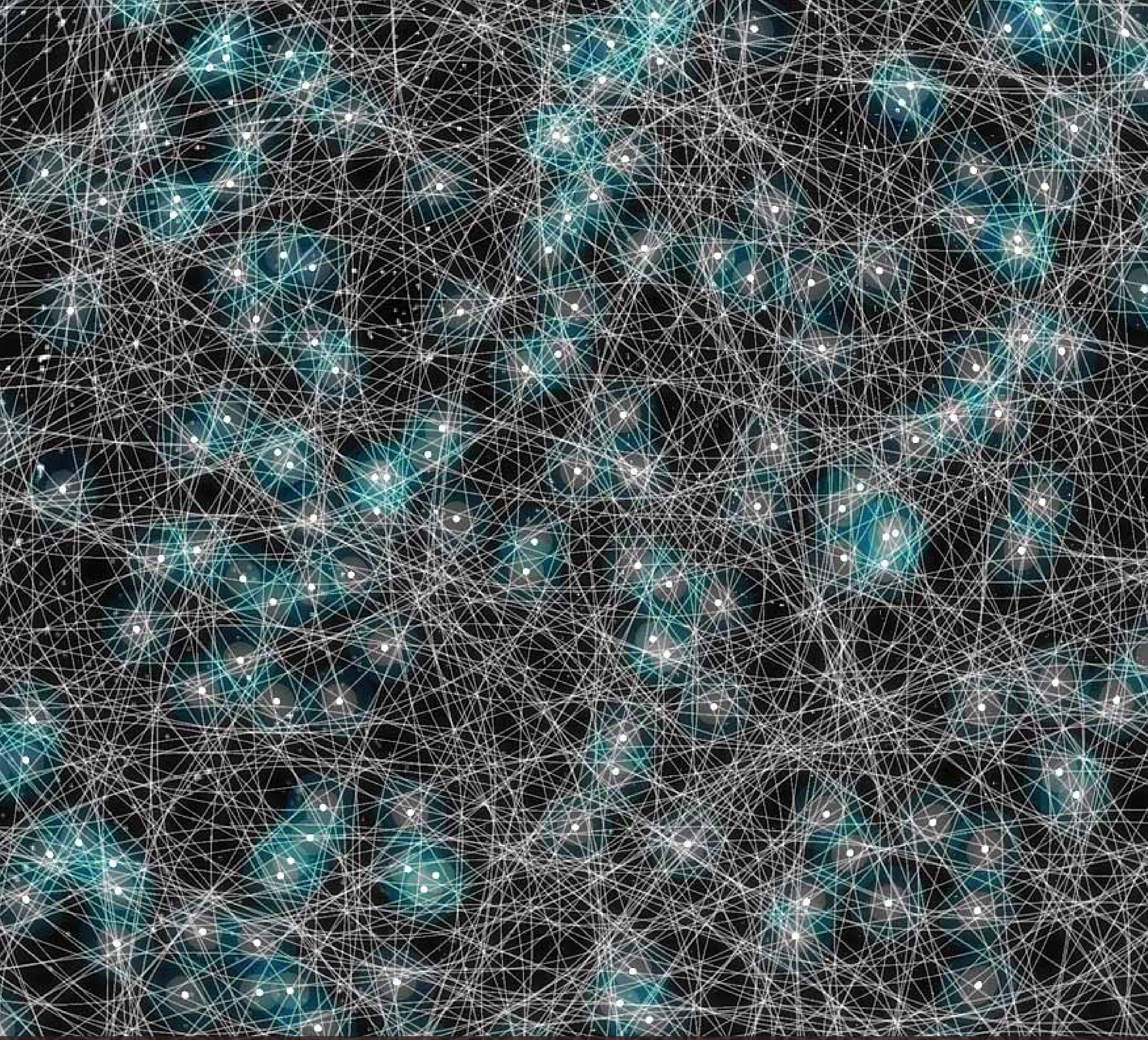


Animation still of Low Earth-Orbiting Satellites generated using 2005 Satellite Situation Report data.
(D. SCOTT HESSELS AND GABRIEL DUNNE, “CELESTIAL MECHANICS” HTTP://CMLAB.COM)

FIELDING OF LARGE-SCALE COMPLEX SYSTEMS

The aerospace industry designs, implements, and operates systems that are so complex that it is not possible for any one person to completely understand the entire system. One example is the Joint Strike Fighter, which is being developed by a geographically distributed team consisting of 8000 design engineers, half of whom are computer scientists. Another example is the NASA Constellation project, which will create a replacement for the Shuttle and conduct manned missions to the Moon and to Mars, and which is anticipated to take decades to design, implement and operate. Yet another is the new Missile Defense System, which involves integrating hundreds of separate systems, some of which have existed for decades (e.g., early warning systems) with new radar and delivery systems.

New systems may contain millions of lines of software, tens of thousands of physical components, and hundreds of subsystems of various types and technologies. Further, while flight control software failures can be just as disastrous as a broken wing spar, very different methods are required to design, evaluate, and ensure the safety of these integrated systems. In addition, it is now recognized that the technological parts of these systems cannot be divorced from the social and organizational parts; the systems must be developed and modeled as socio-technical systems, not simply technical systems.

Many aerospace systems are so complex that it is not possible for any one person to completely understand them.

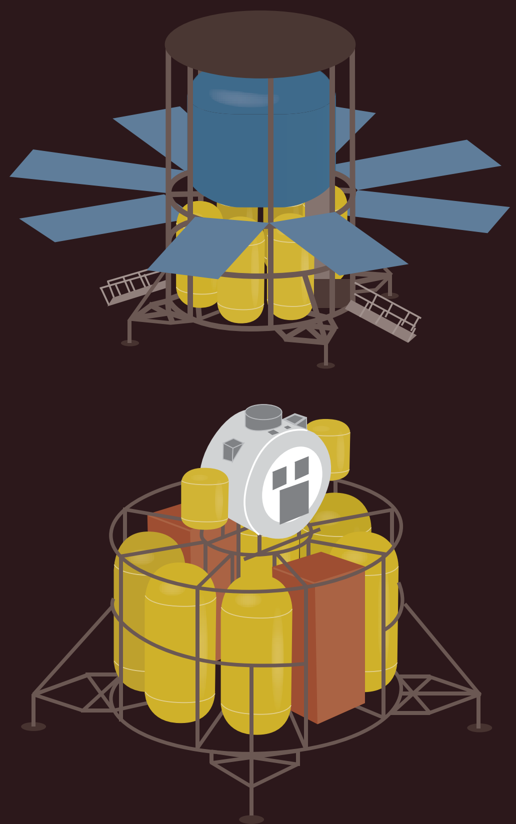
Traditional systems engineering processes, where functional requirements are contractually agreed to and frozen early, are not effective for the expensive, complex, and long-lifecycle systems described above. Because development cycles typically can take 5-10 years or longer, external factors and needs change over time, and systems are sometimes obsolete by the time they are fielded. An example is the commercial communications satellite constellations of the mid-1990s (e.g., Iridium, Globalstar) whose usage predictions were confounded by the rapid emergence of competing terrestrial wireless systems. This led to cumulative losses exceeding $5 billion and the collapse of the commercial satellite and launch industries in the late 1990s. The challenge is to develop strategic approaches to the fielding of large systems such that they can more easily evolve over time, adapting to shifting user and operator needs, emerging technologies, changing policies, and regulations. The opportunity is to maximize lifecycle value by including considerations of modularity, flexibility, commonality, and staged deployment.

07

The issues mentioned are not unique to aerospace systems, but aerospace is facing many of these problems before other industries. Our department is developing new approaches to modeling and analysis; ensuring system properties such as safety, security, reliability, flexibility, sustainability, and operability. We are also developing general risk and opportunity management techniques to understand the relationships and tradeoffs among these system properties; managing complex engineering projects; and addressing the design of systems composed of hardware, software, and humans that interact to achieve common goals.

Our department is closely involved with the new NASA manned space program to return to the Moon and send astronauts to Mars. MIT faculty and graduate students are helping to design system and software architecture. They have developed a new risk management approach to assist with program management decision making, designed tools for planning the program's logistics, and created an innovative safety engineering approach for the Space Shuttle replacement vehicle. In addition, new safety analysis tools have been used in the new U.S. Missile Defense System to evaluate the potential for inadvertent launch, resulting in identification of extra protection and changes required before the system could be deployed and tested. The Missile Defense Agency has adopted these tools as its primary approach to safety.

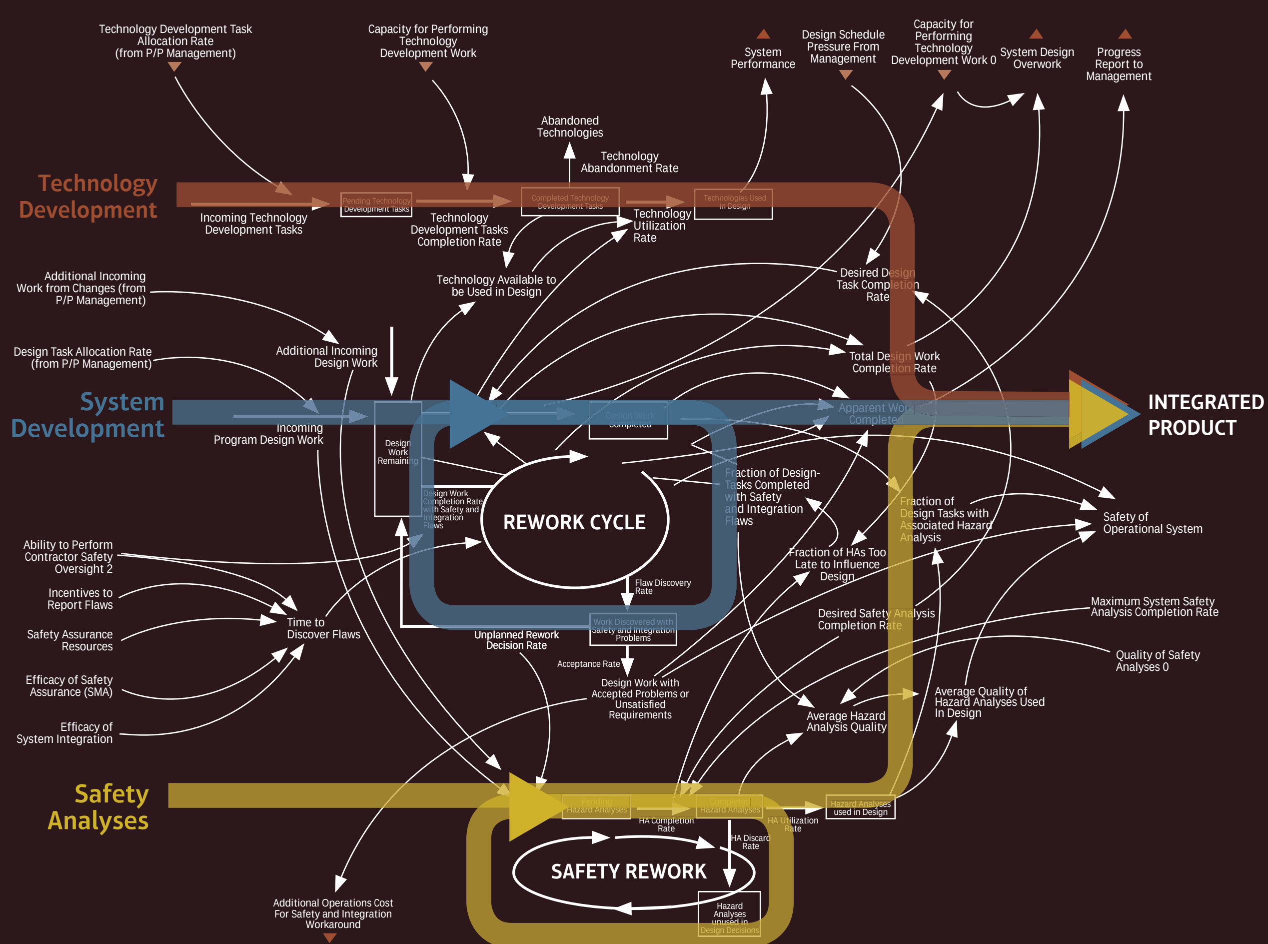
Our abilities to address these complex socio-technical systems are augmented by cross-disciplinary bridges to other departments in MIT's School of Engineering and Sloan School of Management.



Concepts for a pre-deployed lunar outpost (top) and a lunar lander developed for NASA by Aero-Astro students and faculty working with Professor Edward Crawley.

Boeing 737s travel along a new moving production line. The line enhances quality and reduces flow time and inventory levels when creating complex systems. (BOEING)

ENGINEERING - SYSTEM DEVELOPMENT COMPLETION AND SAFETY ANALYSES



A section of a systems dynamics model depicting NASA's Exploration Systems Mission Division development process. The model, constructed by Professor Nancy Leveson's Aero-Astro Complex Systems Research Lab students, will help manage risk in human spaceflight.