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Editorial

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The human in the system - a legacy of flight

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Abstract

Human spaceflight has been a key element of exploration for more than 70 years. Human presence in space and exploration of low Earth orbit and planetary sojourns are possible because of complex systems. As humans are involved in all aspects of this endeavor it is important to have constructive dialogue across diverse disciplines. This Editorial highlights the interaction between different disciplines in support of the complex systems for human spaceflight. It highlights the establishment of the University of Cincinnati's Armstrong Institute for Space, Technology and Research (ASTRO) and the efforts by faculty and students in fundamental and translational research. Space exploration has many facets and includes a wide variety of complex systems to support launch systems, human habitats, and opportunities in low Earth orbit and human health.

Keywords: Human spaceflight, complex systems, legacy, human factors, aerospace

1. INTRODUCTION

In the early part of the 20th century, the Wright Brothers of Dayton, Ohio, achieved controlled flight on the sand dunes of Kitty Hawk, North Carolina. A mere six decades later, humans would be launched into space on intercontinental ballistic missiles and walk on the lunar surface. From the Wrights to Neil Armstrong's first step on the surface of the moon on July 20, 1969, engineers, physicians, and life scientists developed

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technologies and capabilities unmatched in all of human history. This unprecedented growth was fueled by two world wars and a space race - an element of the Cold War.

After World War II, a diaspora of German scientists and engineers were brought to the United States (U.S.) in the program, Operation Paperclip, to assist the U.S. in developing its rocket program and eventually achieving human space flight. The Americans and Soviets were in a race to achieve superiority in space and to get to the moon first. At first, this was an exercise in engineering prowess with limited support for humans, who would be integrated into the various complex systems. While astronauts and cosmonauts were embedded in these systems, it was originally thought they would have little impact or utility in the operation of the spaceflight or during any mission activities - in other words, a passenger! Before the Mercury Program began, engineers did not believe that astronauts needed a window, but the astronauts and their flight surgeons fought for a window. This changed when during his Mercury flight, Virgil "Gus" Grissom observed a train entering a tunnel in China during his historic flight. Windows are a necessary element of design. Literally from the beginning of human spaceflight, engineers and physicians were often at odds. They use different terminology and approach research and design in different ways.

During my 33 years of work at NASA in support of the Chief Health and Medical Officer, we wrote a book, entitled, Engineering, Life Sciences, and Health/Medicine Strategy in Aerospace Human Systems Integration: The Rosetta Stone Project[1,2]. This publication lays out challenges that these three disciplines face when interacting with one another, especially in complex systems. When we do not include human factors and human systems integration into design, then bad things will happen. Engineers have done tremendous things throughout history. They can test things to destruction, whereas, physicians cannot do that. So, designing complex systems requires all users to be at the design table. Spacecraft to support humans have many symbiotic and complex systems that interact to enable and enhance human habitation and mission success.

Human-rated spacecraft are extremely complex as they must sustain the forces of launch, on orbit operations, long stays in space, and eventual return to the Earth. There are of course many other space-based craft that support our insatiable desire to understand our Earth and solar system. As we move forward with the emerging commercial space economy, return missions to the moon, and future human missions to Mars, it is necessary to not only understand where we have been but to innovate and research new approaches.

2. HUMAN FACTORS AND COMPLEX ENGINEERING SYSTEMS IN SPACE EXPLORATION

Since the late 1950s, only a few countries have achieved spaceflight and the integration of humans as active participants in these systems. Whether it is launching vehicles, habitats or extravehicular suits, engineers, medical personnel, and researchers are actively engaged in the design. Today, we have seen several commercial efforts launch individuals into low Earth orbit, ferried astronauts and supplies to the International Space Station, and commercial flights for paying customers[3,4].

This industry is poised to grow in the coming decades and with it challenges of addressing humans in the systems that will support exploration, research, and tourism. Landon *et al.* address the human factors challenges in order to ensure health and safety as well as survivability in low Earth orbit and beyond[5]. Spaceflight is also influenced by the growing threat of trash in space as well as security threats[6]. The implication here is that with more countries and companies launching spacecraft and satellites, the debris field will grow. This could grow into an entirely new field of work, whereby debris is collected, perhaps recycled or returned to Earth. Baba *et al.* address this in their work published in the journal, Materials

Today: PROCEEDINGS[7].

3. ARMSTRONG INSTITUTE FOR SPACE, TECHNOLOGY AND RESEARCH

Here at the University of Cincinnati, a 2007 philanthropic gift provided the foundation for the establishment of an interdisciplinary institute for studying space exploration and aerospace constructs. Originally called the Space Research Institute for Discovery and Exploration (SRIDE), the focus has been on (a) research, (b) interaction with students through a competitive fellowship program, and (c) establishment of the University of Cincinnati as a viable partner with academia, government, and industrial organizations within the state of Ohio and the region.

Ohio ranks very high in aerospace jobs and research as it is home to a number of highly ranked universities, the NASA Glenn Research Center (Cleveland), the Wright Patterson Air Force Base of the United States Air Force (Dayton), the Defense Logistics Agency (Columbus), and numerous companies that support NASA, the military, and the aviation industry.

SRIDE sought to incorporate Neil Armstrong's name into the space institute. After his return from the moon, Armstrong was a professor of aerospace engineering for nearly a decade at the University of Cincinnati. His work, among others, positioned the university as a key participant in the nation's aerospace industry. SRIDE became Armstrong Institute for Space, Technology and Research (ASTRO) in the fall of 2024 to commemorate Armstrong's legacy in research and education. The Armstrong name is controlled by Purdue University, which granted permission in 2024.

4. STUDENT INTERACTION - LEADING THE WAY

All universities serve as cornerstones for humanity. Their sole purpose is to prepare the next generation of leaders through pedagogical interaction, and fundamental and basic research. Faculty and students interact in the classroom and in the laboratory. To promulgate interest in students to pursue career paths in space exploration and aerospace, ASTRO established two competitive fellowships. The first is the Armstrong Fellowship for Discovery for undergraduate students in their 3rd or 4th year. This is for one semester. The second, which is for a 12-month period, is the Armstrong Fellowship for Exploration. The latter is for graduate students.

Students from across the diverse, multidisciplinary colleges and departments are invited to submit proposals for both Fellowships. Each is thoroughly vetted by the faculty and a select number is chosen. The graduate students prepare a lengthy report, which is often manuscript ready. ASTRO Fellows graduate and take positions within the aerospace or commercial space industries.

I invited several students to submit their work to this special issue.

The manuscripts below highlight several graduate students work conducted during their fellowship.

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