A Robot Factors Approach to Designing Modular Hardware. N. Melenbrink[1] and J. Werfel[1], [1]School of Engineering and Applied Sciences, Harvard University (Contact: melenbrink@seas.harvard.edu)

Introduction: For space hardware that would be needed to support a Lunar habitat, even routine maintenance tasks typically require a coordinated sequence of complex bimanual motions. Few robots are capable of the dexterity and fine motor control needed to execute such tasks. Rather than relying on highly sophisticated robots, a "robot factors" approach [1] instead promotes autonomy by designing hardware to be easily manipulable by typical robot platforms and end effectors. Here, we outline the design principles that informed the redesign of a power module, and demonstrate its operation by a 6 DoF robot arm.

AMPS: NASA's Advanced Modular Power Systems (AMPS) project seeks to standardize future space power system architectures by using a modular approach [2]. All modules conform to a standardized form factor, but provide different functions (e.g., Bi-Directional Converter, Load Switchgear Module, etc.). Removing and replacing modules is a two-handed dexterous operation (a fingernail or small screwdriver may even be required to unlock wedge-locks). Module replacement is not suited to current NASA robots.

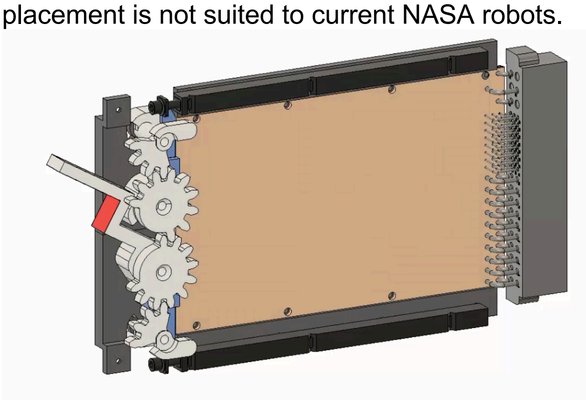

Fig. 1: The redesigned power module uses a gear assembly to coordinate different types of motion output from the single input (supplied by the robot moving a lever along a 120° stroke). For insertion, the first 90° causes the injectors to press against tabs in the chassis, mating the 47-pin connector at the rear of the module with the corresponding connector attached to the chassis. The remaining 30° engages wedge-locks that tighten against the chassis, locking the module into place. For ejection, these steps are reversed.

Robot Factors: Previous work has recognized the value of designing hardware specifically to facilitate robot manipulation, using the terms "robot factors" [1] and "robot ergonomics" [3]. However, this work has not demonstrated robotic operation or quantitative performance analysis.

Design Principles: The most important redesign feature consolidates compound motions into simple mechanisms, using a gear system (Fig. 1). The design also incorporates filleted corners and edges to enforce correct alignment of the module. While planning for robot operation, a key concern was to avoid the workspace boundaries and joint limits, where accuracy and power are reduced.

Fig. 2 shows a 6-DoF robot arm demonstrating removal and insertion of a power module (making full electrical mating between the connectors). The simple mechanical advantage afforded by the longer lever reduces the torque requirement to fall within the robot's specified range.

In future work, we expect that the "Robot Factors" approach, and a similar design, could be applied to other hardware like filtration systems.

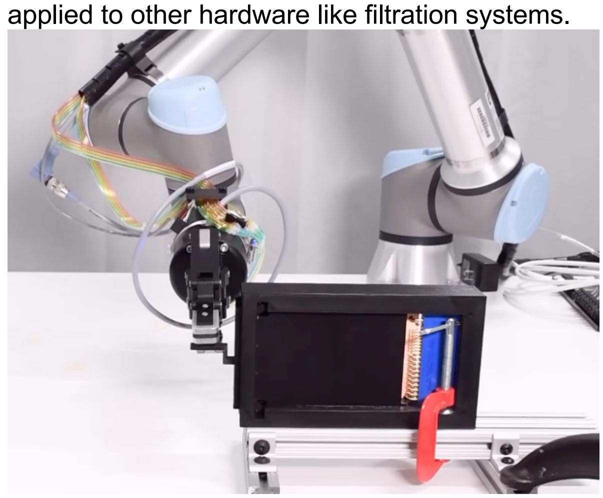

Fig. 2: A 6 DoF robot arm with a standard parallel-jaw gripper is able to autonomously insert a module, mate its connectors, and lock it into place with the simple input motion of pivoting a lever.

References:

[1] W. C. Chiou and S. A. Starks "An Introduction to the Concept of Robot Factors And Its Application to Space Station Automation", Proc. SPIE 0580, 1985.

[2] Advanced Modular Power Systems (AMPS), NASA. https://techport.nasa.gov/view/10759

[3] R. Sosa et al., "Robot Ergonomics: Towards Human-centered and Robot-inclusive Design", Proc. 15th Intl. Design Conference, 2018.