

OpenSpace Annual Progress Report – Year 1
NASA Science Mission Directorate Science Education Cooperative Agreement Notice
(CAN)

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I. ADMINISTRATIVE

Recipient Name and Address: American Museum of Natural History
Central Park West at 79th Street
New York, NY 10024

Recipient Cooperative Agreement Number: NNX16AB93A

Principal Investigator: Ro Kinzler

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II. ACCOMPLISHMENTS

The American Museum of Natural History (AMNH) is pleased to submit this first annual report on the achievements to date of *OpenSpace: An Engine for Dynamic Visualization of Earth and Space Science for Informal Education and Beyond*, referred to below as the OpenSpace project. The overarching goal of the OpenSpace project is to build a pipeline for transmitting visualized science content from across NASA SMD divisions to Informal Science Institutions (ISI), secondary school classrooms, and the public. Central to achieving this goal is the development of open source software, known as OpenSpace, and the promotion of the software's use in informal settings through the establishment of a network of ISI partners. During the project's first year, AMNH made significant progress toward these objectives by bringing together all major stakeholders in a variety of meetings and through the accomplishment of ongoing code development and content visualization, as well as public programming. These activities are described in greater detail below.

Stakeholder Meetings

Throughout the first year, key meetings among all OpenSpace stakeholders took place at the Museum, and included meetings among developers, ISI partners, and Advisory Board members.

- **Developer meeting**, in which our grant-funded collaborators from New York University and the University of Utah, our two codemasters, and our SpaceApps partners from the New York City open source community joined us with our developers from Linköping University to kick off work on the project. We spent two days reviewing relevant research, identifying near-term and long-term development goals, and setting software deliverables for the year ahead. [February 2016, see attached agenda]

- Informal Science Institution (ISI) User Network meeting**, in which our grant-funded and leveraged partners from the Adler Planetarium, California Academy of Science, the Denver Museum of Nature and Science (DMNS), the Franklin Institute, the Houston Museum of Natural Science (HMNS), the North Carolina Museum of Natural Sciences (NCMNS), and a representative from Evans and Sutherland, one of the field’s largest planetarium vendors, convened for two days to discuss upcoming OpenSpace networked programming opportunities and long-term software usability goals. The ISIs also met with our software codemasters to gain insight into the software development process, and had the opportunity to contribute valuable end-user input towards the software and content development goals and public programming objectives. [July 2016, see attached agenda]
- Advisory Board meeting**, in which five members of the project’s Advisory Board met to discuss work to date and long-range OpenSpace planning and strategic initiatives. Members present were: Marc Horowitz, Edward R. Murrow High School; Lucian Plesea, ESRI; Kevin Hussey, NASA JPL; Julie Edmonds, Carnegie Academy for Science Education; and Ka Chun Yu of the Denver Museum of Nature and Science. Also present at the meeting was Kate Haley Goldman, our outside project evaluator. [October 2016, see attached agenda]

Software Development

The project’s advances in code development and creation of visualization content included the following:

Digital Universe Atlas (DU)

AMNH completed work on OpenSpace’s scale graph functionality to support navigation of AMNH’s multi-scale Digital Universe dataset and other astronomical atlases. The DU atlas is currently being integrated into OpenSpace, including the incorporation of data released from the European Space Agency’s Gaia mission in mid-September.

Heliophysics

AMNH continued its collaboration with NASA Goddard’s Community Coordinated Modeling Center (CCMC) to portray space weather through the visualization of Earth’s magnetosphere as

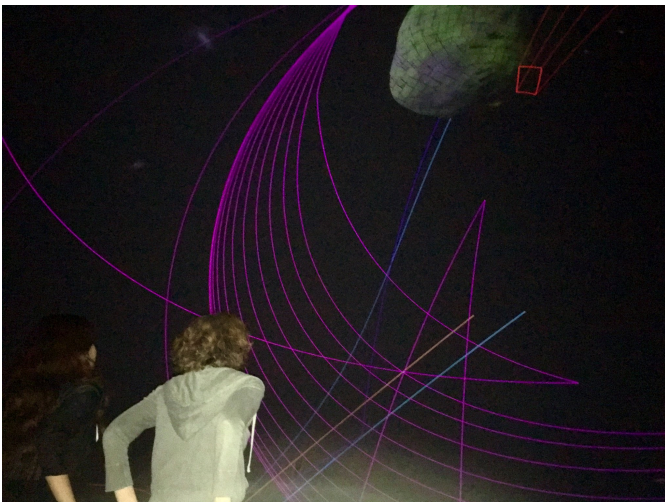


ENLIL Solar Wind visualization in OpenSpace

as simulated by CCMC’s Bats-R-US code, and the ENLIL real-time solar wind application. Linköping University sent two OpenSpace graduate interns to NASA Goddard for six months to work on this functionality and, in July 2016, project Co-Is Carter Emmart and Vivian Trakinski, along with two AMNH OpenSpace graduate interns, met with CCMC’s science director, Dr. Masha Kuznetsova, to discuss plans for further collaboration.

Planetary

- Work progressed on OpenSpace's **Globe Browsing** functionality for interfacing with Web Map Services (WMS) protocols to enable the use of multi-resolution map archives such as NASA Goddard's Global Imagery Browse Services (GIBS) and NASA's multi-center Lunar Mapping and Modeling Project (LMMP). We used the code to visualize Mars, combining nested images and elevation data from the Mars Reconnaissance Orbiter's CTX (6-meter-resolution) and HiRISE (.25-meter-resolution) instruments, the Mars Orbiting Laser Altimeter (MOLA) height map, and the Voyager true color map. Linköping University sent two graduate students to AMNH for five months and the University of Utah sent one graduate student to ESRI for four months (under the supervision of project Advisory Board member Lucian Plesea, formerly of JPL) to work on this project.
- Code for accurately visualizing **atmospheres**, including for Earth and other planets, is near completion. The work was executed by programmers at New York University.
- The **New Horizons** visualization was updated with refined graphics and newly released images from the spacecraft's LORRI camera, including the "stereo mosaic," which provides "stereo" coverage from multiple angles enabling creation of a height map.
- A visualization of the **Rosetta** mission was created, which portrayed the orbital trajectory and projection sequence onto Comet 67P Churyumov-Gerasimenko, the orbit from which the Philae lander was dropped, and comet outgassing during its post perihelion phase in September 2015.



- A visualization of the **OSIRIS-REx** mission, from launch to orbital mapping of asteroid Bennu was completed in time for the mission launch.

Visualization of OSIRIS-REx orbit and camera operation during mission mapping campaign

OpenSpace Public Programs

- **New Horizons Science Update**

Cathy Olkin, Deputy Project Scientist for New Horizons, joined project Co-I Carter Emmart in AMNH's Hayden Planetarium to present the latest images of Pluto to 420 visitors. (February 8, 2016. A podcast of the lecture is available here:

<http://www.amnh.org/explore/news-blogs/podcasts/frontiers-lecture-the-pluto-encounter>)

- **OSIRIS-REx Launch Event**

Just days after launch, Harold Connolly, Jr., Mission Sample Scientist for OSIRIS-REx, joined project Co-Is Denton Ebel and Carter Emmart in the Hayden Planetarium to describe the engineering challenges and science objectives of the OSIRIS-REx mission to approximately 250 members of the general public using our new OpenSpace mission visualization. The program was video captured and will have a long-term home for educators and lifelong learners on the [amnh.org/openspace](http://www.amnh.org/openspace) website. The OSIRIS-REx event was featured in articles by Spaceflight Insider and Space.com, which can be read via the following links: <http://www.spaceflightinsider.com/missions/solar-system/amnh-osiris-rex-presentation-showcases-visualization-software/> and

<http://www.space.com/34059-osiris-rex-asteroid-journey-visualization.html>

- **Messenger/Cassini Buildathon**

Twenty-six developers were invited from over 65 applicants to a day-long “buildathon” in which two teams were challenged to visualize the Cassini and MESSENGER missions



in OpenSpace. Sean Solomon, PI of the MESSENGER mission, delivered a lunchtime guest lecture. The event was a great success in revealing and fixing code bugs, fostering a community of OpenSpace developers, many of whom are now planning regular Meetups, and surfacing ways to serve that community through improved documentation.

Dr. Sean Solomon describes MESSENGER instrumentation to buildathon participants.

III. STATUS/CHANGES/ ISSUES

In Year One of the OpenSpace project, we concentrated on developing the software codebase and core functionality. Early in the first year of the project we determined that more time and resources would be required for this initial work, which would be crucial for success toward our education and programming goals. Because of this, expanded release of the software to the ISI community will take place next year at ASTC.

In addition, the logistics of coordinating a network of ISIs across the country, in different time zones and with a variety of programming goals, have been challenging, requiring extended lead times and extensive planning. Thus, some of our program goals have been shifted into Year Two. We now plan to hold two major networked events with our ISI partners during Year Two (rather than one in each of Years One and Two): an Earth Day event in April 2017 and an Eclipse event in August 2017. Greater lead time and common interest in these topics make them excellent candidates for networked events. In addition, they both showcase work that was central to the development activities undertaken in Year One: globe browsing and Earth-Sun interactions.

Due to overlap with other major conferences, we did not attend a regional planetarium conference of one of our three leveraged regional planetarium associations. To compensate, we plan to attend two regional planetarium conferences in Year 2: The Great Lakes Planetarium Association conference in June 2017 and the Southeastern Planetarium Association conference in October 2017.

We decided against holding an Educators' Evening this past spring, but will instead offer an Educators' Evening scheduled to coincide with the networked Earth Day public ISI program in April 2017, and we will also target educators, as well as the general public, for the Eclipse event. We will also disseminate resources for educational use from the Eclipse event via the web.

IV. DISSEMINATION ACTIVITIES

In Year One, we hosted several successful OpenSpace public programs at AMNH and shared OpenSpace at multiple conferences and science centers. Through these programs and conference presentations, we were able to garner interest, build support, and cross-collaborate with NASA subject matter experts and current and future ISI partners. Online, we built an OpenSpace web presence for educators, students and the general public on <http://www.amnh.org/openspace>; an OpenSpace project website for partners and developers at openspaceproject.com; a facebook page: <https://www.facebook.com/OpenSpaceVisualization>

Conferences Attended and Organizations Visited on Behalf of the OpenSpace Project

- **Space Apps NYC conference**
- **International Planetarium Society conference (IPS), Warsaw, Poland**
 We presented OpenSpace space during a session on Best Practices of Live Touring through the universe. (At IPS, co-I Carter Emmart also received the Technology and Innovation Award for his pioneering work in data visualization and the “art of flying through the universe.” OpenSpace was described to the audience as a “revolutionary new software” that promises to have “profound impact on countless planetariums and educators around the world.”)

- **Association for Science and Technology Centers conference (ASTC), Tampa, FL**
Co-Is Emmart and Trakinski demonstrated OpenSpace during four one-hour blocks in an inflatable dome on the exhibition floor.
- **NASA / ASU Mars Symposium, Tempe, AZ Search for Habitable Environments Symposium and Field Trip** The symposium was particularly useful in informing the creation of public programs and educational material surrounding the globe browsing functionality and Mars visualizations within OpenSpace.
- **American Geophysical Union conference, San Francisco, CA**
Plans are for presenting OpenSpace as a platform for live presentation of Earth data sets in the Morrison Planetarium dome at California Academy of Sciences
- **NASA Goddard’s CCMC, Greenbelt, MD**
- **Copernicus Center, Warsaw, Poland**

OpenSpace Web Presence

- www.amnh.org/openspace. For students, educators, and lifelong learners.
- www.openspaceproject.com. For developers and the open source community.
- <https://www.facebook.com/OpenSpaceVisualization>. For open source community, citizen scientists, and the public

V. EVALUATION, COLLABORATORS, AND CROSS-COLLABORATION AGREEMENTS ACTIVITIES

As a multi-faceted project with partnerships among commercial, non-profit, and academic institutions, OpenSpace has had the opportunity to strengthen several strong cross-collaborative partnerships over the course of the project’s first year.

- **Houston Museum of Natural Science**

HMNS has been hard at work incorporating OpenSpace into their theater spaces and student internship programs. After intense collaboration with our developers at Linköping



Student Interns at HMNS.

University in Sweden, they can now successfully run OpenSpace in their Burke Baker Planetarium and Discovery Domes. Due to these issues, HMNS wasn’t able to participate in the live OSIRIS-REx public program, but will be receiving a fisheye version of the broadcast to show in their theater for use by adult educators. HMNS also had five student interns working on programming related to the OpenSpace effort.

- **North Carolina Museum of Natural Sciences**

NCMNS was able to dedicate a summer undergraduate intern from Appalachian State University to OpenSpace software development and interactivity. Visitors were able to observe the software manipulated in real time in the NCMNS Daily Planet theater, as well as on a large display in the NCMNS Astronomy and Astrophysics Research Lab. The intern successfully identified and helped to fix several bugs in the software's code, and rendered fly-through videos of the solar system, inner planets, and Jupiter. Approximately 30,000 visitors experienced OpenSpace in June and July, with 25 percent of those coming from underserved/underrepresented populations. Twenty-five middle school teachers were also introduced to OpenSpace during a summer workshop. NCMNS is now in the process of making OpenSpace operational in their hemispheric Immersion and Daily Planet theaters.



NCMNS Astronomy and Astrophysics Lab

The North Carolina Museum of Nature and Science is also collaborating with the North Carolina Symphony to create a multimedia piece for Holst's "The Planets." "The Planets: LIVE!" performances will be held on November 18 and 19, 2016, and if all tickets are sold would yield two evenings of 1,700-person audiences experiencing OpenSpace video imagery, including zooms and tours for each of the seven planets featured in Holst's piece, as well as an overview of solar system orbits made with OpenSpace:

<http://ncsymphony.org/events/index.cfm?view=details&detailid=3223&eid=4193>

- **Adler Planetarium**

Chicago's Adler Planetarium has incorporated OpenSpace into its Space Visualization Laboratory (SVL) and summer teen internship program. Internship participants are recruited from neighborhoods that lack resources and opportunities for high school students to engage in STEM learning, and from audiences traditionally underrepresented in STEM fields. The majority of participants is female and identify as ethnic/racial minorities. In the SVL, scientists, technology experts, artists, and educators work together to create new ways for people to virtually explore the Universe. Sixteen summer interns worked alongside Adler staff to carry out research at the SVL and learn how to ingest Spice Kernel data into OpenSpace to visualize the Juno mission. At the end of the internship, the students presented their work with OpenSpace during Adler's "Community Bash" of about 500 people, including their own friends and family members. The interns made 3D prints of Juno and C67P and experimented in using the model and OpenSpace together to talk about the mission. The "Community Bash" is one of the main ways that Adler reaches out to populations who normally don't make it to the museum. Integration of OpenSpace into Adler's two main dome theaters is scheduled for early 2017.

- California Academy of Sciences**
 Cal Academy is currently installing OpenSpace in their Morrison Planetarium, in time for a presentation on its globe browsing capability at the fall American Geophysical Union (AGU) meeting in December 2016.
- Evaluation and Assessment by Kate Haley Goldman**
 The OpenSpace project’s external evaluator is Kate Haley Goldman of Haley Goldman Consulting Inc. (507 Dartmouth Ave, Silver Spring MD; 301-655-1925; kate@haleygoldman.com). In Year One, Kate has produced an Evaluation Plan and a baseline review of the project. The evaluation plan is designed to help inform materials development, implementation, and ISI collaboration in order to fulfill the SMD Science Education Objectives. Kate conducted telephone interviews with each of the ISI stakeholders in order to draft the baseline evaluation review.
- Planetarium vendors**
 We had productive conversations and demonstrations with all the major planetarium vendors this year. Significant progress was made with SCISS when we installed OpenSpace on their system for presentation at IPS. Another major vendor, Evans and Sutherland (E&S), joined us at our ISI User Network Meeting to provide input on configuring the software to meet E&S Digistar software file configuration standards. E&S is working directly with Houston Museum of Natural Science to integrate OpenSpace into their new system.
- Additional SMD Collaborators and Cross-collaboration**
 We have had ongoing conversations, development activities, and public programming in collaboration with NASA personnel and other awardees, as the chart below shows:

SMD Personnel	NASA Infrastructure	Co-collaboration
Harold Connelly Jr., OSIRIS-REx Mission Sample Scientist	Emily Law, Lunar Mapping and Modeling Project (re: Mars and Moon data)	Leigh Peak, Gulf of Maine Research Institute (possible use of OpenSpace to view ocean data collected by citizen scientists.)
Masha Kuznetsova, Director CCMC, GSFC	Kevin Hussey, Visualization, Technology, and Development, JPL (re: development of Web version and Eclipse graphics)	Denise Smith, Space Telescope Science Institute (re: integrating their visualizations into OpenSpace)
Darren De Zeeuw, CCMC, GSFC		
Cathy Olkin, New Horizons Deputy Project Scientist, SWRI	Daniella Scalice, NASA Astrobiology program (re: public program utilizing Mars and Earth data)	Matthew Penn, National Solar Observatory (re: ingestion of their citizen
Jeffrey E. Schmaltz, Earth Data LANCE Rapid		

<p>Response Team, GSFC</p> <p>Ryan Boller, Data Visualization Lead, Earth Science Data and Information System Project, GSFC</p> <p>Bob Pappalardo, Senior Research Scientist, JPL</p> <p>Sean Solomon, PI for Mercury Messenger Mission, Columbia LDEO</p> <p>Kevin Grazier, Science Planning Engineer, Cassini/Huygens Mission</p> <p>Lika Guhathakurta, Heliophysics Science Division</p> <p>Mark Powell, Mobility Systems Concept Development, JPL</p>		<p>science eclipse data into OpenSpace for public programming)</p>
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VI. KNOWN FUTURE PLANS

We are already engaged in planning with our Development and ISI partners for Year Two. The Year Two Developers meeting is being scheduled for February, 2017 and discussing our development goals, which currently include:

- Ongoing technical integration of OpenSpace across our ISI partner venues.
- User Interface design.
- Mars Visualization: achieving sub-meter image resolution from the Mars Reconnaissance Orbiter’s (MRO) HiRISE camera, sufficient to view the Mars Exploration Rovers (MER), Spirit and Opportunity, and the Mars Surface Laboratory’s (MSL) Curiosity rover.

Educational Program and Resource Development activities for Year Two include:

- Earth Day networked program event (tentatively scheduled for April 21, 2017), in which we will hold an Earth-focused public program that capitalizes on the OpenSpace globe browsing functionality.

- An Evening for Educators at AMNH (scheduled for May 12, 2017) titled Mapping Global Change during which co-Investigator Carter Emmart, will guide educators through immersive visualizations of global change using OpenSpace, from sources such as NASA's Global Imagery Browse Service (GIBS).
- Sun-Earth connection program for the 2017 spring equinox (3/18/17), which will use OpenSpace to talk about the Sun-Earth connection. The program will showcase the heliophysics modeling and simulation work that's been developed in OpenSpace in collaboration with NASA Goddard's CCMC.
- Total Solar Eclipse program in August 2017, in which we will network with other ISIs to follow the eclipse's path of totality.
- Built out educators content for a 2017 Educator's evening and online educator's content at www.amnh.org/openspace.
- OpenSpace Interactive programs during Astronomy Days event at North Carolina Museum of Natural Sciences the end of January, which annually attracts nearly 15,000 visitors over a weekend, that will integrate undergraduate students from Appalachian State University to help with interaction and interpretation among visitors.

VII. ATTACHED INFORMATION

- Association of Science-Technology Centers (ASTC) OpenSpace flyer
- OpenSpace Developer Meeting agenda
- OpenSpace ISI Network Meeting agenda
- OpenSpace Advisory Board Meeting agenda