Educate, engage and advocate with the public and policymakers to mitigate climate change to protect global security and natural ecosystems

WHITE PAPER

PROPOSED: NATIONAL ARCTIC CLIMATE RESTORATION INITIATIVE (NACRI)

Stanley Farkas, PhD; Steven Zornetzer, PhD; Tony Strawa, PhD; Philip Russell, PhD; Gary Latshaw, PhD

EXECUTIVE SUMMARY

Global warming (GW) is causing a dramatic shrinking in Arctic sea ice, land ice and snow. A National Oceanic and Atmospheric Administration (NOAA) study reports that the Arctic has warmed more than twice as fast as the rest of the planet, due to a phenomenon known as Arctic Amplification. Arctic warming also drives the thawing of permafrost releasing greenhouse gasses (GHG) from the Arctic land and shallow seabed off the Siberian coast, further accelerating global warming. With loss of sea ice left unchecked, global warming will soon exceed the 1.5°C (2.7°F) target set by the UN Intergovernmental Panel on Climate Change(IPCC) for 2100, resulting in food and water shortages, damage to infrastructure and the environment, mass human migrations, and destabilization of governments, all threatening U.S. national security interests at home and abroad.

U.S. national security at home is at risk because of extreme weather patterns and sea level rise linked to Arctic warming impacting our agriculture, infrastructure, and economy. The balance of power in the Arctic region is in transition as Russia is pursuing resource exploitation and shipping in the region. China is also showing increased interest in the region. Juxtaposed upon these growing threats, U.S. military installations and facilities in the Arctic are at risk of significant infrastructure damage resulting from erosion, thawing permafrost, and rising sea levels.

We believe the U.S. urgently needs a mitigation strategy focused broadly on Arctic cooling to prevent the effects of a warming Arctic from reaching a tipping point. This White Paper proposes to the Biden-Harris Administration that the U.S. establish, in the spirit of a coordinated "whole-of-government approach", a multi-agency effort for an applied R&D program called the "National Arctic Climate Restoration Initiative" (NACRI). NACRI is designed to better understand Arctic climate processes and develop approaches to help preserve and restore the Arctic climate. Further, we believe the U.S. should take the lead in developing and coordinating an international response to mitigate Arctic warming and its accelerant effect upon global warming (GW) and the climate change crisis. The DoD identifies GW as a threat multiplier. Annual funding for NACRI would notionally be at 2022 levels of relevant elements of participating Agency budgets ***augmented*** by an aggregated total of $283M over 5 years. *(Please note: the primary goal and budget of NACRI represents an update from our publication "Strawa, A. et al. Arctic Ice Loss Threatens National Security: A Path Forward. Orbis. 10 Aug 2020").*

A frozen Arctic is essential to a stable global climate. Doing nothing to stop the continued warming of the Arctic and the devastating consequences to the world, at home, and to our National security is not an option.

1.0 OVERVIEW

The principals at "Secure the Future 2100" (https://securethefuture2100.org/) respectfully submit this proposal to the Biden-Harris Administration for consideration. Our organization is dedicated to educating, engaging, and advocating with the public and policy makers to mitigate climate change to protect global security and natural ecosystems. Our perspective on the Arctic region is shaped by a deep interest and commitment to preserving and restoring a cooler and more normal Arctic climate, the dramatic and alarming heating of which is amplifying GW and climate change throughout the northern hemisphere and perhaps world-wide. Accordingly, we believe our organization's goals are in alignment with the Biden-Harris Administration's commitment in making climate change a whole-of-government approach with a national security and foreign policy priority to slowing down and reversing GW and climate change. We appreciate the opportunity to provide our perspective on research priorities for the Arctic: particularly at a time when the Arctic is in crisis.

This white paper proposes a bold new plan for multiple Federal Agencies to add a major new Arctic Climate restoration research initiative to their existing Arctic R&D programs. A fundamental underlying driver behind our proposal is the strong belief that observational science alone is not enough to address the impending climate disaster the world is now facing. Active and focused R&D targeted on possible ***mitigation and restoration*** strategies to slow GW are now needed. Our proposal first describes *why* the Arctic, including its sea ice in particular, appears to be a critical leveraging element in the rate of GW going forward. The proposal then describes some initial data suggesting there may be safe and reversible ways in which Arctic climate restoration could potentially be preserved and possibly restored. If these data are correct, and considerably more research is needed to verify and potentially extend such preliminary findings, then a coordinated effort by multiple Federal Agencies (see below) can play a critical and impactful role in enabling the U.S. to be at the forefront of a multi-national effort to slow GW thereby buying time for global decarbonization. We propose that the U.S. take the lead in developing and coordinating an international response to mitigate Arctic warming and its accelerant effect upon GW and the climate change crisis. We believe this proposal is consistent with the spirit and intent of the recent National Academies of Science, Engineering and Medicine report, "Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance (2021)", which focused attention exclusively on atmospheric approaches to mitigate GW.

Put simply, our proposal is for an ***action-oriented*** basic and applied research initiative to directly address the possibilities of restoring the Arctic climate to slow global warming. **We strongly recommend that in this time of Arctic crisis the national Biden-Harris Administration climate action plan embrace a more pro-active research and development agenda, an agenda incorporating the goal of potentially restoring the Arctic climate to its more historic norm.**

The Arctic's natural environment, the Arctic Indigenous Peoples of the region, and flora and fauna are in desperate need of help. Arctic warming has reached crisis proportions. Studies have shown that the Arctic sea ice albedo (reflectivity) feedback has become a driver of GW, not merely a consequence of it. In the next five-years **we believe we must lean forward to understand both the science and engineering of safe and effective Arctic climate restoration techniques**

2.0 NEEDS STATEMENT

In summarizing the annual 2020 Arctic Report Card, NOAA stated that "The sustained transformation to a warmer, less frozen and biologically changed Arctic remains clear" [1]. The Arctic has played a central role in keeping the global climate relatively stable throughout human

history. GW is upsetting this stability, causing a dramatic reduction in Arctic sea ice, land ice and snow, thereby impacting local Arctic ecosystems, infrastructure, and the four million inhabitants of the region (including Arctic Indigenous Peoples).

This loss of ice and snow is increasing the absorption of solar radiation by land and ocean, causing the Arctic to warm more than twice the global average (Arctic amplification), and releasing GHG from the thawing of land and offshore permafrost (with combined reserves of five times the amount of CO_2 equivalent to that in the atmosphere) [1,2,3,4.] With warming of the Arctic, a number of feedback loops have been established that enhance Arctic amplification. A sea ice reflectivity feedback loop from heating of the ocean contributes the equivalent of an additional 25% of global CO_2 emissions to the atmosphere (based on anthropogenically derived CO_2 emissions from 1979 to 2008) [5]. Similarly, a land ice/snow reflectivity feedback loop from heating of the land is estimated to contribute an additional 25% equivalent of global CO_2 emissions to the atmosphere [6].

In addition to a land reflectivity feedback, an accelerating and potentially irreversible permafrost carbon-climate feedback loop may also be underway with the rapid increase of microbial breakdown of ice-age land-based organic matter to methane and CO_2 and the release of methane from the permafrost residing on the shallow east Siberian Arctic Ocean shelf (microbial breakdown of organic matter and melting of methane hydrate) [7,8, 9]. A covering of sea ice over the East Siberian Arctic Shelf has historically helped maintain the quantity of methane released. With ice loss the potential of irreversibly releasing large amounts of methane becomes more plausible [4, 10,11]. This phenomenon is still under assessment [6, 10,11]. Arctic warming is also increasing Arctic wildfires (consuming both plants and soil organic matter) releasing large amounts of CO_2 and black carbon, further enhancing permafrost thaw [12,13,14]. Also, about 20% of Arctic land permafrost is vulnerable to abrupt permafrost thaw producing thermokarst lakes as ground subsides and fills with water [15, 16, 17]: rapidly decomposing organic matter and releasing methane and CO_2 to the atmosphere. Sea ice decline and associated changes in Arctic regional climate are drivers of changes to tundra and boreal forest ecosystems with boreal forests expanding into tundra and differential growth of shrubs in tundra [18, 19]. These changes complicate the projection of tundra vegetation in cycling carbon as permafrost degrades (up-take or release of carbon to the atmosphere by vegetation) [11, 19]. This rapid decomposition of permafrost, coupled with boreal forest wildfires, is changing the Arctic from a carbon sink to a carbon source further contributing to Arctic amplification and GW [20, 21, 22]: a scenario that may be slowed with effective mitigation techniques [11]. The link between ice and snow loss and rapid thawing of permafrost is evident not only currently but is also noted in the paleoclimate record [23, 24].

Unfortunately, GHG emitted from decomposition of permafrost has not been included or is underestimated in most models used to predict future climates [15, 25, 26]. The importance of thawing permafrost was addressed by climate scientists to policymakers during a U.S. State Department conference in 2015 [27, 28]: also testifying on the severe impact of loss of sea ice to the Arctic, global warming, and national security before the Senate Commerce Science and Technology Committee in 2020 [29]. "...70% of current infrastructure in the permafrost domain is in areas with high potential for thaw of near-surface permafrost by 2050. One-third of the pan-Arctic infrastructure and 45% of the hydrocarbon extraction fields in the Russian Arctic are in high hazard regions where the ground is susceptible to thaw-related ground instability. ... fundamental Arctic infrastructure will be at risk, even if the Paris Agreement target is achieved." [30]. Damage to buildings, power stations, pipelines, manufacturing facilities, roads, and railways

have a value estimated to be at least in the $10's of billions. [31, 32]. Resolving Arctic warming is critical to prevent thawing permafrost from reaching a tipping point.

Arctic amplification also impacts atmospheric and ocean circulation patterns, such as weakening of the jet stream and slowing of the Atlantic Meridional Overturning Circulation (AMOC) that circulates water between the Arctic and Antarctica, causing changes to weather patterns in the Northern Hemisphere and possibly globally [33, 34]. A weakened polar jet stream has been linked to the extreme weather events of 2018 [34]. Temperatures in the southwest United States rose above 37.8ºC (100ºF) for days, heavy rains and floods inundated the mid-Atlantic states, and California experienced unprecedented droughts and wildfires. The Southwest witnessed a persistent heat wave, and the mid-Atlantic endured heavy flooding. Japan, Scandinavia, and much of Europe had persistent heat waves leading to wildfires in Greece. A slowing of the AMOC would cause cooler weather for Europe and potentially increase the risk of the collapse of the Western Antarctic Ice Sheet increasing sea level rise by 3 meters (9.8 ft) [35, 36, 37]. There is "...the possibility that rapid and unstoppable sea-level rise from Antarctica will be triggered if Paris Agreement targets are exceeded" [38].

Arctic Indigenous Peoples of the region are especially vulnerable to climate change since they are so deeply tied to the land. Changes in the region are threatening their health, livelihood, food gathering, economy, and culture [39]. In the US alone, approximately 140,000 Alaskan Natives are spread throughout the state including 213 villages [40, 41] : most of these villages being located along its 47,300 miles of coastline [42]. For thousands of years sea ice has protected the Alaskan coast from erosion. Without the protection of sea ice, 6,600 miles of its northern coastline are now subjected to severe erosion and flooding from storms and sea level rise destroying homes and structures and causing sea water to infiltrate drinking water sources and sewage - affecting public health and communities [39, 43]. Two hundred villages of Alaskan Natives are affected to some degree by flooding and erosion with 31 villages on the coastline facing imminent existential threats [44]. The loss of sea ice also limits their capability to hunt marine mammals, a main source of their diet. Thawing of permafrost is also destabilizing Alaskan Natives homes, structures, roads, and airstrips, and with soil instability making it difficult to hunt, gather food, and to conduct their daily activities [29,39,45]. Alaskan Natives traditionally rely on ice roads (frozen rivers) as a means of transportation in the winter, but that is being threatened [39,45]. Without transportation, villages can be isolated and cut off from needed resources and medical facilities.

Changes in the Arctic are leading to increasing tensions in the area, threatening U.S. national security. Both Russia and Canada have proposed charging for passage through the Northern Sea Route and Northwest Passage, respectively [46]. Russia is revitalizing its northern fleet (including a weaponized icebreaker) and bases in anticipation of increased military activity to reinforce Russia's position with the threat of force [46,47,48.] China is pursuing economic interests in the Arctic by partnering with Arctic nations and sees itself as a "near-Arctic" country with equal rights to develop the region's resources, engage in scientific and other projects, and participate in regional governance [49, 50,51].

The economic cost of GW is high. With the likely current trajectory of rising temperature, 2ºC – 2.6ºC by 2050, the global GDP could fall between 11-14% [52]. In the US, the combined value of market and non-market damage across agriculture, infrastructure, human mortality, and labor sectors could cost roughly 1.2% of gross domestic product per each 1°C rise in temperature [53]. Maintaining a business-as-usual scenario and doing nothing to mitigate climate change could cost

in the 100's of trillions globally by 2300 in today's dollars, threatening 1.2 billion jobs worldwide [54, 55].

Rising temperatures and CO_2 concentrations are threatening (reduce) productivity and nutritional value of our most basic food crops. High winter temperatures affect fruit tree and winter grain production while high summer temperatures affect many annual food crops [56,57]. The nutritional value (minerals, vitamins, protein) of wheat, rice, maize, soybeans, and other food crops could be reduced by as much as 30% and productivity reduced by as much as 28% by 2100 with rising levels of Atmospheric CO_2 [58,59,60,61]. Rising temperatures combined with high humidity in regions like south Asia are reaching extremely dangerous levels (95% and 85-95°F respectively), threatening productivity of field works and even the survivability of humans, livestock, and wildlife [56,62, ,63,64,65].

Left unchecked, GW will exceed the 1.5°C (2.7°F) target set by the IPPC for 2100 resulting in food and water shortages, sea-level rise, damage to infrastructures and the environment, mass human migrations, and destabilization of governments, all threatening U.S. national security interests [30, 66,67,68,69,70].

Implementation of an Arctic climate warming mitigation strategy is urgently needed within this decade to prevent effects of Arctic amplification like permafrost thaw and shift of boreal forests from reaching a tipping point.

3.0 OUR PROPOSAL: A MULTI-AGENCY COORDINATED R&D INITIATIVE

We propose that the Biden-Harris Administration support the establishment of a focused multiagency R&D program to develop technologies to cool and restore the Arctic climate closer to historic norms. Such an effort, if successful, could slow Arctic amplification, providing some stability to the Arctic region and thereby buy time for the international community to develop more fundamental global economic mitigation efforts and move from a fossil fuel economy to one based on carbon-free energy sources. Much effort has been focused on reducing and eventually eliminating the use of fossil fuels and removal of GHG from the atmosphere, essential efforts that must be seriously accelerated. A recent IPCC report finds that global net CO_2 emissions would need to go to zero by 2055 to have a chance of keeping warming below 1.5° C (2.7°F). Given the failure of all signatories to the Paris Accord to meet their current commitments to reduce CO_2 emissions to date, this does not seem politically realistic. More needs to be done in the short-term to mitigate GW before it is too late. Cooling of the Arctic climate would complement and work in concert with reducing fossil fuel use along with other mitigation efforts to reduce atmospheric GHG. ***We need to use every safe and effective tool in the toolbox to win the climate crisis battle.***

4.0 PROGRAM DESCRIPTION - A NEW FEDERAL INITIATIVE: NATIONAL ARCTIC CLIMATE RESTORATION INITIATIVE (NACRI)

We propose the U.S. take a strong international leadership position in addressing Arctic climate issues and the possibility of climate restoration. We propose the U.S. establish a new research and development (R&D) initiative inspired by NOAA's National Hurricane Center (NHC) where both intramural and extramural scientists perform extensive modeling and monitoring research, and engineers develop mechanisms to deal with the destructive forces of hurricanes. This new R&D initiative, NACRI, would be focused on Arctic climate restoration. ***NACRI would be a multiagency coordinated effort whose core would be comprised of NASA, NSF, NOAA, DoE***

and DoD earth sciences and relevant allied programs associated with climate change and climate modeling. Other Agencies and Departments would participate as needed (e.g., Department of State). Annual funding for NACRI would be at 2022 levels of appropriated budgets to the above Agencies ***augmented by an aggregated total of $283M over 5 years.*** Augmented funds would be apportioned through NACRI among participating Agencies and devoted to R&D into methodologies and demonstration projects designed to restore the Arctic climate. NACRI would also place significant emphasis and resources on updating and modernizing climate models incorporating a more accurate representation of the contribution of Arctic climate changes and Arctic ice representation in global warming models, thus improving prediction accuracy and capabilities. NACRI would solicit and select concepts for research and projects from government, academic, non-profit and industry organizations in keeping with the standard practices currently used by federal agencies. To achieve more inclusive engagement of villages of Alaskan Natives, scientists, engineers and, when appropriate, community members, NACRI will emphasize collaborative opportunities in Federally funded R&D.

Given the predicted enormous deleterious impacts of GW and associated climate changes, NACRI would provide a coordinated and rigorous U.S. national multi-Agency R&D effort to understand the potential risks and benefits associated with proposed climate intervention approaches. It is important that the nation, and the world, have a variety of tools to use to avoid the disastrous impacts of GW on humans and global ecosystems. Only through R&D investments can such understanding be gained. We further propose that NACRI invest in experimental efforts designed to actively and safely geoengineer climate restoration through a variety of potential approaches. Approaches for restoration would be selected through solicitation. While NACRI is primarily an R&D effort, engagement and participation of Alaskan Natives is essential for eventual buy-in. Outreach to Alaskan Natives, scientists, engineers, and policy makers for inclusion into the multiple program elements of NACRI will be essential. Additionally, eventual execution and deployment of potential methodologies to cool the Arctic requires the implementation of an appropriate and accepted governance structure. Accordingly, NACRI will explore governance structures that might be utilized for potential implementation.

4.1 Primary Program Goal: Develop technology(s) to cool and restore the Arctic climate thereby reducing the Arctic's contribution to GW produced by greenhouse gas emissions. Develop candidate technologies to Technology Readiness Level (TRL) 6-7 (Prototype demonstrated in applicable Arctic environment) by end of Year 5 and transfer technologies to a deployment organization for development to TRL 9.
Secondary Goal: (1) Demonstrate feasibility of Arctic sea ice restoration in critical target areas overlying the Eastern Siberian Arctic Ocean shelf to effectively slow release of methane from thawing sub-sea permafrost and from associated melting of methyl hydrates. (2) Explore governance structures and stimulate engagement of Alaskan Natives and other Arctic Indigenous Peoples of the region.

4.2 Program Oversight
We suggest a NACRI coordinating Program Office be formed, reporting to OSTP, that would manage, integrate, and coordinate NACRI projects and activities. Multi-Agency cooperation and communication would be essential to ensure seamless and synergistic efforts by all participating Agencies. An annual report from the Program Office Agency Administrator to OSTP, coordinated through all participating Federal Agencies and Departments, would provide data on progress of the initiative.

5.0 AREAS OF RESEARCH

Note that budgets and goals described below are notional and reflect *5-year totals* for each program element. Specific budgets, goals, milestones, and requirements will, of course, be finalized by the President's Budget and Congressional appropriations.

Climate models continue to underestimate the rate of loss of ice and cryospheric radiative forcing in the Arctic as compared with observations, leading to doubts about how well these models can be trusted to predict future global impacts. These underestimates are likely due to an incomplete understanding of cryospheric processes exacerbated by a lack of relevant observations. Augmenting current programs aimed at better understanding Arctic processes is needed in three sub-elements listed below.

5.1 Augment Cryospheric Science ($25M)

All the organizations which would participate in NACRI already have programs that study Arctic processes. We recommend that these be augmented because of the important role of the Arctic in global (at least Northern Hemisphere) weather and climate change. This program element would provide augmented funding for modeling, continued exploitation of current observations and further observations. This program element could be modeled after, or augment, NASA's Cryospheric Science Solicitation of the RESEARCH OPPORTUNITIES IN SPACE AND EARTH SCIENCES – 2020 (ROSES-2020), NNH20ZDA001N-CRYO. The budgets presented in the table below are scoped based on funding levels similar to the CRYO Announcement of Opportunity. Since changes in sea ice will likely impact ocean biology, air-sea exchanges, and ocean circulation this program element should provide funding for interdisciplinary research other related solicitations, for example Ocean Biology and Biogeochemistry, Physical Oceanography and Ocean Salinity.

Goal: Develop a better understanding of how the Arctic interacts with global weather through atmospheric and oceanic circulation patterns (teleconnections), the effects and consequences of Atlantification (intrusion of warmer Atlantic waters into the Arctic Ocean) regionally and globally, and the extent and potential impacts of carbon release due to thawing permafrost and melting of methane hydrate in the ocean.

5.2 Augment Field Measurements ($25M)

This program element would fund additional *in situ* and satellite observations needed to better understand cryospheric processes. Field measurements, especially in the harsh Arctic environment are more expensive. Thus, this program element is notionally scoped at $5M per year with participating Agencies determined by the NACRI Program Office.

Goal: To better understand cryospheric processes with additional *in situ* and satellite observations

5.3 Field Mission ($50M)

We propose the U.S. lead an international follow-on mission to MOSAIC. The total 5-year cost of this field mission is estimated to be $50M (U.S. portion) .

Goal: Obtain quantitative measurements and characterizations of important dynamic Arctic processes.

6.0 DEVELOPING ARCTIC CLIMATE RESTORATION TECHNOLOGIES TO TRL 3 BY YEAR 5

6.1 Solicitation, Feasibility and Concept Development to TRL 3 ($38M)

This program element may be modeled after NASA's Innovative Advanced Concepts (NIAC). The NIAC Program "nurtures visionary ideas that could transform future NASA missions with

the creation of breakthroughs." This new element would be similar to these but focused on Arctic climate cooling and restoration. It is suggested that all participating agencies solicit proposals designed to cool and restore the Arctic climate to slow both warming in Arctic regions and globally. Projects selected should include lab and small-scale deployments and plans for monitoring appropriate metrics during deployment. Climate modeling, required to develop a scheme to determine the smallest, lowest cost, temporal and spatial application of the proposed technique, should be included. Finally, this task could help determine if cooling and restoration of the Arctic climate can effectively slow release of CO_2 and methane from thawing permafrost and release of methane from melting methyl hydrates from shallow offshore permafrost.

6.2 Technology Maturation of Concept from TRL 3 to TRL 6/7 by year 5. ($40M)
This program element may be modeled after NASA's Game Changing Developments (GCD) Program. The Tipping Point solicitations of this program "seeks to identify and rapidly mature high-impact capabilities and technologies…". This NACRI program element would be focused on maturing technologies to restore the Arctic climate: it is critical to give the scientific community, policy makers and the public confidence the concept(s) selected by NACRI has the potential of meeting the program goal of developing technology(s) that can preserve and restore the Arctic climate. Specific goals, requirements, and milestones would be determined by Agency program managers with the assistance of the research community which should devise an efficiency metric with which to judge various methodologies. It is expected that any proposed technique would achieve at least TRL 6/7 by year 5. It is anticipated that later stages of deployment may involve public-private partnerships and Nation-state level participation.
The goals of this task would be to mature current concept technology(s) from TRL 3 to TRL 6/7 by year 5 and demonstrate that sufficient levels of Arctic cooling can be developed to significantly reduce summer Arctic energy absorption.

6.3 Test Deployment of 2 concepts ($30M)
This task should down select and fund 2 concepts for testing at meaningful scale under field conditions. Finally, this task should develop a notional plan on how the candidate technology can be applied to scale in the field at TRL 9.

7.0 ASSESS THE IMPACTS OF PROPOSED ARCTIC MITIGATION CONCEPTS ON WEATHER, CLIMATE AND ECOSYSTEMS IN THE ARCTIC REGION, NORTHERN HEMISPHERE AND GLOBALLY ($25M)
Modeling impact studies will be conducted to determine how the planet will respond to proposed mitigation concepts. This program element is critical to give the scientific community, policy makers and the public confidence that the effects of these techniques are not likely to produce undesired or unintended consequences, are easily reversible, and have no (or acceptable) termination effects. Studies funded by this program element would necessarily interact with other relevant programs elements. This program element could also provide supplemental funding for interdisciplinary research in other related solicitations. For example, Ocean Biology and Biogeochemistry, Physical Oceanography and Ocean Salinity. It could be modeled after Geoengineering Model Intercomparison Project (GeoMIP). Specific, goals, requirements, and milestones would be determined by the program manager with the assistance of the research community.

8.0 COST-BENEFIT AND RISK ANALYSES OF ARCTIC CLIMATE RESTORATION TECHNOLOGY ($50M)

It will be critical to demonstrate to national stakeholders, international partners, and the public that the regional and global damage resulting from further warming and Arctic ice and snow loss far outweigh any short-term economic benefits from augmented commercial opportunities due to such ice loss. For example, increased fossil fuel extraction in the region would both endanger local habitats and the traditional livelihood of Alaskan Natives and other Arctic Indigenous Peoples of the region and contribute to accelerating GHG emissions that the world should be aggressively seeking to limit. This program element would fund researchers to perform cost-benefit analyses that would include the effects on Arctic Indigenous Peoples, infrastructure and Arctic flora and fauna. **Active participation and engagement of Alaskan Natives and Arctic Indigenous Peoples in this program element is essential.** Finally, this program element will also be used to explore potential international governance structures for potential deployment of successful candidate technologies. We expect the Department of State to play a key role in this aspect of the program.

9.0 NOTIONAL BUDGET AUGMENTATION (TOTAL FOR NACRI)

Annual funding would notionally be at 2021 levels of appropriate elements of participating Agency budgets ***augmented*** by an aggregated total of $283M over 5 years. *(Please note: this proposal budget is updated from the recent publication "Strawa, A. et al. Arctic Ice Loss Threatens National Security: A Path Forward. Orbis. 10 Aug 2020")*

NACRI BUDGET AUGMENTATIONS ($M)	**Yr 1 Total**	**Yr 2 Total**	**Yr 3 Total**	**Yr 4 Total**	**Yr 5 Total**	**TOTAL Yrs 1-5**
Area of Research						
Augment Cryospheric Science (all agencies)	**5**	**5**	**5**	**5**	**5**	**25**
Augment Field measurements (all agencies)	**5**	**5**	**5**	**5**	**5**	**25**
Field mission	**2**	**5**	**13**	**14**	**13**	**50**
Achieving Arctic Climate Restoration Technologies To TRL 6/7 By Year 5						
Solicitation, Feasibility and Concept Development to TRL 3 (all agencies)	**3**	**5**	**10**	**15**	**5**	**38**
Technology Maturation of Concept to TRL 6/7 (NASA)	**3**	**7**	**10**	**10**	**10**	**40**
Test Deployment of 2 Concepts	**0**	**0**	**10**	**10**	**10**	**30**
Assess impacts of Arctic Mitigation Concepts to Planet (all agencies)	**5**	**5**	**5**	**5**	**5**	**25**
Cost-benefit and Risk Analyses of Arctic Restoration Technology (all agencies)	**10**	**10**	**10**	**10**	**10**	**50**
Total across all agencies	**33**	**42**	**68**	**74**	**63**	**283**

FURTHER INFORMATION AND CONTACTS:

For more information on NACRI please visit our website at SecureTheFuture2100.org

If you have questions, you can e-mail us at: ScienceTeam@securethefuture2100.org. We can give you more information, talk with you, or arrange to give a presentation to your group or organization.

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