Human Space Exploration
The Next Fifty Years

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ABSTRACT: Preparation for the fiftieth anniversary of human spaceflight in the spring of 2011 provides the space faring nations with an opportunity to reflect on past achievements as well as consider the next fifty years of human spaceflight. The International Space Station is a unique platform for long duration life science research that will play a critical role in preparing for future human space exploration beyond low earth orbit. Some feel the future path back to the Moon and on to Mars may be delayed with the current commitment of the United States to support the development of human-rated commercial spacecraft. Others see this as a unique opportunity to leverage the capability of the private sector in expanding access to space exploration. This article provides an overview of the past achievements in human spaceflight and discusses future missions over the next fifty years and the role space medicine will play in extending the time-distance constant of human space exploration.

Keywords: Human spaceflight, space medicine, career astronauts, spaceflight participants, commercial spaceflight

The past five decades will stand for eternity as the formative period of载人航天飞行. From the first flights of Yuri Gagarin and Alan Shepard in the spring of 1961 to the Apollo 11 lunar landing in 1969, people throughout the world were mesmerized by the incredible progression of space exploration. The decade culminated with the achievement of President Kennedy’s vision for human exploration of the lunar surface and safe return to Earth. Meeting this goal required the expertise within the United States and Russia. For that vision to become reality, the acclimation of humans to space had to be studied over the course of months not days. The Russian Salyut series of space stations and the NASA Skylab (4) (5) (6) program that highlighted the next decade of human spaceflight were used to evaluate the capacity of specialists for long duration missions on board a new generation of space stations.

The scientific utilization of space stations as microgravity research platforms provided an additional technical challenge in developing the capability to bring payloads to and from low earth orbit. The Space Shuttle was designed to meet this unique requirement along with additional roles as an autonomous science platform and as a vehicle that could be used to launch and repair satellites. The need for onboard robotics as a critical enabling technology was identified and Canada was invited to design and produce a robotic arm for the Shuttle program. Referred to as the Canadarm, or “the arm” for short, this contribution to the Shuttle program led to the first selection of six Canadian astronauts in 1983, with the prospect of a series of three or four flights for Canadian scientist astronauts referred to by NASA as payload specialists. Twenty-five years ago, Mark Garneau became the first Canadian to fly in space aboard the Space Shuttle Challenger.

A number of dedicated Canadian experiments were selected for the STS-41G mission, creating an opportunity for Canadian scientists to obtain first-hand experience with microgravity research. These experiments were referred to with the acronym CANEX, a descriptor which was used for the remaining two flights of Canadian payload specialists that took place in 1992.

By this time, the concept of a partnership of the major space faring nations working together to create a world-class orbiting research platform had become a reality, and the newly emerging space station program led to the need for, and selection of a second group of Canadian astronauts. During a six-month selection process, the Canadian Space Agency used a complex set of selection criteria to hire four new astronauts that would train as mission specialists for long duration missions on board the International Space Station (ISS). Roberta Bondar and her back-up Ken Money retired after participating in the International Microgravity Laboratory (ML-2) mission in January 1992, leaving Marc Garneau, Bob Thirsk, Bjarni Tryggvason and Steve Maclean to be joined in January 1993 by Chris Hadfield, Julie Payette, Mike McKay and Dave Williams for mission specialist training and potential assignment to shuttle flights or space station construction missions. This was a pivotal time for the Canadian Space Agency that had raised the Canadian profile as a major space faring nation, now with an expanded team of 8 astronauts, two with mission experience, capable of leveraging the Canadian robotic and scientific expertise.

The initial design requirements for the proposed space station included a health maintenance facility (HMF) (7) in recognition of the potential medical issues that could arise during long duration missions in low earth orbit. In addition to the HMF, the proposed airlock design provided both a hyperbaric capability necessary for suited astronauts to egress the station for spacewalks as well as a hyperbaric capability to treat potential episodes of decompression sickness (DCS) that could arise during a space walk. The designated operating pressure of the space station was 1 atmosphere (14.7 p.s.i.), similar to that of the pressure of the extravehicular mobility unit (EMU) which was 4.3 p.s.i., thereby introducing the risk of DCS while transitioning to the lower suit pressure. Despite the pressure in the EMU on board the station for closed healthcare, these facilities were not implemented in the construction of the International Space Station primarily due to cost constraints.

Historically, during the Shuttle era, the clinical approach to prevention, diagnosis and treatment of illness and injury in space had a strong emphasis on prevention. This was accomplished through medical selection criteria, regular medical screening, and the development of countermeasures to mitigate the many physiologic changes associated with exposure to microgravity. This approach evolved from the early work in the Mercury, Gemini and Apollo programs that was based primarily on a preventive strategy with rudimentary on-orbit diagnostic and treatment capabilities based on the use of small medical kits with support from flight surgeons in mission control. The Skylab program provided an excellent opportunity for biomedical research during long duration missions that helped further delineate the physiologic changes associated with exposure to microgravity. These results of the six Skylab missions provided the foundation for and development of countermeasures implemented in the early Shuttle program and led to a further series of life science experiments conducted on dedicated Shuttle research missions. These studies were concluded by the launch of the first element of the International Space Station (ISS) in the fall of 1998 and were published a year later as a comprehensive extended duration orbital medical project (EDOMP) (9) (10).

Canadian researchers participated in a number of collaborative studies over this period to help understand the many physiologic changes associated with acclimation to microgravity and to evaluate potential preventive and treatment countermeasures. In 1998, the Canadian Space Agency (CSA) worked in collaboration with experts in DCS at the Defence Research and Development Canada Centre in Toronto to participate as one of three NASA supported research sites to develop the new pre-breath protocols for use in preparation for spacewalks from the Interna-
nional Space Station. This led to widespread recog-
nition among the international partners of Canadian expertise in life science and space medicine re-
search, which has continued into the current phase of ISS utilization.

The first twenty missions to the ISS were made up of three international crew members living aboard for approximately six months. Last year the crew configuration was extended to the original de-
ginal environment. Medical practice in space involves the administration of medication orally, intramuscularly or intravenously. Foley catheters have been inserted for isolated cases of urinary retention (18) and intravenous access has been used for research studies and for some clini-
cal interventions. There are no reported cases of wound repair using sutures or wound cement in human biomedical activities. Prior to the development of urethral stents, bladder outflow obstruction due to urethral diverticulum in humans, a condition resembling a urethral diverticulum in humans, was managed with endoscopic incision of the urethral diverticulum.
on a combination of historical data, expert opinion, analogue studies and epidemiological studies from other related high-risk occupations (23) to facilitate development of future medical protocols.

Unfortunately, the rarity and complexity of medical illness during spaceflight makes it difficult to evaluate the effectiveness of these protocols and new medical technologies. High-fidelity medical simulation has been suggested as an effective tool to assess the performance of high-level medical systems and interdependent medical teams (24). Electromechanical robotic mannequins can be used to simulate a wide variety of physiologic parameters, medical emergencies and illnesses in a controlled, reproducible, and risk-free environment to evaluate clinical protocols. Beyond research and testing, medical simulation is also an ideal platform for providing medical education and training opportunities for CMOs who may not be exposed to the required breadth of clinical experience necessary for supporting a space mission. In addition, it provides a context-specific opportunity for CMOs skill retention during a mission, or to provide just-in-time medical training to deal with an in-flight medical emergency.

The next decade provides an opportunity for further ISS research to develop new diagnostic and treatment capabilities, assess new technologies and evaluate strategies for CMO skill retention and just-in-time training. This research will be important to prepare for exploration class missions beyond low Earth orbit in addition to developing on-board healthcare for commercial ocean cruises, for further ISS research to develop new diagnostic and treatment capabilities, assess new technologies and evaluate strategies for CMO skill retention and just-in-time training. This research will be important to prepare for exploration class missions beyond low Earth orbit in addition to developing on-board healthcare for commercial ocean cruises.

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