Completed Element (2012 - 2014)

Human Robotic Systems (HRS): Controlling Robots over Time Delay Element

Game Changing Development Program | Space Technology Mission Directorate (STMD)

ABSTRACT

The high level objective of the Controlling Robots Over Time Delay activity is to develop technologies that enable safe and effective control of remote robots. First, new techniques will be explored to enable remote operators to supervise multiple complex systems over near-Earth space time-delays of up to 50 seconds, while increasing the level of coordination between the robotic assets, and maintaining the safety of crew and critical systems. Secondly, a tightly integrated sensor/software system will be developed, which can rapidly capture images and depth data of the surrounding environment and construct a 360-degree 3D virtual model optimized for remote interactive display within common visualization software packages, game engines, and immersive display systems. This technology will increase remote operator situational awareness through visualization and control in an immersive environment.

ANTICIPATED BENEFITS

To NASA funded missions:

The results of the supervisor technology developments will be delivered to the Exploration Ground Data Systems (xGDS) area within HRS. The xGDS team will then deliver its software to Science Mission Directorate (SMD) funded Pavilion Lakes Research Project (PLRP) and Mojave Volatiles Prospector (MVP) project field tests, to improve the technology readiness, potentially leading to its being used for the lunar Resource Prospector (RP) ground data system.

To NASA unfunded & planned missions:

The RAPID technology will increase the safety and effectiveness for operation of cooperative robots over greater distances and longer time delays than currently possible, enabling control of robots from Earth in situations such as: onboard or outside the International Space Station; on the surface of the moon; or at an asteroid that has been moved into orbit in near-Earth space for

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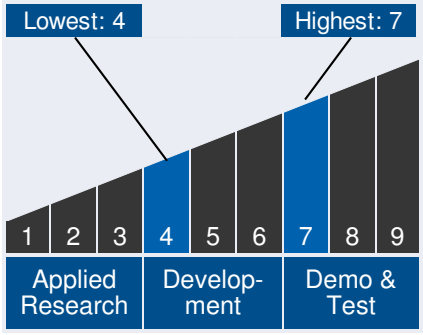
Technology Maturity



Management Team

Program Executive:

- Ryan Stephan

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Human Robotic Systems (HRS): Controlling Robots over Time Delay Element

scientific research. This software could potentially be used for the lunar Resource Prospector (RP) ground data system.

DETAILED DESCRIPTION

This element involves the development of software that enables easier commanding of a wide range of NASA relevant robots through the Robot Application Programming Interface Delegate (RAPID) robot messaging system and infusing the developed software into flight projects. In June and July of 2013, RAPID was tested on ISS as the robot messaging software for the Technology Demonstration Mission (TDM) Human Exploration Telerobotics (HET) Surface Telerobotics experiment. RAPID has also been made available to — and integrated with — the Robot Operating System (ROS), a popular software framework for developing state-of-the-art robots for ground and space. While ROS powers a number of new robots and components such as Robonaut 2's climbing legs and R5, the addition of RAPID allows these robots to interoperate in collaborative human-robot teams, safely and effectively over time-delayed communications links. The objective this year is to take this space-tested software and extend it to providing video streaming from remote robots and delivering this new capability to the Exploration Ground Data Systems (xGDS) area within HRS. xGDS will then deliver its software to Science Mission Directorate (SMD) funded field tests to improve the technology readiness moving leading (potentially) to being used for the Lunar Prospector Mission ground data systems. Success will involve delivering RAPID to xGDS and then xGDS supporting SMD field test. The team is also developing algorithms for sensors capable of reconstructing remote worlds and efficiently shipping that remote environment back to earth using the RAPID robot messaging system. This type of system could eventually lead to scientists on earth gain new insights as they are able to step into the remote world. This sensor also has the ability to engage the public, bringing remote worlds back to earth. During

Management Team *(cont.)*

Program Manager:
- Stephen Gaddis

Project Manager:
- William Bluethmann

Principal Investigator:
- Robert Ambrose

Technology Areas

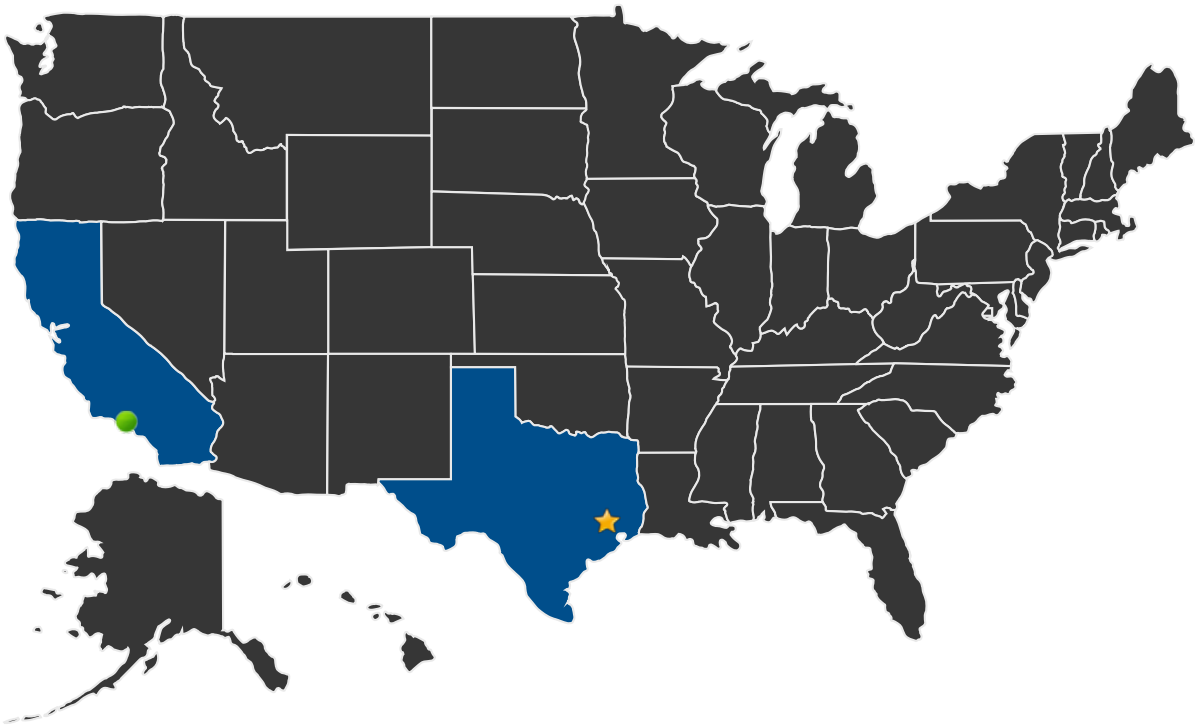
- Robotics and Autonomous Systems (TA 4)
- Robotic Architecture and Frameworks (TA 4.7.4.1)

Human Robotic Systems (HRS): Controlling Robots over Time Delay Element

Game Changing Development Program | Space Technology Mission Directorate (STMD)

FY13, this task used science operations personnel from current SMD projects to objectively measure improvement in remote science target selection and decision-making based. The team continues to work with SMD projects to ensure that the technologies being developed are directly responsive to SMD project personnel needs. The objective of this work in FY14 is to expand the range of science operations tasks addressed by the technology, and to perform laboratory demonstrations for JPL/SMD stakeholders of the immersive visualization of data from a sensor using an SMD representative environment. During 2014, the "Controlling Robots Over Time Delay" project element will develop two technologies: Develop RAPID robot messaging for unified cross-center operations platform for TDM, xGDS, and CCSDS Sensor Systems for the Construction of Immersive Virtual Environments

U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Johnson Space Center

Human Robotic Systems (HRS): Controlling Robots over Time Delay Element

Supporting Centers:

- Jet Propulsion Laboratory

DETAILS FOR TECHNOLOGY 1

Technology Title

Develop RAPID robot messaging for unified cross-center operations platform for TDM, xGDS, and CCSDS

Technology Description

This technology is categorized as complex electronics software for ground scientific research or analysis

The goal of this task is to develop and demonstrate the capabilities necessary for the safe and effective operation of cooperative robotic systems from Earth and within the near-Earth environment. New techniques for supervising multiple complex systems, increasing remote operator situational awareness, and maintaining the safety of crew and critical systems will be explored while increasing the level of coordination between the robotic assets under development within the Human Robotic Systems (HRS) Project.

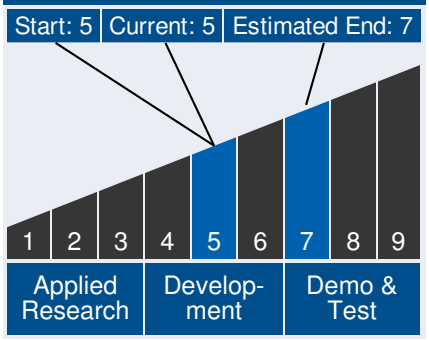
Specifically, this task will extend the *Robot Application Programming Interface Delegate* (RAPID) system of common telerobotic monitoring & control messages and services for a unified cross-center operations platform for Technology Demonstration Mission (TDM), xGDS, and the Consultative Committee for Space Data Systems (CCSDS).

In FY14, the results of the supervisor technology developments in RAPID will have a software release that will be used as part of Exploration Ground Data Systems (xGDS) in support of its mission support, including the SMD-funded Pavilion Lakes Research Project (PLRP) field testing and the SMD-funded Mojave Volatiles Prospector (MVP) project field testing. HRS will also mature this technology, providing the agency with a new

Technology Areas

Primary Technology Area:
Robotics and Autonomous Systems (TA 4)
└ Systems Engineering (TA 4.7)
└ Robot Software (TA 4.7.4)
└ Robotic Architecture and Frameworks (TA 4.7.4.1)

Technology Maturity



capability for missions that might include the AES Resource Prospector (RP) and the Asteroid Redirect Mission (ARM).

Capabilities Provided

This task will develop and tests improvements to the RAPID system of common telerobotic monitoring and control messages and services. This technology will increase the safety and effectiveness for operation of cooperative robots over greater distances and longer time delays than currently possible, enabling control of robots from Earth in situations such as: onboard or outside the International Space Station; on the surface of the moon; or at an asteroid that has been moved into orbit in near-Earth space for scientific research.

The capabilities developed this year, will focus on the following:

- Extend RAPID to incorporate video data such as H.264
- Extend the RAPID monitoring and control protocol to the operation of additional HRS robots
- New techniques for supervising multiple complex systems, increasing remote operator situational awareness, and maintaining the safety of crew and critical systems
- Increased safety and effectiveness for operation of cooperative robots over greater distances in the presence of time-delay and communications network disruption
- Continue support to NASA and robotics for RAPID integration across organizations
- An Open Source release of RAPID to support the growing community of RAPID users
- Delivery of RAPID to the xGDS team at ARC for use in field testing of the SMD-funded Pavilion Lakes Research Project (PLRP) and Mojave Volatiles Prospector (MVP) project

Potential Applications

Once matured, this technology could potentially provide:

- The ability to safely and effectively operate cooperative robotic systems from Earth and within the near-Earth environment in the presence of time-delays and communications network disruptions, which could include operation of cooperative EVA robots at the International Space Station, at an asteroid that has been moved to a safe orbit in near-Earth space, or on the surface of the Moon
- New techniques for operating cooperative robots safely in the vicinity of crew and critical systems

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- This technology will increase the safety and effectiveness for operation of cooperative robots over greater distances and longer time delays than currently possible, enabling control of robots from Earth in situations such as: onboard or outside the International Space Station; on the surface of the moon; or at an asteroid that has been moved into orbit in near-Earth space for scientific research.

DETAILS FOR TECHNOLOGY 2

Technology Title

Sensor Systems for the Construction of Immersive Virtual Environments

Technology Description

This technology is categorized as complex electronics software for ground scientific research or analysis

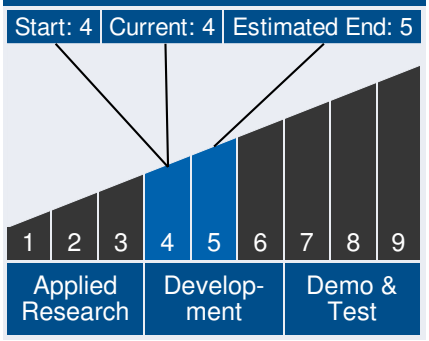
This task is developing algorithms for existing sensors that will be capable of reconstructing remote worlds and efficiently shipping that remote environment back to earth using the RAPID robot messaging system. This type of system could eventually lead to scientists on earth gaining new insights as they are able to step into the remote world. This sensor also has the ability to engage the public, bringing remote worlds back to earth. During FY13, this task used science operations personnel from current SMD projects to objectively measure improvement in remote science target selection and decision-making based. We continue to work with SMD projects to ensure that the technologies being developed are directly responsive to SMD project personnel needs. The objective of this work in FY14 is to expand the range of science operations tasks addressed by the technology, and to perform laboratory demonstrations for JPL/SMD stakeholders of the immersive visualization of data from a sensor using an SMD representative environment.

The developed system will be demonstrated to elements of SMD interested in obtaining large amounts of high-quality science data from increasingly capable robotic platforms.

Technology Areas

Primary Technology Area:
Robotics and Autonomous Systems (TA 4)
- Systems Engineering (TA 4.7)
  - Robot Software (TA 4.7.4)
    - Robotic Architecture and Frameworks (TA 4.7.4.1)

Technology Maturity



Candidate missions include Mars surface exploration, MER, MSL and the upcoming Mars 2020 missions.

The team will also engage NIAC and other advanced exploration and mission concept communities to demonstrate how the developed system can aid in understanding novel environments such as lunar lava tubes.

Capabilities Provided

This task will develop algorithms for existing sensors, which rapidly capture images and depth data of the surrounding environment and reconstruct a 360-degree 3D virtual model, optimized for remote interactive display within common visualization software packages, game engines, and immersive display systems.

The system will:

- Provide reconstruction of a broad range of environments with varied lighting conditions;
- Possess small volume, mass, and power consumption to facilitate mounting on a variety of robotic agents;
- Provide continuous integration of captured data with increasing detail over time;
- Fill in gaps in the virtual model caused by occlusions;
- Provide for continuous, low-latency update of the virtual model;
- Enable the seamless integration of multiple copies of the system in order to reconstruct larger environments;
- Include tunable degradation of virtual model quality;
- Be easily integrated with existing HRS assets via the RAPID-compliant interface.

Developed technologies will be aligned with potential SMD science operations customers, will use SMD science operations personnel as test subjects, and will document measurable improvements in science return from SMD-relevant instruments and environments.

Potential Applications

Candidate missions for this technology (a tightly integrated sensor and software systems that can rapidly capture images and depth data of the surrounding environment and reconstruct a 360-degree 3D virtual model optimized for remote interactive display within common visualization software packages, game engines, and immersive display systems) include Mars surface exploration, MER, MSL and the upcoming Mars 2020 missions.

This type of system could eventually lead to scientists on earth gaining new insights as they are able to step into the remote world.

This sensor also has the potential to engage the public, bringing remote worlds back to earth. Data sets could be explored in NASA visitor centers or science museums with 3D immersive kiosks.

It is also feasible that this technology could be modified to make it accessible to the public at large over the internet, utilizing home 3D game systems like the Kinect, allowing them to explore previously recorded data sets.

Terrestrial applications could include military use for immersive exploration of terrestrial locations via remotely located robots.