Fostering Visions for the Future

A Review of the NASA Institute for Advanced Concepts

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Statement of Task

The objectives of the review are to:

1. Evaluate NIAC's effectiveness in meeting its mission
2. Evaluate the method by which grantees were selected
3. Make recommendations on whether NIAC or a successor entity should be funded by the Federal government
4. Make recommendations as to how the Federal Government in general and NASA in particular should solicit and infuse advanced concepts into its future systems.

In evaluating NIAC's performance, the committee will address:

- To what extent were the NIAC-sponsored advanced concept studies innovative and technically competent?
- How effective was NIAC in infusing advanced concepts into NASA's strategic vision, future mission plans, and technology development programs?
- How relevant were these studies to the aerospace sector at large?
- How well did NIAC leverage potential partnerships or cost-sharing arrangements?
- What potential approaches could NASA pursue in the future to generate advanced concepts either internally or from external sources of innovation?

Committee

Membership:

- Dr. Robert D. Braun, Georgia Institute of Technology (Co-Chair)
- Dr. Dianne S. Wiley, The Boeing Company (Co-Chair)
- Dr. Henry W. Brandhorst, Jr., Auburn University
- Mr. David C. Byers, Consultant (previously TRW)
- Dr. David L. Chenette, Lockheed Martin Advanced Technology Center
- Dr. Inderjit Chopra, University of Maryland, College Park
- Dr. Frank D. Drake, SETI Institute
- Dr. Olivia A. Graeve, Alfred University
- Dr. Marshall G. Jones, GE Corporate Research and Development
- Mr. Robert A. Moore, DST, Inc. (previously DARPA)
- Dr. E. Phillip Muntz, University of Southern California
- Dr. Laurence R. Young, Massachusetts Institute of Technology

Schedule:

- Committee Formed: November 18, 2008
- First Meeting: December 8-9, 2008
- Second Meeting: February 19-20, 2009
- Reports: Final July 24, 2009 (pre-pub); September 30, 2009 (official)

NIAC History and Scope

- NASA formed NIAC in 1998, reporting to the Agency's Chief Technologist.
- NASA invested $36.2 million in NIAC studies over 9 years.
- The NASA SOW specified that NIAC perform revolutionary advanced concept studies that could impact a NASA mission 10 to 40 years in the future.
- NIAC received 1,309 proposals
- NIAC made 126 Phase I awards and 42 Phase II awards
- The NIAC Phase I awards were led by 109 distinct principal investigators.
- NIAC received an "Excellent" performance rating in each NASA annual review
- NIAC program management was transferred to ESMD in 2004.
- NIAC was terminated in 2007

Major Findings and Recommendations

NIAC met its mission and accomplished its stated goals

- Aligned with NASA SOW (see Finding 1.1)
- Encouraged a broad community of innovators (see Finding 1.3)
- Sponsored innovative research efforts (see Finding 1.4)

NIAC had infusion successes and challenges

- 14 NIAC projects (awarded $7M by NIAC) received $23.8M from a range of organizations. (see Finding 1.8)
  - 12 of the 42 Phase II received post-NIAC funds from a range of sponsors
  - 9 of these 12 received post-NIAC funding from NASA itself
  - 3 NIAC Phase II efforts appear to have impacted NASA's long-term plans
  - 2 of these efforts have either been incorporated or are currently under consideration by the NRC Astronomy and Astrophysics Decadal Survey as future NASA missions.
- Substantial additional resources were needed before NIAC advanced concepts could be deemed technically viable for implementation. This technology readiness immaturity created infusion difficulties for NIAC. (see Finding 1.9)

Major Findings and Recommendations

The Federal Government should fund a NIAC successor (NIAC2)

- At present, there is no NASA organization responsible for evaluation of advanced concepts and subsequent infusion of worthy candidates into NASA planning and development activities. (see Finding 4.1)
- NASA should reestablish a NIAC-like entity (NIAC2) to seek out visionary, far reaching advanced concepts relevant to NASA's charter and begin the process of maturing these concepts for infusion into NASA's missions. (see Recommendation 3.1)

NIAC2 management and reporting structure are important to its success

- NIAC2 should report directly to the Office of the Administrator, be outside Mission Directorates, and be chartered to address NASA-wide mission and technology needs. (see Recommendation 4.2)
- NIAC2 should be funded and administered separately from NASA development programs, mission directorates, and institutional constraints. (see Recommendation 3.3)
- Future NIAC proposal opportunities should continue to be managed and peer-reviewed external to the agency. (see Recommendation 3.4)

Major Findings and Recommendations

Recommended NIAC2 modifications

- NIAC2 should focus on concepts that are scientifically and/or technically innovative and have the potential to provide major benefit to a future NASA mission in 10 years and beyond. (see Recommendation 3.5a)
- Proposal opportunities should be open to principal investigators or teams both internal and external to NASA. (see Recommendation 3.5c)
- NIAC2 proposal opportunities should include the potential selection of a small number of Phase III "proof-of-concept" awards (< $5M/4 years) to demonstrate/resolve fundamental feasibility issues. Phase III selections would be made jointly by NIAC2 and NASA management. (Recommendation 3.5e)

Recommended NASA modifications

- Identification of center technical champions and technical participation of field center personnel in NIAC2 efforts is encouraged. NASA Center participation in NIAC2 activities is expected to increase as NIAC2 projects mature. (see Recommendation 4.3)
- NASA should consider reestablishing an aeronautics and space systems technology development enterprise to provide maturation opportunities and agency expertise for visionary, farreaching concepts and technologies. (see Recommendation 4.1)*

*See also: *A Constrained Space Exploration Technology Program: A Review of NASA's Exploration Technology Development Program, The National Academies Press, Washington, D.C., 2008; and America's Future in Space: Aligning the Civil Space Program with National Needs, The National Academies Press, Washington, D.C., 2009.*

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1. Effectiveness of NIAC

Finding 1.1: NIAC's approach to implementing its functions met NASA-defined objectives, resulted in a cost-effective and timely execution of advanced concept studies, afforded an opportunity for external input of new ideas to the agency, and provided broad exposure of NASA programs.

Finding 1.2: The utilization of an Internet-based management environment enabled public scrutiny of NIAC-funded concepts and brought efficiency to the proposal submission and review process.

Finding 1.3: NIAC was successful in encouraging and supporting a wide community of innovators from diverse disciplines and institutions. NIAC received 1309 proposals in its 9-year lifetime. The 126 NIAC Phase I studies were led by a total of 109 distinct principal investigators, each of which led a team of 3-10 persons, often across several organizations.

Finding 1.4: The majority of the NIAC-supported efforts were highly innovative. Many pushed the limits of applied physics.

Finding 1.5: NIAC was successful in providing widespread positive publicity for NASA, as evidenced by TV and media coverage and Internet interest.

1. Effectiveness of NIAC

Finding 1.6: Through establishment of the NIAC student undergraduate Fellows program and media coverage, NIAC motivated young people to pursue studies in engineering and science.

Finding 1.7: NIAC-funded projects were distributed well across the NASA Exploration Systems, Science, and Space Operations Directorates. However, a low number of aeronautics proposals were submitted.

Finding 1.8: NASA invested $36.2 million in NIAC studies. Fourteen NIAC Phase I and II projects, awarded $7 million by NIAC, received $23.8 million in funding from a range of organizations. NIAC matured 12 of the 42 Phase II concepts as measured by receipt of post-NIAC funding; nine of them received post-NIAC funding from NASA. Three NIAC Phase II efforts appear to have impacted NASA's long-term plans, and two of these efforts have either already been incorporated or are currently under consideration by the NRC Astronomy and Astrophysics Decadal Survey as future NASA missions.

Finding 1.9: A substantial additional infusion of resources was needed before these advanced concepts could be deemed technically viable for implementation as part of a future NASA mission. This technology readiness immaturity created infusion difficulties for the NIAC program and innovators.

1. Effectiveness of NIAC

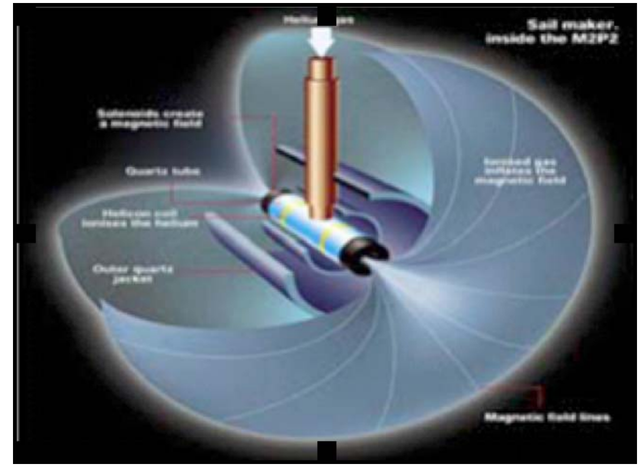
Finding 1.10: NIAC produced studies that were of relevance to the aerospace sector at large, including other government agencies and aerospace industries, as evidenced by the fact that 19 percent of the Phase II advanced concepts received additional funding from other agencies and industry. In addition, three new small business entities were created based on NIAC-spinoff technology.

Finding 1.11: Partnerships and cost sharing were not required in NIAC's statement of work. However, a number of projects were partially supported by the grantees' organizations, thus leveraging the impact of the NIAC grant.

Additional Funds Expended Post-NIAC Investment

Project Title	**External Funds Received from NASA**	**External Funds Received from Other sources**
Swarm Array Space Telescope (Phase I)	0	$345 k
Propagating Magnetic Wave Plasma Accelerator (Phase I)	0	$100 k
The Space Elevator (Phase II)	$2.5 M	$6.0 M
Moon and Mars Orbiting Spinning Tether Transport (MMOSTT) (Phase II)	$2.1 M	$1.3 M
Global Environmental Micro Sensors (Phase II)	$50 k	$2.75 M
The New Worlds Observer (Phase II)	$1.5 M	$2.1 M
Micro-Arcsecond X-ray Imaging Mission (MAXIM) (Phase II)	$1.0M	0
Electromagnetic Formation Flying (Phase II)	$650 k	$1.0 M
Global Constellation of Stratospheric Scientific Platforms (Phase II)	$650 k	0
Mini-magnetospheric Plasma Propulsion (M2P2) (Phase II)	$700 k	0
Lorentz-Actuated Orbits: Electrodynamic Propulsion without a Tether (Phase II)	0	$550 k
The Biosuit (Phase II)	$146 k	0
Scalable Flat-Panel Nano-particle MEMS/NEMS Propulsion (Phase II)	0	$100 k
Very Large Optics for the Study of Extrasolar Terrestrial Planets (Phase II)	0	$75 k

NIAC Highlight: Mini-Magnetospheric Plasma Propulsion



- PIs: R. Winglee & J. Slough, University of Washington
- NIAC Phase I: 1998; NIAC Phase II: 1999
- Revolutionary means for spacecraft propulsion that efficiently utilizes the energy from space plasmas to accelerate payloads to much higher speeds than could be attained by chemical oxidizing propulsion systems. Offered potential propulsive solution for an Interstellar Probe mission, or for the large payloads that may be required for a human Mars mission.
- NIAC funded analysis of the concept and laboratory-scale testing
  - Experimental confirmation of the simulation results in the laboratory provided evidence that the high thrust levels (1-3 N) anticipated may be achievable for low energy input (~ 500 kW) and low propellant consumption (< 1 kg/day)
- Infusion:
  - External to NIAC, the M2P2 was funded by various NASA organizations in the amount of $900k
  - In 2001-2002, the M2P2 concept was considered as a viable technology by the NASA Decadal Planning Team and the NASA Exploration Team and folded into their technology development plans.
  - In 2002, a NASA review panel that included plasma experts concluded there were additional unresolved technical issues that centered around magnet field strengths, mass and power requirements. While partially addressed by the M2P2 team, this work came to a stop due to changing priorities within the Agency.

NIAC Highlight: X-Ray Interferometry

- PI: W. Cash, University of Colorado
- NIAC Phase I: 1999; NIAC Phase II: 2000
- An array of grazing-incidence x-ray mirrors on free-flying spacecraft, coordinated to focus the x-rays on a set of beam-combining and detector spacecraft. Concept offered the potential to image the event horizon of a black hole.
- NIAC funded analysis of the concept and a laboratory scale means to test the performance
- Initial tests of a prototype x-ray interferometer were performed at MSFC with additional NASA support, demonstrating an angular resolution of 100 milli-arcseconds, a factor of 5 improvement over the best previous results.
- Infusion:
  - External to NIAC, the MAXIM was funded by various NASA organizations in the amount of $1M
  - In 2000, Micro Arcsecond X-ray Imaging Mission (MAXIM) appeared in the National Academy Decadal Review of Astronomy, which identified x-ray interferometry for $60M in funds over the following 10 years.
  - In 2002, MAXIM Pathfinder mission was the subject of a NASA Integrated Mission Design Center study.
  - In 2004, MAXIM was selected as one of the NASA Vision Mission studies by SMD.
  - At present, the x-ray interferometry technology that was the subject of the initial NIAC study is the first of three competing methods that NASA is pursuing under its Black Hole Imager (BHI) mission. The BHI team presented a white paper to the 2010 NAS Astronomy and Astrophysics Decadal Survey, and anticipates being identified as one of the compelling astrophysics missions for NASA to pursue in the near future.

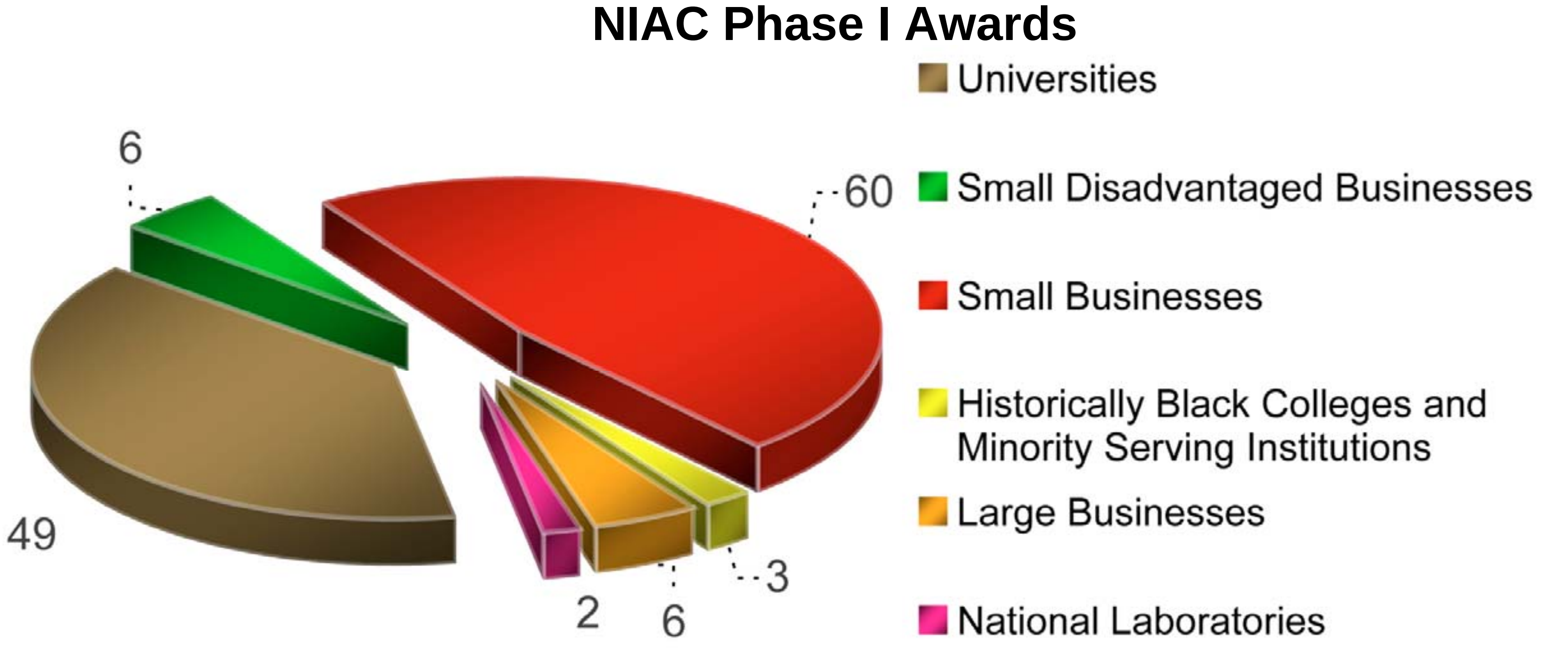
NIAC Highlight: New Worlds Observer

- PI: W. Cash, University of Colorado
- NIAC Phase I: 2004; NIAC Phase II: 2005
- A variety of pinhole camera and occulting mask designs to enable imaging of planetary systems around other stars. Implementation envisioned a five spacecraft constellation consisting of two sets of starshade and telescope combinations, plus a fifth spacecraft carrying a beam combiner/interferometer.
- NIAC funded analysis of the concept and a laboratory-scale means to test the performance
- Demonstrated performance advantages of occulting mask designs and suppression performance <10-7 in a lab test of a miniature 16-petal occulter
- Infusion:
  - The NIAC efforts identified an occulter design that could meet the contrast requirements of the NASA Terrestrial Planet Finder (TPF) and ESA Darwin exo-planet exploration missions.
  - External to NIAC, the NWO has been funded by NASA and industry in the amount of $3.6M.
  - In 2006, GSFC issued a sole-source RFP to Northrop Grumman and Ball Aerospace for development of the New Worlds Imager.
  - In 2008, NASA announced that a team led by Prof. Cash was awarded $1M for the New Worlds Observer as one of its Astrophysics Strategic Missions Concept Studies. The results of this study are being used to prepare the New Worlds Observer mission concept for the 2010 NAS Astrophysics Decadal Survey.

2. Grantee Selection Process

Finding 2.1: The process for selecting NIAC grantees was well documented, disciplined, met the charter of NIAC, and was generally commensurate with practices of other federal funding agencies.

Finding 2.2: The process for selecting NIAC grantees led to a variety of involved organizations, principally from universities and small businesses.



3. A Successor to NIAC

Recommendation 3.1: NASA should reestablish a NIAC-like entity, referred to in this report as NIAC2, to seek out visionary, far-reaching, advanced concepts.

Recommendation 3.2: NIAC2 should employ the internet-based, technical review and management processes developed by the original NIAC.

Recommendation 3.3: NIAC2 should be funded and administered separately from NASA development programs, mission directorates, and institutional constraints.

Recommendation 3.4: NIAC2 proposal opportunities should be managed and peer-reviewed outside the agency.

3. A Successor to NIAC

Recommendation 3.5:

a) The key selection requirement for NIAC2 proposal opportunities should be that the concept is scientifically and/or technically innovative and has the potential to provide major benefit to a future NASA mission.

b) A major review of NIAC2 grants should occur every 5 years, to ensure continuous infusion opportunities into NASA missions and planning.

c) NIAC2 proposal opportunities should be open to principal investigators or teams both internal and external to NASA.

d) NIAC2 proposal support should be: Phase I, up to $100,000 each for 1 year; Phase II, up to $500,000 each for 2 years.

e) NIAC2 proposal opportunities should include the potential selection of a small number of Phase III "proof-of-concept" awards for up to $5 million each for 4 years to demonstrate and resolve fundamental feasibility issues and that such awards be selected jointly by NIAC2 and NASA management.

f) NASA should allow awardees to retain rights to intellectual property developed under NIAC2 awards. NIAC2 should be proactive in coaching the awardees in protection of IP.

g) Efforts should be made to disseminate solicitations to the largest possible number of researchers.

h) NIAC2 should encourage the widest possible demographics of reviewers, while ensuring that breadth of experience and technical competence are paramount considerations.

4. Infusion of Advanced Concepts into NASA

Finding 4.1: There is no NASA organization responsible for solicitation and evaluation of advanced concepts, defined as those at technology-readiness level (TRL) 1 or 2, and subsequent infusion of worthy candidates into NASA planning and development activities.

Finding 4.2: Any expectations of a NIAC2 will depend on the management approach provided by the agency. Management with senior, NASA-wide perspectives and resources outside the near-term focus of the NASA mission directorates should, based on successful Innovative Partnership Program experiences, materially increase the probability for sustained value from a NIAC2 program.

4. Infusion of Advanced Concepts into NASA

Recommendation 4.1: To improve the manner in which advanced concepts are infused into its future systems, the committee recommends that NASA consider reestablishing an aeronautics and space systems technology development enterprise. Its purpose would be to provide maturation opportunities and agency expertise for visionary, far-reaching concepts and technologies. NASA's consideration should include implications for the agency's strategic plan, organizations, resource distributions, field center foci, and mission selection process.

Recommendation 4.2: To allow for successful, sustained implementation of NIAC2 infusion objectives, NIAC2 should report directly to the Office of the Administrator, be outside mission directorates, and be chartered to address NASA-wide mission and technology needs. This organizational structure was in place during the formation and initial operation of NIAC. To increase NIAC2's relevance, NASA mission directorates should contribute thematic areas for consideration. The Innovative Partnership Program (IPP) offers characteristics compatible with effective and healthy, long- and short-term advanced concepts projects. The agency should consider adding a new element to the existing IPP to house the (internal management of) NIAC2, with its focus on TRL 1-2 and higher concept studies.

Recommendation 4.3: Identification of center technical champions and provision for technical participation of NASA field center personnel in NIAC2 efforts—participation that can be expected to increase as NIAC2 projects mature—is recommended. Increased participation of NASA field center personnel, beyond review and management functions, may significantly enhance advanced concept maturation and infusion into NASA mission planning. As appropriate, Phase II and Phase III NIAC2 projects should include realistic transition plans to the appropriate NASA enterprises.