Teleoperating Attachment for the Canadarm3 Design and Technical Report

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Abstract

Regarding the Artemis mission and need for extravehicular activities to assemble the Lunar Gateway station, this report examines the design of a proposed teleoperating robotic arm attachment that allows for flexible mobility comparable to human hands. The proposed innovation offers a unique opportunity to remove the need for human manned EVAs by allowing the operating astronaut to perform the same repair tasks from inside the station. The robotic arm itself is designed to mimic the human hand in order to allow the operating users’ own movements be translated into the motion of the robotic arm as well as the robotic hand. Furthermore, the report looks at the feasibility of training astronauts for the operation of the robotic device and finds the teleoperating robotic arm to be ideal in removing the need for humans by allowing seamless human control of robotic systems.

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The onset of the Artemis mission in the coming years will correspond with the largest increase in public interest towards NASA’s activities since the era of the Apollo missions. As humanity returns to the moon, the Gateway module will play an undoubtedly critical role in both supporting the mission and providing for future endeavors into deeper space as it becomes the first human outpost orbiting a separate celestial body. However, the assembly of the Lunar Gateway will inevitably see the same increase in extravehicular activities (EVAs) as those that resulted from the construction of the ISS. With the difficulty, cost, and human value of each astronaut sent to the Gateway, it thus becomes imperative that the frequency of these relatively dangerous EVAs is mitigated in order to make more tasks accomplishable without humans. With the successor to Canadarm2, Canadarm3, present on the Gateway station, opportunities arise with novel innovations to target the necessity of human-independent repairs. Utilizing a teleoperating robotic attachment on the Canadarm3 will allow for remote work to be accomplished as basic repair and maintenance tasks can be carried out while astronauts remain onboard but in full control of repair tasks.

The proposal for a new and innovative attachment to Gateway’s Canadarm3 will tackle many of the primary hurdles facing both current tools and assembly of the station. Primarily, this novel arm will prevent astronauts from needing to perform dangerous and taxing EVAs outside of the station. Intended to solve the problem of EVAs for repairs requiring humans solely for the mobility of human hands, the teleoperating nature of the robotic device will allow astronauts to retain direct and real-time human control over a robotic hand that matches the mobility of human hands. Currently on the ISS, Dexter, a complicated robotic arm with a variety of joints, is for minor repairs as well as analysis of the outer side of the ISS. However, unlike the proposed robotic attachment, Dexter cannot be used for finer repairs due to the inability to adequately mimic the hands of humans and its controllers being on the ground (<https://www.asc-csa.gc.ca/eng/iss/dextre/about.asp>). With the new proposed arm, Gateway’s Canadarm3 will have a modern attachment capable of finer movements by building on the advancements in surgical robots and prosthetics initially spun off from NASA, which in turn will allow for significant improvements in the initial construction and long-term maintenance of the station. Specifically, by replacing the need for humans to go on EVAs, this robotic arm will allow for more construction and maintenance to be done as it would eliminate the need for astronaut decompression prior to spacewalks, which takes great lengths of time. Furthermore, by being a teleoperating robotic arm, handoffs between astronauts would be much simpler, allowing for astronauts trained on certain repairs to switch immediately to control and perform repairs on their own specialization. Most critically overall, the use of a teleoperating robotic hand controlled by a user inside the Gateway overcomes the challenge of operating robotic devices for tasks with delay due to the distance traveled by communications necessary to operate the device from the ground.

In order to overcome the hurdles faces by currently deployed robotic arms, the proposed arm will utilize a variety of advanced components and systems. The larger segment of the arm shall focus on macroscale movement in the local area of a needed repair. These primary two segments will be controlled by a controller, aside from the main teleoperating controller, that is similar to those operating the Canadarm2. At the base of these larger segments are a pair of two segments representing the human upper arm and forearm. These segments are controlled by the arm sensors astronauts will have on inside the station and mimic the movements of the human arm to scale. Finally, these pairs of arms end with an assortment of digits that are controlled by gloves adorned with sensors calculating the pull of each finger. As the astronaut curls their own fingers, these sensors will recognize the force required and copy the force and positions of each digit onto the robotic hands’ fingers. Furthermore, the astronaut will also feel the force of pulling against the gloves’ elastic strings, providing a sense of the resistance encountered by the robotic hand as it holds a tool due to the ability of elasticity to operate in microgravity conditions. The operating user of the robotic hand will be able to see the motions of the robotic device due to their VR headset, which will receive updates from 360-degree cameras without the time delay that ground crews would encounter. By operating the robotic device remotely, these astronauts will be able to achieve the intended ability to make EVAs for basic tasks obsolete.

Training the operating astronauts will thus become the crucial challenge as astronauts must become comfortable with the operation of the robotic device. Initial training of the device would likely occur through computer simulations developed to recreate the robot in mockup virtual environments. These computer simulations can be modified to mimic the microgravity environment of the Gateway module, and have been shown to effectively train humans utilizing teleoperating robotics (Rochlis et al. 2001). For more in-depth practice, astronauts would effectively be able to train in the NASA’s Neutral Buoyancy Lab as a waterproof replica of the robotic arm attachment could perform under microgravity condition alongside the operating trainee, who could utilize their own waterproof teleoperating controllers. Modifying the software for mimicking operation under microgravity could also work on the physical model, although the operating user would still necessarily have to be in a microgravity environment to emulate the real feeling of controlling in microgravity. During the actual operation of the robotic device, the operating user would be well-versed as a result of these training simulations. In the Gateway, without the ability to instantaneously communicate with the coarse controller, the astronaut would begin operation by initially setting the robotic arm to the right area with the two large coarse adjustment segments or by having a fellow astronaut operate the joystick for repairs over larger areas. The operating astronaut would then be able to put on the teleoperating controller and begin the repairs by moving in their own space inside the station while visually seeing the robot through their headset. Making the process of repairs and maintenance more seamless with other intravehicular activities, astronauts using the robotic device will no longer face the hazards of EVAs and be confident through their operation with the realistic simulated training.

The Artemis mission will be a historic and monumental endeavor in human history, setting the stage for simpler missions to the moon as humanity begins to expand into the reaches of the solar system. Paving the way for travel further into deep space, the long-term maintenance of the Gateway station will become essential and necessitate the replacement of overwhelmingly unsafe EVAs. By utilizing the proposed teleoperating robotic arm attachment, this new frontier of space and future will become that much safer as astronauts no longer face arduous spacewalks and instead gain the ability to precisely and effectively perform tasks as the innovative design bridges the gap between humans and robots. With the potential for humanity’s largescale and long-term presence in space, bringing down the dangers to maximize safety will concretely build towards making science fiction a reality.

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