FIELD TESTING NEXT-GENERATION GROUND DATA SYSTEMS FOR FUTURE MISSIONS

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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.

During 2010, xGDS was used to support submarine flights at the Pavilion Lake Research Project (PLRP) (British Columbia, Canada), K10 robot traverses at Haughton Crater (Nunavut, Canada), and 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 starting from a-priori map information including remote sensing data, known operational hazards or constraints, and targets of interest. xGDS enable teams to create and share map content.
2. *Monitoring execution* is done via map-based tools to visualize real-time locations. Telemetry panels show current status of systems and data. Real-time and post-hoc documentation and annotation are 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, we supported traverse planning, execution monitoring, data archiving, and data search. Traverse plans were developed using Google Earth and uploaded to a remote xGDS server for analysis, cataloging, and sharing. Real time science support was done on chase boats. 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.

K10 had a real time science back room and flight control room at Ames, connected to the robot via satellite. Strategic planning was done in advance. xGDS provided tools to develop many tactical robot plans per day, monitor the robot in real time, and archive and browse science data in real time or after the mission. K10 data included robot telemetry and data from Gigapan panoramic camera, a 3D lidar, Ground Penetrating Radar, an Xray Fluorescence (XRF) spectrometer, and a downward facing hand lens resolution imager.

D-RATS had Tactical and Strategic science teams working in shifts. xGDS provided tools for the Tactical team science ops, including tracking the rover and crew and automatically catalog data products. xGDS supported the Strategic team overnight science operations, including analyzing the day's data and replanning for the next day. Data included rover telemetry, suit telemetry, and videos from the rover and crew.

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.

Open Standards: HTML content is easily viewed. Google Earth and the KML [7] open standard simplify creation, distribution, and visualization of map based content. xGDS leverages Google Earth, a tool that our science teams already use. This minimizes development *and* training costs.

Open Source: We use open source tools rather than implementing functionality ourselves [8]. We build our web applications on the Apache web server, the MySQL database, the Django web framework for Python, and the jQuery JavaScript library. This allows us to focus on writing the "glue" code between modules rather than the modules themselves. We release our own tools open source when possible, to more easily share code with colleagues and students. Potential users can then evaluate our tools with minimal overhead.

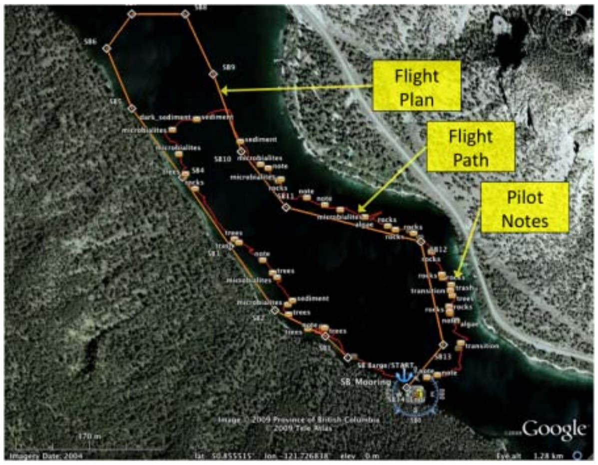

Figure 2. *Pavilion Lake flight plan and submarine track with real time annotations.*

Figure 3. *Desert RATS traverse with comm. coverage overlay, vehicle tracks, and geolocated data products.*

Figure 4. *Browsing K10 data from Haughton Crater.*

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.

Related Work: The Mission Control Technologies platform developed at NASA Ames focuses on flexible status monitoring for human mission operations in orbit [6]. The ENSEMBLE platform's approach differs in that it relies more on in-house software development and requires clients to install an application locally rather than using a web service [5].

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 [2] 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 software, open standards, and testing in multiple field tests has helped us to efficiently create flexible tools for ground data systems. xGDS has broad applicability to crewed and robotic missions, and new destinations.

xGDS and its successors should be used to improve all future planetary surface exploration missions—human and robotic.

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Acknowledgements: This work was supported by the ESMD Exploration Technology Development Project, by the Moon and Mars Analog Mission Analysis program, and by the DIO Analogs Program.