PROVIDING OBSERVATION CONTEXT VIA KERNEL VISUALIZATION AND INFORMATICS FOR PLANNING AND DATA ANALYSIS. John N. Kidd Jr.[1], Sanford Selznick[2], and Carl W. Hergenrother[3], [1]Ascending Node Technologies, LLC. 2548 E. 4th St. Tucson, AZ 85716, johnkiddjr@gmail.com, [2]Ascending Node Technologies, LLC. 2548 E. 4th St. Tucson, AZ 85716, sanford-psdi@selznick.com, [3]Ascending Node Technologies, LLC. 2548 E. 4th St. Tucson, AZ 85716, carlhergenrother@gmail.com.

Introduction: To fully understand the impact of planetary data, the lighting and viewing geometry of said data must be well known for planning and analysis. Typically this information can be gleaned from SPICE kernel files detailed by NASA's Navigation and Ancillary Information Facility (NAIF) [1]. The SPICE data system consists of specific kernel types which describe objects (both planetary and spacecraft) position and orientation as a function of time with respect to the J2000 coordinate system [2]. Additionally, SPICE kernels contain (1) geometric definitions of custom coordinate frames that may be of particular use for a given mission, (2) position, (3) orientation, and (4) field-of-view details for each of the instrument payloads onboard a spacecraft. From these sources, along with custom software, extensive details of an observation (i.e.: viewing angle, lighting angle, range to surface, phase angle, etc.) can be ascertained [2]. For this reason, SPICE files are often the underlying foundation of a planetary exploration mission [2][3]. Figure 1 provides a high level example of the relationships defined within SPICE kernels [1][2].

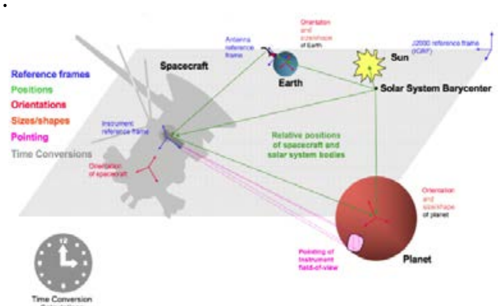

Figure 1: Solar System Geometry as recorded by SPICE kernels [1]

However, the utilization of SPICE kernels requires a not insignificant amount of prior knowledge to use effectively. Generally, planetary exploration missions have a small handful of SPICE experts whom are tasked with assisting other team members' use and understanding of kernels in addition to their regular duties. Additionally, the act of visualizing, verifying, and/or debugging data contained within kernels regularly involves using a gamut of tools and processes to glean partial facts regarding the kernels.

Features: Herein we introduce a novel software system to allow engineers and scientists to rapidly leverage our SPICE expertise and experience through an easy-to-use and configurable application with advanced visualization capabilities. The intent is to make the SPICE architecture more readily accessible to a larger audience of engineers and scientists working on any given mission. To make SPICE as accessible as possible, the proposed tool is designed for online deployment for all users of all platforms. To this end, anyone either on an active mission or using historic data from the Planetary Data System (PDS) can quickly and easily understand the context of a mission's SPICE kernels.

This tool provides two central features: (1) SPICE Visualization and (2) SPICE Informatics and Kernel Debugging.

SPICE Visualization. A common task for many engineers and scientists on a mission is to visualize data contained within kernels to confirm that either a plan that is in work is designed to meet mission goals, or to determine whether or not an observation which has already occurred was compliant with said plan. The use of rapid visualization can allow for more agile operations design by the fact that any team member can quickly verify the validity of an observation design as well as offer more informed and constructive feedback if the design is invalid. An example of such a visualization is provided in Figure 2.

A few COTS tools have attempted to provide this capability to varying degrees of success, but no publically available tool has yet to reach the point where a user can simply upload their kernel pool and immediately generate meaningful visualizations that depict the kernel's content [4][5][6]. By focusing on this specific need, direct kernel visualization is more accessible than it has ever been. Using this tool allows mission engineers and scientists to relax demands upon the team's group of SPICE experts.

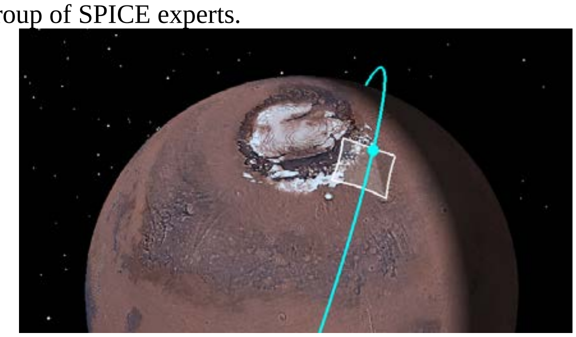

Figure 2: Example visualization of a spacecraft orbiting Mars.

SPICE Informatics and Kernel Debugging. Frequently on a planetary exploration mission, questions come up regarding which kernels contain which data, which kernels link together, and which data sources take priority, and at what time, depending upon the coverage intervals. Sometimes these questions have simple answers, but more often than not a much more involved answer is necessary. To address these issues, scientists and engineers draft either a long email or a rough sketch of what the kernels contain.

The proposed tool offers a more thorough and robust response: interactive visualization of the kernel content combined with relationships to other kernels can be computed on the fly from a given meta-kernel, as demonstrated in Figure 3 and Figure 4.

A common pitfall experienced while using the SPICE architecture is that a particular coordinate frame or reference data is not available within a meta-kernel to allow a query to be computed. In response to this, the software is designed to provide insight regarding a failed connection in a query. An example of this is depicted in Figure 3 below in which the state of a spacecraft object, "MRO" was queried with respect to the "SN_FRAME" coordinate frame at planet "Mars". However, a SPK doesn't exist providing Mars' J2000 state with respect to the Sun, and thus the query fails.

Figure 4 provides timelines showing which kernels are informing a spacecraft's trajectory and attitude as a function of time. Further extensions of this capability can include additional information becoming available in scroll-over windows.

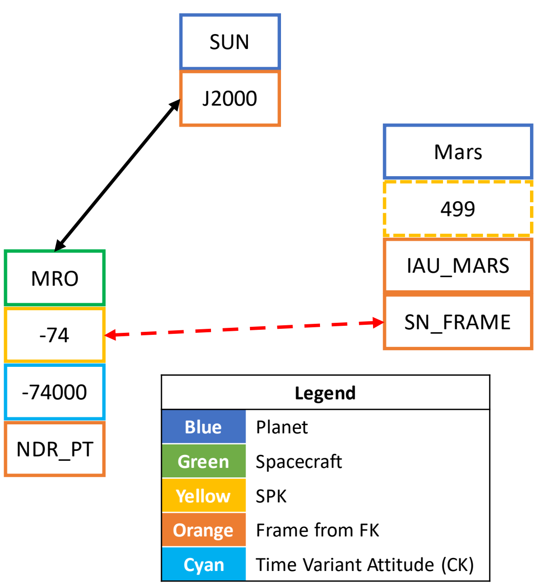

Figure 3: Example SPICE kernel flow diagram.

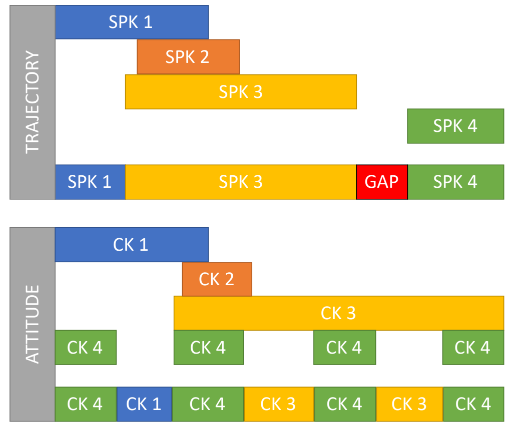

Figure 4: Example SPICE kernel data source timeline.

Summary: From our lessons learned and SPICE expertise we have laid out the features and capabilities of a new web-based tool to provide an accessible platform to obtain context and informatics from a planetary mission's SPICE kernels.

With modern, agile development practices, the foundation is laid to be easily extendable to service the particular needs of any mission. This will be greatly beneficial to a mission operations team, science team, and especially the efficiency of the interaction between the two.

Additionally, the proposed tool provides key functionality to scientists whom are analyzing data products already delivered to the PDS. In this circumstance, individuals familiar with the mission and the details of its kernels may no longer be readily accessible; this tool can instead provide these insights.

References:

[1] "Ancillary data services of NASA's Navigation and Ancillary Information Facility", Acton, Charles H., Planetary and Space Science, Volume 44, Issue 1, p.65-70. Jan 1996. [2] "SPICE Products Available to the Planetary Science Community", Acton, C.H., 30th Annual Lunar and Planetary Science Conference, March 15-29, 1999, Houston, TX. [3] "What's New in SPICE", Liukis, M., Third Planetary Data Workshop and The Planetary Geologic Mappers Annual Meeting, June 12-15, 2017, Flagstaff AZ. [4] https://naif.jpl.nasa.gov/naif/cosmographia.html [5] "WebGeocalc and Cosmographia: Modern Tools to Access SPICE Archives", Semenov, B. V.; Acton, C. H.; Bachman, N. J.; Ferguson, E. W.; Rose, M. E.; Wright, E. D., Third Planetary Data Workshop and The Planetary Geologic Mappers Annual Meeting, June 12-15, 2017, Flagstaff, AZ. [6] "How STK Automatically Loads SPICE Files", http://help.agi.com/stk/index.htm#stk/SPICE.htm?Highlight=spice