AN INTERDISCIPLINARY APPROACH TO HUMAN-ROBOT COOPERATION IN NEAR-TERM EXPLORATION SCENARIOS

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Introduction: Human and robotic capabilities differ, with each offering their own benefits and drawbacks. Robots are reliable and accurate, and can operate in hostile environments: all attributes well-suited for space exploration. However, when faced with new scenarios and unexpected events, robots pale in comparison with the intuition and creativity of humans. Future space exploration will have to intelligently balance the flexibility and ingenuity of humans with robust and sophisticated robotic systems.

Based on various space agency goals and the 2011 ISECG (International Space Exploration and Coordination Group) Roadmap, this paper selects an exploration objective for the timeframe between 2015 and 2035, and drafts different scenarios to accomplish this objective. Each scenario uses different degrees of human-robot interaction. The extended Cooperation of Humans and Robots Model (CHARM) is then applied to select an optimal mix of human and robotics in order to accomplish the stated objective. CHARM uses an interdisciplinary approach, including technical, scientific, political, social, financial, and legal perspectives. The results of CHARM are then further analyzed using these interdisciplinary aspects, with considerations given to the future studies outlook on future human-robot cooperation. The CHARM team believes that this decision-making model can be used to select missions efficiently and rationally, and thereby bring down both mission costs and risks, make space exploration more feasible, and make long-term space exploration sustainable.[1]

Exploration Objectives: The ISECG framework of common goals and shared objectives allows for space agencies to develop long-range exploration mission scenarios and reference missions at destinations of interest.[1] The ISECG Roadmay identifies ways of achieving the ultimate goal of human presense on Mars, using Asteroid Next and Moon Next approaches.[2]

The Moon Next approach is pushed by the need to develop the capabilities to live self-sufficiently on a planetary surface. This will entail developing capabilities for surface habitation, long-range mobility, extended operation in dusty environments, advanced surface power, robust and routine EVAs (Extra-Vehicular Activities), as well as precision landing and hazard avoidance.

Conversely, the Asteroid Next approach is to develop capabilities for extended crew missions at increased distances from the Earth. This approach will promote the development of space radiation mitigation techniques, living without a supply-chain from the Earth, as well as long-term storage and management of expendables.

For this iteration of CHARM, the focus centered around two exploration objectives from the ISECG Roadmap's common objectives.[2] These objectives were:

1. *To develop and demonstrate the capabilities needed to live self-sufficiently on a planetary surface, and*
2. *To develop and demonstrate the capabilities needed for extended crew missions at increased distances from the Earth.*

Both objectives need to occur prior to an eventual Mars mission, but inevitably only one can be pursued in the near future.

The HRC (human-robot cooperation) team chose the first objective of developing and demonstrating the technologies needed to live self-sufficiently on a planetary surface for the second iteration of CHARM. This iteration will look at a number of mission scenarios, and ultimately one will be selected which best uses both humans and robots.

Mission Development for Evaluation: Based on the first iteration of the ISECG Roadmap,[1] six design reference missions are proposed:

1. Robotic Precursor Mission
2. Crew-to-Low Lunar Orbit
3. Crew-to-Lunar Surface (7 day sortie mission)
4. Crew-to-Lunar Surface (28 day extended stay Mission)
5. Cargo-to-Lunar Surface (small)
6. Cargo-to-Lunar Surface (large)

In this paper, the Crew-to-Lunar Surface (28 day extended stay mission) is selected for effective human robotic cooperation evaluation, as successful human robot cooperation is considered to have the greatest impact on this mission in particular. The three following mission scenarios are proposed for evaluation. They are based on a literature review and cover a wide spectrum of human robotic cooperation levels. This type of evaluation is meant to be a high-level decision aid for mission design, specific design or selection is beyond the scope of this paper

Mission Scenario 1: This scenario proposes an autonomous rover to be sent on daily traverses to collect data and samples while the astronauts perform experiments in their stationary habitat. Throughout the day, the astronauts have the opportunity to monitor the performance and the quality of the samples being collected from their habitat without being exposed to many hazards directly. The autonomous rover has the capability of obstacle avoidance and path planning while the experts can always overwrite the path plan or redirect it to a new rock to collect further data. This opportunity provides a more effective and efficient method of sample return mission as the current rovers are only capable of communicating with mission control from Earth once every day during the three hour uplink.[3]

Mission Scenario 2: In this scenario, a multifunctional rover is used to assist human explorers during extra-vehicular activities. The capabilities of the Lunar Roving Vehicle (LRV) of the Apollo 15, 16 and 17 missions are used for a baseline mission structure, to which current and relevant capabilities are added, regarding moon-base exploration activities. The rover considered in this scenario would be a small, reliable utility vehicle, capable of transporting and using different scientific payloads and would be equipped with emergency life support for a crew of two. The rover could be tele-operated from both the Earth and the lunar base. Semi-autonomous capabilities would be necessary for the safety of the rover as well as for scientific investigation purposes. As an extension of its cargo ferrying capabilities, the rover could be used to position and assemble portions of the lunar habitat prior to the arrival of the astronauts or during the short stay mission.

Mission Scenario 3: In this scenario, a Human Habitat is used as a stationary base on the lunar surface. It is capable of supporting four crew members for the duration of 28 days and is designed to provide a habitat environment and medical support to crew members as well as to perform sample analysis and ISS (International Space Station)-type science in reduced gravity.[4] The mobile surface exploration is performed by a pressurized rover, with a baseline design provided by the Space Exploration Vehicle (SEV).[5] The SEV is designed to provide mobility and habitat support to two crew members for up to fourteen days for the purpose of planetary exploration, superficial soil drilling, sample return, and initial analysis. The SEV is modular, consisting of a pressurized cabin module equipped with two space suits for EVAs, and a mobile chassis module. The SEV can be docked to the stationary Human Habitat to extend the crew space. The SEV's main purpose is to allow astronauts to work and explore a planetary surface for longer durations and extend human presence at longer distances from the stationary Human Habitat base.[5]

Conclusions: These three scenarios were compared using CHARM. Using this model, Scenario 2 was selected as having the optimal degree of human-robot cooperation to accomplish to Obejctive of developing and demonstrating the capabilities needed to live self-sufficiently on a planetary surface. This was based off of the aspects of Science, Life Science, Technical, Economic, Social, and Politics for each mission scenario.

CHARM is an interdisciplinary decision-making model to select optimal degrees for human-robotic cooperation for space exploration objectives. This iteration looked at the Moon Next approach from the ISECG 2011 Roadmap, and applied CHARM to the Crew-to-Lunar Surface - 28-day Extended Stay Mission, which is set to occur in the mid to late 2020s.

References:

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