2-pager for Jenny Read

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Dreams

The research I dream to do spans design, development, and testing of space robotics (software/hardware) technologies needed to achieve assembly and maintenance of space stations with roughly tenfold capacity of the International Space Station (ISS). Larger stations can serve as fabs, labs, and habs for off-Earth semiconductor manufacturing and 3-D printed artificial hearts. The latter would cut down the donor organ waitlist but manufacturing them terrestrially is challenging as they collapse under their own weight. In- space manufacturing is one potential solution.

This work is principally in "systems research" resulting in a sum greater than its parts. It does however require the development of parts such as novel sensors for proximity and contact; novel robot designs using commercial-off-the-shelf (COTS) actuators; and innovative software interfaces for physics simulation with photo-realistic visualisation of the assembly process (see Fig. 1). A key precursor technical demonstration is a space robot capable of relocating to different points of its base satellite (Fig. 2). Both images are from an Airbus-funded study I led as a postdoc, some of which is publicly reported [1].

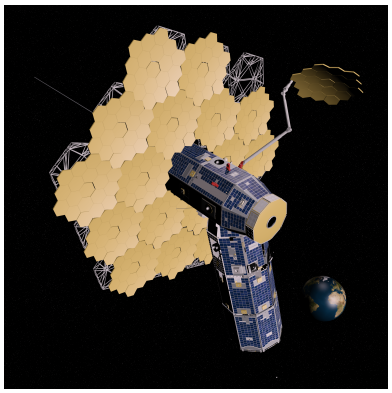

Figure 1: Grand vision to robotically assemble telescopes and space stations.

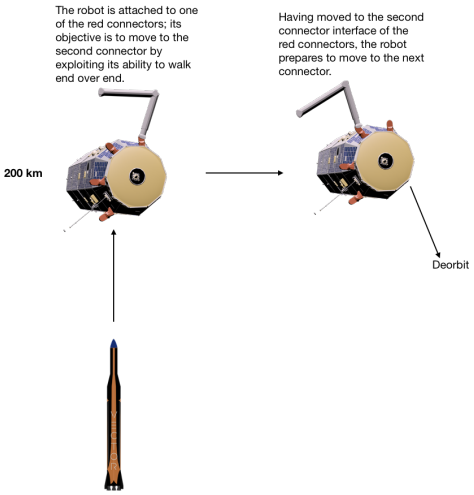

Figure 2: Conceptual mobile space robot

Wishlist (or what we would love to do in the lab)

I would love to build a ground-based version of this relocatable robot that emulates micro-gravity for space-relevant experiments. A full experimental setup (see Fig. 3 comprises 4 elements: large flat-floor (typically granite); motion tracking cameras; air-bearing space robot simulators (see Fig. 4; and external computers wirelessly communicating with one or more of the simulators.

Unlike industrial robots, one cannot buy COTS space robots for experiments. So, in July 2023, I proposed building a prototype to DSTL's space experts. They deemed it "desirable, feasible and viable enough to fund by UK defence. However, funding constraints prevented DASA from being able to fund it". Fig. 4 shows a relevant prototype at California's Naval Postgraduate School. I first proposed working on such systems in 2019 in a 5-year RAEng Research Fellowship. So it is an idea that I have been dwelling on for some time. Institutional delays and poor luck with grants have hindered progress but I have sought other mechanisms to fund this work.

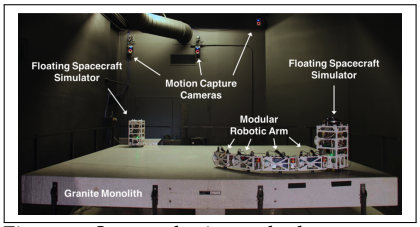

Figure 3: Space robotics testbed

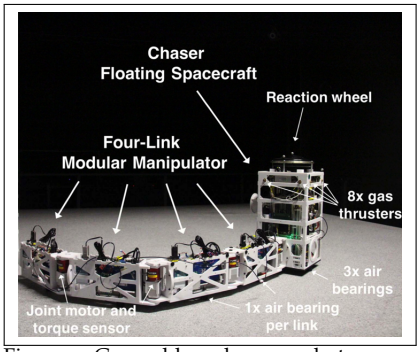

Figure 4: Ground-based space robot

YCombinator and DSIT applications to realise this research

In 2022, I applied to Y-combinator to start a space company called SpaceHQ whose goal is to robotically build and maintain 100-person space stations. In October 2023, YC informed me this was a top 5% application, which (among many other things) served as the fuel to apply for DSIT's RVC program to rethink SpaceHQ as an FRO (thank you for reading that proposal!) to develop space robotics technologies shared as public goods- ideally this will culminate in the orbital demonstration mission shown in Fig. 2.

Pointers

The space robot idea links to the beliefs of your opportunity space in that it frees human astronauts from dangerous physical labour; astronauts perform risky extravehicular activities to repair the ISS and Hubble telescope. Automating such work in dangerous environments is far less contentious than automating terrestrial human jobs. Further, these robots do not necessarily have to mimic the human body in their design- in fact, designing inflatable soft robots that are performant would be a compelling avenue of research as this would make them lower mass than an astronaut or rigid robots, which also translates to lower launch costs.

I would recommend talking to NASA JPL's Robotics Section where researchers have tackled recent DARPA manipulation challenges [2]. A recent paper on robotics simulators may be of interest [3]. I can introduce you to Abhi Jain[1], a co-author on both papers, whose lab develops multi-domain robotics simulators[2].

[1] Abhi Jain's profile

[2] DARTSLab website

Networking

Terrestrial roboticists deploy armies of cheap robot arms to collect data to learning motion controllers. Few space roboticists have even a protoype such as in Fig. 4. Terrestrial roboticists have also shown using simulators can speed up training. This approach (called sim2real) is possibly better suited to space applications, given the reliance on simulations for all aspects of research (further indicating the importance of open-source space simulators, which are also in short supply)- learned controllers could be demonstrate in testbeds such as in Fig. 3. They could be integral one in unlocking new capabilities of space robots. Being introduced to researchers who work in this area would be useful if we could collaboratively pursue research in simulator development in parallel with developing sim2real capabilities that is demonstrated on space-relevant physical testbeds such as those shown in Fig. 3.

References

[1] A. Nanjangud, C. I. Underwood, C. P. Bridges, *et al.*, "Towards robotic on-orbit assembly of large space telescopes: Mission architectures, concepts, and analyses," in *Proceedings of the IAC*, pp. 1–25.

[2] N. Hudson, J. Ma, P. Hebert, *et al.*, "Model-based autonomous system for performing dexterous, human-level manipulation tasks," *Autonomous Robots*, vol. 36, pp. 31–49, 2014.

[3] H. Choi, C. Crump, C. Duriez, *et al.*, "On the use of simulation in robotics: Opportunities, challenges, and suggestions for moving forward," *Proceedings of the National Academy of Sciences*, vol. 118, no. 1, 2021.