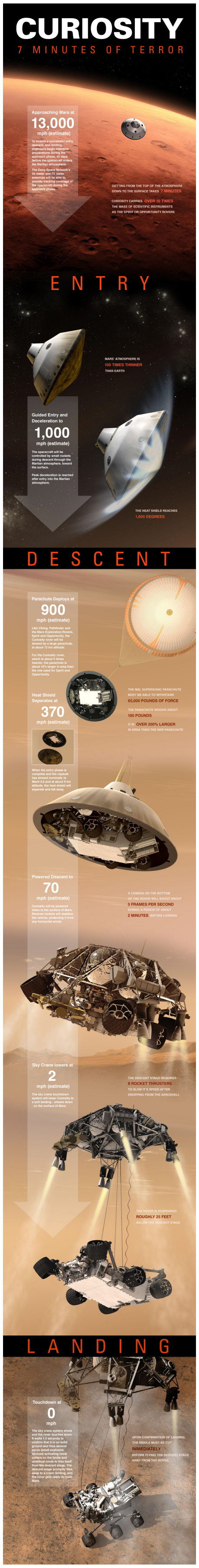


Enabling Curiosity's Safe Landing: Engineering at its Finest

In the past decade, NASA's robotic explorers have opened our eyes to the scientific beauty and dynamic complexity of our solar system. We have found intriguing evidence for water and just begun to understand the implications for life on Mars and on three outer planet moons (Europa, Titan and Enceladus). We have returned pristine samples of a comet that could hold clues to the formation of the solar system and the Earth within it. We have sent robotic spacecraft to Mercury and onward towards Pluto, exploring the extreme environments of our solar system.

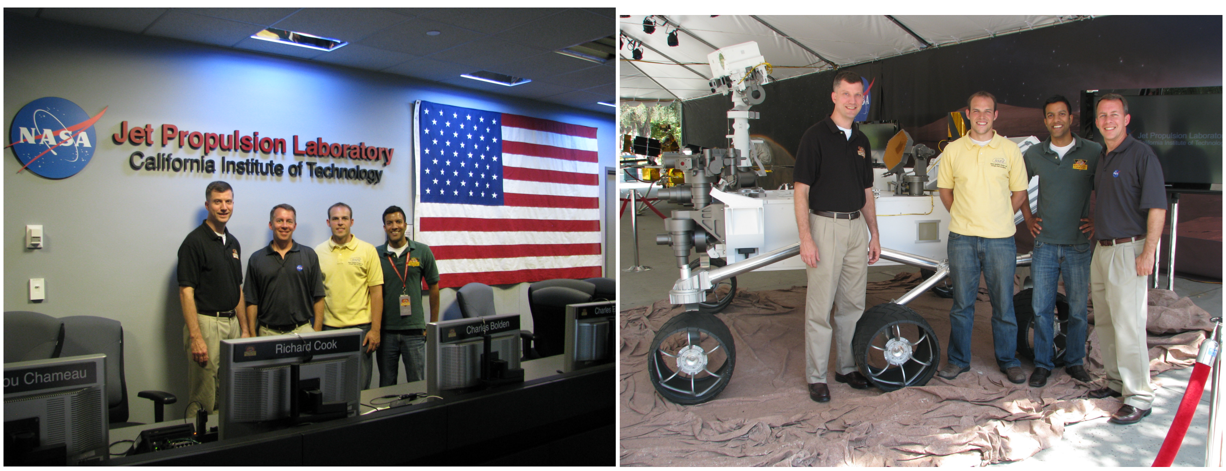
We explore the planets to expand our knowledge of the universe and determine our place within it; to determine if we are alone; to understand how the planets change over time; and to comprehend what these insights imply for all of us on the Earth. In planetary exploration, scientific knowledge is enabled through engineering innovation. While this journey consists of many steps, none of the missions of the past decade have matched the complexity and engineering drama of landing the Curiosity rover safely on the Mars surface.

In the early morning hours of August 6 (Eastern Time), the Mars Science Laboratory (MSL) reached Mars and autonomously completed a series of choreographed steps to slow and configure the Curiosity rover for landing. Each step was precisely planned and required for mission success. Each step had to proceed precisely as designed. Building on past landing missions, the MSL entry, descent and landing process was one of the most complex operations NASA had ever attempted. Adjusting its configuration multiple times as it plummeted to the Mars surface, this sequence concluded with a nuclear-powered rover, the size of a small car, loaded with advanced scientific instrumentation ready for strategic exploration of the Mars surface.

Turning seven minutes of terror into success was no small task. In fact, the fate of the most ambitious machine humans ever sent to another planet rested on an innovative entry, descent and landing (EDL) sequence more than eight years in the making. The MSL EDL system consists of the largest aeroshell ever flown, outfitted with a new thermal protection system, the largest supersonic parachute ever constructed and deployed at the highest Mach number to date, flight of a new radar system, new engines, and an entirely new mission architecture – the sky crane, to safely and precisely place a nearly 1 ton rover on the Mars surface. Controlled hypersonically by an entry guidance algorithm, MSL was also the first planetary exploration vehicle with sufficient landing accuracy and terrain tolerance to target a small region beside a mountain within the walls of a crater.

Entry, descent and landing is a systems engineer's dream. Success requires mastery of aerodynamics, aerothermodynamics, flight dynamics, structures & materials, avionics, software, sensors and propulsion. Design and optimization skills are used to integrate system requirements, assess a range of probabilistic scenarios, and develop a robust flight system and mission architecture.

Since 2003, Georgia Tech has had one of the only research groups in the country focused on entry, descent and landing. Students in this research program design, develop and test advanced EDL technologies, concepts and mission architectures, proving their feasibility and advancing their readiness for flight. These talented engineering students hone their skills at Tech before applying them in practice on flight missions. As examples, Georgia Tech alumni Devin Kipp and Ravi Prakash have been part of the MSL entry, descent and landing team since graduating in 2005 with M.S. degrees in Aerospace Engineering. In the years leading up to the Curiosity landing, Kipp focused on the parachute descent segment and interactions of the descent stage with the Mars surface. Prakash designed tests to help prove performance of the radar system and also worked to include heatshield instrumentation on this flight. Georgia Tech alumnus Dr. David Way has been part of this team since 2002, perfecting the flight dynamics simulation that predicted this systems performance in the Mars atmosphere. Alumnus Andy Etters worked more than three years on the propulsive capability for the descent stage since graduating from Georgia Tech in 2004 with a B.S. degree in Aerospace Engineering. At Tech, they built the foundation necessary for this success. Following graduation, they honed their craft through years of design, analysis and testing on this critical flight project.



Professor Bobby Braun (AE) with former Georgia Tech AE students Ravi Prakash, David Way and Devin Kipp in the Mission Control Room and with a full-scale model of the Mars Curiosity rover at the Jet Propulsion Laboratory in Pasadena, CA.

Curiosity is now poised to return new insights regarding the potential that Mars could once have harbored life – and may still. Traveling over 350 million miles in eight months, Curiosity landed just a few miles from its target. This is a destination we could only dream of exploring a few years ago. As the first flagship mission to Mars in more than 30 years, MSL will investigate a major new science pathway while laying the technological foundation for future deep space exploration missions.

Flagship missions are difficult and risky. They require one-of-a-kind spacecraft with cutting-edge technology and must overcome steep technical challenges. Not surprisingly, landing a science payload as large and sophisticated as the MSL has proven to be a complex operation. As if accomplishing this mission were not enough, the project has also advanced some of the very technologies needed by future robotic and human explorers. As one example, the MSL payload will be protected during its fiery descent by the same heat shield technology that NASA recently transferred to Space X for use in the first commercial cargo delivery flights to the International Space Station.

Landing on Mars is something I have studied and worked toward for most of my professional career. Since 2004, I served on the MSL standing review board, assisting the team as they created, built, tested and re-tested this amazing machine. While a successful landing was never ensured, the MSL EDL team earned their success through hard work, dedication and innovation. Demonstrating the value of engineering at its finest, this team showed remarkable focus, dedication and innovation in the face of tremendous challenges.

I am captivated by the MSL team's journey of human discovery. Making the impossible possible is simply what engineers do. This team epitomizes all that is right about NASA, an agency whose pursuit of bold challenges remains capable of inspiring and bringing out the best in us all. We explore, not only because of what we expect to find, but also because of what the journey will teach us about ourselves and our future. This urge to discover is woven into the very fabric of our being. This is a pursuit worthy of a great nation. Engineering makes such pursuits possible.

Robert D. Braun is the David and Andrew Lewis Professor of Space Technology in the Daniel Guggenheim School of Aerospace Engineering at the Georgia Institute of Technology. He has been a member of the mission design and flight operations teams for several spacecraft that have landed on Mars and flown throughout the solar system. He served as the NASA Chief Technologist in 2010-2011.