One of the fascinating possibilities of space systems research is the development of reconfigurable, autonomous robotic networks that explore and perform science or assist human spaceflight missions in extreme environments for long durations. These robots can explore extreme planetary environments such as rugged mountains, exposed cliffs, canyons, craters and caves or set the stage for a permanent human habitat. Conventional robotics is faced by challenges in design, control and power that limit autonomy and mobility required for these missions. Conventional robot control lack the ability to autonomously improvise; perform long duration planning and team coordination in response to unexpected situations. Conventional power technologies limit energy autonomy because they have low energy densities, are inefficient, expensive or pose launch safety risks.

In this talk, I will show that a multidisciplinary approach encompassing design, networking, control and power is essential in developing robotic systems for extreme environments. To illustrate this point, I will discuss three examples from my recent work. First, I will discuss a new controls method called Artificial Neural Tissues (ANT) inspired by neurobiology that can self-organize, plan and solve difficult tasks that would otherwise require human experts. This approach shows promising applications in lunar base construction and in-situ resource utilization tasks. Second, I will show how ANT has been extended to automatically design and control elements of a network robotic system towards achieving robust performance. This method has given us new insight into effective networking, control and design of robotic systems. (cont.)

(abstract cont.) Third, using effective methods of design and control, I will present a promising new system for powering robot networks for long durations. This is using high-efficiency lithium hydride fueled Polymer Electrolyte Membrane (PEM) fuel cells with lives of 3-5 years, efficiency of 60-65 %, theoretical energy density of up to 2,000 Wh/kg in space and 5,000 Wh/kg in air respectively, translating to 15 and 40 times the energy density of lithium ion batteries. Together, these examples provide a glimpse of the exciting possibilities stemming from a multidisciplinary approach to engineering robust space systems of the future and further suggest the broad range of opportunities that become accessible by employing this method as a general design tool.

biosketch
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