A Lockheed Martin Atlas 5 lifts from Cape Canaveral on January 19, 2006 bearing the New Horizons spacecraft, which will explore Pluto and the edges of our solar system. (PAT CORKERY/LOCKHEED MARTIN)

Ever since I was 3 years old, I wanted to be an astronaut.

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SPACE EXPLORATION

Each year, we informally survey our entering undergraduate students and find the same result: half of them want to be astronauts. Most go on to develop strong interests in other exciting areas of aerospace, and to pursue other aerospace careers (although, at 34 and counting, MIT has educated more astronauts than any other private institution—only the U.S. Naval Academy has educated more). Nonetheless, our students come to us with a passion for manned space exploration, and, independent of other interests they develop, this interest stays with them. Many of our faculty members have this same interest.

Recently, NASA has refocused its attention on increasing knowledge of the Earth, Moon, and Mars. To enable the new vision, a man-rated launch vehicle, the Ares I, is being designed and built, along with a capsule-based manned spacecraft, the Orion. These systems, and others that will follow them, offer exciting and important opportunities for new contributions, particularly in the areas of space system design and architecture, avionics and software, systems safety, human-machine interaction, and autonomous system operations.

50 million miles from home, in an atmosphere devoid of oxygen, with only 20,000 kg of payload, it takes 200 days to return, and communications take 30 minutes to reach Earth.

It is hard to imagine an environment more safety critical than one where humans are put 50 million miles from home, in an atmosphere devoid of oxygen, with only 20,000 kg of payload, where it takes 200 days to return, and communications take 30 minutes to reach Earth. Conquering such an environment requires that we answer questions such as: What system designs and architectures should we consider for returning to the Moon and building a lunar outpost? How can systems be developed for lunar exploration, while being extensible to Mars? How can humans and robots work together most effectively in rugged and unknown terrain? How can spacesuits be designed to be more ergonomic, lightweight and resilient to threats such as micrometeorites and tears? How can we characterize the effects of microgravity on the human body and counteract these effects for long-term space flight?

MIT Aero-Astro has made major contributions to space exploration in the past, especially as part of the development of the Apollo guidance and navigation system during the 1960s. More recent activities include our NASA Concept Evaluation & Refinement (CE&R) study, conducted jointly with the Draper Laboratory. Eight faculty members and 25 students worked together pioneering the "Mars-back" approach—developing systems primarily for Mars as a basis for developing derivatives for the nearer term lunar missions. Other recent research for NASA headquarters has contributed innovative lunar lander

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configurations, new concepts for modular lunar habitats that have broadened the concepts being considered by NASA's Lunar Architecture Team, and revolutionary approaches to safety engineering and risk management for the space exploration mission that are being used by NASA and its contractors.

We are also leading the development of interplanetary logistics models where space exploration missions are considered as part of an interplanetary supply chain, capturing the flows of vehicles, crews, and cargo in an integrated fashion. We have used these models to understand the optimal mix of pre-positioning, carry-along and resupply flights for a lunar outpost, and to quantify the effects of system reliability, commonality, and reconfigurability on resupply needs. Novel experiments at the Haughton-Mars-Project station on Devon Island in the high Arctic have been used to test and calibrate our models. NASA has adopted our SpaceNet simulation software to reduce the time required to evaluate the feasibility and effectiveness of competing lunar campaigns to minutes, rather than the weeks or months previously required. We were first in quantitatively demonstrating that reconfigurability and commonality of orbital replacement units can save up to 30 percent in spares mass with no loss in system availability for a typical Mars design reference mission.

The department is also developing advanced electric propulsion systems where particles are charged by gas or liquid ionization and then accelerated with electromagnetic fields to velocities much greater than with conventional rockets. This has included the design and demonstration of a high efficiency 200 Watt Hall thruster. We have developed silicon liquid-bipropellant micro-rocket engines using microelectronic fabrication processes, demonstrated chip-sized thrust chambers, turbopumps, and valves, and demonstrated more than 1N thrust to date. We have extensively studied the use of these motors as the enabling technology for tiny launch vehicles (80-200kg), extending the definition of low cost access to space to encompass low cost per mission, rather than simply cost per pound. Other revolutionary technologies we

NASA

SPHERES are innovative micro-satellites designed for operations in microgravity by the MIT Space Systems Laboratory in cooperation with Payload Systems Inc. Here, astronaut Jeff Williams is performing autonomous formation flight testing aboard the International Space Station during Expedition 13 in 2006.

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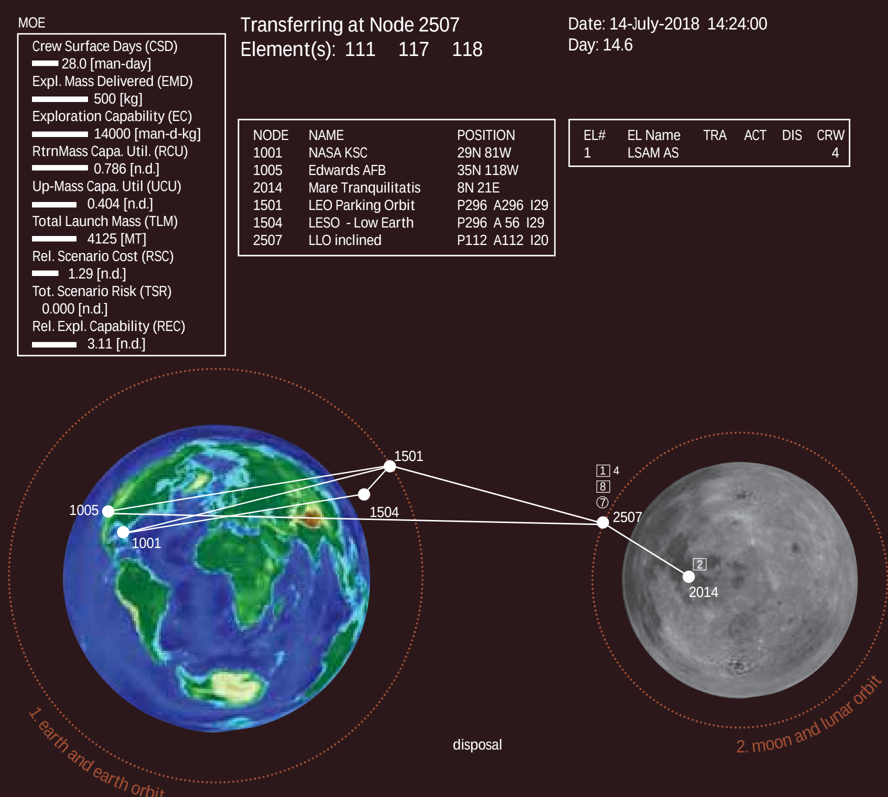

The SpaceNet 1.3 simulation software was developed by Professor Olivier de Weck and his students along with partners at JPL. This image shows a lunar exploration sortie mission in 2018, capturing the flow of vehicles, crew and cargo including the feasibility and measures of effectiveness predicted for the mission.

have invented are the Electro-Magnetic Formation Flight concept, and a revolutionary spacesuit called BioSuit that provides enhanced astronaut extravehicular activity locomotion and life support.

Despite the renewed emphasis on human explorers, robotic surface explorers and remote sensing satellites remain the primary means for gathering scientific knowledge about the Earth, Moon, Mars, and the universe. Important questions for this endeavor include how can a new generation of space telescopes be designed with aperture sizes that exceed launch vehicle payload faring dimensions and how can arrays of satellites operate collaboratively as interferometers?

To answer these questions, we have led the development of on-orbit microgravity testbeds and satellites. We recently developed guidance, navigation, and control algorithms and a software architecture for fleets of multiple spacecraft that can be used for formation flight, assembly, and docking systems. In tests onboard the International Space Station, the Aero-Astro-developed SPHERES satellite formation flight testbed has demonstrated the performance, predictability, modularity, and ease of interfacing of this architecture. In doing so, we have developed the first documented embedded software validation and verification process for multi-satellite systems, performed the first three and four vehicle precision formation flight in microgravity, performed the first on-orbit docking with a tumbling satellite, and enabled multiple researchers and partner institutions to rapidly and predictably test their component algorithms through the modularity of our architecture. Other research in this area is pushing the envelope in integrated modeling and simulation of large-aperture segmented space, air, and ground telescopes.

Future challenges in space exploration will be met only by thinking “out of the box” and going beyond traditional paradigms and well established technologies. This is one of our strengths. We will work together with our long-term partners in NASA, JPL, other universities, and industry to advance our understanding of the Earth, the Moon, Mars, our solar system, and the universe.