Design of a Robust Robot for Minimally Invasive Surgery in Space

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Introduction: In traditional laparoscopic surgery, most surgical tools are disposable and only used once. While this is feasible on earth, it is unsustainable in remote environments where tools are not readily available, in space for example. Such an extreme environment necessitates an entirely new framework for performing surgery. <u>Our objective is to enable surgery in space, through the design of a robust, reusable surgical robot platform</u>, that can be controlled remotely, easily cleaned, and easily fixed in case of failure.

Barriers to deployment: The following system requirements have been identified as barriers that must be overcome prior to deployment of robot in space:

- Compact mechanical design enabling laparoendoscopic single-site surgery (LESS)
- Compact high-quality pan/tilt vision system
- Telestration, telementoring, and telesurgery capability
- User friendly graphical user interface
- Non-destructive sterilization of electro-mechanical systems

Fig. 1. During the spring of 2014, we tested a flight-ready surgical console in microgravity on a ZeroG parabolic flight; a first step in understanding the challenges of deploying a surgical robot in space first hand.

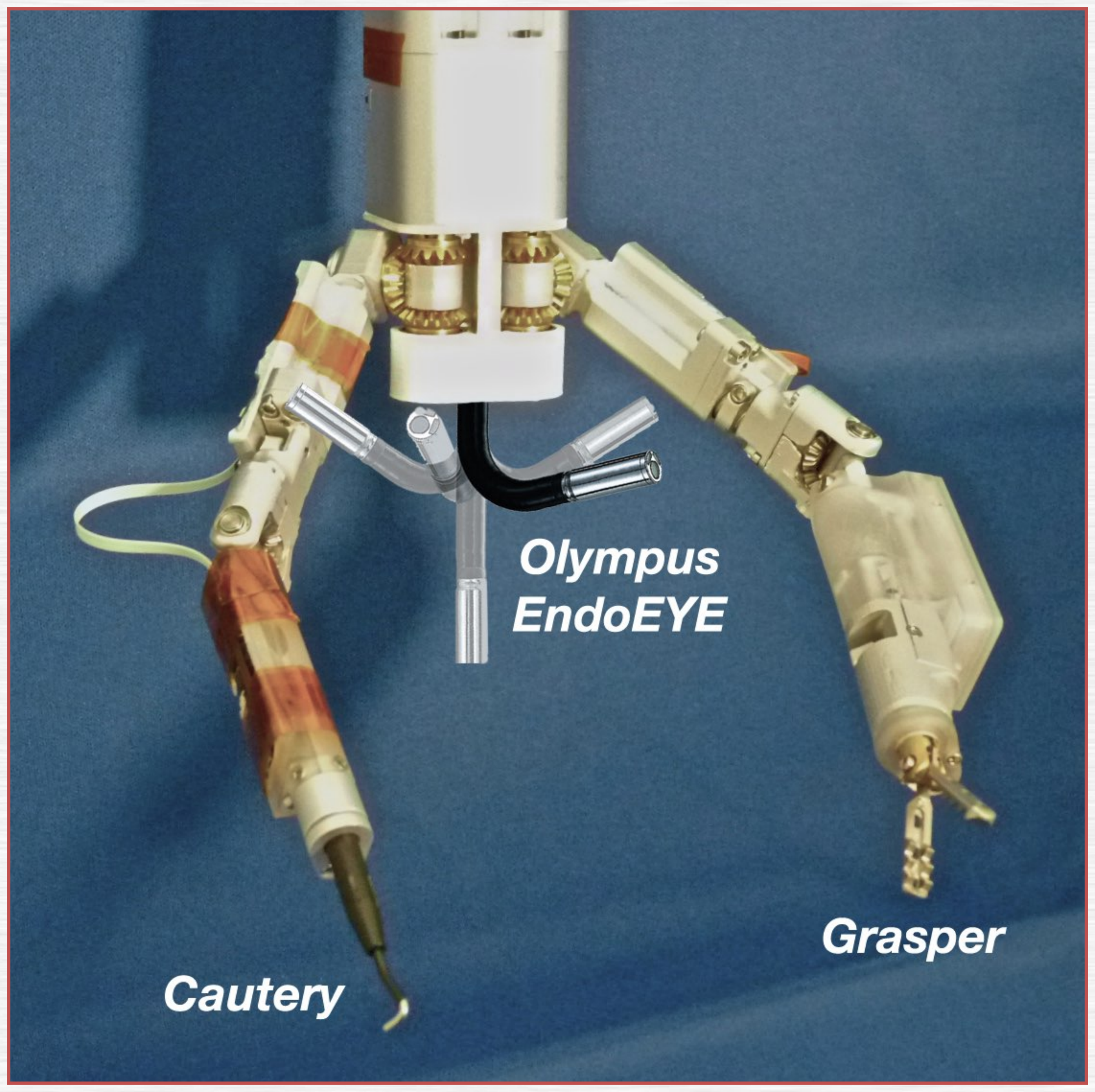

Fig. 2. Our four degree of freedom robot, with cautery, grasper, and fully actuated high definition video endoscope can fit through a 2 inch incision to perform many abdominal surgeries.

Results: We designed a robust robotic surgical platform, and demonstrated its functionality through bench-top testing. Our platform overcomes many barriers to deployment through the following features:

- Compact mechanical design includes cautery, grasper, and HD video camera, all of which fits through a 2 inch incision
- Integrated Olympus EndoEYE high definition video endoscope, with actuated pan and tilt capabilities
- Telestration system enabling shared control of robot from Phantom Omni haptic controllers at multiple locations, simultaneously
- Configurable graphical user interface, allowing plugins such as ‘foot pedal’ for joint locking, multiple haptic controllers, automatic recognition of motor control boards, and easy configuration of robot kinematics for easy implementation of future robot models
- Plug & Play distributed motor control boards are daisy-chained together down the robot. In the case of failure, an operator must connect no more than three cables to replace a faulty board

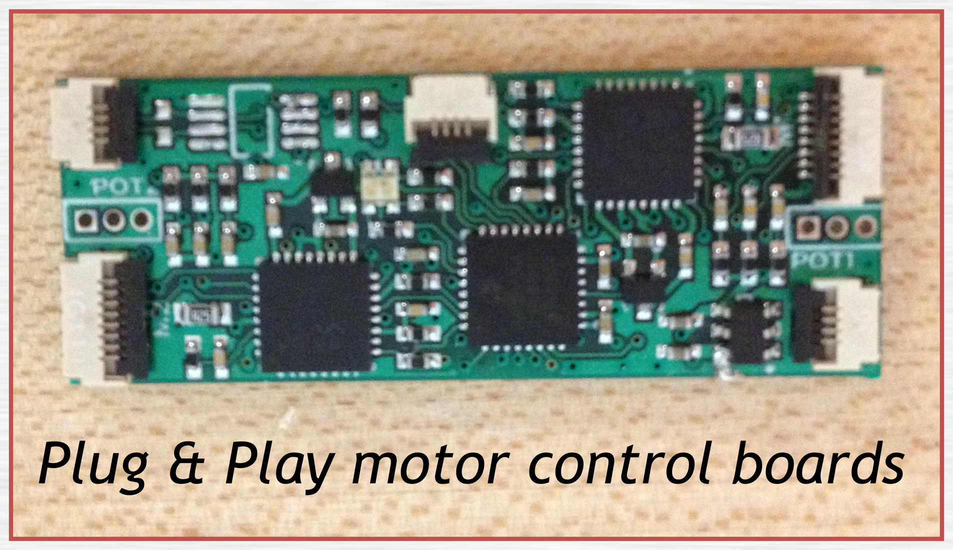

Fig. 3. We designed distributed brushless motor control boards, each with an RS485 link to allow a “daisy-chain” configuration for serial communication

Continuing development: We designed a novel multi-tool forearm prototype with suction, irrigation, and grasping capabilities (Figure 4), but we have yet to integrate it with our robot. Integration will enable true robotic-LESS through our robotic surgery platform.

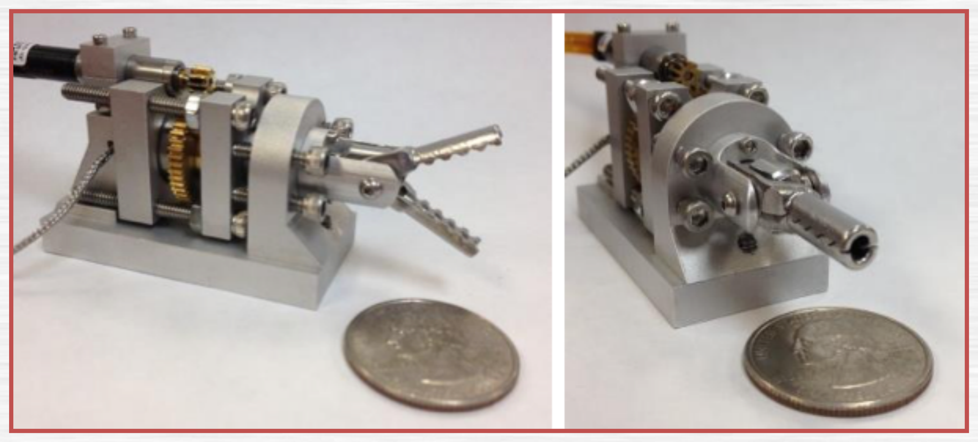

Fig. 4. Suction/ Irrigation grasper combines multiple tools into a single forearm. The grasper closes to form a tube for aspiration.

Through extensive research, we have identified many feasible methods of sterilizing our robot. Hermetically sealing our electronic components in a urethane polymer enabled limited autoclave sterilization. Vaporized Hydrogen Peroxide was used successfully on previous robots from our group. Yet, more work is required to find a method of sterilization that is best fit for a spacecraft, and repeatable for our robot.

Take-Home: Our compact and robust robotic platform paves the way for extraterrestrial telesurgery, enabling experienced surgeons on earth to assist in complicated procedures remotely, without patient relocation. Simply put, while previous versions of our robotic surgery platforms required cumbersome data acquisition hardware and outdated software, this robotic platform runs on any Windows based laptop over USB, and can be operated, repaired, and reconfigured without significant technical knowledge. Future work will focus on the optimization of a sterilization protocol, mechanical improvements to the robot, and *in vivo* testing.

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