NASA Institute for Advanced Concepts
An Institute of the Universities Space Research Association
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Short Report: Long-term Success of NIAC-Funded Concepts

*Excellence is the result of caring more than others think is wise,
risking more than others think is safe, dreaming more than others think is practical,
and expecting more than others think is possible" (Mac Anderson)*

NIAC, an institute of the Universities Space Research Association, was established in 1998 to inspire and explore innovative aerospace systems and architectures. This virtual institute, using a well-regarded peer review process, seeks out aerospace and space science concepts that are systems or architectures aimed ten to forty years in the future. For many NIAC concepts, the enabling technologies may not be available and the science may not be totally understood. NIAC has funded 126 Phase 1 (6 months, up to 75,000 dollars) and 42 Phase II (2 years, up to 500,000 dollars) studies based in a wide range of universities and businesses.

As NASA focuses on a return to the moon, the value of investing in long-term activities like NIAC has been a topic of discussion. This analysis focuses on aspects of the value, in particular, of investing in the NIAC's suite of investigators and activities.

Leveraging of NIAC Support

Continuing support of advanced concepts development from other sectors is a form of return on investment (ROI) for NIAC. ROI is difficult to analyze for NIAC because the institute has only been in existence for 9 years, but focuses its activities on far-term projects. It is certain that the data we have so far represent only a portion of the economic assets that will be devoted to the realization of the most promising concepts. That said, to date numerous NIAC projects have become incorporated into the agency's plans; some have received follow-on funding from the agency; some have received additional funding from other agencies or the private sector.

Recently, we asked NIAC Fellows to provide us information about additional funding they may have received to continue NIAC-sponsored work. This summary describes a dozen efforts that have gone on to garner funding support from NASA or other sources. **Initially funded by NIAC at the level of 5.9 million dollars, these efforts garnered at least 21.2 million dollars additional support from NASA, from other agencies, and through the private sector.** This estimate is a conservative one as some NIAC projects have trickle effects throughout the space sector, some produce spin-offs that are difficult to track but which also create ROI, and also because some projects become classified and data are no longer broadly available. It should be noted that ten of the projects were funded through Phase II. This means that to date, nearly 25% of Phase IIs have received further validation by additional funding. This is a significant measure of the excellent credibility of NIAC's results. The distribution of follow-on funding is summarized in Figure 1.

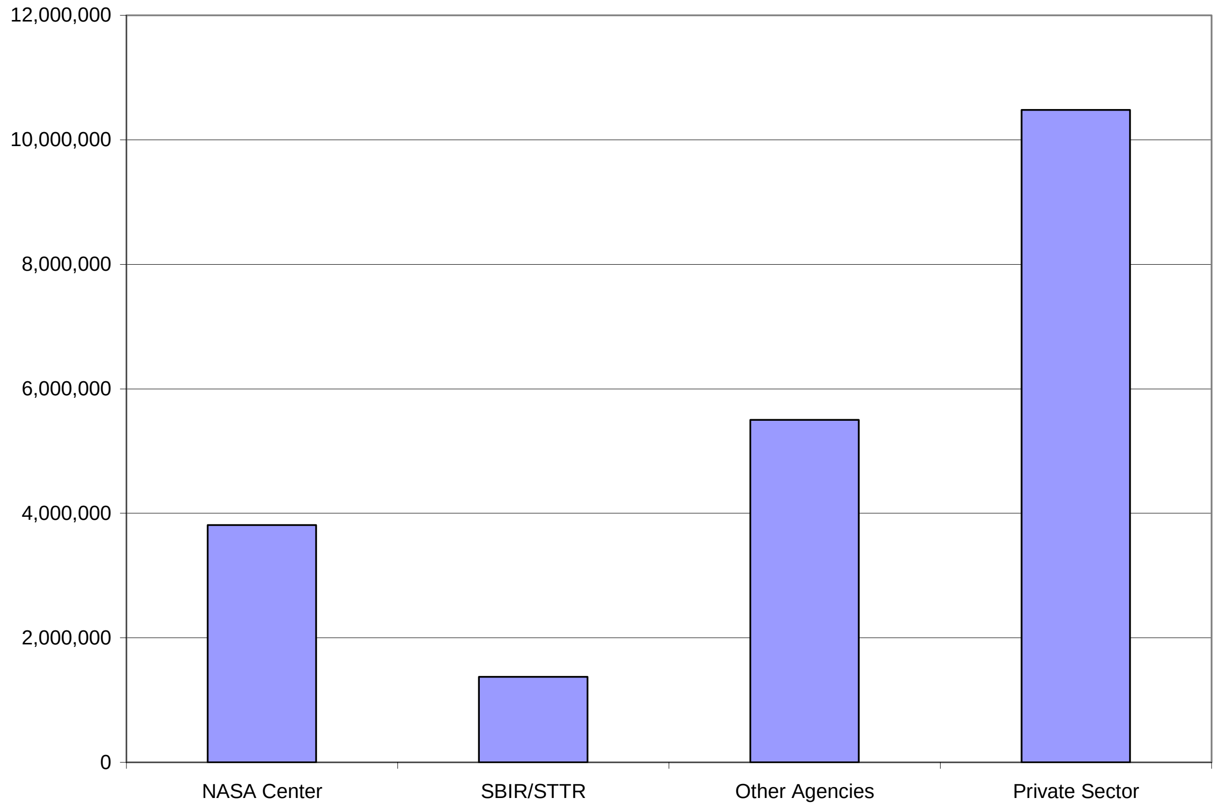

Figure 1. Millions of dollars of support provided beyond the NIAC investment. This graph reflects a dozen NIAC concepts having an initial NIAC investment of 5.9 million dollars.

Because of the sheer diversity in NIAC projects, a case-by-case description follows with further information.

The Space Elevator (Bradley Edwards, PI) This effort sparked the creation of numerous businesses and attracted funding with a particular emphasis on the development of carbon nanotube materials. Space Elevator has been the focus of numerous prize competitions, including NASA's Centennial Challenges program. Additional support: **at least 8.5 million dollars**. Future impact: billions if not trillions of dollars in launch savings relative to current methods. As one NIAC Fellow explained: "The Space Elevator would change everything."

Moon and Mars Orbiting Spinning Tether Transport (MMOSTT) (Robert Hoyt, PI). Momentum exchange electrodynamic reboost (MXER) tethers represent magnitudes of reduction in cost for earth-to-orbit and in-space propulsion. Like the space elevator, tethers too have stimulated the development of new business so the data we have for additional funding is an underestimate. Additional funding has arisen from NASA, DARPA, and other sectors.

Additional support: **at least 3.4 million dollars**. Future impact: millions if not billions of dollars in launch and propulsion savings.

Global Environmental Micro Sensors (John Manobianco, PI). This innovative atmospheric sensing system of in situ airborne probes garnered support from the Air Force and from NASA, as well as investment from ENSCO company funds. Protoyping will be carried out in concert with Kennedy Space Center this spring. Additional support: **approximately 2.8 million dollars**. Potential impact: billions of savings as a consequence of enhanced forecast accuracy for weather-sensitive space launch and aviation industries. Mitigation of loss-of-life associated with violent storm trajectories.

The New Worlds Observer (Web Cash, PI). This concept for planet finding was only months into its Phase II funding when it burst onto the global scene by gracing the cover of Nature. This concept has benefited from continuing support from NASA and more notably, at least two million dollars in support for additional development from Northrup Grumman and its partners. Cash, the PI, says this concept would never have seen the light of day without NIAC backing. Additional support: **at least two million dollars**. NASA GSFC has also contributed substantial in-kind support but we do not have numerical data. Potential impact: the same, or better, science return than the Terrestrial Planet Finder, at a savings of five billion dollars.

Electromagnetic Formation Flying (Ray Sedwick and Dave Miller, PIs). This system represents an important enabling technology for space missions, especially space telescopes or in deploying large structures. NIAC has funded a few formation flying concepts with this being most successful to date. Development of the EMFF continues with support from DARPA and STTR. Additional support totals **1.7 million dollars**. The potential impact will be the enabling of a whole new class of space telescopes and structures.

Global Constellation of Stratospheric Scientific Platforms (Kerry Nock, **PI)**. Constellations of stratospheric balloons could result in superior monitoring of environmental conditions. This project has seen **further investment of 650,000 dollars** from NASA Centers and SBIR.

Mini-magnetospheric Plasma Propulsion (M2P2), (Robert Winglee and John Slough, PIs)
The M2P2 was included in the NASA Decadal Plan and funded by MSFC to continue experiments confirming computer models. A plasma sail review panel identified a number of technical issues needing further research before feasibility could be assessed. Subsequent research results have addressed most of these issues. Additional support: **700,000 dollars** to continue development of Helicon component.

Lorentz-Actuated Orbits: Electrodynamic Propulsion without a Tether (Mason Peck, PI).
This revolutionary concept relies on one of the last areas of classical physics that could be applied to propellantless propulsion. Additional funding: **550,000 dollars** from DARPA and NRO. Potential impact: significant cost-savings in propulsion.

Swarm Array Space Telescope (Ivan Bekey, PI). This project received Phase I funding only. The use of this revolutionary telescope, employing a large membranous reflector element and a holographic crystal second stage, could represent significant upload mass savings over present next generation space telescope designs. Additional funding: **345,000 dollars** from NRO. Potential impact: not assessed.

Propagating Magnetic Wave Plasma Accelerator (John Slough, PI). This project, funded only at the level of Phase I support, now enjoys annual support from the Air Force of **100,000 dollars**.

The Biosuit (Dava Newman, PI). The Biosuit concept uses mechanical counter-pressure created by spray-on materials to provide a spacesuit that assists and protects astronauts at work on partial gravity surfaces. Additional follow-on funding from NIAC and NASA Headquarters has been directed towards this project. It is likely that other NASA center resources have been deployed. Additional funding: at **least 50,000 dollars** from NASA with matching funds from NIAC and partial funding believed to be in place from at least one center. Potential impact: enhanced safety for astronaut EVA activities. Additionally, assistive technologies planned for the suit are now being prototyped for locomotion support for individuals suffering from gait disturbances following stroke.

Scalable Flat-Panel Nano-particle MEMS/NEMS Propulsion, (Brian Gilchrist, PI). Currently in its first year of Phase II funding, this work utilizing a dramatically different form of charged-particle propulsion has already attracted additional funding from within the University of Michigan. Additional support: **100,000 dollars**. Potential impacts on propulsion expected, and new studies will examine medical applications as well.

Very Large Optics for the Study of Extrasolar Terrestrial Planets (Nick Woolf, PI). This concept is directly associated with the “Life Finder” that is specifically mentioned in the NASA Science long range plan.   Additional funding was received from the National Reconnaissance Office for continued development of light-weight optical components. Additional support: **75,000 dollars**.

Other Measures of Return on the Investment in NIAC

In the course of working with NIAC Fellows, or listening to their recent responses, we have anecdotal evidence of other kinds of return on the investment in NIAC.

Intellectual contributions or acceptance that have resulted in an agency putting resources into its own studies of a concept. For example, prompted by the success of a Phase I or Phase II concept, an agency convenes panels to study the work, includes it in a decadal plan, or otherwise funds R&D studies of its own. We indicated above work that elicited this response from NASA, e.g. the M2P2 study by Winglee and Slough. Another example is the Tailored Force Fields study by Narayanan Komerath. This not-yet-complete study has attracted interest from NASA Langley Research Center. Yet another example is the X-Ray Interferometry concept articulated by Webster Cash. Dubbed MAXIM, Micro Arcsecond X-ray Imaging Mission, this concept appeared in the National Academy Decadal Review of Astronomy released in 2000.

Unexpected spin-off technologies. For example, some NIAC studies have resulted in new medical technologies; the Biosuit is mentioned in this context. Another example is the work of

Steve Dubowsky on hopping microbots; the materials used for the hopping apparatus are being developed for use in surgical procedures relying on real-time use of MRI instruments for positiong.

The training of technical PhD and Master's level students. Most NIAC-funded studies based in Universities utilize student research assistants, and while not yet compiled, we are aware of many PhD and Master's level projects conducted with NIAC support.

The production of new jobs. Some of our small business NIAC Fellows indicated that new jobs have been produced as a consequence of NIAC funding. In some cases new business divisions have been launched (Manobianco) or entire new businesses spawned (Space Elevator: e.g Black Line Ascension, Liftport).

Finally, an ongoing result of the NIAC investment has been, and will continue to be, inspiring both present and future generations of space scientists, engineers, and enthusiasts. In a modern setting where the presence of humans in space is now routine, the fact that NIAC captures the public and technical imagination represents a priceless contribution to our national space effort.

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