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challenge. Year-round, multi-domain access for science is required to provide the observations, measurements and analysis required to build effective predictive, decision-informing models. Year-round, multi-domain access for emergency response and national security is required to develop and test Arctic hardened technologies, enable robust domain awareness and facilitate Arctic operational experience. The proposed High Arctic Research Center (HARC) has the potential to provide year-round, cost-effective access to atmosphere, ocean and coastal environments for both scientific and national security research, development and technology testing. Coordination and collaboration across North American Arctic research and development infrastructure has significant potential scientific and security leveraging value. The HARC has a potentially important role as a cooperative Arctic research infrastructure hub within this North American Arctic research and development collaborative. This cooperative infrastructure network also has the potential to play a contributing role to informing policy dialogues and planning for the North American Arctic. The following paper explores each of these topics in more detail.

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The Arctic is undergoing major, accelerating change and this change brings a complex mix of impact, opportunity and challenges. Multiple recent studies highlight the multifaceted character of this rapidly changing environment. The 2018 NOAA Arctic Report Card reports that surface temperatures continue to warm at twice the rate of the rest of the globe (National Oceanic and Atmospheric Administration, 2018). The twelve lowest years of sea ice coverage have all occurred in the past twelve years. In the Bering Sea region, ocean primary productivity levels in 2018 were sometimes 500 percent higher than normal levels.

The 2017 AMAP report emphasizes that effective mitigation and adaptation policies require a solic

understanding of Arctic climate change, in particular improving predictions of the timing of future Arctic changes.

Accelerating Arctic change will have complex and interconnected impacts in multiple areas (National Science & Technology Council, 2016; United States Arctic Research Commission, 2019). Coastal communities are experiencing permafrost thaw, accelerated coastal erosion and rapidly diminishing access to traditional food sources (Gibbs and Richmond, 2015). Energy infrastructure, surface and marine transportation systems are impacted by rapidly changing conditions (Arctic Council, 2009). The opening Arctic ocean is attracting significant US and international interest and activities focusing on new access to significant natural resources (National Petroleum Council, 2015; Rosen and Thuringer, 2017; Brigham, 2014). The opening Arctic also brings new and significantly more complex national security, safety and emergency response challenges (Department of Defense, 2019A; Department of Defense, 2019B; United States Navy, 2019; United States Coast Guard, 2019).

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The recently launched Mosaic expedition will focus on these dynamics for a full annual cycle in the central Arctic Ocean (Mosaic, 2016). This expedition will make detailed observations on seasonally varying energy sources, mixing processes and interfacial fluxes. Measurements will be made on the processes contributing to the formation, properties and behaviors of Arctic clouds. Mosaic will deploy an extensive set of measurements extending from the atmosphere,



Figure 1. HARC location (Hardesty et al, 2019).



Figure 2. HARC conceptual design (Hardesty et al, 2019).

FAA Restricted and Warning areas at the HARC site provide access to airspace 700 miles northward across the Arctic Ocean toward the North Pole. This FAA airspace, coupled with support for unmanned aerial systems operational support, is a major asset for scientific observation and technology testing (Figure 2). This airspace, coupled with an onsite runway, enable coordinated terrestrial-aerial-marine research by a range of different unmanned aerial system types. Nearby ocean access provides the capability to field complementary surface and subsurface unmanned vehicle operations, enabling complementary observations and measurement in the atmosphere, as well as at and below the ocean and ocean-ice interface.

Figure 3. FAA Restricted and Warning areas at HARC provide cross-Arctic access for aerial observations and measurements (Hardesty et al, 2019).

HARC is intended to provide a science platform that will enable complementary, year-round measurements and observations in the Beaufort and Chukchi Seas. This data will enable research to understand and develop robust predictive models for this region of the Arctic. As previously noted, while extended summer observations are reasonably well developed, there is currently no research infrastructure that can support development and maintaining multi-domain observations on a year-round basis and over the multi-year time periods during which

From a national security and emergency response perspective, HARC will enable research, development and technology testing in support of expanding missions. These missions potentially include increased search and rescue needs for ships and personnel; oil spill detection and response; illegal and unregulated fishing; migration and illegal entry into the US; foreign surveillance and intrusion; cyber incursions and other communications disruptions, missile defense; and direct physical and other attacks on the US homeland. Supporting these missions will require research, development and Arctic-condition testing for domain awareness

In addition, both technical cooperation and policy negotiation will be required to address important North American Arctic issues, including negotiation of continental shelf boundaries and effective management of increased maritime traffic across the Beaufort Sea north of Alaska and through the adjacent Northwest Passage (Baker, 2009; Steenson, 2016; Higginbotham and Spence, 2018).

The recently released Canadian Arctic and Northern strategy specifically calls out the value of North American Arctic cooperation. "We will target cooperation with our North American Arctic partners: the United States-Alaska and Kingdom of Denmark-Greenland. Demographic, geographic and socio-economic similarities between the Canadian Arctic and north, Alaska and Greenland provide a strong case for cooperation... Additionally, we will regularize a bilateral dialogue with the United States on Arctic issues as this will strengthen the leadership role both countries take on Arctic issues and enhance the Canada-U.S. bilateral relationship across government and with Northerners." (Government of Canada, 2019A, 2019B, 2019C)

Canada has recently established the Canadian High Arctic Research Station (CHARS), a permanent, multi-mission Arctic research station with year-round access to multiple Arctic domains (Polar Knowledge Canada, 2019). CHARS strategic priorities include providing baseline information to prepared for northern stability, including developing capabilities for predicting the impacts of changing ice, permafrost and snow on shipping, infrastructure and

Greenland" (Wilson Center, 2019). At this program, Greenland's minister responsible for foreign affairs highlighted the dramatic physical and environmental changes that Greenland is experiencing as the Arctic warms. In addition, she highlighted the active reconfiguration of coordination of international research in Greenland, including the establishment of a new international research hub in Nuuk. This research center will coordinate logistical and administrative services for international science facilities located in Greenland. This center will also facilitate the coordination, collaboration and incorporation of multiple generations of

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