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The highlights from the Resilient ExtraTerrestrial Habitats (RETH) workshop

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Abstract

This Reference Document presents the highlights from the 2018 Resilient ExtraTerrestrial Habitats (RETH) workshop held 22–23 October 2018 at Purdue University, West Lafayette, IN. The purpose of RETH was to bring together academic, industry, and government experts in order to discuss challenges of operating in extreme conditions and imposing a presence in such environments. The non-classified nature of the workshop allowed for open discussion and exchange of ideas about important issues such as the operational integration, capabilities to operate in extreme environments, and identifying research directions and framework for future operations. The topic of commercial investment and operations was also discussed. The RETH highlighted the importance of ongoing discussion and joint effort to tackle the challenges surrounding the operational requirements and opportunities in extreme environments, including the importance of discussing issues that will inevitably become part of our space exploration and expansion into that realm (e.g., extra-terrestrial military bases, missile defence in orbit, space-based weapons, and dominance over the space domain).

Significance to defence and security

The 2018 Resilient ExtraTerrestrial Habitats (RETH) workshop held 22–23 October 2018 at Purdue University brought together academic, industry and government experts in order to discuss challenges of operating in extreme environments. While the main objective was to discuss these issues in the context of space exploration, there are direct and important implications for defence and security. One of the important considerations is the ability and preparedness to operate in extreme environments (e.g., the Arctic) for extended periods of time. Another important and inescapable defence and security issue that has potential to become a large scale problem stems from the competing interests (of several nations) in expanding military operations in space (e.g., extra-terrestrial military bases, orbital missile defence, space-based weapons, dominance over space domains). It is thus imperative for the Canadian military to be aware of such issues and develop the capability to devise and implement mitigation plans when the time for such action comes.

Résumé

Le présent rapport expose les principaux points abordés lors de l'atelier sur les habitats extraterrestres résilients (RETH) qui a eu lieu les 22 et 23 octobre 2018 à l'université Purdue de West Lafayette (Indiana). Cet atelier avait pour but de réunir des experts provenant du milieu universitaire, ainsi que des secteurs public et privé pour discuter des difficultés liées au travail dans des conditions extrêmes et au maintien d'une présence dans les milieux où règnent de telles conditions. Comme il s'agissait d'un atelier non classifié, les participants ont pu débattre librement et échanger des idées sur des enjeux importants tels que l'intégration opérationnelle, les capacités nécessaires pour évoluer dans des environnements extrêmes, les avenues possibles de recherche et l'élaboration d'un futur cadre d'exploitation. Les participants à l'atelier RETH ont également discuté des questions relatives aux opérations et aux investissements commerciaux. On a en outre souligné l'importance d'assurer une collaboration et un dialogue soutenus pour aborder les questions relatives aux possibilités et aux besoins opérationnels dans les environnements extrêmes, notamment celles intrinsèquement liées à l'exploration spatiale et à notre expansion dans ce domaine (p. ex., bases militaires extraterrestres, défense antimissile en orbite, armes spatiales et conquête de l'espace).

Importance pour la défense et la sécurité

L'atelier sur les habitats extraterrestres résilients (RETH), qui a eu lieu les 22 et 23 octobre 2018 à l'université Purdue, rassemblait des experts provenant du milieu universitaire, ainsi que des secteurs public et privé afin de discuter des difficultés liées au travail dans des conditions extrêmes. Bien que, dans le cadre de cet atelier, ces questions devaient être abordées d'abord sous l'angle de l'exploration spatiale, on a également souligné les conséquences importantes directes en matière de défense et de sécurité. Un des aspects importants est l'état de préparation et la capacité de travailler dans un environnement extrême comme l'Arctique pendant une longue période. On ne peut passer sous silence les questions de défense et de sécurité qui peuvent devenir problématiques sur une grande échelle pour plusieurs pays qui ont des intérêts opposés en ce qui concerne l'expansion des opérations militaires dans l'espace (p. ex., bases militaires extraterrestres, défense antimissile en orbite, armes spatiales et conquête de l'espace). Il est donc impératif que les Forces armées canadiennes soient bien au fait de ces questions et qu'elles développent la capacité de concevoir et de mettre en place un plan d'atténuation le temps venu.

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1 Background

The 2018 Resilient ExtraTerrestrial Habitats (RETH) workshop was held 22–23 October 2018 at Purdue University, West Lafayette, IN, USA. RETH provided a platform for academic, industry and government experts to discuss challenges of operating in extreme environments and implications for imposing a presence in such environments. The colonization of space will have to occur as a joint and collaborative effort among all stakeholders; of many institutions (academia, industry, government, private), as well as many nations.

While the panel discussions focused on space exploration and future human colonization of space, there are parallels relevant to defence and security. The preparedness and ability to operate in extreme environments, such as the Arctic, for extended periods of time is of utmost importance for military operations. Additional consideration relevant to defence and security is the fact that there are competing interests (of several nations) in expanding military operations in space (e.g., extra-terrestrial military bases, orbital missile defence, space-based weapons, and dominance over the space domains). Therefore, it is of critical importance for the Canadian military to be aware of such issues and develop the capability to devise and implement mitigation plans when the time for such action comes.

This Reference Document is organized as follows: the highlights from talks and panel discussions are presented in Section 2, and the summary is outlined in Section 3.

2 Highlights from invited talks and panel discussions

To embark on exploration, it is essential to train and prepare in small steps. For example, one cannot take their first camping trip in a harsh and unforgiving environment. Rather, smaller steps are needed to achieve the knowledge and expertise necessary to perform and even thrive in a given environment. This is **relevant to defence**, because military operations are often performed in harsh environments, requiring resilience training and preparedness.

In terms of space exploration and steps necessary to conquer the obstacles presented to us, we should go to the Moon first. In fact, the US Space policy directive 1 states the following: "…*The US will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destination*" (signed in 2017). NASA's charter is to explore and also to develop space, and therefore, NASA is willing, and sometimes even capable, to provide framework for commercial partners and the private sector.

Strategic principles of human space exploration include fiscal realism, gradual buildup of capability, architecture, openness and resilience, global collaboration and leadership, and continuity of human spaceflight. However, there are many difficulties, requiring many nations need to cooperate. One institution has no capabilities to do it all, and so it has to be an international effort. This aspect is **relevant to defence**, as many technologies are developed internationally, and in collaboration with allies and third parties. Some issues might include, for example, the risk of reverse engineering or a certain intellectual property being used for malicious purposes.

We also need to think about governance structure and laws for any future colonies on the Moon (and beyond). Such issues translate to the present day issues **relevant to defence**: for example, what is the governance structure and laws that should be imposed in the Arctic? How can these be enforced? Who will be the enforcer? How do we ensure the protection of assets?

Away from home, how do we address the issue of resilience? The people might be days to many days away from home, and thus need capabilities to repair things on site, and deal with other aspects. For example, the first object 3D printed on the International Space Station (ISS) was a tool. While this particular topic is applicable to space, it is **relevant to defence**, because military operations need to be carried out at top performance in the harshest environments on our planet.

Can we utilize the resources better? How do we learn along the way? We often see conceptual and innovative designs (whether that be tools, technology, and capabilities), but typically there is no engineering behind it. There are no hard numbers. It is important that realistic and achievable plans, with proper engineering support, are put forth. As much as such concerns are discussed in the framework of space exploration, they are as much **relevant to defence**, especially in terms of development of new technologies and capabilities in warfare.

Deep space inter-operability system standards and domain areas include: avionics, communications, power, rendezvous, robotics, thermal, environmental control and life support systems. Other systems are: radiation protection, fire safety (smoke eater, single cartridge mask), logistics (long wear clothing, laundry, resource recovery and then disposal, bags and foam repurposed with 3D printer, automatic RFID), cross-cutting (ops independent of earth and crew, manufacture replacement parts in space).

Hazard characterization is another important concern. One of the sources of hazard is impact threat. Impact threat can come from very small objects called micrometeoroids, or large objects (e.g., *Silber et al*., 2009), called meteoroids or asteroids, depending on their size. One of the implications of micrometeoroid impacts is the effect on satellites (e.g., *Pisacane*, 2008; *Cooke et al*., 2017). A sudden jolt or electromagnetic discharge can render a satellite inoperable. For example, GOES-13, one of the satellites in the Geostationary Operational Environmental Satellite (GOES) system operated by the United States' National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite, Data, and Information Service division, went off-line as a result of a micrometeoroid impact in 2013.

Typically, we hear only about most notable and dramatic events, such as the recent Chelyabinsk bolide that exploded over Russia in 2013 and produced a strong blast wave. The shockwave produced luminous, audible, and inaudible phenomena, and most notably, it caused significant window damage on the ground, injured numerous people, and illuminated the fact that such events are not as rare as we might hope. Most interestingly, the Chelyabinsk bolide was not seen before impact, given that it came from such an angle and direction, that there was no advance warning. In fact, the revised impact flux is higher than previously estimated, attesting to the great need to include the meteoroid hazard high up on the list when considering challenges in space exploration.

The characterization of impact hazard is also **relevant to defence**, because such events can mimic the first strike (*Altmann*, 2005). The signature (seismic, infrasound, luminous) of a bolide is similar to that of a missile, and thus, the capability to recognize such an event and make a crucial decision in real time is of utmost importance for national security.

3 Summary

Before humans embark on extensive space exploration and human colonization of space, there are numerous aspects to consider. Besides developing the necessary technology that will takes us on such journey, it is imperative to evaluate the implications for the defence and security community. Altruistic motives for space exploration aside, one should not escape the fact that there are nations with keen interest in expanding their presence (including military dominance) into the space domain.

The relevance of being and remaining on the frontier of knowledge relevant to space related issues is multifold. This certainly applies to Department of National Defence (DND), and by extension, DRDC. Even though we might not have current projects directly related to this particular topic, it is important to remain in the forefront of knowledge and cutting edge research related to the defence community. There is a growing interest in characterization and identification of airborne sources, and inevitably, more of such research will be thrown our way in the coming years. Moreover, DND is interested in human response to and survivability in a harsh environment (e.g., the Arctic), thus, new knowledge related to the frontiers of space environment is directly related to military applications. Networking with the USA-based governmental agencies and their partners, which are directly working on military applications, is essential. A common theme of planetary defence and space exploration is a venue for establishing a common ground and learning more about their capabilities and how we could potentially benefit from that in the future (e.g., sensing).

References

Altmann, J. (2005), Acoustic-seismic detection of ballistic-missile launches for cooperative early warning of nuclear attack, *Science and Global Security*, 13(3), 129–168.

Cooke, W., Matney, M., Moorhead, A. V., and Vavrin A. (2017), A Comparison of Damaging Meteoroid and Orbital Debris Fluxes in Earth Orbit, paper presented at *7th European Conference on Space Debris*, Darmstadt, Germany, 18–21 Apr. 2017.

Pisacane, V. L. (2008), The space environment and its effects on space systems, *American Institute of aeronautics and Astronautics*.

Silber, E. A., ReVelle, D. O., Brown, P. G., and Edwards W. N. (2009), An estimate of the terrestrial influx of large meteoroids from infrasonic measurements, *Journal of Geophysical Research: Planets*, 114(E8), doi:10.1029/2009JE003334.

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