Canadian Space Agency

Planning Canada's Next Chapter in Human Space Exploration: Health and Biomedical Roles

Summary Report

National Forum on Space, Health and Innovation: Emerging Challenges, New Opportunities and Benefits to Society

Held on November 29-30, 2017

John H. Chapman Space Centre, Saint-Hubert, Quebec

Canadian Space Agency

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Introduction

Space agencies from around the world are looking towards the future of deep-space exploration beyond the International Space Station (ISS). The 2016 extension of Canada's commitment to participate in the ISS also provided opportunities to develop leading-edge space technologies and conduct research to position Canada to take part in the next phase of human space exploration.

The Canadian Space Agency (CSA) is providing multiple opportunities for Canada's space community (academia, industry and government departments) to propose innovative ideas for science and technologies in areas that could contribute to future human space exploration and generate benefits on Earth. As part of this effort, the CSA is looking at various disciplines and fields of activity where Canada could make significant contributions, including in the health and biomedical field.

In the fall of 2017, the CSA, embarked on a process to engage with Canada's health and biomedical stakeholders, to help identify potential Canadian health and biomedical roles in human deep space missions. The engagement spanned several activities, including a number of regional information sessions organized in collaboration with NRC-IRAP, and an establishment of an Expert Group on the Potential Canadian Healthcare and Biomedical Roles for Deep Space Human Spaceflight.

The National Forum acted as a capstone for a series of five regional information sessions held in October and November of 2017, in Montreal, Toronto, Halifax, Calgary, and Vancouver. It brought together Canadian health and biomedical experts with space stakeholders to identify shared space and terrestrial healthcare challenges, explore opportunities to collaborate and leverage research and technology development activities, and exchange ideas on potential integrated, solution-driven partnerships between academia, government, industry and clinicians to stimulate innovation.

The Forum provided an opportunity to hear from some of Canada's former and active astronauts as they shared their unique perspective of the health dimensions of space flight and the challenges of future human missions to the Moon and Mars. Participants also heard from and were able to exchange with leading researchers and innovators on the latest advances in health technologies, and how emerging fields such as artificial intelligence, data analytics, robotics and genomics are creating new possibilities for space and terrestrial applications.

What follows is a summary of panel discussions and breakout sessions that took place at the National Forum on Space, Health and Innovation, held on November 29-30, 2017.

Opening Remarks

Mr. Sylvain Laporte, the CSA President, Mr. Gilles Leclerc, DG Space Exploration, and Ms. Mary Preville, DG Policy provided opening remarks. Key points include:

- The international partnership of space agencies is looking at the next steps in human space exploration. This involves building an outpost around the moon – the Deep Space Gateway. This will be a Moon orbiting platform that will serve as a staging point for both lunar surface missions and future missions to Mars. Construction will begin in 2021.
- Canada is well positioned with respect to space science and technology to be a partner in this endeavour.
- International Space Station is viewed as the stepping stone – a science and technology demonstration platform - for preparing for human exploration of deep space. Canada's research work on the ISS to date has mainly focused on health and life sciences.
- New funding has been provided by the government in 2016 to hire two new astronauts, to extend Canada's stay on the ISS until 2024, and to explore options for Canada's contributions to deep space exploration.
- The Agency is currently studying different contribution options, including in health and biomedical fields. Common challenges between space and terrestrial health could open a multitude of opportunities for collaborations between space and health and biomedical sectors. The CSA engagement with the health and biomedical community suggests there is interest and capabilities that could be taken to the next level.
- Forum participants were presented with 3 challenges to keep in mind: 1) any space health solution must have an earth-bound benefit that will improve quality of life for Canadians; 2) must leverage a Canadian strength and help take it to the next level; and 3) must contribute to Canada's economic growth and skilled workforce objectives.

Panel 1 - The Health Risks of Spaceflight: an Insider Perspective

This session discussed health-related challenges of human spaceflight and realities of dealing with health and medical care in space.

Panelists:

- Dr. David Saint-Jacques, Canadian Astronaut, engineer, astrophysicist and physician
- Dr. Dave Williams, former Canadian Astronaut, physician, and healthcare administrator
- Dr. Robert Thirsk, former Canadian Astronaut, engineer, physician, and Chancellor of the University of Calgary
- Moderator: Dr. Douglas Hamilton, Clinical Associate Professor of Internal Medicine and Adjunct Professor of Electrical Engineering at the University of Calgary, and Former NASA Flight Surgeon

Summary

The panelists shared several stories of their experiences with spaceflight preparations and spaceflight missions. One of the most important messages was that in space things go wrong unexpectedly: medical emergencies are not uncommon. Because of this, the panelists emphasized the need for versatile skills, as well as personal flexibility and adaptability (i.e., thinking on one's feet to come up with solutions and fixes using what's on hand).

The panelists noted that there are many aspects about the effects of spaceflight on humans that we don't know yet. Because of the many unknowns, it is difficult to prepare for spaceflight. This is particularly true for long duration deep space missions, when astronauts are far away from Earth, not knowing what to expect, and not having the ability to turn back. Autonomy, and in particular, medical autonomy will be key for success of these missions.

Panelists also spoke about the issue of consumables and supplies, and the challenges of long-duration space flights when replenishing supplies is not an option. Long term exposure to radiation of supplies (medical supplies included), technology (hardware) as well as humans is one area that needs to be understood better.

Canada is well positioned to learn about, and solve the health problems related to human spaceflight. The Canadian health sciences community has the skills, knowledge and credibility to address these challenges.

Quotes from Panelists:

"Humans are the most fragile part of the whole system. "

"Every time I've been in space, something medical has happened."

"Need to have things that are robust and don't break down. Design things that can be serviced – need to be able to take it apart, and fix it – can't have a lot of parts."

"Need to figure out what we need to be autonomous. We don't have shipping and receiving in space."

"Need to find a way to maintain skills – need vehicles/tools to do that."

"We are just starting to figure out what hardware will be needed in an autonomous situation."

"The role of supporting families and spouses on earth is very important."

The panelists also spoke about the dependence between flight crew make-up and space flight hardware needs. Astronauts who are also physicians will be key crew members in long duration deep space missions. Astronauts' responsibilities, however, make them astronauts first and physicians second. The issue of skill maintenance and keeping up to date on medical knowledge was flagged.

Psychological aspects of space flight were also discussed, with all panelists recognizing the importance of human dynamics on board of space craft for the success of mission. They recognized that deep space missions are likely to exacerbate this aspect. Dealing with being away from friends and families and not

being able to support them was flagged as one of the hardest things astronauts have to deal with while on orbit.

Panel 2 - Health Innovation in Canada: Pushing Frontiers of Healthcare by Leveraging Technology Innovation

This session discussed new healthcare innovation and business models and the use of disruptive technologies to change the ways we use and deliver healthcare.

Panelists:

- Dr. Anne Snowdon, RN, BScN, MSc, PhD, FAAN, Chair, World Health Innovation Network, and Scientific Director & CEO, SCAN Health
- Dr. Linda Maxwell, MD, MBA, FRCSC, FACS, Founding and Managing Director of the Biomedical Zone
- Ms. Susan Wooldridge, Director, Sales and Marketing, ThoughtWire
- Dr. Ricardo Baltazar, Senior Product Manager, Think Research
- Moderator: Phil Carr, The Strategic Review Group Inc.

Quotes from Panelists:

"The public face of CSA is very inspiring. We've got to leverage that to increase awareness and receptor capacity. CSA can be a convener on a national level."

"Improving autonomy would be an important accomplishment - need to find health care delivery models to get people to help themselves – autonomous tools."

"We need to make solutions: desirable (address human factors); feasible (that work); viable (business factors/sustainability in our health care system)."

"What helps innovation work: a multidisciplinary approach, diversity of skillsets and attitudes, bringing together energetic people and entrepreneurs, young people who challenge the traditional way of thinking."

"Health care is about how *teams* operate – not about how *individuals* operate."

Summary

Panelists indicated that there are many parallels between healthcare in Canada – particularly remote and rural health care delivery – and healthcare in space. Therefore, solutions to space health challenges will likely find practical applications on Earth.

Healthcare innovation today is achieved through multi-disciplinary teams. The teams are composed of a wide variety of people from different disciplines working together. This produces a great potential for innovation. At the same time, there are obstacles to this approach. For example, risk aversion is a barrier to innovation, there are no standards for interoperability, and the business model of the health care system does not adapt to change quickly.

Increasing the receptor capacity for innovation in healthcare can accelerate change, and space-related health R&D can contribute to increasing receptor capacity. Panelists also talked about transformational

innovations. Small, incremental improvements (small "i" innovations) in healthcare play an important role in addressing or overcoming risk aversion in the system.

Furthermore, the importance of linking technology development to real clinical/user needs was noted as being key: there are many technologies sitting on the shelves, not being used. Open innovation should be encouraged, although panelists recognized that monetizing ideas that are results of open innovation could prove to be problematic.

Panel 3 - Space and Terrestrial Healthcare: Identifying Shared Needs and Solutions

This session discussed linkages between space healthcare and long-term, chronic care and rehabilitation, as well as delivery of health and medical care in northern and remote communities, and extreme environments and military settings.

Panelists:

- Dr. Goldie Nejat, Associate Professor, Department of Mechanical Engineering, University of Toronto and Canada Research Chair for Robots in Society
- Dr. Keith MacLellan, MD, Shawville, QC, and Former President of the Society of Rural Physicians
- Dr. Peter Suedfeld, Psychology Professor Emeritus, University of British Columbia
- Dr. Joan Saary, MD, MSc, PhD, FRCPC, CIP, FACOEM, Assistant Professor of Medicine, University of Toronto
- Moderator: Phil Carr, The Strategic Review Group Inc.

Summary

Psychological factors facing astronauts are not discussed a lot, but they are very important. For example, cooperative problem solving, addressing isolation and stressful environments, and working in teams are all matters of psychology. Panelists debated the role of technology in addressing psychological space flight factors. Technological innovations, such as robotics and virtual reality, can help with some aspects of psychological factors. However, as one panelist noted, it most often comes up when it's broken.

There are many similarities between the circumstances and needs of astronauts, rural doctors, and members of the military. These professionals are often on their own, making important decisions, and relying on a

Quotes from Panelists:

"There are many similarities between medicine in space and rural medicine. The bulk of rural healthcare is given by non-specialists. Rural doctors acquire the skills that the community needs (as is the case for flight doctors)."

"Cooperative problem solving and innovative problem solving are psychological, and these were discussed a lot by the astronauts. Let's not pretend that the psychological aspect is not important."

"Technology can help solve some of the psychological problems that come up. Virtual reality technology may be a solution."

"Robots can help with cognitive stimulation. A new area of technology is the socially interacting robot that helps with everyday living. They are being used to encourage independence.

"Technologies have been developed for military applications that can also be used for space."

mix of skills that apply to the specific problem or situation. These skillsets need to be updated continuously. There are joint opportunities to develop and maintain those skills, and to develop supporting technologies.

Panelists discussed technologies and approached that have been developed for military applications or for use by rural and remote health care providers that can also be used for space.

Panel 4 - Transforming Healthcare through Artificial Intelligence

This session discussed the potential of Artificial Intelligence (AI) to advance healthcare through improved diagnostic speed and accuracy, decision support, patient monitoring, predictive analytics, and behavioral therapies.

Panelists:

- Dr. Francois Laviolette, Professor, Department of Informatics and Engineering, Laval University, and Director of Big Data Research Center
- Dr. Carolyn McGregor, Professor, Associate Dean and Canada Research Chair in Health Informatics, Faculty of Business and Information Technology, University of Ontario Institute of Technology
- Dr. Gary Hasey, Associate Professor of Psychiatry, McMaster University
- Dr. Miroslava Cuperlovic-Culf, Senior Research Officer and Team Leader, National Research Council, and Adjunct Professor, University of Moncton
- Dr. Valerie Bécaert, Director of Research, Element AI
- Moderator: Dr. Jacques Corbeil, Professor and Canada Research Chair in Medical Genomics, Department of Molecular Medicine, Université Laval

Summary

Quality data and computing capacity are key challenges to fully harnessing the potential of AI for health care purposes. Panelists talked about different data sources (e.g., genes, proteins) and the power of combining these data sources to create new knowledge. They also talked about "data noise" and "errors in measurement" and how the way we collect and process data will influence the application of AI in the healthcare context. One specific issue that was flagged was the "fat data" problem: data collected from a few patients with a lot of features. Fat data provides large quantities of data, but does not support "deep learning" analysis because its population is too low.

Quotes from Panelists:

"The way you gather the data will influence your AI. Much data collected in the past is of no value in applying it to AI. The major problem now is that data is in different formats – in pictures, in text, in datasets, etc."

"We have developed what we call a "genius tool" for diagnosing psychiatric conditions. This tool has made better predictions than psychiatrists."

"Figuring out the most useful architecture for the data is an iterative process"

"We are not perfect, and the machines are learning from us. They actually help point us to our mistakes."

"Access and ownership of the data is a big issue. However, that may be changing, and data availability is opening up. We should consider data as a public good."

Two other issues resonated with the panelists and forum participants. First, the need to handle and process different data formats presents a challenge, since the computing requires a degree of standardization across formats. Standardization of data formats can play an important role in harnessing the power of data and AI. Second, ownership of health-related data, including that needed for health-focused AI systems, was a significant barrier because it limited access to the data. These issues were closely tied to privacy and ethics considerations that needed to be addressed within the legal and regulatory regime involving big data and big data analytics.

The discussion also touched on specific applications, including for diagnosing psychiatric conditions, and whether those applications could have practical applications in monitoring and diagnosing psychological conditions that may arise during long duration space flight.

Summary of Breakout Sessions

Topic1: What are the emerging burdens/demands on the Canadian healthcare system? What space needs would be well aligned with relief of these future stressors?

- Policy and regulatory frameworks – do not correspond to the pace of technological change in health care field and the need for new service delivery models
    - need to see patients as "consumers" of health care services and products
    - facilitate technology adoption
    - integration and standards
    - service delivery models that enable people to take care of themselves
- Access to care - health care delivery in remote and non-clinical settings (e.g., remote and rural communities, management of chronic diseases and health care delivery to the growing aging population)
    - on-site and mobile diagnosis and tools
    - tele-monitoring and telehealth solutions – connectivity to expertise you need when you need it
    - assistive technologies and self-care
    - autonomy – doctor in a box, lab on a chip, pharmacy on a chip
- Patient-centric models
    - personalized medicine
    - prevention and prediction – look at the whole human system, not only focusing on treatment
    - patient access to their own data and tools to enable informed decision-making

Synergies in Technology Trends:

- AI and machine learning
- Virtual and augmented reality
- Medical training and simulation
- Wearable technology and self-monitoring
- Advanced bioanalysis
- 3D printing for medical tools and supplies
- Digital health

Topic 2: What capabilities in healthcare innovation could be translated to support astronaut healthcare?

- Portability and miniaturizing of tools and devices
- Reusing/repurposing of healthcare products/supplies/tools (e.g., 3D printing of custom medical equipment or tools)
- Maximizing the use of omnipresent technologies and platforms to facilitate innovation (e.g., smartphones and diagnostic devices)
- Process efficiency:
    - reduce multiple specialists, concentrate diagnosis and treatment in one unit
    - optimize the supply chain (storage, scheduling)

Topic 3: What are the barriers to translation and adoption of health innovations? Could space-based applications of technology and systems play a role in mitigating the barriers to innovation?

- Data is at the centre of both health innovation and ethical and privacy debates
    - issues: timely access to data, management of big data, data ownership, data quality, data compatibility, data interpretation
- Innovation needs to happen with patient/end user in mind
    - there is a disconnect between innovators and end users (both patients and researchers) – no feedback loop
- Procurement rules and funding models
    - terrestrial analogs: high cost of doing research in space for private companies
    - crowd-sourcing: can we capitalize on the astronaut dream?
    - hackathons and x-prize type approaches vs. traditional grants, contributions, and contracts
        - opportunity for the CSA to inspire collaboration through innovative/creative use of procurement and funding mechanisms

Topic 4: What kind of collaborative framework and ecosystem could support a Canadian initiative in astronaut healthcare for deep space missions?

- Build better collaboration between industry, academia and government
    - create a repository of problems that need solving
    - build common infrastructure and identify common priorities
    - foster a community, friendly competition - who can bring support and ideas for solutions
- Scalling-up collaboration
    - expand beyond industry and academia – open to the public
    - multidisciplinary create a repository of problems that need solving
    - CSA role? Give space, time and nudge both for new ideas and new collaborative mechanisms

Concluding Remarks

- Over the upcoming months, the CSA will continue its engagement, both with external and internal to government partners.
- The Expert Group will be finalizing its advice to the CSA.
- The CSA has dedicated funding to further explore options for Canadian contributions to deep space missions. Calls for ideas in health and biomedical fields are forthcoming.
- Announcements:
    - Announcement of Opportunity (AO) for Flights and Fieldwork for the Advancement of Science and Technology (FAST) for students and research organizations across Canada. The next announcement will be a call for ideas under "buy-sell" – a statement asking for a broad range of ideas.
    - NASA released an Announcement of Opportunity for a variety of short medium and long duration missions (6 weeks, 6 months and 1 year). This AO is open to Canadians and other non-US nationals. Those from Canada who submit proposals and pass through the first stage of assessments by NASA will need a letter of support from the CSA.