Minerva: User-Centered Science Operations Software Capability for Future Human Exploration

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1. INTRODUCTION

- Science & exploration with humans & robots is part of Mission concepts for cis-lunar, Near Earth Asteroid, Phobos & Deimos, and Mars.
- The **BASALT** Project studies lava flows in Hawaii and Idaho as analogs to early and late Mars, operating under mission-like constraints.
- ***Minerva*** is our **Ops and Science Ops** software
- Testing in analog missions helps us research and develop better tools for future missions by testing them under realistic conditions like **comm latency** (5 to 15 minutes) and **bandwidth restrictions** (low bandwidth).

2. APPROACH

- Design Minerva
  - Use past field work and BASALT science program to elicit requirements and flesh-out designs
- Build Minerva
  - Bring together existing pieces, tailor or modify where we can
    - Playbook
    - Exploration Ground Data System (xGDS)
    - SEXTANT
  - Provide interfaces between tools where appropriate
  - Integrate workflows where integrating software is low priority or high effort
- Test Minerva
  - Use Minerva to plan, execute, and document BASALT field work
  - Capture utility and usability metrics, and user feedback during tests
  - Iterate over project cycle

2. APPROACH: Playbook

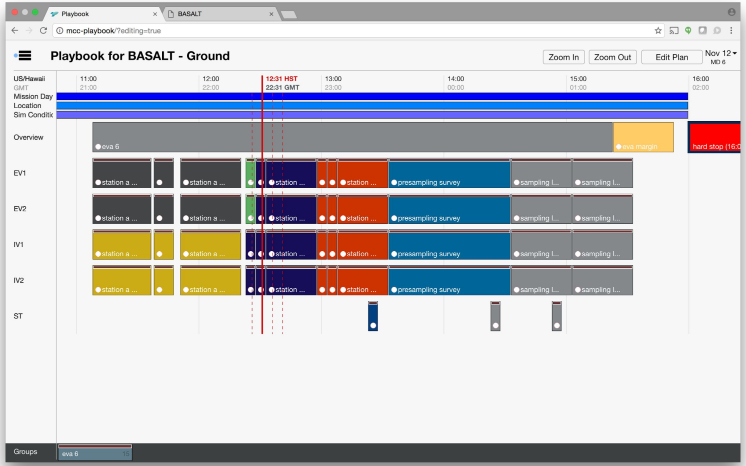
Playbook is a mobile, easy-to-use timeline software used in various analogs.

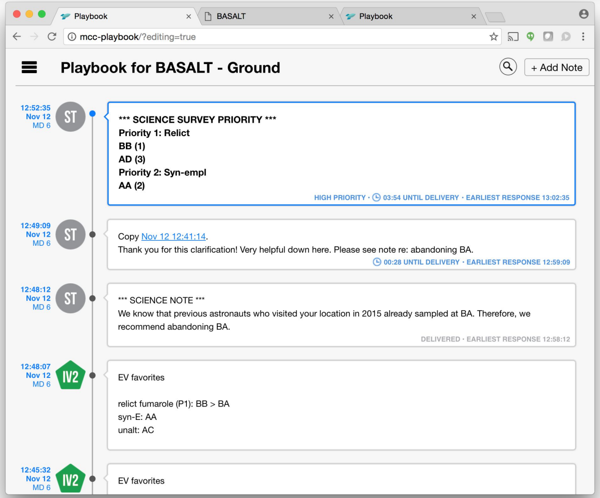
Integrated execution tool with multiple views for:

- Mission and Extravehicular Activities (EVA) timeline
- Mission Log, multimedia communication
- Centralized Procedure repository

Unique aids to support execution under time-delay:

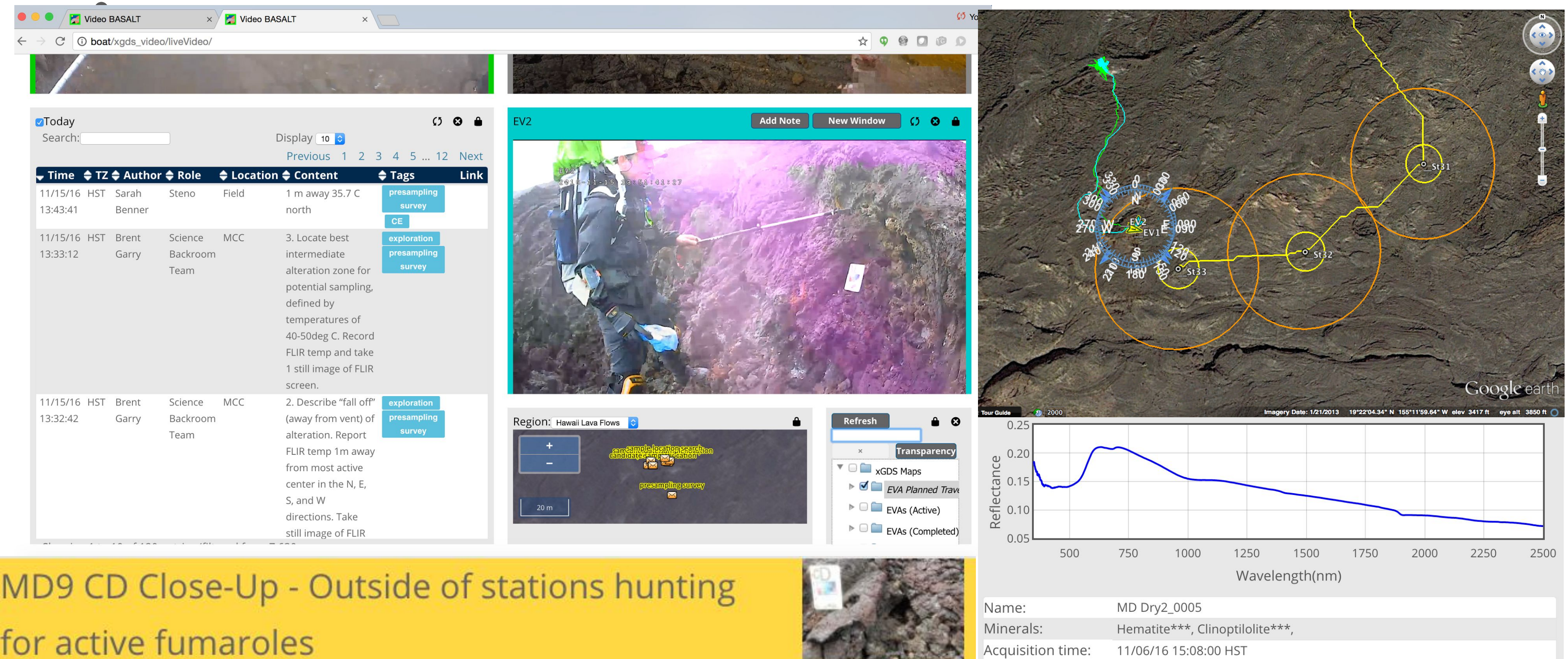
- Timers/counters, multiple off-set Marcus Bains lines





2. APPROACH: xGDS

- Supports all phases of a science deployment (planning, execution, data collection & analysis).
- Provides tools and interfaces for **rapid science decision making** during and after operations.



2. APPROACH: SEXTANT

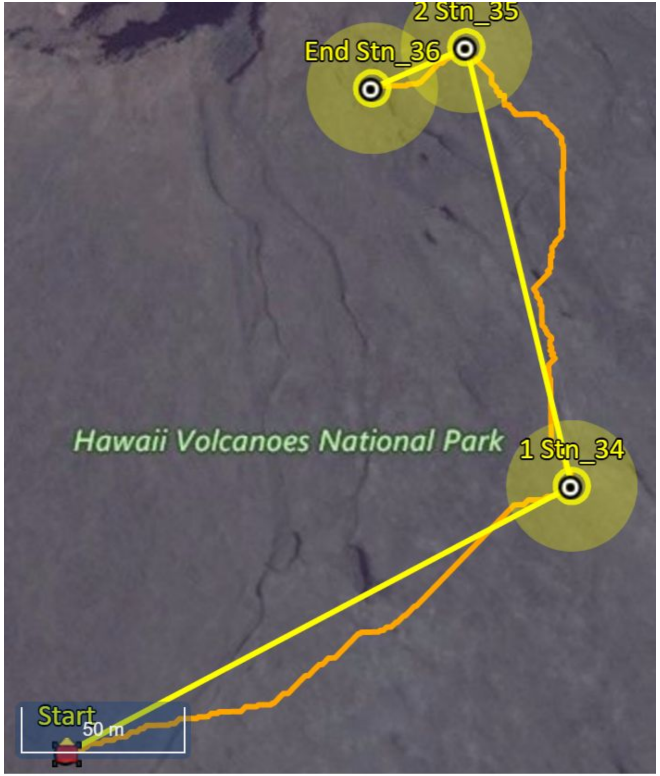
Optimizes human traverses through several science stations.

Key advantages:

- Automated planning, no manual resources invested
- Speed of planning allows for life-replanning due to change in plans during operation

SEXTANT includes three key parts:

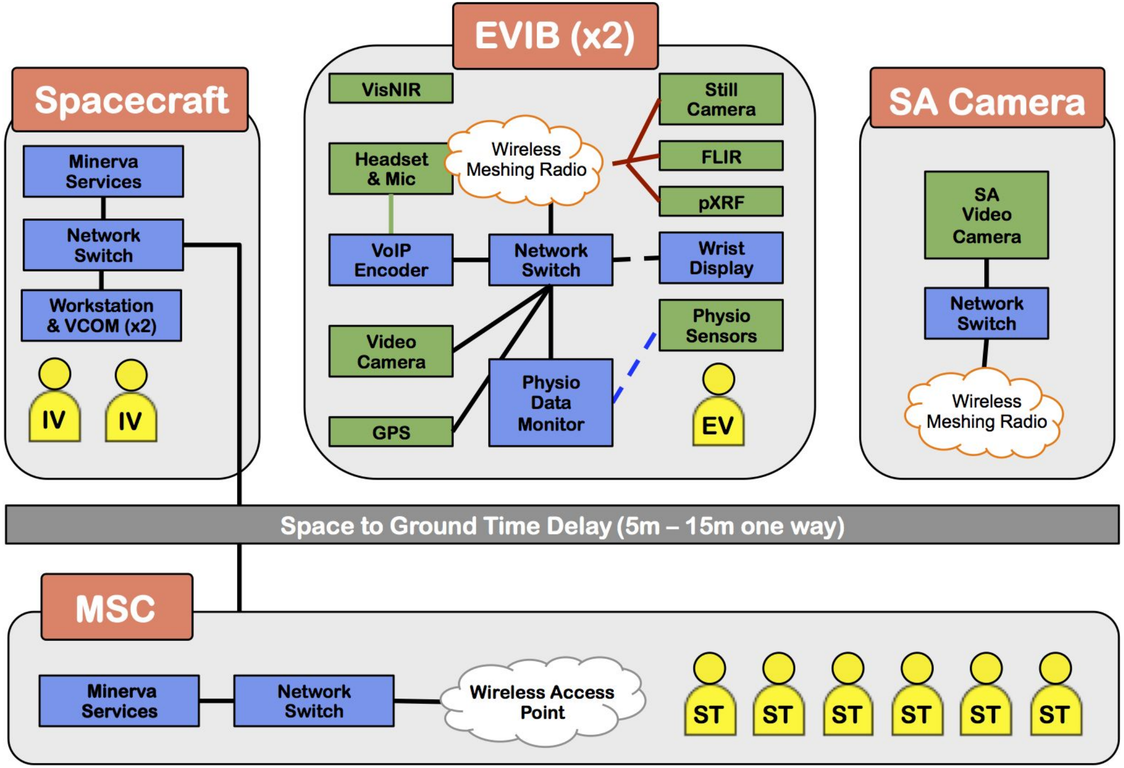
- Data elevation model(DEM) of the environment
- A cost function selected by the user:
  - Metabolic energy consumption, based on empirical data, distance, and time
- An optimizer/search function



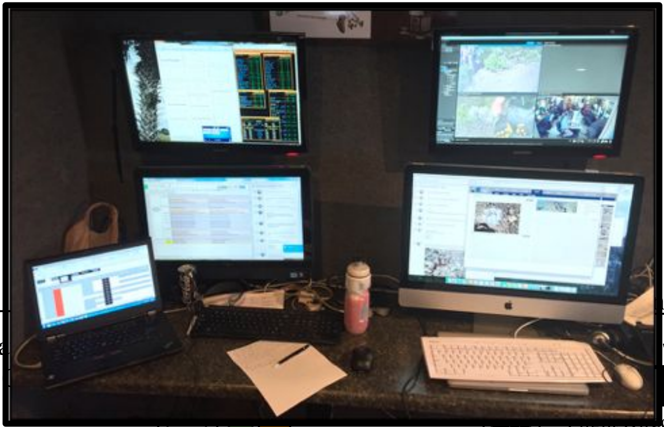
2. APPROACH: Integration and Workflow

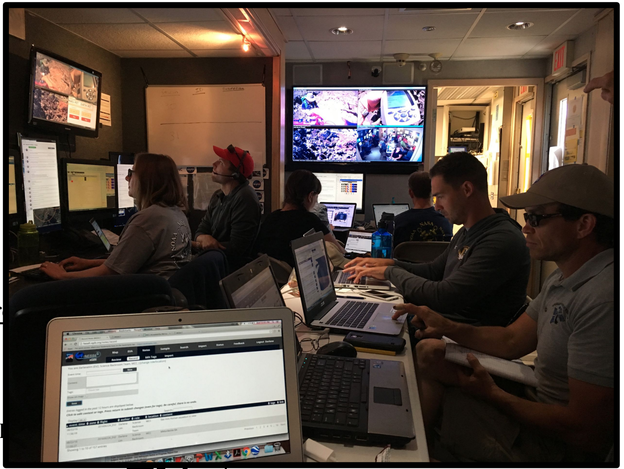
Example: EVA Plans

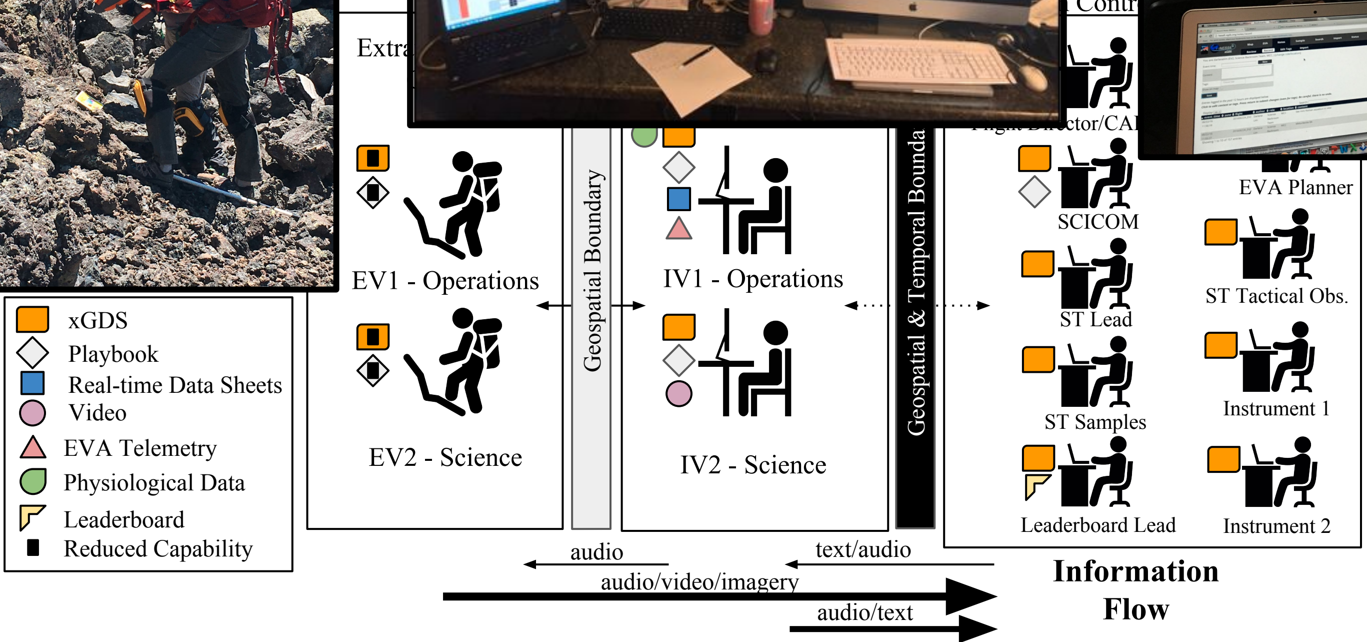
- Scientists edit and review plans in xGDS
- xGDS invokes SEXTANT to optimize routes
- Planned Traverses are exported from xGDS into Playbook as a timeline



3. BASALT-1 CoTM Field Testing







4. RESULTS

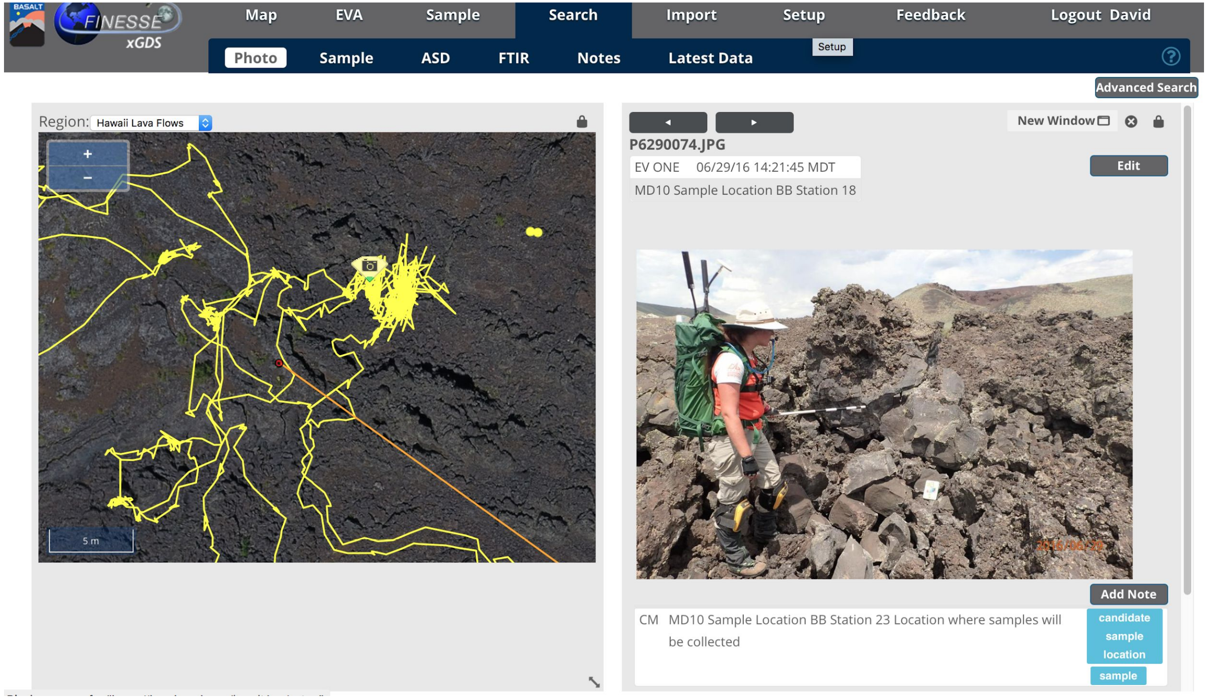
- Playbook preliminary evaluation
- xGDS preliminary evaluation
- SEXTANT preliminary evaluation
- Lessons learned

4. RESULTS: Playbook Evaluation

- When Science Team gets busy, they need a **quick way of catching up**.
  - Positive integration with Science Team to use Playbook for tracking EVA activity progress.
- Science Team and IVs **chat a lot**. Playbook's Mission Log essential for text and image communication.
  - More aids are still warranted to improve communications.
- Integrated EVA timeline tracking between IVs and Science Team should **minimize miscommunications**.

Emergent use case: show image from Science Team to EVs through Playbook's Mission Log.

4. RESULTS: xGDS Evaluation

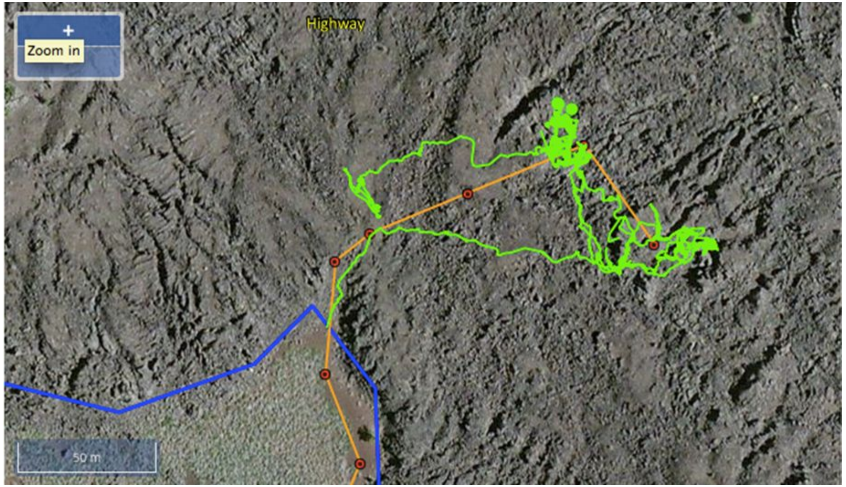


- Putting EVA data and tracks in context helps understanding
- Traverse planning and data sharing

Need to improve:

- Tailor UI by user's role
- Deliver real-time updates
- Search and tagging
- Timeline Integration

4. RESULTS: SEXTANT Evaluation



Poor plan(manual) forced the EV crew to spend a lot of time finding their way

Good plan(manual) allowed the crew to spend more time doing science and exploration

Manual plans have the risk of failing, SEXTANT ensures an optimal route clear of obstacles

4. RESULTS: Lessons Learned

1. We should improve the integration of timeline monitoring and tracking between IVs and Science Team, and between Minerva tools.
2. We should continue providing aids that will enhance high rate text communication exchanges over time-delay.
3. We should provide better methods to help scientists create traverse path routes.

Hawai'i 2016 deployment successfully tested some of these improvements.

5. FUTURE WORK

- Increased SEXTANT + xGDS integration
  - More feedback, faster performance, dynamic displays
  - Improve support for mixed-initiative planning by human and path planning algorithm
- Increased Playbook + xGDS integration
  - Better coupling between timelines and plans
  - Pre-mission and during mission
  - Tracking activity status and capturing statistics on planned vs. actual execution
- Improve situation awareness through “push” updates to IV & Science displays and notifications.
- Improve semantic tagging and search for post-mission data analysis.

- Additional field testing
  - BASALT field deployment in Hawai’i in November 2016 & 2017

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