FIELD TESTING NEXT-GENERATION GROUND DATA SYSTEMS FOR FUTURE MISSIONS M. C. Deans[1], D. S. Lees[2], T. Smith[2], T. E. Cohen[3], T. F. Morse[3], T. W. Fong[1]. [1]NASA Ames Research Center, Moffett Field, CA. [2]Carnegie Mellon Silicon Valley, Moffett Field, CA. [3]Stinger Ghaffarian Technologies Inc., Moffett Field, CA.

Overview: Our Exploration Ground Data System (xGDS) provides software for dealing with mission data for science operations, including tools for planning, monitoring, visualization, documentation, analysis, and search.

In 2011, we incorporated several pre-existing and new tools into a common web framework to better support distributed science teams. These new tools were used to support submarine flights at the Pavilion Lake Research Project (PLRP) in British Columbia, Canada and at the NASA Extreme Environments Mission Operations (NEEMO) in Key Largo, Florida, USA, as well as pressurized crew rover traverses at Desert RATS (Arizona, USA).

Our tests showed improvements in science operations on each field test we supported, and resulted in many operational lessons that we will apply to the next generation of our tools. Our tests showed improved planning efficiency, crew and operator situational awareness, and ease of data browsing and search.

We believe our software architecture, commitment to software reuse, and adopting open standards can greatly improve the utility and reduce the development and operational cost of ground data systems.

Use Cases: Our xGDS is designed to support four mission phases:

1. *Planning* missions start with a-priori map information including remote sensing data, known operational hazards or constraints, and targets of interest. xGDS enables teams to create and share a priori map content and collaboratively edit traverse plans.
2. *Monitoring execution* is done via map-based tools to visualize real-time where things are. Telemetry panels show the current status of systems and data. Real-time and post-hoc documentation and annotation are also supported.
3. *Archiving* tools ingest telemetry in real-time, reducing data to more meaningful or more efficient representations and organizing it into searchable databases.
4. *Exploring* data after it is collected requires the ability to quickly find out what data 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.

Field Tests: The primary objectives of our testing was to evaluate the effectiveness of our xGDS for planning, monitoring, archiving, and search.

For PLRP, real time science support was done on chase boats and in a remote back room with a real time data link over fiber optic cable from the submarine and ship-to-shore wireless backhaul. Post-mission analysis was done daily, with flights archived and reviewed the same day data was collected. PLRP data consists of submarine telemetry and underwater video. NEEMO had essentially the same infrastructure, operational setup, and science ops approach.

D-RATS had a real time tactical science team working one shift per day. The EVA Information Systems (EVAIS) crew backpack and Multi-Mission Space Exploration Vehicle (MMSEV) crew rover broadcasted streaming video and audio form the crew with real time location and other telemetry. xGDS provided real time maps of rover and crew locations, maps of geolocated data products, and a console log for all console operators to take real time notes on operations.

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. Our development this year emphasized three tools.

Planner: The planner has an interactive map view of the plan, and an interactive table of waypoints with instructions for pilots. The PLRP science team developed all of the 2011 flight plans in this tool, which output printed flight plans and maps for pilots in the sub, and KML views for the backroom team to view with real time flight tracking in the same map.

Console Log: The console log allows the science backroom to take real time notes. It automatically recognizes data product names in the freeform text, and pulls in a preview image and link to the data product with complete information about it. A typical workflow was to take a snapshot of the live video, then type a note. The system would automatically associate the snapshot to the note. The D-RATS team recorded over 3,000 log entries in two weeks. The console log is visible across consoles. Users can see all entries in an integrated timeline view, and search or filter entries.

Data Browser: The primary tool used to access data collected in the field is the data browser. Similarly to the planning tool, the data browser contains a map on the left and a table ("gallery") on the right. The gallery shows a paginated view of the data products contained in the current map view. As the map zooms or pans,

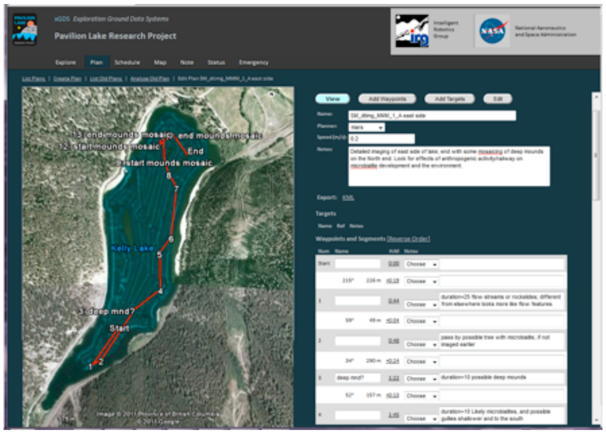

Figure 1. *Web-based planning tool and a flight plan for Kelly Lake. The tool contains a map view of the plan on left, with waypoints and tasks on the right.*

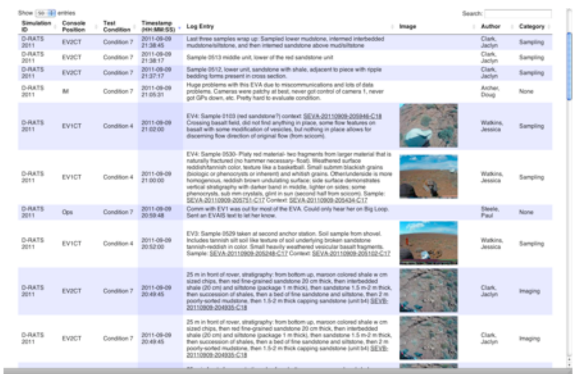

Figure 2. *xGDS Console Log columns contain the log entry time, author, console position, and freeform text, preview images and links to more information.*

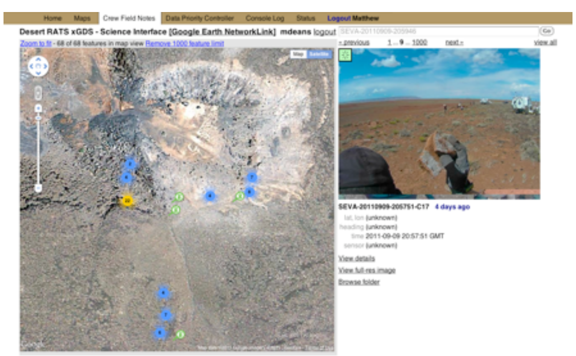

Figure 3. *The Data Browser for Desert-RATS shows the map on the left, and a preview image from a crew-member taking a hand sample on the right.*

the table of products updates. Searches can also be performed, limiting the map and gallery to show products that match the search.

Results: Our tools enable scientists to work together effectively, organize their plans, understand what is being accomplished during and after execution, and explore data in a natural way. Scientists can rapidly create and modify plans based on up to the moment information, thereby maximizing efficiency in the field test. 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 in three ways. First, integrating tools originally developed specifically for one field test will enable us to apply all of our tools across field tests. Second, we will support the RAPID[rapid] middleware standard for telemetry and help the RAPID team build data product delivery capability into RAPID. Third, we will work to streamline the overall architecture and release it for others to use.

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.

Lessons from research and testing with xGDS will improve future planetary surface exploration missions—human and robotic.

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