Human Exploration Telerobotics (HET)

Enabling Technology Development & Demonstration Program
Exploration Systems Mission Directorate

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Context

"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

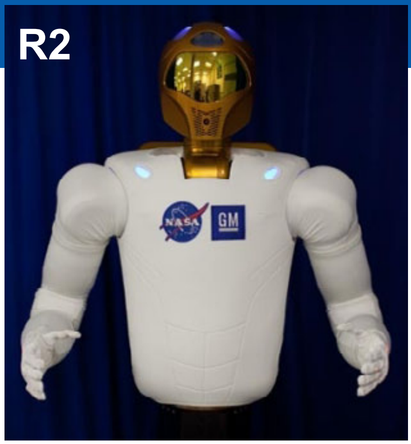
FY11

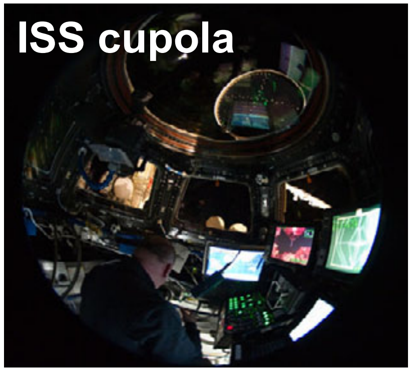
- ISS crew remotely operates K10 rover (ground)
- Ground remotely operates Robonaut 2 on ISS
- Ops simulations with Centaur 2 & SPHERES

FY12

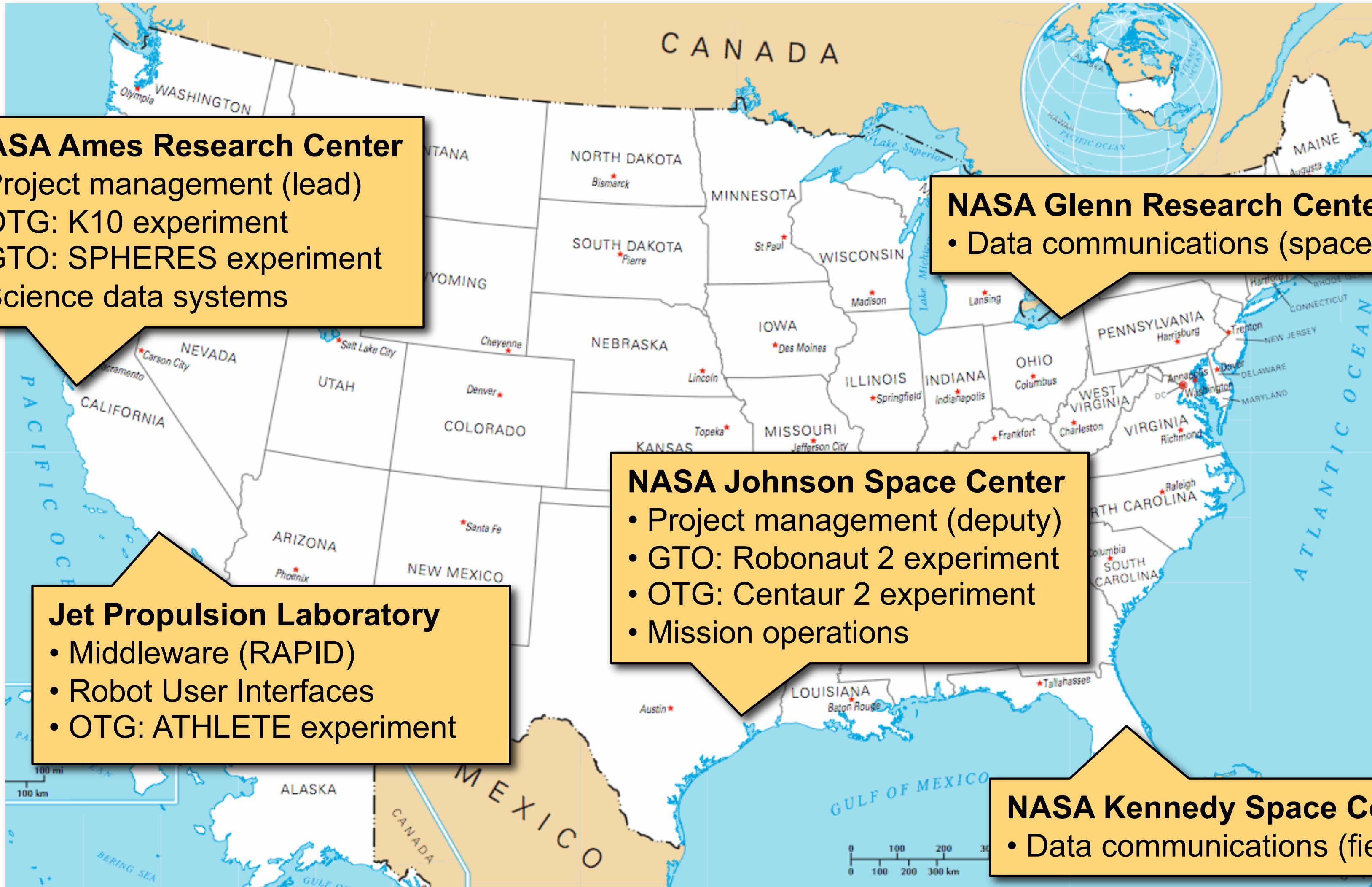
- ISS crew remotely operates multiple robots
- Ground remotely operates R2 & SPHERES on ISS

** from HET formulation plan (July 2010)*





Team (Proposed)



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

NASA Glenn Research Center
- Data communications (space)

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

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

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

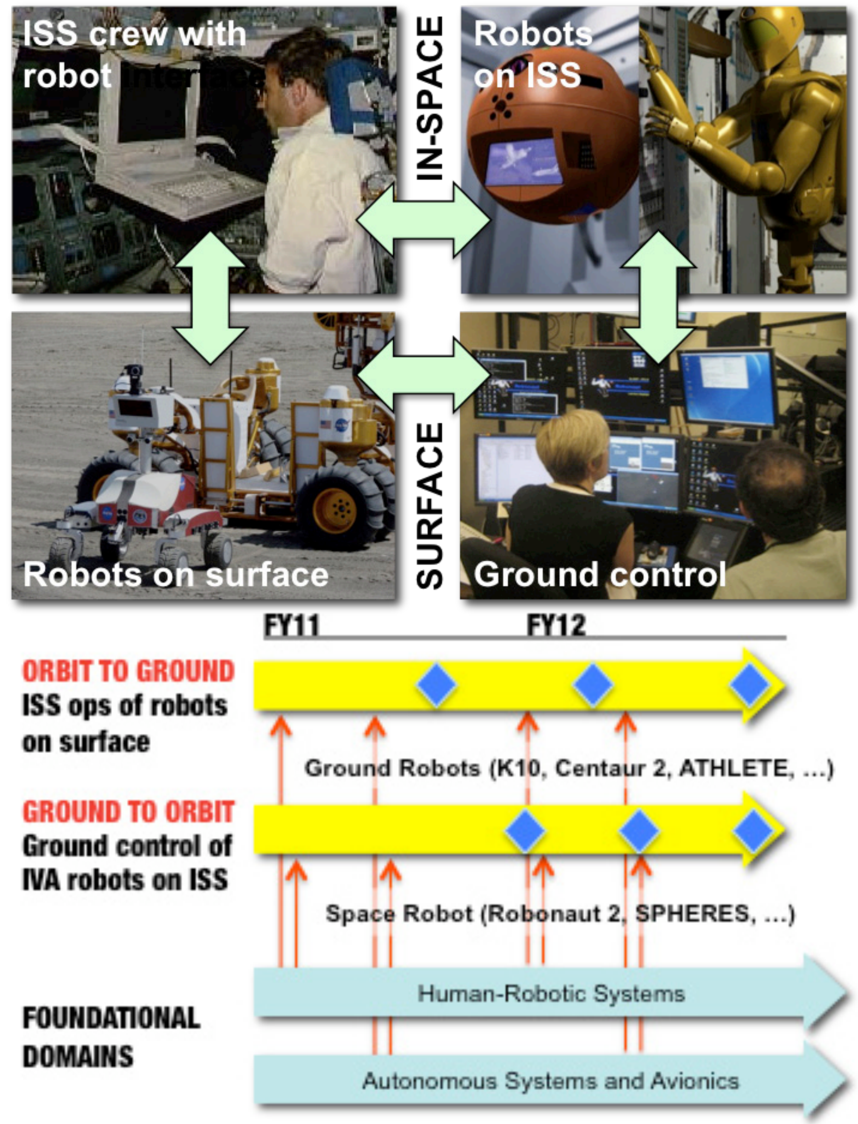
- Rigorous experimental plan
- Quantitative metrics & data
- Scientific peer & board reviews

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”
- Conops: crew-centric, crew/ground shared, ground-centric

Exploration tasks

- Equipment filter replacement
- Experiment maintenance and monitoring
- ISS inventory
- Atmospheric sampling
- Remote / mobile camera

** from HET formulation plan (July 2010)*

Collaboration Opportunties

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
- Use NASA user interfaces to operate CSA or ESA robots
- Test sites: laboratories, outdoor testbeds, analog sites