Breakout 2: "Surface" topic group … (initial summary)

QUESTION: If you put humans & robots in "proximity", what does that enable (in terms of supporting surface science)?

(Implicit) Assumptions

- 1 to 4 human operators **in orbit**
  - If goal is surface science, then presumably **at least 1** will be a scientist…
- Robot **on/above planetary surface**
  - Planetary rover(s) (with manipulators & tools)
  - Remotely piloted/supervised drone(s)
  - note: surface robot may NOT be MER-like.. robot may be high-powered and thus can move quickly, can carry more, etc

robot might have simple rad-hard computing with high-performance processing off-loaded to orbiter via high-bandwidth link

- Robot activities support **planetary surface (field) science**
- Science is not "just done" by proximity telepresence/robotics ops
  - Humans in orbit / robot on surface is only part of a larger social structure (i.e., Earth mission operations, science team, etc)
  - Scientific inquiry is a larger (and longer) process
  - Telepresence **will likely only improve part** of (science) exploration

e.g., tactical ops for data collection

Breakout 2: “Surface” topic group membership

Chair: Terry Fong (NASA Ames)

Andre Schiele (ESA)

Leila Takayama (Willow Garage)

Dave Akin (Univ Maryland)

Jonathan Bohren (Johns Hopkins)

Steve Ellis (NASA Ames)

Dov Adelstein (NASA Ames)

Hans Thomas (Monterey Bay Aquarium Research Institute)

David Mittman (Jet Propulsion Laboratory)

Proximity enables …

Lower comm latency

- Bilateral force-reflection (due to low latency)
- Force/haptic user interfaces

High comm bandwidth

Potentially do processing on orbiter and return results to robot

- Collect more data (more GB logged)
- More sensor data (downlink **all** of the data we want to get from MER)
- Use new sensors (that have very high data volumes)

Better comm quality of service

- Less jitter, more link availability, less loss of signal
- Can operate continuously (commanding and/or monitoring) unlike Earth-based ops

Collect "more" (and better?) stuff

- Bring more/better kgs of samples to humans (on-orbit triage)
- Transfer more/better electronic data (due to higher bandwidth)
- Q: how much of this will you be able to bring back to Earth?

Proximity enables …

"Flexicution"

- Enabled by lower-latency, high-bandwidth
- Real-time **"data collection"** decision making
  - Retargeting/fine-tuning of passive sensors data (imagers, etc.)
  - Down-selection of samples to collect
- **Continuous & flexible operations**
  - Instead of (or supplement to) planned command sequence cycle
- Address **seredipitious** discoveries
  - Re-task to target dynamic phenomena (Mars dust devils)
  - Interrupt plan to focus on something unexpected (Apollo 17 Shorty Crater)

More frequent command cycles (requires skilled operator and/or scientist in orbit)

Additional options for failure recovery

- Human-in-the-loop for contingency handling (getting unstuck)
- Diagnosing what went wrong

Assumes that robot operator in orbit has skills & authority to deal with contingencies (contrast with large team that worked to diagnose Spirit loss)

Negatives

(very) small science team

- Oceanography research cruise can have large science team on-board & off-board, but in Mars orbit may only have **1-2 scientist astronauts**

Does not increase speed of overall science

- Speeding up data collection likely **will not speed up** the rest of the scientific process
- Still need to do (re)planning, analysis, interpretation
- A two-week research cruise will often collect data that takes more than a year to process and analyze (to first order)

Cannot operate indefinitely

- Cannot ask astronauts to "just stay in orbit for another year…" (nominal Mars mission may only last 30-60 days)
- Finite consumables, fixed return windows
- Will not be able to run an extended, multi-year mission (e.g., MER) **with humans in orbit** that is able to take advantage of long-duration interpretation for (re)planning

but could switch to MER style (Earth supervisory control) ops afterwards…

Technical gaps

A few areas that need development and testing…
with proximity in mind

NASA Robotics, Telerobotics & Autonomy Roadmap (TA04)

4.1 Sensing and Perception

4.2 Mobility

4.3 Manipulation

4.4 Human-Systems Integration

4.5 Autonomy

Comments

Kip: we should challenge the notion that you need a (large) backroom… lots of single PI / small groups doing very good science on Earth… The Beagle just had Darwin

Red: should think about "persistence"… can it be achieved? What does it require?

Technology Findings

Robotics, Telerobotics & Autonomy Roadmap (TA04)

4.1 Sensing and Perception

4.2 Mobility

4.3 Manipulation

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Technology Findings

Sensing and Perception

- **High-data volume sensors** might provide nearby operators with better **situation awareness** (SA) and **better information** for real-time decision making (for robot operations or science observations)
- Tactile sensing (and display) **does not** require low-latency or high bandwidth

Improving SA should be the goal, not just the sense of "Presence". This does not imply that low-latency or high-bandwidth are necessary or sufficient…

Technology Findings

Mobility

- **Human-equivalent mobility** (speed, agility, etc.) would help robots to be moved around in real-time "like a field scientist"
- **Super-human mobility** (e.g., flying) would allow robots to be used to provide real-time access to different perspectives, scales, etc.

But may require more processing & automation for safe/productive movement; or high operator proficiency (for manual control)

Technology Findings

Manipulation

- **Bilateral force-reflection** would enable humans to feel (force, torque, tactile) objects in the remote environment (this requires low-latency, if not high-bandwidth)
- **Grasp planning** in unstructured environments highly benefits from direct teleoperation (in terms of execution time)

Need to identify which planetary surface science activities require grasping or dexterous manipulation (vs. coring, drilling, RAT'ing, etc)

Technology Findings

Human-Systems Integration

- A system that supports **multiple modes of control** could be operated by humans in proximity (when they are in orbit) and by human teams on Earth (like MER)... after humans leave orbit
  - Proximity: direct rate control
  - Proximity: safeguarded teleop (shared autonomy)
  - Both: command sequencing
- **Real-time situation awareness** would help improve robot safety

Technology Findings

Autonomy

- **Higher performance computing** would enable better robot performance at all levels
- Low-level **safeguarding** is autonomy too!
- Vision processing for collision avoidance at “high-speeds” requires a good CPU

(Other) Technology Findings

- What can you put in proximity (e.g., a human orbital habitat) so that you **do not have to put it on the robot**?
  - **“SneakerNet in the sky”** (data cache to return to Earth)
  - **On-orbit power** (beamed to robot)
  - **Non rad-hard supercomputer** in orbit (simple robot CPU)
- **Terrestrial telerobotic science operations** can provide best practices for operations (organizational structure, flow of control, decision making processs) that might be relevant
  - The field **science must be real** (not simulated)
  - ROV used for science on an oceanographic research cruise

Technology Findings

- High-fidelity analog missions with authetic science that test a range of **operational concepts** and **telerobot control modes** would provide insight into the efficacy of these concepts and modes
  - Test different robot sensors
  - Test different human-robot team configurations
  - Test different operational tempo
  - Test different communication parameters
  - Science has to be real, or you will learn the **wrong** lessons

This would be best done by a **combination** of OCT (technology), SMD (science), and HEOMD (mission ops & crew). Would also be highly useful to involve relevant non-NASA practitioners (oceanographers, special ops teams, etc.) that use “similar” ops concepts