Human Exploration Telerobotics (HET)
Enabling Technology Development & Demonstration Program
Exploration Systems Mission Directorate

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“How do we use human-robotic partnerships to increase productivity, reduce cost, and mitigate risks?”

Objectives
- Improve the **efficiency** and **productivity** of human explorers
- Increase the return (science, engineering, etc.) of human missions
- Identify **requirements**, **benefits**, **limitations**, **costs** and **risks** of integrating advanced telerobotics into future exploration campaigns

Relevance to ETDD
- “Demonstration” project: FY11 to 13, test-driven, NPR 7120.8
- Provide focal point for integrating tools, techniques, and technology from “Foundational Domains” (HRS, ASA, etc.)
- Validate end-to-end systems that can be infused as flight experiments into future missions (NASA and international)

Disclaimer
- FY11 budget uncertainty: project scope & schedule are **not** final …
- Partnerships & collaborations are very important (especially now)
Overview*

Focus

• Robotics for human exploration (pre-cursor, assistant, & follow-up work)
• Advanced telerobotics: hardware, software, control modes, communications, & conops
• Use ISS as a testbed
  ▪ Orbit-to-Ground (OTG) experiments
  ▪ Ground-to-Orbit (GTO) experiments

FY11

• ISS crew remotely operates K10 rover (ground)
• Ground remotely operates Robonaut 2 on ISS
• Ops simulations with Centaur 2 & SPHERES

FY12

• ISS crew remotely operates multiple robots
• Ground remotely operates R2 & SPHERES on ISS

* from HET formulation plan (July 2010)
Team (Proposed)

NASA Ames Research Center
- Project management (lead)
- OTG: K10 experiment
- GTO: SPHERES experiment
- Science data systems

Jet Propulsion Laboratory
- Middleware (RAPID)
- Robot User Interfaces
- OTG: ATHLETE experiment

NASA Glenn Research Center
- Data communications (space)

NASA Johnson Space Center
- Project management (deputy)
- GTO: Robonaut 2 experiment
- OTG: Centaur 2 experiment
- Mission operations

NASA Kennedy Space Center
- Data communications (field)
Technical Objectives*

- Remotely operate robots to support human exploration
  - Different types: dexterous manipulators, free-flyers, planetary rovers
  - Different modes of control: time-delay mitigated, supervisory, interactive
    - Different conops: crew-centric, crew/ground shared, ground-centric
- Quantify benefits & limitations
- Demonstrate heterogeneous robots collaborating with human teams
- Implement large-scale participatory exploration
- Evaluate productivity, workload, safety, costs and performance
- Mature dexterous & human-safe robotics for use in space
- Conduct high-fidelity experiments involving ISS
- Develop approach to infuse prototype systems into missions

* from HET formulation plan (July 2010)
Approach*

Test-driven Project
- Rigorous experimental plan
- Quantitative metrics & data
- Scientific peer & board reviews

Orbit to Ground
- Crew operates surface robot from flight vehicle
- NEO’s, Phobos-to-Mars
- Tasks: instrument platform, mobile manipulator, field work

Ground to Orbit
- Ground operates robot on flight vehicle
- Off-load routine & tedious work from crew to ground control
- Tasks: basic maintenance, inventory, payload experiment support

* from HET formulation plan (July 2010)
Candidate OTG Experiments*

Key Questions
- When is it worthwhile for astronauts to remotely operate surface robots from a flight vehicle during a human exploration mission?
- Under what operational conditions and scenarios is it advantageous for crew to control a robot from orbit, rather than a ground control team on Earth?

“Worthwhile”
- Increases human productivity
- Increases crew safety
- Reduces crew workload
- Reduces dependency on consumables
- Reduces mission risk
- Improves likelihood of mission success
- Improves science return

* from HET formulation plan (July 2010)
Candidate OTG Experiments*

Variables

• Robot configuration: form, function, autonomy, sensors, etc.
• Control mode: rate/position, interactive, supervisory, etc.
• User interface: planning, commanding, monitoring, analysis
• Comm link: bandwidth, latency, delay tolerance, QoS, etc.
• Tasks: “easy to automate” vs. “hard for a robot”
• Conops: crew-centric, crew/ground shared, ground-centric

Exploration tasks

• Mobile sensor platform (scouting, site survey, mobile camera)
• Dexterous mobile manipulation (payload deploy, sample collect)
• Field work (repetitive or long-duration tasks)
• Real-time support (contingency handling, emergency response, etc)

* from HET formulation plan (July 2010)
Candidate GTO Experiments*

Key Questions
• How can robots in space be safely and effectively remotely operated to enable more productive human exploration?
• Under what operational conditions and scenarios can robots be controlled by a ground control to improve how crew work in space?

Off-loading crew
• Tedious tasks (inventory, inspection, etc.)
• Routine tasks (in-flight maintenance)
• Repetitive tasks (science experiment manipulation)

Augmenting crew
• Force (manipulating large / bulky payloads)
• Vision (remote / mobile camera views)
• Assistant (another “set of hands”)

* from HET formulation plan (July 2010)
Candidate GTO Experiments*

Variables (same as OTG!)
- Robot configuration: form, function, autonomy, sensors, etc.
- Control mode: rate/position, interactive, supervisory, etc.
- User interface: planning, commanding, monitoring, analysis
- Comm link: bandwidth, latency, delay tolerance, QoS, etc.
- Tasks: “easy to automate” vs. “hard for a robot”
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Exploration tasks
- Equipment filter replacement
- Experiment maintenance and monitoring
- ISS inventory
- Atmospheric sampling
- Remote / mobile camera

* from HET formulation plan (July 2010)
Collaboration Opportunities

Education & Public Outreach
- Engage & inspire students (formal & informal education)
- Large-scale public participation (contribution & collaboration)

Communications
- Direct-To-Earth: more realistic NEO ops simulation
- DTN: for internetworked ops & delay tolerance
- Middleware: robotic command & control API (e.g., RAPID)

Experiments
- Share data on different approaches
- Use CSA or ESA user interfaces to operate NASA robots
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- Test sites: laboratories, outdoor testbeds, analog sites