**Introduction:** OpenSpace [1] is an open source interactive data visualization software designed to visualize the entire known universe and portray our ongoing efforts to investigate the cosmos. OpenSpace supports interactive presentation of dynamic data from observations, simulations, as well as space mission planning and operations, and allows visualization at the outcrop level on extraterrestrial bodies. The software works on multiple operating systems (Windows, Mac, Linux) with an extensible architecture powering high-resolution tiled displays and planetarium domes, making use of the latest graphic card technologies for rapid data throughput. In addition, OpenSpace enables simultaneous connections across the globe creating opportunity for shared presentations among audiences worldwide.

**Invitation:** Several participants in the OpenSpace project are present at LPSC 2020. We invite you to:

1) Visit the OpenSpace booth in the exhibitions area for a demonstration any time this week.

2) Let us know what you want from the project.

Scientists are welcome to team with programmers at their home institutions to develop modules for OpenSpace. A module could include, e.g., a visualization of part or all of an individual mission, including spacecraft model and SPICE navigation kernels and visualization of science results.

**Content Development:** The last year has seen an increase in the number of interactive scenes of visualized NASA data available in OpenSpace to 17, with the goal to reach 20 scenes by the end of this year. Non-technical story guides and user-friendly presentation buttons that align with content points have also been introduced, and can be accessed on a mobile device. The creation of new content continues to depend on collaboration with NASA agencies and infrastructure along with outside scientists and agencies. New scenes include:

- **Apollo 8, 11, and 17:** Models and trajectories for these missions are included, as well as the Apollo 11 and 17 landing sites. The Apollo 8 and 11 orbit trajectories were supplied by NASA GSFC SVS Media Specialist Ernest T. Wright. Imagery of the Apollo 8 Command Module interior was created from the Smithsonian National Air and Space Museum’s scan of Apollo 11’s Columbia Command Module (Fig. 1). The 3D Lunar Excursion Module model for Apollo 11 and 17 was created using photogrammetry of LM-2, on display at the Smithsonian National Air and Space Museum. Photogrammetry of boulders from Apollo 17 Haselblad photography has also been implemented, along with USGS/German Aerospace Center visualizations of Apollo 17 rover traverses.

- **Mars Surface:** The Mars surface scene was enhanced with two new map layers: local HiRISE data patches, and a blended CTX map from CalTech’s Jay Dickson. 

- **Saturnian Moons:** Hyperion and Mimas were added to the Saturnian system in all scenes.

- **Satellites:** Trails of Pioneer 11 and 12 were added, and the Pioneer model was improved. Trajectories of the Swift-Tuttle comet, Tesla Roadster, and ‘Oumuamua are optional content that can be added to any scene.

- **Earth:** In addition to the existing daily atmospheric layer in OpenSpace, oceanographic datasets such as sea surface temperature (Fig. 2) have been added.
Software Development: As in previous years, software engineers and graduate research associates at AMNH, Linköping University, New York University Tandon School of Engineering, and the University of Utah Scientific Computing and Imaging Institute have collaboratively contributed to a workflow that fosters near real-time, memory-efficient algorithms to handle data intensive tasks, multi-modal rendering, integration of new data sets, and hardening of the software code.

During the last year, three significant updates of the OpenSpace software were published, the most recent being Beta-5 (v0.15.0), released on September 17, 2019. Each improved software stability and usability, particularly for older hardware. Releases also included high priority technical improvement such as an enhanced Graphical User Interface, the means to control OpenSpace on a handheld device for easier presentation, and increased documentation. Major new features include:

OpenSpace Launcher: This new start-up option allows users to select their screen output and scene, negating the need to edit a text file to do so.

Session Recording: This feature enables the recording of camera movements, state changes, time, speed, and user interface interactions which can then be played back or shared between computers. This is done from a recording menu that allows users to create, play, and stop the recording, as well as stream live to YouTube.

Slides Menu: This menu allows users to show online and downloaded image files within OpenSpace. This has been used to show historic mission images within an OpenSpace visualization of that mission.

Anchor and Aim: This feature enhances the previous Focus Node. It is still possible to focus the camera on a single object and have all camera movements occur relative to that object, but it is now also possible to anchor on one object while aiming at another, which stays fixed on the screen. This presents a view of the objects in relation to each other, affording cinematic results.

Search: Scene and settings menu search bar functionality were significantly improved, easing usage.

Discussion: OpenSpace allows visualization of scientifically important data, as well as the technology, engineering, and math of space missions. It enables science communicators to visually explain how we engage in discovery across the solar system and beyond, accomplished in part by accurate rendering of image pointing and regions of acquisition projected from instruments as view frustums in OpenSpace. Navigation kernels and the DU allow time- and space-accurate rendering of spacecraft paths throughout the solar system. The open source nature of the software encourages module development by collaborators beyond the existing team. Academic publications about OpenSpace are at [3].

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