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 that era is held as the 'Space Age'. Each of the past four decades have focused on the development of a long duration capability for human spaceflight. The vision of sending humans farther into the solar system was shared by many experts 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 astronauts to live and work in microgravity for long periods of time. Both programs provided fundamental data on space physiology (7) relevant to space medicine, but they also demonstrated the need for additional 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 flights for Canadian scientist astronauts referred to by NASA as payload specialists. Twenty-five years ago, Mark Gameau 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 firsthand 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 space station. 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 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) (8) 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 hypobaric 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 Space Shuttle while transitioning to the lower suit pressure. Despite the improved on board medical and 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, cardiac, neurovestibular and neuromuscular 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 Shuttle missions throughout this time to help understand the many physiologic changes associated with acclimation to microgravity and to evaluate potential preventive and countermeasures. In 1992 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-breathe protocols for use in preparation for spacewalks from the Interna-
ional Space Station. This led to widespread recog-
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search, which has continued into the current phase of ISS utilization.

The forty-seven 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-
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Extending the opportunity to visit the ISS to space tourists challenged the space medicine com-
munity to decide whether or not a similar approach to pre-flight medical screening would be used for the SFPs. While these individuals were paying mil-
lions of dollars for the privilege of visiting the ISS, a significant on board medical event could have a profound mission impact and it was decided that a pre-flight medical assessment was needed as a risk mitigation strategy. Seven SFPs have visited the ISS the most recent being Guy Laliberté from Canada, and to date to significant medical events have been reported.

Space medicine can be defined as the area of medical practice that deals with the provision of healthcare in partial and microgravitational envi-
rnments. The scope of care not only deals with the prevention, diagnosis and treatment of illness and injury, but involves pre-flight medical screening and selection as well as post-flight rehab-
ilitation. The expansion of commercial space operations to include SFPs and potentially career astronauts operating in microgravity extends the scope of care. The ISS, which is now operated as a "load-and-go" approach to returning to Earth for definitive medical care. Current approaches to on orbit health care use both approaches with the combination of immediate clinical care combined with the potential for an urgent or emergent deorbit and landing for definitive medical care. As humans travel farther into space, a medical abort to Earth scenario becomes less practical and at some point transitions to continued flight to the destination. This raises a number of questions about defining the appropriate level of care, the effect of longer mission to Earth on crew autonomy and the role that new technologies will play in the deliv-
ery of healthcare during the different phases of the mission.

On the ISS, as the complexity of medical interventions increases, there is greater reliance on ground expertise through the use of teledermics, a fundamental component of linking the flight sur-
geon in mission control to the CMO for health care delivery in space (19). Teledermics is the use of information and communication technology in near real-time to support the delivery of appropriate level of care, the effect of longer mission to Earth on crew autonomy and the role that new technologies will play in the deliv-
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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 illnesses 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 clinical care for commercial space complexes. Based on the terrestrial approach of providing on-board healthcare for commercial ocean cruises, it is likely that commercial space complexes will have an on-board clinic with a physician or other health care professional providing clinical care. The evolution of commercial space travel in the decades to come will extend the scope of space medicine beyond the realm of the government supported human spaceflight into the realm of civilian spaceflight. While the objectives of human space travel will differ between the government and commercial groups, there will be a shared interest amongst practitioners of space medicine in developing the best approaches to prevent and treat illnesses and injuries during a mission. Clearly, the future opportunities for those interested in space medicine are very exciting.

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