and Drive R2 can experience what it is like to control a robot over a distance with a time delay, simulating the time delay that would occur between ground control and an on-orbit robot. The initial ISS experiences were built using parts of code from the NASA Enigma software. The models used in these experiences were also from the Integrated Graphics Operations and Analysis Lab model database. The PlaySpace experience incorporates surface data obtained from NASA rovers and satellites and was built by NASA JPL.

This work was done by Sharon Goza and David Shores of Johnson Space Center; William Leu, Raymond Kraesig, Eric Richeson, Clinton Wallace, Moses Hernandez, and Cheyenne McKeegan of Tietronix Software Inc.; and Jeffrey Norris, Victor Luo, Alexander Menzies, Dara Kong, and Matt Clausen of JPL. Further information is contained in a TSP (see page 1). *MSC-25110-1*

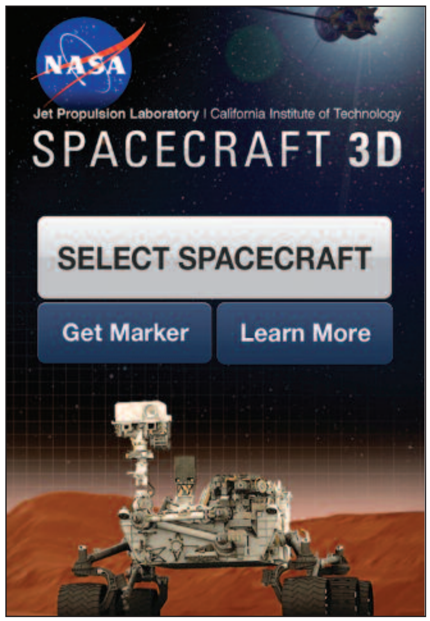
Spacecraft 3D Augmented Reality Mobile App

NASA's Jet Propulsion Laboratory, Pasadena, California

The Spacecraft 3D application allows users to learn about and interact with iconic NASA missions in a new and immersive way using common mobile devices (see figure). Using Augmented Reality (AR) techniques to project 3D renditions of the mission spacecraft into real-world surroundings, users can interact with and learn about Curiosity, GRAIL, Cassini, and Voyager. Additional updates on future missions, animations, and information will be ongoing.

Using a printed AR Target and camera on a mobile device, users can get up close with these robotic explorers, see how some move, and learn about these engineering feats, which are used to expand knowledge and understanding about space.

The software receives input from the mobile device's camera to recognize the presence of an AR marker in the camera's field of view. It then displays a 3D rendition of the selected spacecraft in the user's physical surroundings, on the mobile device's screen, while it tracks the device's movement in relation to the physical position of the spacecraft's 3D image on the AR marker.



Spacecraft 3D Application allows one to interact and learn about different missions.

This work was done by Kevin J. Hussey, Paul R. Doronila, Brian E. Kumanchik, Evan G. Chan, and Douglas J. Ellison of Caltech; and Andrea Boeck and Justin M. Moore of Mooreboeck Inc. for NASA's Jet Propulsion Laboratory.. For more information access:

https://play.google.com/store/apps/details?id=gov.nasa.jpl.spacecraft3D

http://www.space.com/16569-nasa-app-spacecraft-hand.html

http://www.nasa.gov/mission_pages/msl/news/app20120711.html

http://www.engadget.com/2012/07/1/nasa-spacecraft-3d-ios-app/.

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-48763.

MPST Software: grl_pef_check

NASA's Jet Propulsion Laboratory, Pasadena, California

This innovation is a tool used to verify and validate spacecraft sequences at the predicted events file (PEF) level for the GRAIL (Gravity Recovery and Interior Laboratory, see http://www.nasa.gov/mission_pages/grail/main/index.html) mission as part of the Multi-Mission Planning and Sequencing Team (MPST) operations process to reduce the possibility for errors. This tool is used to catch any sequence related errors or issues immediately after the seqgen modeling to streamline downstream processes.

This script verifies and validates the seqgen modeling for the GRAIL MPST process. A PEF is provided as input, and dozens of checks are performed on it to verify and validate the command products including command content, command ordering, flight-rule violations, modeling boundary consistency, resource limits, and ground commanding consistency. By performing as many checks as early in the process as possible, grl_pef_check streamlines the MPST task of generating GRAIL command and modeled products on an aggressive schedule.

By enumerating each check being performed, and clearly stating the criteria and assumptions made at each step, grl_pef_check can be used as a manual checklist as well as an automated tool. This helper script was written with a focus on enabling the user with the information they need in order to evaluate a sequence quickly and efficiently, while still keeping them informed and active in the overall sequencing process. grl_pef_check verifies and validates the modeling and sequence content prior to investing any more effort into the build. There are dozens of various items in the modeling run that need to be checked, which is a time-consuming and error-prone task. Currently, no software exists that provides this functionality. Compared to a manual process, this script reduces human error and saves considerable man-hours by automating and streamlining the mission planning and sequencing task for the GRAIL mission.

This work was done by Jared A. Call, John H. Kwok, and Forest W. Fisher of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-48658.

Real-Time Multimission Event Notification System for Mars Relay

NASA's Jet Propulsion Laboratory, Pasadena, California

As the Mars Relay Network is in constant flux (missions and teams going through their daily workflow), it is imperative that users are aware of such state changes. For example, a change by an orbiter team can affect operations on a lander team. This software provides an ambient view of the real-time status of the Mars network.

The Mars Relay Operations Service (MaROS) comprises a number of tools to coordinate, plan, and visualize various aspects of the Mars Relay Network. As part of MaROS, a feature set was developed that operates on several levels of the software architecture. These levels include a Web-based user interface, a back-end "ReSTlet" built in Java, and databases that store the data as it is received from the network. The result is a real-time event notification and management system, so mission teams can track and act upon events on a moment-by-moment basis.

This software retrieves events from MaROS and displays them to the end user. Updates happen in real time, i.e., messages are pushed to the user while logged into the system, and queued when the user is not online for later viewing. The software does not do away with the e-mail notifications, but augments them with in-line notifications. Further, this software expands the events that can generate a notification, and allows user-generated notifications.

Existing software sends a smaller subset of mission-generated notifications via email. A common complaint of users was that the system-generated e-mails often "get lost" with other e-mail that comes in. This software allows for an expanded set (including user-generated) of notifications displayed in-line of the program. By separating notifications, this can improve a user's workflow.

This work was done by Michael N. Wallick, Daniel A. Allard, Roy E. Gladden, Paul Wang, and Franklin H. Hy of Caltech; and Corey L. Peterson for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-48288.

SIM_EXPLORE: Software for Directed Exploration of Complex Systems

NASA's Jet Propulsion Laboratory, Pasadena, California

Physics-based numerical simulation codes are widely used in science and engineering to model complex systems that would be infeasible to study otherwise. While such codes may provide the highest-fidelity representation of system behavior, they are often so slow to run that insight into the system is limited. Trying to understand the effects of inputs on outputs by conducting an exhaustive grid-based sweep over the input parameter space is simply too time-consuming. An alternative approach called "directed exploration" (see figure) has been developed to harvest information from numerical simulators more efficiently. The basic idea is to employ active learning and supervised machine learning to choose cleverly at each step which simulation trials to run next based on the results of previous trials.

SIM_EXPLORE is a new computer program that uses directed exploration to explore efficiently complex systems

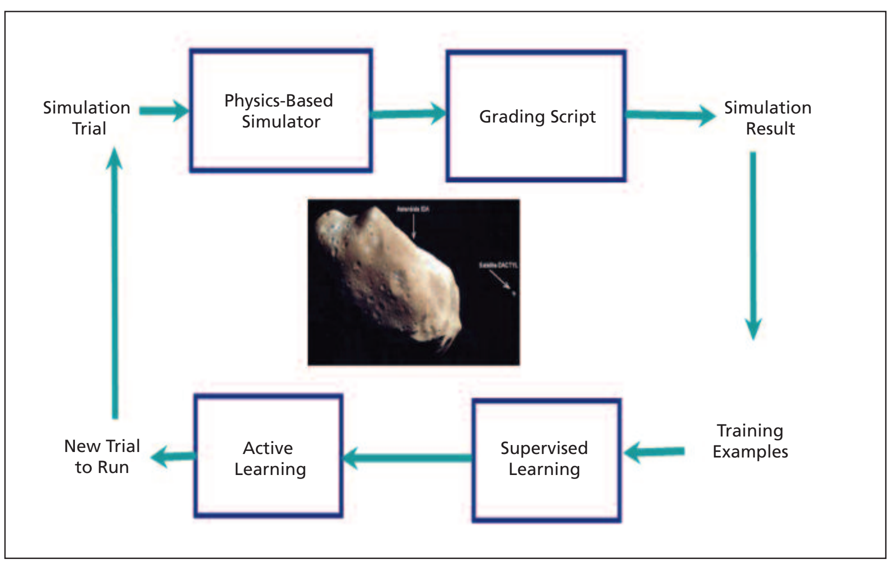


Illustration of the **Directed Exploration** approach in an asteroid collision application. The central image shows the Ida-Dactyl asteroid pair observed serendipitously by the Galileo spacecraft. Planetary scientists are interested in understanding how such systems form and more generally in how asteroid families form. Physics-based numerical simulations offer a means to gain insight into such systems; however, the simulations are so slow to run that a *directed exploration* strategy is required.