Evolution of the Human Space Program: The Human Element

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Abstract

For millennia, humans have yearned to explore the unknown. Looking into the night sky, the thousands of generations before us, wondered what was out there. It was not until the 19th century that one could be above the ground in a balloon. The Wrights conquered flight in the early 20th century and Goddard developed rocketry in America in the 1920s—but it was a World War that brought rapid change. Operation Paperclip brought German scientists to the United States beginning in 1945 and they helped usher in the Space Age. The advent of human space flight began in earnest in 1958 and it eventually led to humans on the Moon, orbiting space stations, reusable spacecraft and commercial companies that ferry astronauts and supplies to the International Space Station. Over the past seven decades, we have evolved our space program from one of governmental priorities and investment to one of a burgeoning commercial program that now sends tourist above the Kármán line and into space.

Keywords: history, spaceflight, politics, exploration, aerospace, aviation

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Evolución del programa espacial humano: el elemento humano

Resumen

Durante milenios, la humanidad ha anhelado explorar lo desconocido. Al observar el cielo nocturno, las miles de generaciones anteriores se preguntaban qué había allí afuera. No fue hasta el siglo XIX que se pudo volar en globo. Los hermanos Wright conquistaron el vuelo a principios del siglo XX y Goddard desarrolló la cohetería en Estados Unidos en la década de 1920; sin embargo, fue una Guerra Mundial la que trajo consigo un cambio rápido. La Operación Paperclip trajo científicos alemanes a Estados Unidos a partir de 1945, quienes contribuyeron al inicio de la Era Espacial. El advenimiento de los vuelos espaciales tripulados comenzó en serio en 1958 y finalmente condujo a la llegada de humanos a la Luna, estaciones espaciales en órbita, naves espaciales reutilizables y compañías comerciales que transportan astronautas y suministros a la Estación Espacial Internacional. Durante las últimas siete décadas, nuestro programa espacial ha evolucionado, pasando de ser una prioridad gubernamental y de inversión a un floreciente programa comercial que ahora envía turistas por encima de la línea de Kármán hacia el espacio.

Palabras clave: historia, vuelos espaciales, política, exploración, aeroespacial, aviación

人类航天计划的演变：人的因素

摘要

千百年来，人类一直在探索未知领域。仰望夜空，我们之前的数千代人都在思考宇宙的奥秘。直到19世纪，人们才得以乘坐热气球升空。20世纪初，莱特兄弟实现了飞行，戈达德在20世纪20年代在美国发展了火箭技术——但真正带来快速变革的是一场世界大战。“回形针行动”于1945年开始，德国科学家来到美国，他们助力开启了太空时代。载人航天真正开始于1958年，最终实现了人类登月、空间站绕地运行、可重复使用航天器以及为国际空间站运送宇航员和物资的商业公司。过去七十年，我们的太空计划从政府的重点投资项目演变成为蓬勃发展的商业项目，后者如今已能将游客送上卡门线以上的太空。

关键词：历史，太空飞行，政治，探索，航空航天，航空

Introduction

From the beginning of human existence, our ancestors looked to the night sky and wonder what was there, and perhaps if they could ever go there. While it took millennia to develop technologies that improved human existence, it was not until we, as humans, harnessed energy and natural resources to create ways of getting off the ground.

While there is a rich history and a plethora of material on the history of the human spaceflight program in the literature, this short abridgement provides a summary of our desire to get off the ground and into space. It also provides a human element perspective of where we are going as a species.

Pre-World War II

From antiquity to the beginning of the modern era, a transformation occurred with each passing century, whereby new technologies, like gunpowder, and science fiction writers, dreamed of new worlds. In the 18th century, the Montgoflier Brothers built and flew hot air balloons. Étienne Montgolfier was the first human to actually lift off the earth. In the mid-19th century, British researchers James Glaisher and Henry Coxwell flew a balloon to 37,000 ft without supplement oxygen.[1] They both suffered significant challenges in physiological response to the change in pressure and temperature; laying the foundation for future aviation questions.[2]

At the beginning of the 20th century, the Wright Brothers, building on earlier work by Otto Lillenthal and others, developed and flew a powered bi-wing airplane, incorporating pitch, yaw, and role on the sand dunes near Kitty Hawk, North Carolina (See **Fig. 1**). This ushered in a new era where humans could go aloft in aeroplanes. Initially thought to be a skeptical adventure, the aeroplane became invaluable tool of war. A decade later, Robert Goddard was experimenting with liquid-fueled rockets. By the time World War II began in the late 1930s, the boundaries, capabilities and utility of balloons, airplanes, and rockets were expanding.

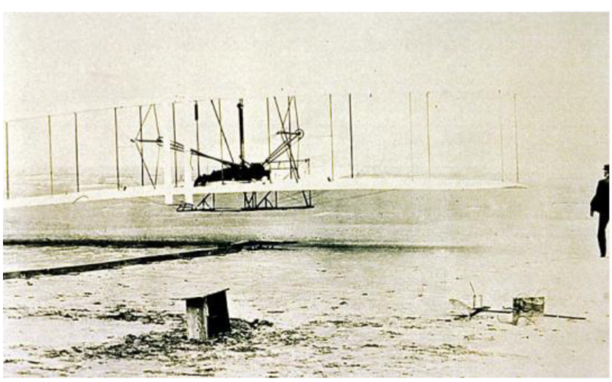

Fig. 1. Wright flier at Kitty Hawk 1903

Since human beings were in both balloons and airplanes, medical personnel began to develop a general understanding of how human physiology was impacted above 10,000 ft and below 35,000 ft. This new discipline, aviation medicine, began in 1918 with the United States Army School of Aviation Medicine, with a focus on the human in the system.

Beyond the Biosphere

In 1915, the National Advisory Committee on Aeronautics (NACA) was established.[3] This organization was the precursor to the National Aeronautics and Space Administration (NASA) focused on aviation and when NASA was formed, it absorbed thousands of NACA employees, assets, labs and buildings.

Toward the end of World War II, allied forces descended upon Peenemünde, in the far northern region of Germany. This was where the Nazi regime perfected the V2 rocket. The United States (U.S.) Army and the Red Army (USSR) were focused on capturing both technology and the scientists and engineers.[4] In 1945, the U.S. established a secret program, named Operation Paperclip, with the sole purpose of moving material (unused rockets) and more importantly over 1,600 captured German scientists, engineers, and technicians to the U.S. A key leader of this group, Dr. Wernher von Braun, was a vital German expert.[5] He eventually designed the Saturn V rocket, which would take Americans to the moon a mere 14 years later in 1969.

With rocket capabilities, albeit, in early development, the implication of sending humans into space was no longer an impossibility. There was limited knowledge on whether or how humans could survive in this austere environment.

In the 1950s, research was conducted on animals using intercontinental ballistic missiles. When the USSR launched Sputnik on October 4, 1957, America was caught off guard, prompting President Dwight Eisenhower to react. In 1958, NASA and the Defense Advanced Research Project Agency (DARPA) were established. NASA established the Space Task Group (STG) at Langley Research Center with a focus on the early Mercury Program (See **Fig. 2**), including vehicle design and crew selection.

While the U.S. and USSR had captured and patriated the German cadre of expertise, the issue of "could humans actually survive?" was front and center. In the U.S. all of the expertise in bioastronautics was within the U.S. Air Force (USAF), which itself was less than 10 years old, having been created out of the U.S. Army Air Corp in 1949. **Table 1** lists a number of questions experts had at the beginning of human space flight.

Fig. 2. NASA's Space Task Group 1959

Table 1. A partial list of unanswered question (ca 1960)

Question No	Question
1	What happens to the body in space?
2	Can man survive with all the stresses he will experience?
3	How to live and work in space?
4	How to monitor the human in this environment?
5	How to eat?
6	How to eliminate wastes?
7	What will acceleration do to the body?
8	What about radiation?
9	How to provide healthcare in space?

The launch of Sputnik and President Kennedy's directive to land a man on the moon and return him safely to the Earth, laid the foundation of the Space War, which of course was a significant element of the Cold War.

Prior to the launch of Yuri Gagarin on Vostok 1 in April 1961 and Alan Shephard on the Mercury-Redstone 3 in May 1961, the knowledge base of human capabilities in space was limited. Primate and other mammalian studies in the 1950s as well as the Manhigh Studies in the late 1950s provided a growing knowledge base of the physiological impacts. With each successive flight of astronauts and cosmonauts, it became apparent that while spaceflight affected the individual's physiology, they could survive and function to meet mission objectives.

There were several challenges as NASA began. Aside from political machinations, engineers and physicians were often at odds. In the early design phase of the Mercury capsule, the engineers placed a narrow window out of reach of the astronaut's view. The flight surgeons at the time argued that a window was necessary, positing that the astronaut could see the earth below. The engineers countered with doubt that they would be able to see anything. The flight surgeons, with concurrence from the astronauts, won out, and all spacecraft have windows that are accessible by the astronauts.

Exploration Paradigm

Once the Mercury program was completed, the Gemini and Apollo programs began to accelerate in development, including design, training and mission objectives. In the early 1960s, the USAF had developed the Manned Orbiting Laboratory (MOL), which was competing with NASA and of course access to funding, which was being directed to the conflict in Vietnam. The MOL astronauts transitioned to NASA in 1969 with several eventually flying in the Shuttle Program.

The Russians continued to pursue short missions with the Vostok, Voshkod, and Souyz including the first woman, Valentina Tereshkov. The Russians began to develop and maintain successive space stations in orbit (Salyut, DOS, and Mir) for longer duration missions with, where crews rotated after months on orbit. On the U.S. side, the longest missions, initially were on the Skylab in the early 1970s.

Each successive U.S. program built on the previous from an engineering perspective. The Mercury and Gemini programs provided new knowledge on crew health, but research was limited due to the limited workspace in the spacecraft. The objective of the human spaceflight program in the 1960s was to get a man on the moon.

The buildup of the Mercury and Gemini program entailed many new technologies, capabilities, and challenges. This included crew selection, crew observation using early telemedicine capabilities, tracking of the spacecraft, communications and recovery. **Fig. 3** illustrates the tracking stations around the world where medical observes were ensconced.

While there were early discussions between President Kennedy and Premier Nikita Kkrushchev about a joint mission to the moon, there was limited interests and each nation pursued their own paths.

Through many challenges, including the Apollo 1 (AS-204) fire, which claimed the lives of three astronauts (Roger Chaffee, Gus Grisson, and Ed White), NASA landed on the moon

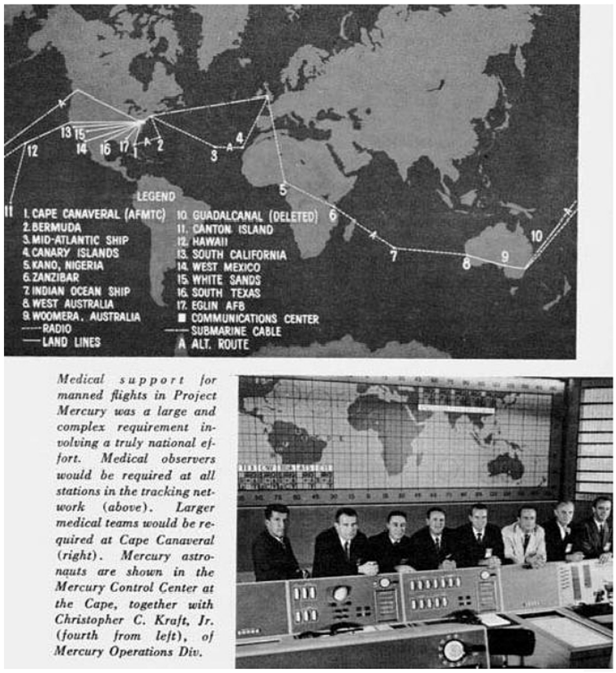

Fig. 3. Mercury medical support locations.

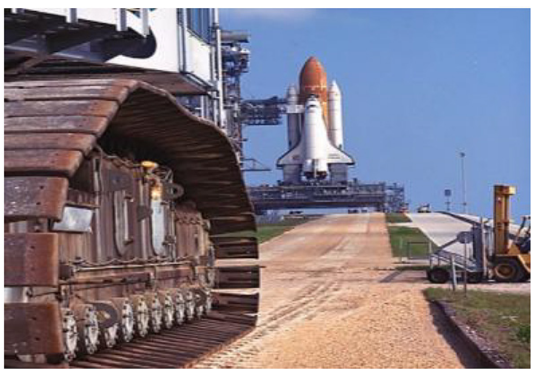

Fig. 4. Space Shuttle and crawler (courtesy of NASA).

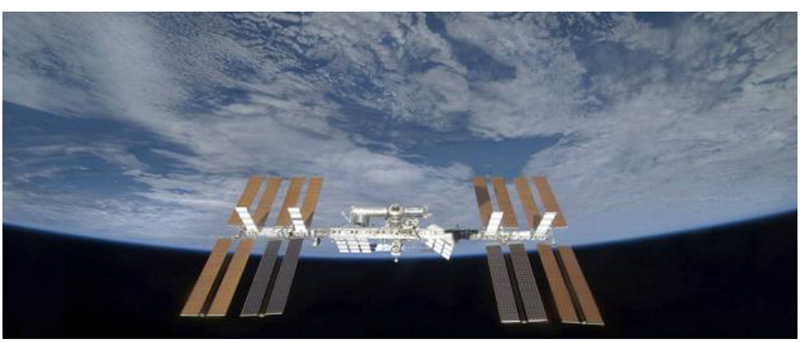

Fig. 5. The International Space Station.

on July 20, 1969, fulfilling Kennedy's challenge. In the years that followed, additional missions landed on the moon and several brought back samples.

In NASA's formative years, the concepts of orbiting space station and reusable winged spacecraft were conceived. By the early 1980s, NASA had built and launched the Space Shuttle Columbia (STS-1) (See **Fig. 4**). From the human perspective, crew selection and medical care systems were developed without the lead of the USAF. In 1977, NASA established its own standards for crew selection and a medical policy board to review issues related to crew health.[6]

Permanent Presence

From the first Shuttle launch in 1981 to the last Shuttle launch in 2011, NASA flew 135 missions. The Challenger and Columbia were lost in horrific accidents. The Shuttle docked with the Mir Space Station in successive missions in the 1990s, built the International Space Station (ISS), and delivered or repaired various satellites, including the Hubble. (See **Fig. 5**)

For more than 25 years, humans from around the world have continuously lived and worked on the ISS conducting valuable research and increasing our knowledge of both human physiology and the natural sciences of space and of the Earth. In order to support the ISS, the lessons dating to the beginning of human spaceflight in the 1960s served as a foundation. Based on the U.S. and Russia efforts in early flight programs, the international community developed a framework that embodies collaboration for the common good.[7-11] This framework and knowledge has set the stage for new programs like Artemis, Gateway and eventual human exploration of Mars and other celestial bodies. The ISS has provided an opportunity to understand human challenges for durations that now measure more than a year. This will be of value in developing human presence on transit missions to Mars and surface exploration.

There are many unknown challenges for human mission to Mars, including radiation exposure, impact on human physiology, lack of real-time communications, resources (food, water, etc.), limited gravity, temperature extremes, operational tempo, and of course human psychology, tempered with ethics and isolation.

Conflict Management

As mentioned earlier, there is perceived conflict between various disciplines in support of human spaceflight. This paradigm goes back to the very beginning of NASA in 1958. The STG, which was relocated Houston, TX as the Manned Spacecraft Center believed it needed little impact from NASA Headquarters in Washington, D.C. The physicians and engineers were often in conflict as they viewed the human in the loop differently.[12] In 2016, NASA developed a book that reviewed these challenges.[13]

Engineers...	Life Scientists...
...design their systems	...reverse engineer Nature to understand the system
...use quality controlled components	...study diverse individuals with diverse components
...use established frameworks to employ physical laws	...discover concepts and qualitative relationships before developing quantitative understanding
...design PID controllers	...discover biased walks in chemotaxis

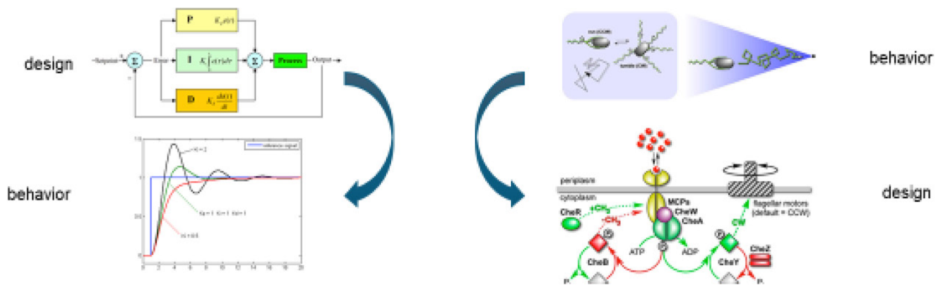

Fig. 6. Differences between Life Sciences and Engineering.

Fig. 6 illustrates the differences between engineers and life scientists. Simply put, engineers can test things to destruction and in medicine, this is not the approach. Over the past seven decades, much of this dichotomy has been ameliorated in part due to effective communication, the development of health and medical technical authority in the aftermath of the Columbia accident, and physician astronauts.

In international programs, such as the Apollo-Soyuz Test Project in 1975 and the ISS Program, highly effective frameworks were established to support design and human health.[8]

Commercial Paradigm

For most of the history of human spaceflight, the purview has been government-funded and operated systems. In 1985, President Ronald Reagan signed the Commercial Space Launch Act of 1984 to support commercial spaceflight, which was amended in 2004 and signed into law by President George W. Bush. These laws provided the foundation for investment and launch services for commercial companies to serve NASA and paying customers to travel to space. Governed by the Federal Aviation Administration, commercial companies have rapidly expanded capabilities in support of human spaceflight.

Companies like SpaceX, Blue Origins, and Virgin Galactic, each with unique platforms have sent paying customers into space. These companies have built successful models based on the experience and lessons learned over the past seven decades. While the future is unwritten, it will be a collective effort by both governments and commercial entities that will expand the horizon for human spaceflight. Perhaps one day, in the not too distant future, the number of individuals flying to Earth-orbiting platforms for a long weekend, may be similar to taking a commercial aircraft to a destination on the ground.

The Next Giant Leap

Human exploration of the Moon and Mars are now a central focus of the exploration narrative by NASA, other nations, and commercial companies. Challenges and unanswered questions remain, especially with regards to Mars.[14] The foundations of human spaceflight are built on the experiences and lessons learned by those men and women who have supported programs or have flown in space.

Once humans escaped the surly bonds of earth and ventured in space, the concept of traveling to distant planets was no longer science fiction. There is no doubt the challenges of a human mission to Mars would be immensely challenging. But as President Kennedy espoused so long ago, *"…not because they are easy, but because the hard …."* This may very well become the greatest challenge of the 21st century. Much of the technology to support the transportation of such and endeavor exists. It is the human element and support of the crew that will be a far greater challenge.

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