Space Telerobotics Symposium at GSFC

Breakout-1: Science etc.

First* Impressions

May 3, 2012 (AM)

Refined May 15/27

(notes from Jim Garvin and Noah Petro)

CONTEXT

- Rich discussion by a group of ~ 20 colleagues in the Science Breakout
- Disciplines well represented include:
  - Field Geology
  - Field Engineering
  - Limited Astrophysics
  - Partial Earth Science
  - No heliophysics (except RVondrak)
  - Strong Mars, Moon, and field Earth, but limited outer planets (and only 2 Small bodies experts)
  - Some systems engineering/technology (general)

- Strong opinions voiced on many key issues
  - Many devolve into Capabilities required (what can we have)
  - Limitations of current knowledge about what field telepresence can be (lack of Earth experience to quantify)

First Impressions from Brainstorming

- Field science is an immersive process which is refined here on Earth:
  - *Limited practice of robotic telepresence in Earth context (at least in field geosciences)*

- Examples of problems where low latency telepresence MAY be enabling can be described:
  - *Includes case for volatiles on the Moon (and their access), lunar farside astrophysical/geophysical network/observatory (i.e., microwave), and Mars biogeochemical sampling (and others)*

First Impressions

- New Science can be enabled via telepresence at places that are:
  - Distant (e.g., Mars)
  - Hostile to human presence (25K lunar PSRs , surface of Venus, surface of Titan, surface of Mercury etc.)

- Telepresence can be used to efficiently enable lunar farside observatories, large space structures (construction and emplacement and operation of much larger facilities)

- Need to consider *Science Readiness Level* (SRL) together with TRL in telepresence discussions

Examples *(not exhaustive)*

- Sampling lunar PSR volatiles (25K environments) using real-time telepresence to enable highest priority Planetary DS science (volatile sources, sinks, transport)

- Adaptive science operations on Mars surface for highly-informed sampling and decision making (supports enhanced MSR):
  - Selected Outcrop Exhumation (SEO)
  - Tele-Visional Telepresence ➔ *Situational awareness*

- Larger than JWST observatories in new locations (libration points)

Observation

- Telepresence involves at least 2 factors:
  - Latency (robotic object to nearest controlling human)
  - Bandwidth (for enhanced sensory information)
    - A critical enabling factor (function of distance and assets for communications)

- Not clear that low latency telepresence is always optimal in science problems:
  - But it can be enabling far beyond current capabilities

Observation-2

- Scientists actively must be engaged in technology development of capabilities (*Science pull*) – the more science is involved early the better the tools for science

- **Next Steps**:
  - Periodic face to face workshops
  - Intermediate virtual workshops– target-specific (location specific): use NLSI approach
  - Field human-robotic interactions for science with multiple latencies (multi-scale observations) at analogue sites and small mission test-beds (even on ISS)

OBSERVATIONS/Suggestions (near term)

- Learn from non-NASA *state of the art* what technologies and capabilities are useful (UAV's and telemedicine, deep sea exploration)
- Learn from MER and MSL experience what increased telepresence (LLT) is germane or useful (or how so) to in planetary field science
- Hindsight learning from past (Lunakhod) is worthwhile as well as from Earth (ocean, airborne)

NEXT

- Engage full group in continuing discussions of science enabled by different flavors of Telepresence (LLT, SLT, HLT)
- Identify science examples requiring further study from scientific expertise present
- Prepare consensus set of top level findings and observations
- Iterate initial ideas to secure best results

Breakout-1 V2

some EXAMPLES

Summary findings
and Next Steps

May 3, 2012 (PM)

Small Bodies (SB)

- NEO Telescopic Survey with intervention on the basis of discoveries:
  - Robotic survey with event detection
  - Earth intervention to interrupt
  - Options for deployable “search craft”
  - Human on ground (High latency telepresence)
  - NO reqt on low latency
  - Humans required to break modes to decide on adaptive redeployment

Small Bodies cont'd

- EM-L2 station:
  - Deploy to NEO's discovered for sampling and return
  - Integrates human proximal operations at EML2 with the robots at nearby NEO's
  - Reusable deployable NEO explorer to visit newly discovered
  - Samples cached and analyzed at L2
  - EML2 waypoint laboratory

SB-3

- NEO collision mitigation test
  - Practice diverting a NEO
  - Need telepresence for targeting the impactor, etc.

- Proximal human mission to NEO for low latency operations (safety and science):
  - Complexity of operations of knowing we have a sample (and related issues)
  - Using on site human triage to optimize sample mass to Earth (Planetary Protection factors)

MOON

- Sample collection of polar ices (PSR's) with low latency sampling decision making:
  - Could be part of EML2 architecture with crew at EML2 for ops
  - Could be human on surface controlling sampling in PSR
  - Rationale is safety of assets (people or robots)
  - Humans could be on Earth if Earth visibility of target
  - Realtime observation of cryo samples (as they react)

  - **GENERAL**: huge scientific benefit for rapid sample analysis and reduce env transitions (reduce time lag between analysis and sealing)

MOON, cont'd

- Operation of robotic telepresence in areas hazardous to humans
  - Mare pits, escarpments, fresh craters…
  - CRITICAL ISSUE for SPA basin – rugged terrain to maintain robotic (rover) as resource
- Low Latency Telerobotics will open up all SPA Basin for better sampling:
  - Improved access to better samples
  - QUESTION: lower and lower latency to tolerate a less capable robot (even expendable)? More than one???

MOON

- Low latency telepresence for advanced EDL
  - In the loop control to guide EDL
- Robotic assistants (with Earth control) working with crew on the ground (of the Moon)
  - Robotic scout
  - Crew could be EML2 as well controlling
  - MOON and MARS have parallelisms depending on operator position (greater value of low latency)

MOON

- Farside Observatories (and robotic construction of them)
  - Value of EML2 over on Earth for farside implementation (Latency and bandwidth): uniquely RF-quiet
  - EML2 may be data richer
  - Opportunities for piggyback experiments (GRB detection)

  - Lunar Geophysical Network (LGN):
    - 10 km arrays as lay out for Radio Astronomy to interrogate with interior (and co-locate for Radio Astronomy)
    - Control from EML2 to operate

    - ISSUE: put relay or put telepresence from EML2

  - If motive to send humans then lots of collatoral benefits

MOON/MARS

- Cliffbots from surface for Moon and Mars… and other requiring local telepresence for access (up and down in gravity well)

- PUBLIC impatience and appetite in latency – participatory exploration (commercial?)

Mars

- Example: One or two rovers on surface with both visual tools to allow LL comm and operation from on-orbit crew, and also limited set of instruments on rovers for reconnaissance and capabilities of sending selected samples to on orbit HAB for Lab analysis (recon for sample context and selection: SOE)
  - Two rovers is productivity amplifier – repair each other
  - If Perchlorates are abundant – could be resource for human crew on On Orbit craft (ISRU)
  - Probably work in tandem on project (cooperative)
  - Two entities working on science with low latency control
  - On orbit Hab LAB: engineers and scientists critical
  - Possible value of extracting constituent for resources (storage and experimentation)

MARS

- *Special Region* exploration requires higher fidelity science activities but precludes human access – require low latency robotics to address
  - Need Categ. V facility on SPACECRAFT???

Phobos and Deimos

- Human on orbit lab would benefit analysis of Phobos and Deimos samples?
  - Is this different from Humans nearby at any NEO

Mars-Sun L_n points

- Teleoperate robots on Mars from 1.5E6 km for low latency telepresence (SLT)
  - Needs consideration for Mars examples
  - Mars Example: Polar regions (SR's) for low latency telerobotics with crew on orbit or in libration points (Mars-Sun L_n)
  - *Special regions* – disposable telerobots?

Venus

- Short surface lifetime
- Local decision making
- Network of multiple telerobotics with local communication among them and onto crew on orbit (swarm idea)
  - Large robot can communicate with small ones
  - Low latency between robotics but not have to be between them and crew???
  - Expendable robots to do recon and then deploy larger systems down to get most science return

Outer planets

- There are other targets where low latency robotic exploration for science makes sense including Mercury and Titan (Enceladus?)

CROSSCUTTING factors/issues

- As reduce latency is there a natural breakpoint where increase complexity of tasks gives increase in potential of sci value?
  - For Moon: if it is seconds, do from Earth, but if fractional seconds do from orbit or EML2
- Where does telepresence make a difference:
  - When humans there – augmented reality on surface before the people get there (not doing for first time)

Crosscutting

- Field geologists (2) in field vs role of robust back room (social network) where communications (large cadre)… rely on capabilities of limited #
  - Understand tradespace…
  - Robotic assistant with you brings backroom with you instead of social aspects of backroom

SUMMARY

- Don’t know what doing yet, but think it will be important! No traceability to DECADALS, yet
  - Need programs of activities of milestones for technology and science
  - Understand near term questions
  - Need Investment Strategy

NOTE

- Participatory Exploration assumes low latency (deeper topic)
- Public engagement and education
- Commercial activities that could grow if public thought they could explore (themselves)
- Protein-Folding game – super-challenge and how to fold … gamer figured it out! If we had info for Mars or the Moon … to create virtual presence
  - CITIZEN SCIENCE active program (Moon is part)
  - Create way for public participate to do own via virtual entity via telepresence

NEXT STEPS(2)

- What are the key questions about low latency telepresence that must be answered
- Future workshops:
  - Face to face (topical)
  - Virtual workshops (ala NLSI) : workshops without walls
  - Focus on specific targets/destinations etc.
- Room for inputs from attendees to impact development of white paper (and beyond)
- To determine value need a decision matrix with cost/ benefit for the science that we have suggested (more work to be done)

OTHER

- Technologies that are needed to enable the science via low latency telerobotics
  - *Must be captured in near term to make progress*

  - Q: what are consequences of <u>not</u> doing this?
    - <u>One answer</u>: if people go to planetary surface and not do this then LOWER SCIENCE YIELD (and higher risk)
    - Add value for future human surface exploration for low latency telepresence to get ready (better science)

Noah Petro's Secy Notes

- **Main Take Away's from morning (May 3) session:**
  - -We need more practice with low-latency robotics in conducting field science, and in human-robotic interactions ("We need to learn how to use these tools."). (Kip)
  - -Need to understand the situational awareness "we" have in the field, and how robotics can enhance that.
  - -Need to better understand the interplay between control time and reaction time, faster doesn't necessarily mean better as humans may need time to process, and plan operations.
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- -What is the pace of decision making in the field, how is "field-work done" (Jake would have thoughts on this). High latency missions lead to bigger teams that use all the time they have to make choices. (What is the decision tree a geologist uses in the field?)
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- -What delays efficiency in the field? What are the place where robotics would make key decisions easier/faster?
- -What are the levels of telepresence that are needed for future operations?
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- **Need to define *Science Readiness Level*. [SRL]**
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- Can we find multiple uses for stable "outposts" (i.e., EM L1,L2).
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- ---Scientists need to be involved in the technology development from early stages.
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- **-Robotic recon is important, but having preliminary science analysis of the samples is also key.**
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- --Need to identify what has been or is being done everywhere (in all fields, medicine/undersea) and how well it maps to our issues and how much can be directly used.
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- -Lunar poles present excellent test ground for robotic sample collection, but implementation of this needs to be considered.
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- **Bandwidth is the limiting step in any analysis of telepresence, you can have the most advanced robot in the solar system, but if you can't communicate with it effectively, you aren't being efficient.**
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- What are the knowledge gaps that exist versus work that has/is being done in tele-robotics.
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- <u>Next Steps:</u>
- Hold meetings (face-to-face and virtual).

Science Breakout Attendees

- **Participants:**
  - James Bell (ASU)
    Andrew (Todd) Colangelo (Oceaneering)
    James B. Garvin (GSFC) : CHAIR
    Nadeem Ghafoor
    Nicolas Gorius
    Steven Hard
    Kip Hodges (ASU)
    Jose Hurtado (UNM)
    Dan Lester (Utx/Austin)
    Yvonne Pendleton (NASA ARC)
    Noah Petro (GSFC)
    Andrew Rivkin (APL)
    Livio Tornabene
    Janet Vertesi
    Richard Vondrak (GSFC): Co-CHAIR
    Michael Wargo (HQ)
    Kelsey Young (ASU)
    Ann Parsons (GSFC)
    Kiel Davis
    Robert Fogel (HQ)
  - Jen Eigenbrode (GSFC)

- *Some others drifted in and out to listen in … (not captured)*