REAL TIME SCIENCE DECISION SUPPORT TOOLS: DEVELOPMENT AND FIELD TESTING M. C.
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Overview: In 2012, we tested our Exploration Ground Data System (xGDS) during a simulated lunar polar volatiles exploring rover field test. The tests showed that real time lunar surface science is possible with capabilities present in xGDS.

xGDS comprises web-based services for science operations, including tools for planning, monitoring, visualization, documentation, analysis, and search. We incorporated several pre-existing and some new tools to support distributed science teams. The tools were used to support a field test of the RESOLVE payload [1] carried by the Artemis Jr.[2,3] rover and operating on Mauna Kea, Hawai'i[4].

xGDS has been tested in several other analog missions, allowing us to learn lessons across scenarios[5].

Use Cases: xGDS is designed to support four mission phases: *Planning* starts with a-priori map information e.g. remote sensing data, known operational hazards or constraints, and targets of interest. xGDS enables teams to create and share map content and collaboratively edit plans. *Monitoring* is done via map- and plot-based tools to visualize payload telemetry and vehicle position in real-time, and also includes real-time and post-hoc documentation and annotation. *Archiving* tools ingest telemetry in real-time, reducing data to more meaningful or efficient representations and organizing it into searchable databases. *Exploring* data later requires the ability to quickly find out what was collected, where and when it was collected, and search for particular kinds of data. Real-time semantic labeling greatly facilitates this, by users using xGDS tools to add notes to data products and timelines.

Approach: Our work makes significant use of open standards and open source software. Both enable us to rapidly build scalable systems that are effective, easy to use, and easy to share with our collaborators.

Planner (Fig. 1) has an interactive map view of the plan, and an interactive table of waypoints with notes or instructions for operators. The RESOLVE science team developed all of the rover plans in this tool. It loads map layers for context and computes timelines using distances and a user-configurable average rover speed. It outputs multiple file formats, including XML for Artemis Jr. to load and execute, and KML for the team to view along with real time vehicle tracking in the same map.

Console Log allows users to capture notes in real time, with metadata including time, author, console, rover location (when selected), and user-defined tags. The shared console log is visible across all of the con-soles. Users can see all entries in an integrated timeline view, and search or filter entries. The RESOLVE team recorded about 2,500 log entries in one week.

Time-Based Plots (Fig. 2) show telemetry values vs. time in a set of axes which are synchronized so that the time axes remain aligned as plots update in real time. The plots allow zooming and panning the time axes of the plots together, or scaling the y-axis of any one plot to explore the data. This made it possible to e.g. correlate water signatures from the NIRVS instrument with depth of the drill to understand at what depth the drill tailings contained a water signature.

Raster Maps (Fig. 3) show telemetry data vs. vehicle location visualized as a heatmap. This made it possible to quickly see where, e.g., the Neutron Spectrometer detected an elevated hydrogen signature visualized as a bright yellow or red spot corresponding to peaks on an otherwise blue to green background.

Images (Fig. 4) are shown in a list with metadata (name, capture time, location, size, etc.) along with search and filtering tools. Images also appear in map views as placemarks corresponding to the location of the rover when the image was captured.

Integration: Artemis telemetry was deliverd using the LCM protocol[6]. RESOLVE telemetry used DDS[7]. Both telemetry streams were integrated within xGDS so that payload telemetry could be geolocated using the rover location. Users connected to xGDS over a regular web browser.

Field Tests: The objective of our involvement in the RESOLVE field test was to evaluate the effectiveness of xGDS for planning, monitoring, archiving, and search in the context of a short duration, high-tempo lunar surface volatiles rover mission.

For RESOLVE, real time science support was done on site in a simulated mission control front room at Hale Pohaku, and remotely in back rooms at a few NASA centers (ARC, JSC, and KSC) as well as Canadian Space Agency headquarters in Montreal Canada.

xGDS primarily tracked rover location, rover camera images, and NS, NIRVS, and drill telemetry from the payload. xGDS provided real time maps of rover location, maps of geolocated data products, plots of telemetry vs. time, maps of telemetry vs. rover location, and a console log for all console operators to take real time notes on operations.

Real time science data analysis was done continuously throughought the day. Strong subsurface hydrogen signatures located during real time operations were used to identify places to drill for subsurface samples as soon as the location was mapped sufficiently.
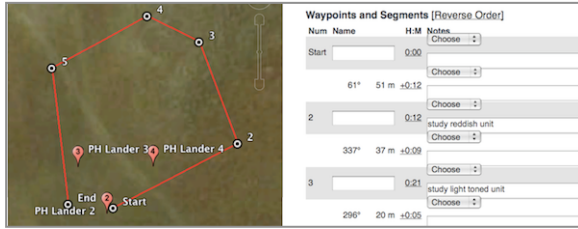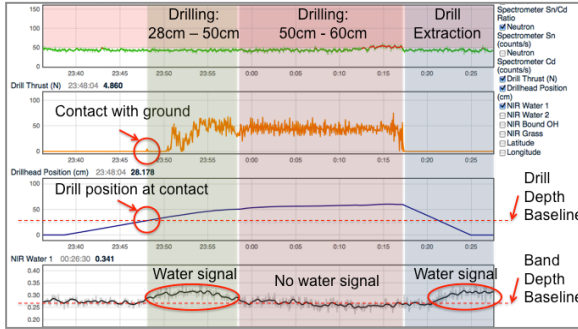
Figure 1. xGDS planner.

Figure 2. xGDS time-based plot of instrument telemetry correlates drill position and NIRVS water signature to show hydration in tailings from different depths.
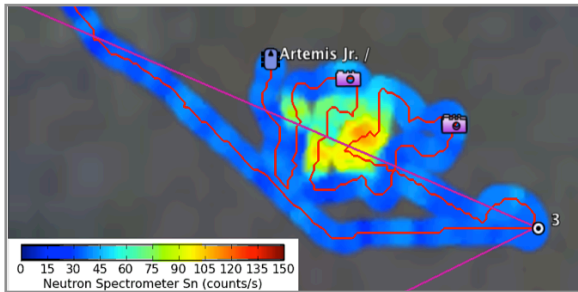

Figure 3. xGDS raster maps show Neutron Spectrometer readings vs. vehicle location, with strong subsurface volumetric hydrogen signature peaks appearing in red.
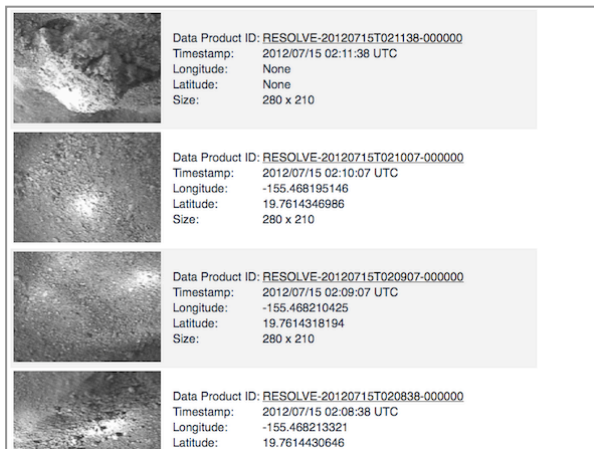

Figure 4. The Image Browser shows images with name, acquisition time, location (if known), and size. Images are also placemarks in the map with camera icons.

Results: The tests showed that real time lunar surface science is possible with capabilities present in xGDS. Our tools enabled scientists to work together effectively, organize their plans, understand what is being accomplished during execution, efficiently replan on the fly, and analyze and explore their data after the operations are over. xGDS is flexible and extensible, allowing us to quickly respond to new feature requests to support field teams.

Future Work: We plan to continue development of xGDS by integrating telemetry from the rest of the RESOLVE payload, supporting the RESOLVE thermal vacuum chamber tests, and supporting future analog tests of robotic lunar polar volatile prospecting in a natural setting where the task is to identify and map the native water content. xGDS is also supporting other field tests.

Conclusion: We are developing and field testing xGDS in order to understand the costs, benefits, limitations, and capabilities of this new approach to ground data systems. Our use of powerful open source web software, open standards, and testing in multiple field tests has helped us to efficiently create powerful and flexible tools for mission control ground data systems. These tools have broad applicability to crew missions, robotic missions, and new destinations.

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