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| **Fiscal Year:** | FY 2011 | **Task Last Updated:** | FY 03/11/2011 |
| **PI Name:** | Adelstein, Bernard Ph.D. | | |
| **Project Title:** | Assessing and Mitigating the Impact of Transmission Delays on Teleoperations | | |
| **Division Name:** | Human Research | | |
| **Program/Discipline:** | HUMAN RESEARCH | | |
| **Program/Discipline--Element/Subdiscipline:** | HUMAN RESEARCH--Space Human Factors Engineering | | |
| **Joint Agency Name:** | | **TechPort:** | No |
| **Human Research Program Elements:** | (1) **SHFH**:Space Human Factors & Habitability (archival in 2017) | | |
| **Human Research Program Risks:** | (1) **HSIA**:Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture | | |
| **Space Biology Element:** | None | | |
| **Space Biology Cross-Element Discipline:** | None | | |
| **Space Biology Special Category:** | None | | |
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| **Zip Code:** | 94035-1000 | **Congressional District:** | 18 |
| **Comments:** | | | |
| **Project Type:** | Ground | **Solicitation / Funding Source:** | Directed Research |
| **Start Date:** | 10/01/2010 | **End Date:** | 09/30/2013 |
| **No. of Post Docs:** | | **No. of PhD Degrees:** | |
| **No. of PhD Candidates:** | | **No. of Master' Degrees:** | |
| **No. of Master's Candidates:** | | **No. of Bachelor's Degrees:** | |
| **No. of Bachelor's Candidates:** | | **Monitoring Center:** | NASA JSC |
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| **Flight Program:** | | | |
| **Flight Assignment:** | | | |
| **Key Personnel Changes/Previous PI:** | | | |
| **COI Name (Institution):** | Ellis, Stephen ( NASA Ames Research Center )<br>Kaiser, Mary ( NASA Ames Research Center ) | | |
| **Grant/Contract No.:** | Directed Research | | |
| **Performance Goal No.:** | | | |
| **Performance Goal Text:** | | | |
| | The objective of the Directed Research Project (DRP) titled "Assessing and Mitigating the Impact of Transmission Delays on Teleoperations" is to examine coupled human-system performance in the presence of temporally varying communication delays between the human controller(s) and remotely operated robot(s), and to propose countermeasures for delay-induced performance decrements. This DRP will be conducted in support of the NASA Enabling Technology Development and Demonstration (ETDD) Program's Human Exploration Telerobotics (HET) Project, in which ground-station operators will control robotic assets on board the International Space Station (ISS). Specifically, the DRP will concentrate on the element led by NASA ARC that is focused on ground-to-orbit control of the "Synchronized Position, Hold, Engage, and Reorient Experimental Satellites" (SPHERES) free-flying robots on the ISS.<br>The DRP will focus on the range of time delays encountered in the ground-based control of the robotic assets on ISS, | | |

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| **Task Description:** | ranging from 20-50 ms (effectively for line-of-sight communication) up to 2-10 s for multiple satellite ground-station relayed (Tracking and Data Relay Satellite System, or TDRSS, and associated ground network) communication, and, in particular, as delay instantaneously varies because of real-time changes in communication paths and data buffering. First, we will conduct human-in-the-loop (HITL) performance experiments using visual display of a dynamic simulation representative of a variety of SPHERES operations requiring different movement precision under this range of time-delay conditions. Next, we will examine HITL performance under these conditions employing mitigation techniques for short time delays such as prediction algorithms that generate compensatory in command signal lead and, for longer delays, predictive "feed-forward" graphical overlays that "look ahead" and provide a virtual view showing the future pose and location of the robot. The goal of the second of the studies is to understand the performance trades between these techniques in a wider variety of environmental and latency conditions than is usually achievable during in situ experimentation. Finally, based on these empirical HITL results, we will design and test a strategy for combining and gracefully switching between mitigation techniques as telerobot system time delays vary across the millisecond to second range.<br><br>To conduct the DRP studies, we will build our experiment testbed derived from elements of the HET ground-to-orbit SPHERES task, encompassing ground operator user interfaces as well as computer-based simulations of the SPHERES robots and ground-ISS communication links. This strategy allows us to run HITL tests that will reduce the operating environment to offer sufficient flexibility and control for human performance experiments, yet still maintain salient features of the HET tasks key for face-validity and applicability of the results. The results from our experimental studies will help define more focused and scientifically revealing experiments that could subsequently be conducted on the ISS.<br><br>The aims of the proposed work are: 1) to employ human-in-the-loop (HITL) testing to empirically investigate the impact of variable communication delays, with latencies spanning from tens of milliseconds up to approximately five seconds, on coupled human-system performance for telerobotic systems; 2) to evaluate empirically the efficacy of existing time delay compensation schemes for this range of latencies for telerobotic tasks and control modes that have different required movement precision levels; and 3) to use the data resulting from these studies to identify the trade points between latency compensation schemes as a function of time delay and required task precision and then design and test strategies for gracefully switching between mitigation techniques as telerobot system time delays vary.<br><br>The guidelines, tools, mitigation techniques and performance metrics developed from this research will help provide a rational basis for the design of teleoperation tasks to be carried out in the presence of communication delays. These products will in turn assist subsequent task, technology design, and validation experiment decisions regarding acceptable or desirable delay compensation techniques and define at what point to engage more autonomous operational modes. |
| **Rationale for HRP Directed Research:** | This research is directed because it contains highly constrained research, which requires focused and constrained data gathering and analysis that is more appropriately obtained through a non-competitive proposal. |
| **Research Impact/Earth Benefits:** | |
| **Task Progress:** | New project for FY2011. |
| **Bibliography Type:** | Description: (Last Updated: 04/13/2017) |