proximity of the Moon to the Earth and the terrain elements (surface characteristics, light/shadow dynamics, communication links) of the Lunar South Polar landing site create unprecedented operational conditions between these two planetary bodies. Apollo era lunar science and exploration included humans *in situ* to operate instruments and assimilate observational inputs in real-time. Previous lunar orbital missions have worked to operational timescales, e.g., decisional timelines and communication exchanges, that were weeks in duration. Mars rover missions have worked to operational timescales, e.g., decisional timelines and communication exchanges between Mars and Earth, that were hours, days, and weeks in length. In the case of the VIPER mission, our operational decisioning for rover driving and instrument commanding will be compressed to minute-scale timeframes.

These operational conditions will directly impact the workflow and speed with which the VIPER Science Team (VST) will be required to synthesize and analyze data and produce timely science-driven decisions throughout surface mission operations [2]. The VST in the VIPER Mission Science Center (MSC) and the Mission Operations Center (MOC) shall provide mission-enhancing scientific input to guide traverse planning and drill site confirmation/selection throughout surface operations. Further, the VST input will be of vital importance to the mission's ability to maximize science return and to meet broader NASA objectives for future lunar ISRU and exploration activities. Specifically, the VST in the MSC and MOC will provide science-driven, consensus-based, timely input and decision-making to enhance mission operations and align mission science return with broader Agency goals. They will enable the characterization of the distribution (lateral and vertical extent, concentration, variability), form (chemical/physical state of these reservoirs of lunar water and key isotopes), and context (e.g., accessibility/overburden, environment, soil mechanics, trafficability, and temperatures) of lunar polar volatiles and water content for the VIPER mission. Additionally, the MSC will be selecting or reconfirming the location and path towards and from the third drill site (Drill Site Charlie) within each Science Station [6].

To enable scientific decision-making within the operational paradigm of the VIPER lunar rover mission requires detailed articulation of the VST's scientific objectives and goals, and the operationalization of these objectives and goals through their association with specific data products, tasks, and decisional procedures. Further, defining and tracking scientific success metrics throughout surface operations will enable the VST to have a quantified understanding of the mission's evolving ability to accomplish the stated scientific objectives and goals both during and after the mission. This abstract provides an overview of the methods and development activities towards defining, operationalizing, and tracking scientific objectives and goals throughout VIPER surface operations. Specifically, we focus on the VIPER Lunar Dynamic Science Table (LDST) and the VIPER "Tracker" tool.

VIPER LDST: The LDST is an applied Science Traceability Matrix: it is a dynamic/reactive document based on the accrual of data and exploration findings. Experimental mission activities [3,4,5] have explored these types of operationally active traceability processes for the following purposes:

- Articulation and organization of multi-disciplinary research goals,
- Articulation of relationships between these multi-disciplinary goals,
- Association of these research goals to strategic objectives (e.g., NASA goals, Decadal Surveys, etc.),
- Articulation and association of specific tasks required to meet these goals during surface operations (or equivalent – e.g. in the field),
- Complete specific tasks required to meet these goals while in the lab and during analytical periods,
- Adhere to specific requirements, such as those associated with contamination, replication, sampling distances, sampling conditions, etc., associated with meeting those goals, and
- Create further tools that enable tracking of success towards these goals both during tactical and strategic operations.

The VIPER LDST was developed to meet similar objectives for the VST to be responsive to the operational responsibilities and cadence of mission activities within the mission timeframe (100-days). Specifically, the VIPER LDST serves to create traceability between science objectives and data products to enable the data/progress-centered situational awareness (SA) needed to inform tactical decisions by the VST during lunar surface mission operations.

VIPER LDST development began in the summer of 2020 with a series of Project Science facilitated discussions with the VST. These meetings were organized starting with small working groups that included representation across four VIPER Science Theme Groups (Compositions, Environments, Geological Context, Modeling and Mapping), and gradually growing to all-hands style review sessions. A weighted scoring system to rank and sort the articulated goals based on their relationship to Strategic Knowledge Gaps, and other community and NASA goals was applied, providing a first cut at ordering the LDST objectives. Further organizational efforts were carried out by VST members to remove duplication, address overlap, improve articulation, and conduct manual organization and prioritization as needed. Once this effort was completed, the LDST moved into the next phase of development to enable dynamic updating and tracking of the LDST objectives in service of anticipated exploration conditions during surface operations on the Lunar South Pole (LSP).

Through work sessions with VIPER Science leadership, LDST custodians, and instrument science team members, as well as a review of relevant VIPER documentation, we identified the need for a 'Data Products Menu (DPM)' to be created. The purpose of a VIPER DPM would be to enable the VST to have a clear understanding of what data products would be available to accomplish the stated science objectives in the LDST, and to uncover if there are presently any missing data products needed to meet LDST objectives. The DPM provides colloquial descriptions of the following:

- Data type and instrument source(s),
- Coverage/view of a single data product,
- Locations or rover conditions associated with data collection,
- Timing of data availability,
- Processing pathway for the data product, and
- Instrument operational mode (if applicable).

The DPM is structured to provide tiered information access, telescoping from DPM categories that are associated with colloquial descriptions to technical instrument mode dictionaries. DPM development required the involvement of Instrument experts to populate the fields with adequate detail. The purpose of this structure is to enable:

- Ease of traceability across degrees of detail
- Entry-level through expert users to engage with available options,
- Links to developing Standard Operating Procedure (SOP) and Standard Analytical Method (SAM) details, and
- Links to other 'living' aspects of the current mission development activities.

VIPER "Tracker" tool: The VST mapped the data products captured in the DPM to each science objective in the LDST. In parallel, the VIPER "Tracker" tool was developed to tactically track progress towards the completion of science goals listed in the VIPER LDST. The Tracker is employed to actively capture progress made, via the confirmed acquisition of instrument data products, towards the completion of minimum and full success criteria for all objectives in the VIPER LDST. The tool was developed and coded within Excel to ease user training and application, and to facilitate its implementation in the secure network framework of the NASA Ames Multi-Mission Operations Center (MMOC) that houses both the MSC and the MOC. The "Tracker" is shared with MSC and MOC users via a closed-MMOC digital space (on-premise SharePoint server) that all participants can interactively and concurrently use during surface operations The data products being tracked are separate for each instrument by way of tabs. Each of the data products listed in the "Tracker" map to those listed in the DPM (which are associated with goals in the LDST).

Tracking is accomplished through real-time monitoring of the data products by the VST in the roles of instrument science leads in the MSC. VST instrument science leads are responsible for marking when the data necessary for a unit-measurement has been acquired by their instrument. For example, a unit-measurement would be 190 m of successful data collection in a specific ISR type (Prospecting) or the completion of 1 drill hole in a specific ISR type (Drilling). Instrument science leads are only responsible for their specific instrument tab but have view-access across all instrument tabs. All MSC and MOC personnel have view-access to the Tracker tabs and may use this tool for "live" situational awareness updates of the progress made towards mission science goals and the LDST goals. This information will be used by the VST in the MSC members as they make decisions on Drill Site Charlie and recommendations on where to prospect and image as the rover explores the Moon.

These LDST and Tracker are currently being honed through Science and Integrated Mission simulations that are on-going.

References: [1] A. Colaprete et al *In: LPSC 2023 pg.2910*, [2] Z. Mirmalek et al. *In: LPSC 2021 pg.1734*, [3] A.H. Stevens et al. (2019) *Astrobiology, 6, 269-286*, [4] Brady et al. (2019) *Astrobiology, 6, 347-368*, [5] Lim et al. (2019) *Astrobiology, 6, 245-259*. [6] D. Lim et al LPSC 2024