NIAC

NASA Institute for Advanced Concepts

Annual Report

February 2000

NASA Institute for Advanced Concepts
555-A 14th Street, NW, Atlanta, GA 30318

An Institute of the Universities Space Research Association

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EXECUTIVE SUMMARY

The NASA Institute for Advanced Concepts (NIAC) has completed the second full year of operation and all functions of the Institute have been fully implemented. During 1999 the NIAC awarded 6 Phase II contracts totaling $2,941,077 and 14 Phase I grants totaling $978,262. Since the beginning of the contract, the NIAC has awarded 30 Phase I grants and 6 Phase II contracts for a total value of $5,066,686. These awards to universities, small businesses, small disadvantaged businesses and large businesses were for the development of revolutionary advanced concepts that may have a significant impact on future aeronautics and space missions. Based on the first 22 months of NIAC's operation, USRA has received an "excellent" rating from NASA in all categories of contract performance evaluation.

NIAC had a significant level of activity related to coordination with NASA and communication with the science and engineering community including:

- Communication with NASA via NASA/NIAC Support Team
- Technical discussions with NASA research staff
- Use of an extensive email distribution list for notification of Calls for Proposals
- Status report visits to all NASA Centers and the Jet Propulsion Lab
- Participation in NASA Steering Committee meetings, working groups and workshops
- Representation and distribution of NIAC information at technical society meetings
- Annual NIAC meeting and semi-annual NIAC Fellows meetings
- Specially targeted seminars at Historic Black Colleges and Universities
- Coordination with other federal research agencies
- Providing information about NIAC activities to the news media
- Information distributed about NIAC awards through the NASA Technology Inventory Database
- Hosting the oversight meeting of the NIAC Science, Exploration and Technology Council

In addition to the activities conducted in the second year, plans for the third year of the contract include:

- Awarding additional Phase I grants and Phase II contracts
- Conducting site visits at the Phase II contractor locations
- Conducting the 2nd NIAC Annual Meeting at NASA GSFC
- Releasing the next Phase I and Phase II Calls for Proposals
- Participating in technical society meetings, technical workshops and technical working groups
- Coordination and communication with NASA HQ, Centers and JPL
- Hosting a meeting of the NIAC Science, Exploration and Technology Council
- Presentations to government oversight boards as requested
- Outreach focused on segments of the research community such as Historic Black Colleges and Universities, Minority Institutions, women researchers, Earth Sciences, biology, aeronautics and information sciences

DESCRIPTION OF THE NIAC

Mission

The NASA Institute for Advanced Concepts (NIAC) has been formed for the explicit purpose of being an independent source of revolutionary aeronautical and space concepts that could dramatically impact how NASA develops and conducts its mission. The Institute is to provide highly visible, recognized and high-level entry point for outside thinkers and researchers. The ultimate goal of NIAC is to infuse NIAC funded advanced concepts into future NASA plans and programs. The Institute functions as a **virtual** institute and uses resources of the Internet whenever productive and efficient for communication with grant recipients, NASA, and the science and engineering community.

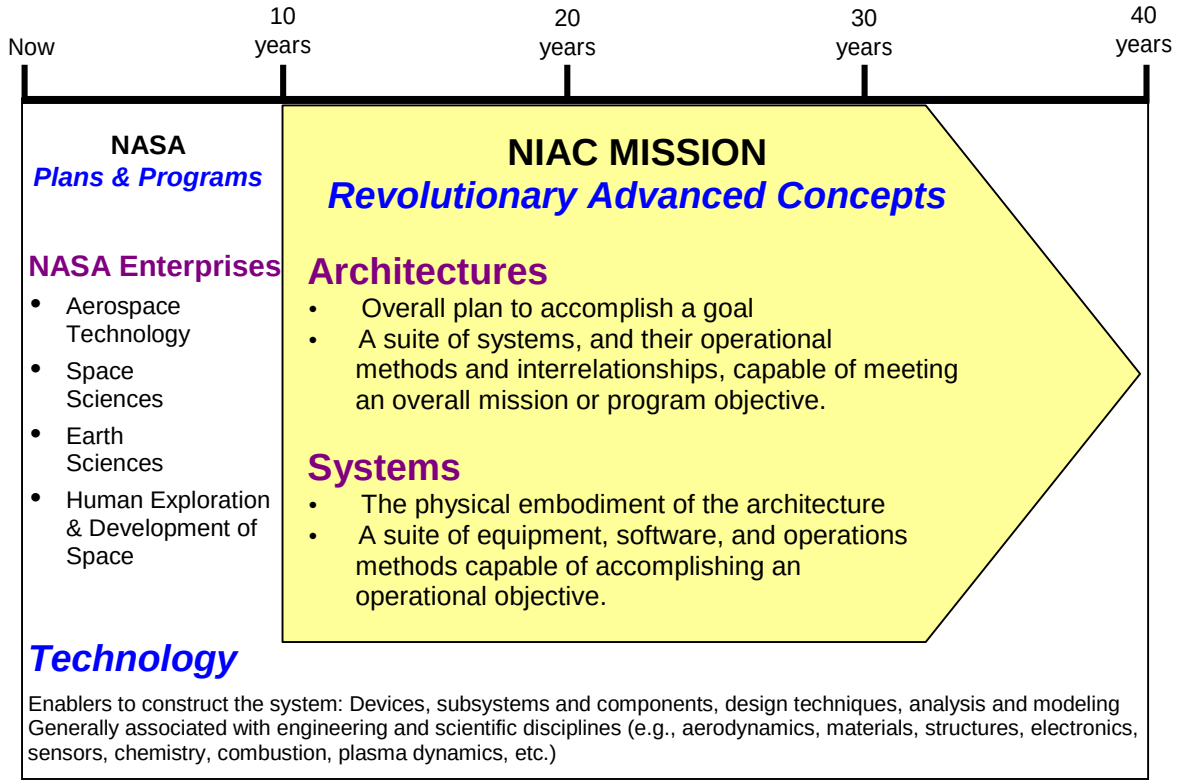


Figure 1. NIAC Mission

Figure 1 illustrates the mission of NIAC relative to the NASA plans and programs and the ongoing technology development efforts. The purpose of NIAC is to provide an independent, open forum for the external analysis and definition of space and aeronautics advanced concepts to complement the advanced concepts activities conducted within the NASA Enterprises. The NIAC has advanced concepts as its sole focus. It focuses on revolutionary concepts - specifically systems and architectures - that can have a major impact on missions of the NASA Enterprises in the time frame of 10 to 40 years in the future. It generates ideas for how the current NASA Agenda can be done better; it expands our vision of future possibilities. The scope of the NIAC is based on the National Space Policy, the NASA Strategic Plan, the NASA Enterprise Strategic Plans and future mission plans of the NASA Enterprises, but it is bounded only by the horizons of human imagination.

Organization

The NIAC organization is illustrated in Figure 2. As an Institute of the Universities Space Research Association (USRA), NIAC reports to the President of USRA.

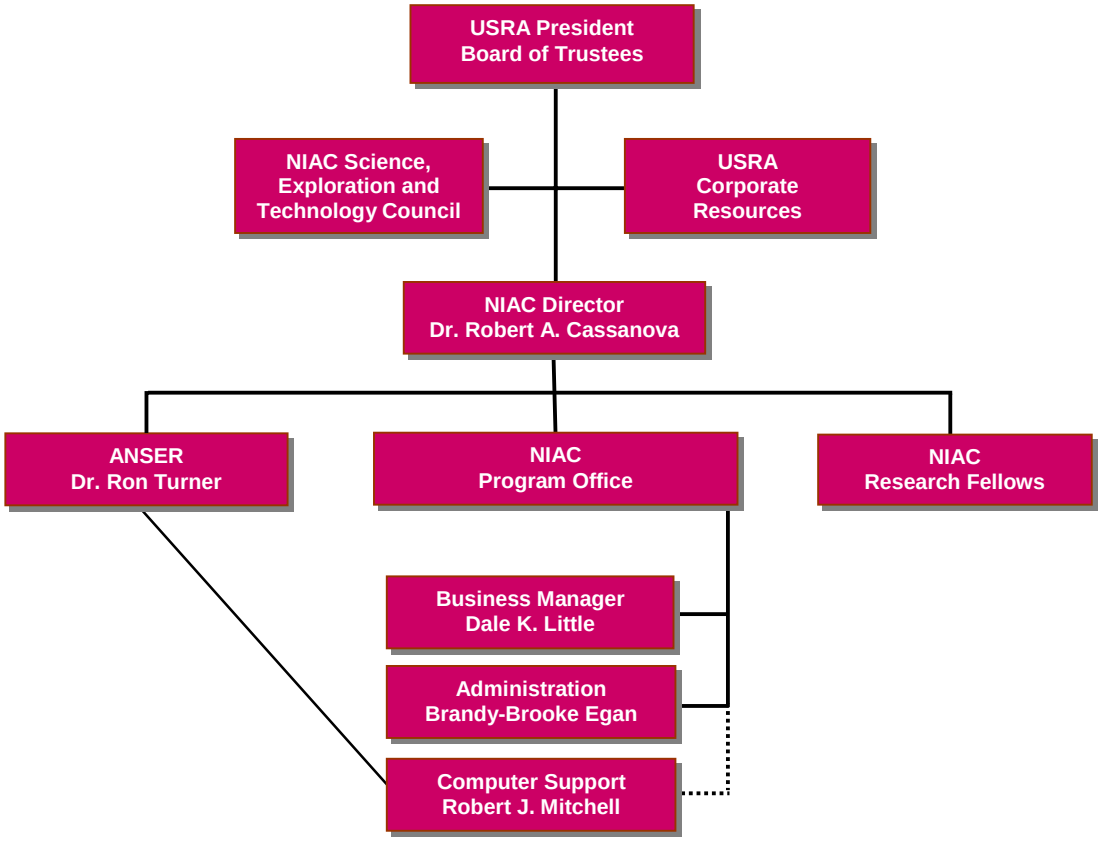


Figure 2. NIAC Organization

The NIAC staff is located at the NIAC HQ office in Atlanta, Georgia, and consists of its director, business manager and administrative assistant. An additional staff member was added by ANSER in March 1999 to provide full-time computer network and software application support at NIAC HQ.

Recipients of NIAC grant or contract awards are designated as "NIAC Fellows."

ANSER, through a subcontract from the USRA/NIAC, provides program support, technical support and information technology support for NIAC's operation. ANSER actively participated in NIAC program reviews and planning sessions, proposal peer reviews, source selection activities, and concurrence meetings. ANSER is responsible for maintaining an understanding of ongoing funded studies and the relationship of these studies to other work underway or previously considered by the aerospace community. To meet this challenge, ANSER reviews aerospace technology databases, conducts on-line data searches, and completes short assessments as needed to identify the status of technologies related to proposed and ongoing studies. To help maintain an understanding of the relevance of potential studies to current and potential NASA enterprises and understanding of relevance of potential studies to current and potential NASA Enterprises and Missions, ANSER attends NIAC meetings with NASA Associate Administrators. ANSER periodically reviews the NIAC website technical content. The periodic review of the website ensured the integrity and timeliness of the posted data and provided an opportunity to add interesting links to related sites maintained by NASA and the aerospace community.

As a corporate expense, USRA formed the NIAC Science, Exploration and Technology Council to oversee the operation of NIAC on behalf of the relevant scientific and engineering community. The Council is composed of a diverse group of thinkers, eminent in their respective fields and representing a broad cross-section of technologies related to the NASA Charter. The Council will have a rotating membership with each member serving a three-year term. The USRA Board of Trustees appoints council members.

The current membership of the NIAC Science, Exploration and Technology Council is as follows:

Dr. Burton Edelson, George Washington University (Convener)
Dr. David Black, Lunar and Planetary Institute
Mr. Peter Bracken, ACS Government Solutions Group, Inc.
Professor Aaron Cohen, Texas A&M University
Dr. Jerry Grey, Aerospace Consultant
Mr. Gentry Lee, Aerospace Consultant and Author
Dr. Lynn Margulis, University of Massachusetts
Dr. Mark Abbott, Oregon State University
Professor Roald Sagdeev, University of Maryland
Dr. Taylor Wang, Vanderbilt University
Dr. Wesley T. Huntress, Carnegie Institute of Washington
Dr. John McElroy, University of Texas, Austin
Dr. Robert E. Whitehead, Aerospace Consultant
Dr. Robert A. Cassanova, NASA Institute for Advanced Concepts (*ex officio*)

One of NIAC's Council members, Dr. Lynn Margulis, was recently honored by President Clinton with the 1999 National Medal of Science. Dr. Lynn Margulis, Distinguished University Professor, Department of Geosciences, University of Massachusetts, Amherst, is being honored for outstanding contributions to the understanding of the structure and evolution of living cells, and for her extraordinary abilities as a teacher and communicator of science to the public. A complete list of honorees can be viewed on the White House website, http://www.whitehouse.gov/WH/EOP/OSTP/html/0022_6.html.

Mr. Bracken, Professor Cohen, Professor McElroy and Professor Sagdeev will step down from the Council and be replaced prior to the next Council meeting on June 8, 2000.

Facilities

NIAC is centrally located in Atlanta, Georgia, and occupies 2,000 square feet of professional office space. Additional conference facilities with a 75-seat auditorium and two conference rooms are also available on-site. The staff is linked via a Windows NT based Local Area Network (LAN) consisting of 5 Pentium II PCs, one Macintosh G3 and one Unix server. Internet access is provided via a fiber-optic link through the Georgia Tech network. Other equipment includes a flat-bed scanner, an HP Color LaserJet 5 printer, an HP LaserJet 4000TN printer, an HP LaserJet 3100 fax machine and a Canon NP6050 copier.

The servers use RedHat Linux for their operating systems, Apache for the web server, Sendmail for the email server, Sybase SQL Server for the database, and OpenSSL for web and email security. The workstations use Windows NT 4.0 for their operating systems, Microsoft Office Professional for office applications, Netscape Communicator for email access, and Adobe Acrobat for distributed documents.

Virtual Institute

NIAC envisions progressive use of the Internet as a key element in its operation. The Internet is the primary vehicle to link the NIAC office with grantees, NASA points of contact, and other members of the science and engineering community. The Internet will be the primary communication link for publicizing NIAC, announcing the availability of Calls for Proposals, receiving proposals and reporting on technical status. All proposals submitted to NIAC must be in electronic format. All monthly reports from the grantees to NIAC and from NIAC to NASA are submitted electronically. The peer review of proposals is also conducted electronically whenever the peer reviewer has the necessary Internet connectivity and application software.

ANSER created and maintains the NIAC website at http://www.niac.usra.edu, which serves as the focal point of NIAC to the outside world. The website can be accessed to retrieve and submit NIAC information and proposals. The NIAC website is linked from the NASA Technology Planning & Integration Office (NTPIO) website at http://ntpio.nasa.gov as well as the NASA Research Opportunities website at http://www.nasa.gov/research.html, and the Office of Earth Science Research Opportunities at http://www.earth.nasa.gov/nra/current/index.html. Numerous other links to the NIAC website are now established from NASA Centers and science and engineering websites. The visibility of NIAC has improved to the point that their website has been receiving almost 60 hits per day. Between May 27, 1999 and January 31, 2000, the NIAC website has logged 14,521 connections. On February 4, 2000, NIAC implemented a redesigned website layout.

Figure 3 depicts the site map of the NIAC website.

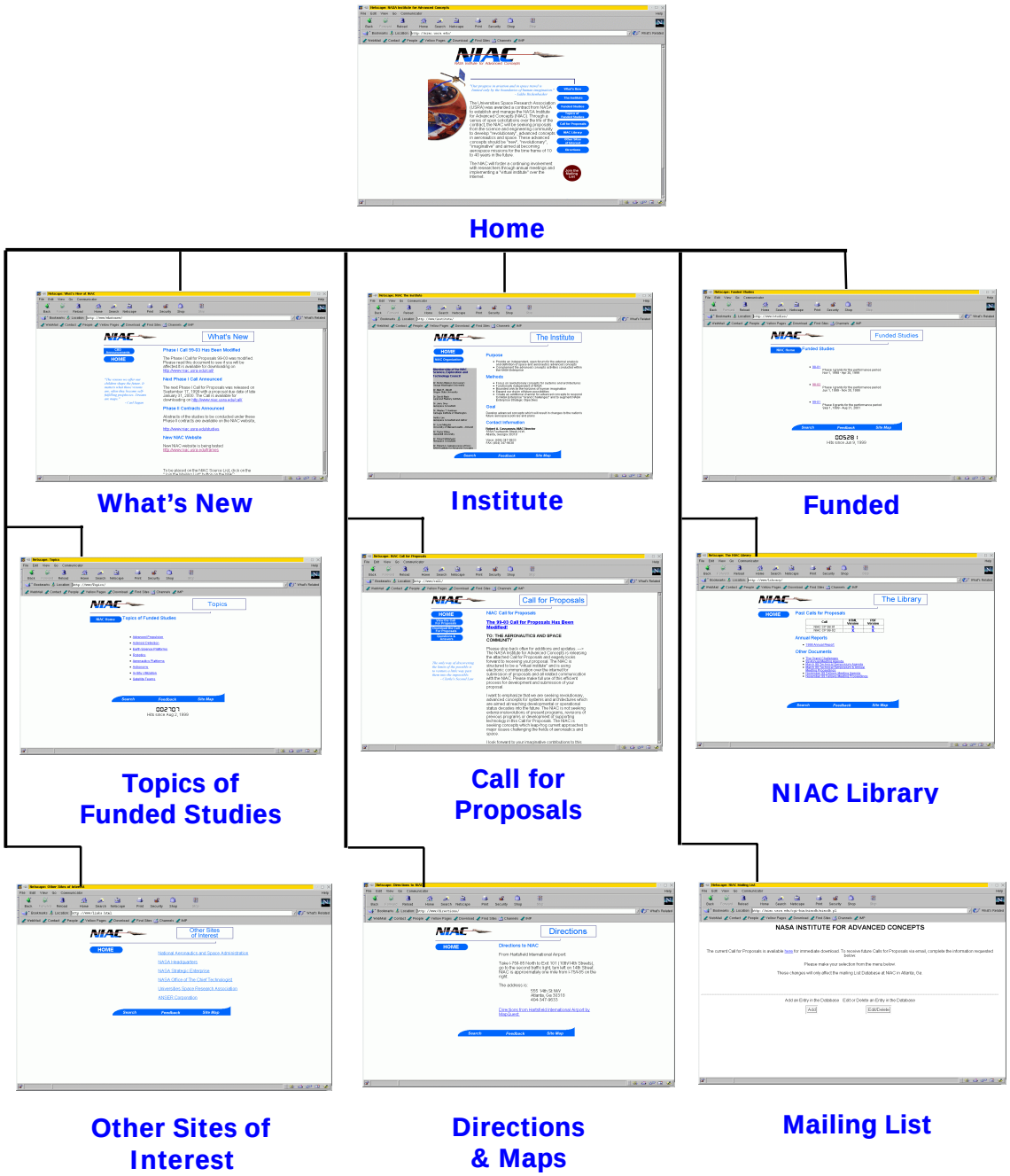


Figure 3. Site Map of the NIAC Website, http://www.niac.usra.edu.

ADVANCED CONCEPT SELECTION PROCESS

Publicity

Publicity regarding the availability of a NIAC Phase I Call for Proposals is provided to the community through:

- Publication of an announcement in the *Commerce Business Daily*
- Notices sent to a NIAC email distribution list generated from responses by persons who signed up on the NIAC web site to receive the Call
- Announcements on professional society web sites or newsletters (American Institute for Aeronautics and Astronautics, American Astronautical Society and the American Astronomical Society)
- Announcements on the USRA and NIAC web sites
- NASA GSFC News Release
- Web links from NASA Enterprise web pages
- Web link from the NASA Coordinator's web page
- Announcements to an HBCU/SDB distribution list provided by NASA
- Distribution of announcements to an Earth Sciences list provided by NASA GSFC
- Announcements distributed at technical society meetings

Since Phase II awards are based on a down select from Phase I winners, all Phase II Call for Proposals are emailed directly to past Phase I winners who have not previously received a Phase II contract.

Solicitation

The actual solicitation for advanced concepts is assembled and published by the NIAC staff. Since the technical scope of the solicitation is as broad as the NASA Mission, the solicitation wording emphasizes the desire for revolutionary advanced concepts that address all elements of the NASA Mission. This is particularly true for Phase I solicitations.

The scope of work is written to inspire proposals in all NASA Mission areas and contains brief descriptions of NASA Enterprise areas of emphases. In general, proposed advanced concepts should be:

- Revolutionary, new and not duplicative of previously studied concepts
- An architecture or system
- Described in a mission context
- Adequately substantiated with a description of the scientific principles that form the basis for the concept
- Largely independent of existing technology or unique combination of systems and technologies

The evaluation criteria are structured to convey what is being sought and are summarized in Figure 4.

PHASE I ***6 months*** **$50 - $75K**	**PHASE II** ***Up to 24 months*** **Up to $500K**
• Is the concept revolutionary rather than evolutionary? To what extent does the proposed activity suggest and explore creative and original concepts?	• Does the proposal continue the development of a revolutionary architecture or system in the context of a future NASA mission? Is the proposed work likely to provide a sound basis for NASA to consider the concept for a future mission or program?
• Is the concept for an architecture or system, and have the benefits been qualified in the context of a future NASA mission?	• Is the concept substantiated with a description of applicable scientific and technical disciplines necessary for development?
• Is the concept substantiated with a description of applicable scientific and technical disciplines necessary for development?	• Have enabling technologies been identified, and has a pathway for development of a technology roadmap been adequately described?
	• Has the pathway for development of a cost of the concept been adequately described and are costing assumptions realistic? Have potential performance and cost benefits been quantified?

Figure 4. Evaluation Criteria

A NIAC Call for Proposal is distributed in electronic form only. At the present time, solicitation for one Phase I and one Phase II is prepared and released every calendar year. These releases occur generally in the latter half of the calendar year.

Proposals

All proposals must be submitted electronically to the NIAC in **.pdf** format in order to be considered for award. Technical proposals in response to Phase I Call for Proposals are limited to 12 pages. Phase II technical proposals are limited to 25 pages. Cost proposals have no page limit.

Phase II proposals are only accepted from authors who have previously received a Phase I award and have not previously received a Phase II follow-on contract. The due date is the same for the Phase II proposal and the associated Phase I final report. Phase I Fellows may submit a Phase II at any time after completion of their Phase I grant, but it must be received by NIAC by the designated due date in order to be considered in a particular review cycle.

Peer Review

NIAC peer reviewers represent a cross-section of senior research executives in private industry, senior research faculty in universities, specialized researchers in both industry and universities, and aerospace consultants.

Each reviewer is required to sign a non-disclosure and no-conflict-of-interest agreement prior to their involvement. A small monetary compensation is offered to each reviewer. The technical proposals and all required forms are transmitted to the reviewer over the Internet, by diskette or by paper copy, depending on the electronic capabilities of each reviewer. Reviewers are given approximately thirty days to review the technical proposals and return their completed evaluation forms.

Each proposal receives at least three independent peer reviews. Each reviewer evaluates a proposal according to the criterion stated in the Call for Proposals. Templates/forms are created to help guide the reviewer through the process of assigning a numerical ranking and providing written comments.
Only NIAC and USRA staff analyze cost proposals.

The ANSER Corporation provided valuable assistance to the peer review process through a search of its archives, knowledge bases and additional resources. These information databases were used to provide additional background on prior and ongoing advanced concept research efforts sponsored by NASA and non-NASA sources.

Results of the peer reviews are compiled by NIAC, rank-ordered by a review panel and prepared for presentation to NASA in a concurrence briefing.

NASA Concurrence

The NIAC Director is required to present the apparent research selections to the NASA Chief Technologist and representatives of the NASA Strategic Enterprises before any awards are announced. Technical concurrence by NASA, required before any subgrants or subcontracts are announced or awarded, is obtained to assure consistency with NASA's Charter and strategy.

Awards

Based on the results of the NIAC peer review, technical concurrence from NASA's Office of the Chief Technologist and the availability of funding, the award decision is made by the NIAC Director. All proposal authors are notified electronically of the acceptance or rejection of their proposal. If requested, feedback based on the peer review evaluator's comments is provided to the non-selected proposers.

The USRA contracts office then begins processing contractual instruments to each of the winning organizations. Also, the NIAC staff inputs all the pertinent technical information regarding the winning proposals into the NASA Technology Inventory Database, as well as the NIAC website.

The "product" of each award is a final report. All final reports are posted on the NIAC website for public viewing.

CONTRACT MANAGEMENT

With each new advanced concept award, contract management increases not only in importance but also in the time devoted to it by the NIAC. The major contract management tools used by NIAC are monthly reports and site visits.

Reports

Monthly reports are used by NIAC to monitor technical and management progress of each selected program. They are contractually required in both Phase I and Phase II subgrants and subcontracts. These reports are for the exclusive management use of NIAC and are not publicly disseminated.

Final reports in .pdf electronic format are required within 30 days of completion of the subgrant or subcontract and are posted on the NIAC website within a few days of receipt.

Phase II contractors are required to submit an interim report during the 12th month of the first year of their contract.

Site Visits

Phase II contracts are structured with a one-year contract plus an option for the remaining performance period. Each Phase II contractor is required to host a site visit by the NIAC Director and other technical experts during the 9th or 10th month of the first year of their contract. Site visits are used to measure program progress on a first-hand basis for all Phase II contracts. These visits are a particularly valuable management tool to the NIAC Director in determining the overall status and operating environment of a particular program at a given point in time. Site visits are conducted by the NIAC Director who will be accompanied by experts in related technical fields and by NASA representatives who may want to consider follow-on funding directly from NASA. Site visits are scheduled prior to the exercise of any subcontract option.

ACCOMPLISHMENTS

Summary

As demonstrated by the accomplishments during the second year of operation, NIAC has established the sequence of activities that will carry forward through the remaining years of the contract. Figure 5 summarizes the performance periods for completed and currently planned awards.

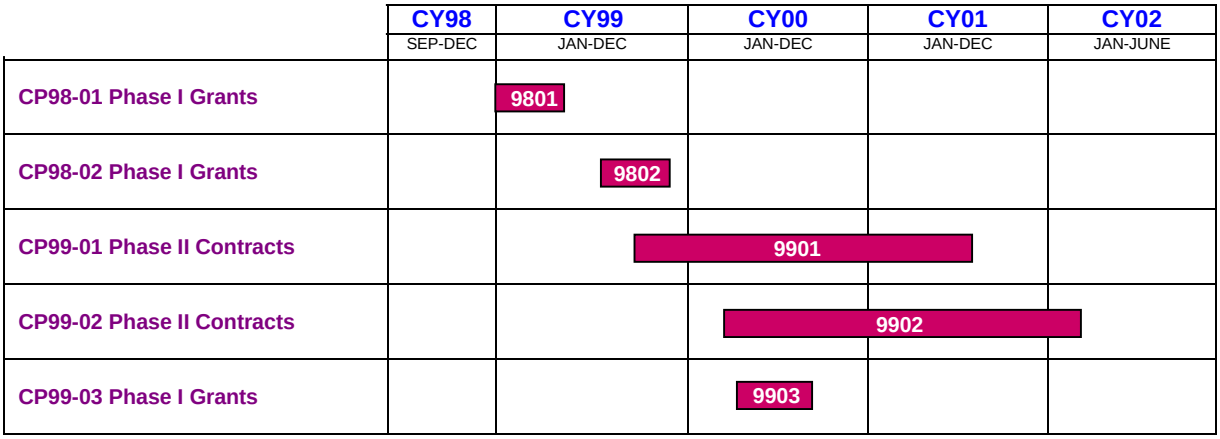


Figure 5. Phase I and Phase II Awards

Call for Proposal CP98-01 Phase I

Call for Proposal CP98-01 Phase I was issued and awarded in the first year of the contract, but is included here as background for the discussion of the strategy for CP99-03. Table 1 shows the distribution of the 119 proposals received from various categories of organizations in response to CP98-01.

Organizational Category	CP98-01 Phase I Proposals
Large Businesses	5
Small Businesses	47
Small Disadvantaged Businesses	7
Universities	58
Historic Black Colleges & Universities and Minority Institutions	0
National Labs	2

Table 1. Summary of CP98-01 Responding Organizations

Abstracts and graphics of each CP98-01 Phase I subgrant were included in the first Annual Report, and may be viewed on the NIAC website at http://www.niac.usra.edu.

Figure 6 summarizes the awards resulting from CP98-01. The primary (represented by●) and secondary (represented by●) relationships of each concept to the Enterprises are noted. In general, Space Science (SS) and Aero-Space Technology (AST) Enterprise areas are well represented, although a few sub-areas are not. While Earth Science (ES) and Human Exploration and Development of Space (HEDS) may benefit from some of the concepts, these Enterprises are not the primary focus of any of the selected concepts. While proposals were received from Small Disadvantaged Businesses (SDB), no proposals were received from Historic Black Colleges and Universities (HBCU) or Minority Institutions (MI), and no SDBs were selected for an award.

PI Name	Advanced Concept Proposal Title	NASA Enterprises			
		AST	HEDS	SS	ES
Bekey, Ivan *Bekey Designs, Inc.*	*A Structureless Extremely Large Yet Very Lightweight Swarm Array Space Telescope*			●	
Campbell, Mark E. *University of Washington*	*Intelligent Satellite Teams (ISTs) for Space Systems*			●	
Dubowsky, Steven *MIT*	*Self-Transforming Robotic Planetary Explorers*		●	●	
Gold, Robert E. *Johns Hopkins University*	*SHIELD: A Comprehensive Earth Protection System*			●	
Gorenstein, Paul *Smithsonian Institute*	*An Ultra-High Throughput X-Ray Astronomy Observatory with A New Mission Architecture*			●	
Hawk, Clark W. *U. of Alabama-Huntsville*	*Pulsed Plasma Power Generation*	●	●	●	
Howe, Steven D. *Synergistics Technologies*	*Enabling Exploration of Deep Space: High Density Storage of Antimatter*	●	●	●	
Hoyt, Robert P. *Tethers Unlimited Inc.*	*Cislunar Tether Transport System*	●	●		
Jacobs, Ron *Intelligent Inference System*	*A Biologically-Inspired MARS Walker*		●	●	
Kroo, Ilan *Stanford University*	*Mesicopter: A Meso-Scale Flight Vehicle for Atmospheric Sensing*	●		●	●
Landis, Geoffrey A. *Ohio Aerospace Institute*	*Advanced Solar- and Laser-Pushed Lightsail Concept*	●		●	
McNutt, Jr., Ralph E. *Johns Hopkins University*	*A Realistic Interstellar Explorer*			●	
Seward, Clint *Electron Power Systems*	*Low Cost Space Transportation Using Electron Spiral Toroid (EST) Propulsion*	●	●		
Stancil, Charles M. *Ga Tech Research Institute*	*Electric Toroid Rotor Technology Development*	●			●
Winglee, Robert M. *University of Washington*	*Mini-Magnetospheric Plasma Propulsion*	●		●	
Woolf, Neville J. *University of Arizona*	*Very Large Optics for the Study of Extrasolar Terrestrial Planets*			●	

Figure 6. CP98-01 Phase I Enterprise Categories

Call for Proposal CP98-02 Phase I

Table 2 shows the distribution of the 64 proposals received from various categories of organizations in response to CP98-02. The small business and university organizational categories were well represented.

Organizational Category	CP98-02 Phase I Proposals
Large Businesses	3
Small Businesses	39
Small Disadvantaged Businesses	5
Universities	15
Historic Black Colleges & Universities and Minority Institutions	1
National Labs	1

Table 2. Summary of CP98-02 Responding Organizations

Figure 7 summarizes awards resulting from Call for Proposals CP98-02 funded with a performance period of June 1, 1999 through November 30, 1999. Abstracts and graphics of each CP98-02 Phase I subgrant are available in Appendix A, and may be viewed on the NIAC website at http://www.niac.usra.edu. The SS and AST Enterprise areas received the largest number of awards and one award was made for a concept whose primary focus was ES. Space propulsion concepts dominated the AST related awards, with only one award having a direct relationship to aeronautics. One award was to a SDB, Diversitech. The primary (●) and secondary (●) relationships of each concept to the Enterprise are noted.

PI Name	Advanced Concept Proposal Title	NASA Enterprises			
		AST	HEDS	SS	ES
Bogar, Thomas J. *Boeing*	*Hypersonic Airplane Space Tether Orbital Launch System*	●	●		
Kammash, Terry *University of Michigan*	*Antiproton-Driven, Magnetically Insulated Inertial Fusion (MICF) Propulsion System*	●	●	●	
LaPointe, Michael *Horizon Tech Develop. Group*	*Primary Propulsion for Piloted Deep Space Exploration*	●	●	●	
Slough, John *MSNW*	*Rapid Manned Mars Mission with A Propagating Magnetic Wave Plasma Accelerator*	●	●	●	
Zubrin, Robert *Pioneer Astronautics*	*The Magnetic Sail*			●	
Spieth, Dean *Pioneer Astronautics*	*Ultralight Solar Sails for Interstellar Travel*			●	
Cash, Webster *University of Colorado*	*X-Ray Interferometry: Ultimate Astronomical Imaging*			●	
Howard, Timothy *SVS Systems, Inc.*	*Planetary-Scale Astronomical Bench*			●	
Farritor, Shane *Univ. of Nebraska-Lincoln*	*A Modular Robotic System to Support the Surface Operations of Human Mars Exploration*		●		
Rice, Eric E. *Orbital Technologies Corporation*	*Development of Lunar Ice Recovery System Architecture*		●		
Rice, Eric E. *Orbital Technologies Corporation*	*Advanced System Concept for Total ISRU Based Propulsion and Power Systems for Unmanned and Manned Mars Exploration*		●		
Nock, Kerry T. *Global Aerospace Corporation*	*Global Constellation of Stratospheric Scientific Platforms*				●
Grant, Carl *Diversitech Inc.*	*An Advanced Counter-Rotating Disk Wing Aircraft Concept*	●			
LaForge, Laurence E. *The Right Stuff of Tahoe, Inc.*	*Architectures & Algorithms for Self-Healing Autonomous Spacecraft*	●	●	●	●

Figure 7. CP98-02 Phase I Enterprise Categories

Call for Proposal CP99-01 Phase II

CP99-01 was a Phase II Call for Proposals that was released to each of the Phase I grantees from CP98-01. All 16 of the CP98-01 Fellows submitted Phase II proposals. Table 3 summarizes the organizational categories of the respondents.

Organizational Category	CP99-01 Phase II Proposals
Large Businesses	0
Small Businesses	6
Small Disadvantaged Businesses	0
Universities	8
Historic Black Colleges & Universities and Minority Institutions	0
National Labs	2

Table 3. Summary of CP99-01 Responding Organizations

Figure 8 summarizes the awards resulting from CP99-01. These contracts have performance periods of 18 to 24 months. Abstracts and graphics of each CP99-01 Phase II subgrant are available in Appendix B, and may be viewed on the NIAC website at http://www.niac.usra.edu. The primary (●) and secondary (●) relationships of each concept to the Enterprise are noted.

PI Name	Advanced Concept Proposal Title	NASA Enterprises			
		AST	HEDS	SS	ES
Dubowsky, Steven *MIT*	*Self-Transforming Robotic Planetary Explorers*		●	●	
Gorenstein, Paul *Smithsonian Institute*	*An Ultra-High Throughput X-Ray Astronomy Observatory with A New Mission Architecture*			●	
Hoyt, Robert P. *Tethers Unlimited Inc.*	*Cislunar Tether Transport System*	●	●		
Kroo, Ilan *Stanford University*	*Mesicopter: A Meso-Scale Flight Vehicle for Atmospheric Sensing*	●		●	●
Winglee, Robert M. *University of Washington*	*Mini-Magnetospheric Plasma Propulsion*	●		●	
Woolf, Neville J. *University of Arizona*	*Very Large Optics for the Study of Extrasolar Terrestrial Planets*			●	

Figure 8. CP99-01 Phase II Enterprise Categories

Call for Proposal CP99-02 Phase II

CP99-02 was a Phase II Call for Proposals that was released to each of the Phase I grantees who had not previously received a Phase II contract. Thirteen of the CP98-02 Fellows submitted and two Fellows from the CP98-01 grants resubmitted Phase II proposals. Table 4 summarizes the organizational categories of the respondents.

Organizational Category	CP99-02 Phase I Proposals
Large Businesses	1
Small Businesses	8
Small Disadvantaged Businesses	1
Universities	4
Historic Black Colleges & Universities and Minority Institutions	0
National Labs	1

Table 4. Summary of CP99-02 Responding Organizations

Peer review of these proposals began during the second week of January 2000. Selection and award(s) are anticipated in March 2000.

Call for Proposal CP99-03 Phase I

NIAC continues to make a concerted effort to attract competitive proposals related to all NASA Enterprises, but applies the evaluation criteria to generate a selection prioritization without regard to the previous distribution of NIAC awards. Based on the results of previous award distribution among the Enterprises, NIAC places special emphasis on selected segments of the research community to increase awareness of the NIAC opportunities and to give special encouragement in the Calls for Proposals to attract competitive proposals in areas that previously lacked competitive responses.

An analysis of the CP98-01 and CP98-02 awards showed that the Earth Science Enterprise and areas within AeroSpace Technology and Human Exploration and Development of Space were marginally represented. This observation resulted in a strategy in CP99-03 to inspire competitive proposals in the areas of:

- Earth Sciences
- Biology
- Aeronautics
- Information Systems and Software
- Human Space Flight

In addition to the special mention of these areas, notional examples of concepts were described related to these under-represented areas. A special note in CP99-03 underscored NIAC's continuing interest in proposals from all Enterprise areas:

"The proposer should not feel constrained by this list of example advanced concepts, which are referenced only as possible focus areas for proposals, and are not meant to be comprehensive or suggestive of preferred topical areas."

In addition to an increased emphasis in the noted Enterprise areas, NIAC has noted the lack of competitive response from SDBs and HBCU/MIs, and is making a special effort to inspire competitive proposals from these segments of the research community. This effort is described in a later section of this report.

Table 5 summarizes the organizational category distribution of the 104 proposals received in response to CP99-03. Peer review will begin in early February 2000, with selection and award by April 2000.

Organizational Category	CP99-03 Phase I Proposals
Large Businesses	10
Small Businesses	48
Small Disadvantaged Businesses	10
Universities	33
Historic Black Colleges & Universities and Minority Institutions	2
National Labs	1

Table 5. Summary of CP99-03 Responding Organizations

Financial Performance

NIAC strives to minimize its operational expenses in order to devote maximum funds to viable advanced concepts. For the second straight year, this objective has been reached as evidenced in Figure 9. Calendar year two actual results indicate 85% of the NIAC's total budget was devoted to advanced concept research. This is opposed to 82% negotiated in the basic contract. No doubt this trend will continue with the obligation of funds for CP99-02 and CP99-03 in the first and third quarter of calendar year three.

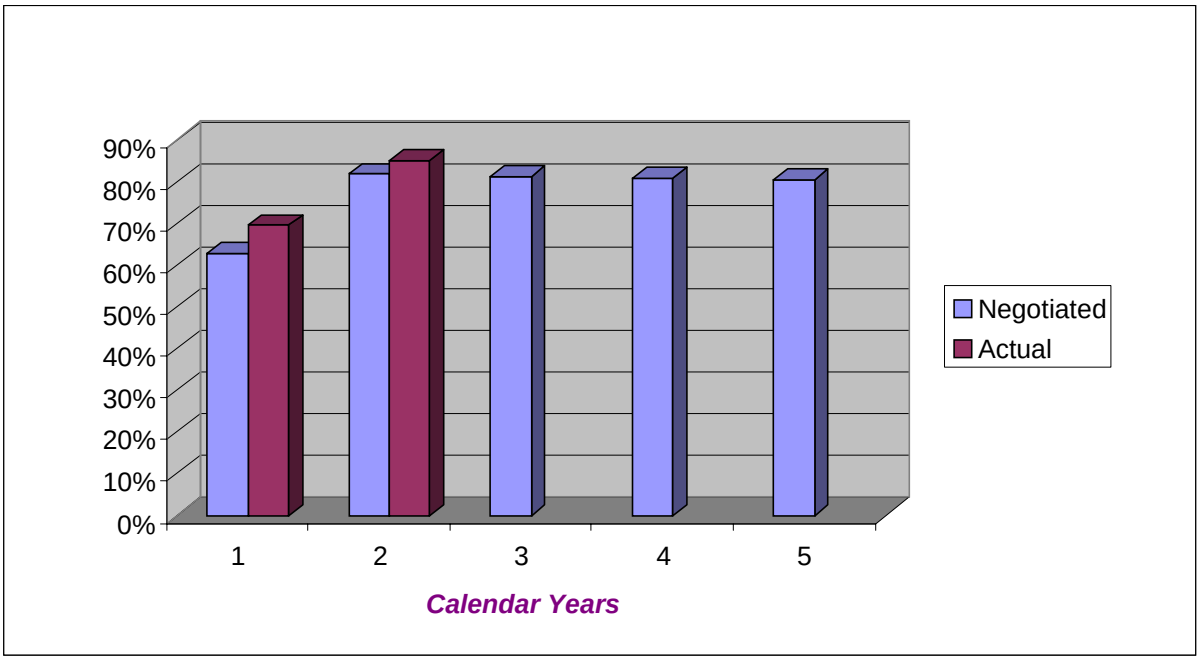


Figure 9. Funds to Research as Percentage of Total NIAC Budget

NOTE: Actual percentages are determined by dividing total annual research obligations by the sum of total actual annual NIAC operations expenses and total annual research obligations. Actual research award amounts reflect obligations through CP99-01.

Communication and Outreach to the Science and Engineering Community

In addition to the continuous, open communication provided through the NIAC website, NIAC uses a variety of methods to provide information to NASA and the research community and to receive feedback. Active and aggressive coordination with NASA HQ and the Centers is an important element in maintaining the flow of feedback to NIAC concerning the eventual infusion of NIAC-developed concepts back to NASA programs. Likewise, open exchange of information with the science and engineering community is critical to creating the atmosphere to inspire revolutionary concepts and to provide an open review of funded concepts by peers.

Coordination with NASA

Sharon M. Garrison is the NASA Coordinator for the NIAC in the NASA Technology Planning & Integration Office (NTPIO) at GSFC. She is the primary point of contact between the NIAC and NASA. Ms. Garrison actively communicates throughout NASA to a review team comprised of representatives from the Enterprises, Centers and Office of the Chief Technologist. Figure 10 is a listing of these representatives. Throughout the process of managing the NIAC, these representatives have been kept informed via Ms. Garrison of the status of the Institute and have been appropriately involved in decisions and feedback. The NIAC provides monthly contract status reports and an Annual Report to the NASA Coordinator who forwards the reports to the Support Team and others within NASA.

NASA COTR	NASA Office of the Chief Technologist	NASA Enterprises	Centers
Sharon Garrison, GSFC	Murray Hirschbein, AF	John Mankins, M David Stone, R Glenn Mucklow, S Roger Crouch, U Lou Schuster, Y Karl Loutinsky, R	Art Murphy, JPL Gale Allen, GRC John Cole, MSFC Ken Cox, JSC Dennis Bushnell, LaRC Bill St. Cyr, SSC Steve Whitmore, DFRC Larry Lasher, ARC Dennis Andrucyk, GSFC

Figure 10. NASA/NIAC Support Team

Very early in the start-up process of the Institute, Dr. Cassanova and Ms. Garrison visited NASA Associate Administrators of the Strategic Enterprises and all NASA Centers to brief them on the plans for the NIAC and to seek their active support and feedback. During the second year of NIAC's operation, Dr. Cassanova revisited all the Centers to update the status of the NIAC and to conduct technical discussions with center staff. Visits to NASA organizations are listed in Table 6.

NASA Center	Dates of Visit	Purpose
USRA Headquarters	February 18, 1999	Coordination with Office of the Chief Technologist, Space Sciences and Aerospace Technology
Johnson Space Center	March 30, 1999	Coordination and to present NIAC Status Overview
Kennedy Space Center	May 27-28, 1999	Coordination and to present NIAC Status Overview
Glenn Research Center	June 8, 1999	Review Panel for Breakthrough Propulsion Physics
Johnson Space Center	August 30, 1999	Presentation of NIAC Overview at the "In-Situ Resource Utilization Steering Meeting"
Stennis Space Center	August 30, 1999	Coordination and to present NIAC Status Overview
USRA Headquarters	June 30 – July 2, 1999	Coordination with AAs of Space Sciences, Earth Sciences, Aerospace Technology, Life Sciences, Chief Scientist and Life Sciences representatives
Goddard Space Flight Center	July 1, 1999	Coordination with Decadel Planning, and Astronomy
NASA Headquarters	August 2, 1999	Coordination with HEDS
Langley Research Center	September 20, 1999	Coordination and NIAC Status Overview
NASA Headquarters	November 2, 1999	Discussions with External Relations, GSFC and HQ-OCT
Jet Propulsion Laboratory	December 7, 1999	Coordination and NIAC Status Overview
Goddard Space Flight Center	December 13-14, 1999	Coordination and NIAC Status Overview

Table 6. NASA Visits

In addition to the periodic coordination visits to the Centers, the NIAC Director has been invited to participate in a number of planning and oversight groups organized by NASA. The NIAC Director has accepted an invitation to join the Space Technology Management and Operations Working Group (STMOWG). The next meeting of the STMOWG will be March 7-9, 2000, in Washington, DC.

In addition to the meetings with NASA for coordination purposes, the NIAC Director met on November 2, 1999 with representatives from the Office of External Relations, GSFC, and the Office of the Chief Technologist to clarify the application of NASA's policy regarding NIAC's potential funding of proposals from foreign entities. The discussion clarified the policy that NIAC should use regarding the funding of proposals from foreign organizations. A decision was made to revise the NIAC contract statement-of-work to change the wording to clarify NASA's policy concerning the funding of international entities.

Annual Meeting and Technical Symposium

The NIAC Annual Meeting was held March 25, 1999 and the USRA/NIAC Technical Symposium was held March 26, 1999 at NASA HQ. Registered attendance totaled 67 for the Annual Meeting and included attendees from NASA (HQ, MSFC, JSC, ARC and GRC), NOAA, universities, private aerospace industry and the news media (Space News and Knight-Ridder). Registered attendance for the Technical Symposium was 131, including representatives from NASA HQ, NASA Centers (GSFC, MSFC, ARC, KSC, JPL), National Research Council, Committee on Science for the U.S. House of Representatives, Office of Management and Budget, American Institute of Aeronautics and Astronautics, Naval Research Lab, European Space Agency, universities, private industry and news media (Space News). Additional attendees from NASA HQ and other organizations who attended and did not register are not included in the attendance count. Paper copies of most presentations were available as handouts for the attendees. Most of the presentations are now available through the NIAC website.

"Grand Visions of Aerospace – The Next 30 Years" was the theme for the USRA/NIAC Technical Symposium, which included presentations by recognized leaders in aeronautics and space. Speakers included:

Mr. Sam Venneri, NASA Chief Technologist
Dr. Robert A. Cassanova, NIAC Director
Dr. Wes Huntress, Carnegie Institute of Washington
Dr. Mark Abbot, Oregon State University
Dr. Laurence Young, MIT
Dr. George Donohue, George Mason University
Dr. Jerry Grey, Aerospace Consultant
Dr. Peter Denning, George Mason University

Available electronic copies of their presentations were posted on the NIAC website.

Fellows Meeting

The NIAC Fellows Meeting was held November 8-9, 1999 at the NIAC HQ in Atlanta, Georgia. All current funded Phase I NIAC Fellows gave a 30-minute presentation at the meeting. Electronic copies of all presentations are available through the NIAC website. Total attendance was 34 including representatives from JPL, MSFC, GRC, GSFC, NASA HQ and ANSER.

The NIAC Fellows Meeting serves a valuable function of fostering interaction of the NIAC Fellows with other Fellows and with representatives from NASA who may eventually have an interest in follow-on sponsorship. With this in mind, the meeting was structured with an informal atmosphere to encourage quality, technical interaction. An informal reception was held on the evening of November 8, 1999.

Participation in Technical Society Meetings, Workshops and National Research Council Boards

In order to expand and maintain NIAC's visibility, NIAC was represented at technical society meetings, technical workshops and at one of the National Research Council Boards as summarized in Table 7.

Meeting	Dates	Sponsor	NIAC Function
NASA Sun-Earth Connection Roadmap Meeting	March 2-3, 1999	NASA GSFC	ANSER attended and distributed NIAC literature
37th Goddard Memorial Symposium	March 17-18, 1999	American Astronautical Society	Director attended
10th Advanced Space Propulsion Research Workshop	April 5-7, 1999	NASA/JPL	Director gave presentation
GSFC University Day	September 29-30, 1999	NASA GSFC	Director gave presentation
AAS Annual Meeting	November 16-18, 1999	American Astronautical Society	Director attended
Faster, Better, Cheaper Workshop	December 8-10, 1999	JPL	Director gave presentation
Space Elevator Workshop	June 8-10, 1999	NASA MSFC	Director gave presentation
Aeronautics and Space Engineering Board	November 3, 1999	National Research Council	Director gave presentation
38th AIAA Aerospace Sciences Meeting	January 10-13, 2000	AIAA	NIAC literature distributed

Table 7. NIAC Participation in Technical Meetings

In addition to the NRC ASEB briefing given on November 3rd, the NIAC Director has been invited to give an overview briefing of the NIAC to the NRC Space Studies Board on March 6, 2000.

Historic Black Colleges and Universities (HBCU) & Minority Institutions (MI)

NIAC has made a special effort to encourage proposal submission from HBCUs and MIs. NIAC obtained a distribution list of HBCU/MIs from NASA HQ that is used to announce the Calls for Proposals. In addition to using this special distribution list, the NIAC Director made contact with HBCU/MIs with direct email communication and personally conducted seminars at selected HBCUs focused on inspiring competitive proposals from these organizations.

Seminars were conducted by the NIAC Director at Hampton University on September 21, 1999 and Howard University on September 22, 1999. North Carolina A&T was scheduled for September 24, 1999, but they asked to reschedule the seminar due to a last minute conflict with a site visit from a potential sponsor. Information about the upcoming Phase I Call for Proposals was distributed to North Carolina A&T through their Vice President for Research and faculty members. Information was provided to the Vice President of Research at Clark-Atlanta also.

The seminar at Hampton University was attended by nine faculty from the following departments:

- Engineering and Technology
- Center for Atmospheric Sciences
- Biological Sciences
- Physics
- Sciences

The two seminars at Howard University were attended by twenty-one faculty and students from the following departments:

- Physics
- Systems & Computer Science
- Chemical Engineering
- Mathematics
- Civil Engineering
- Chemistry
- Electrical Engineering
- Mechanical Engineering
- Physiology and Biophysics
- Radiation Therapy (Hospital)

Coordination with Federal Agencies

NIAC has initiated contact with other federal agencies that also sponsor aerospace research and development. Potential benefits of this interaction include building on the technology and concept basis of these agencies and their contractors and enhancing collaboration on advanced concept development. These contacts may also indirectly enhance the visibility of the NIAC with the contractors who are funded by the agencies. NIAC Overview Briefings and technical discussion sessions have been held with the Office of Naval Research (11/2/99), the Air Force Advanced Concepts Office in the Pentagon (11/4/99), Naval Research Lab (11/4/99), and the Air Force Office of Scientific Research (12/14/99). DARPA has been contacted and will be visited in early 2000.

Public Relations

In addition to the ongoing publicity through the NIAC website, NIAC activities have been the subject of articles in publications serving the general public and the technical community.

Dr. Jerry Grey, a member of the NIAC Council, wrote a commentary to the *AIAA Aerospace America* that was published in the August 1999 issue. The commentary addressed the current overall situation related to declining NASA aeronautics funding, and provided some inspiration for the science and engineering community to respond to NIAC advanced concept development opportunities.

The advanced concept, "Mini-Magnetospheric Plasma Propulsion," by Dr. Robert Winglee at the University of Washington received widespread publicity in August and September 1999. The following articles appeared:

- *Dashing and Coasting to the Interstellar Finish Line,* NASA Space Science News, August 19, 1999.
- *Propulsion for the Next Millennium,* SCIENCE, Volume 285, August 27, 1999.
- *Fantastic Voyager,* New Scientist, September 4, 1999.
- Short paragraph on the "In Orbit" page, Aviation Week & Space Technology, September 13, 1999.

Michael Odenwald, in preparation of an article for the German magazine *Focus*, interviewed Dr. Cassanova on October 6, 1999. The article, published in the 15 November 1999 issue, includes interviews with Marc Millis (NASA-GRC), Bernard Haisch (Lockheed-Martin) and the President of the European Space Agency. The primary topic is related to the future of space flight and is part of a millennium series being published by *Focus*.

Inputs to NASA Technology Inventory Database

NIAC provides inputs to the NASA Technology Inventory Database immediately after awards for Phase I or Phase II concepts are announced. The public version of this database, which is maintained by NASA GSFC, is available at http://technology.gsfc.nasa.gov/technology/.

PLANS FOR THE THIRD YEAR

The activities planned for the third year will build on NIAC's leadership position to inspire, select and fund revolutionary advanced concepts and to orchestrate the transition of successful concepts into consideration by NASA for long range development. Figure 11 summarizes the major activities planned for the third contract year.

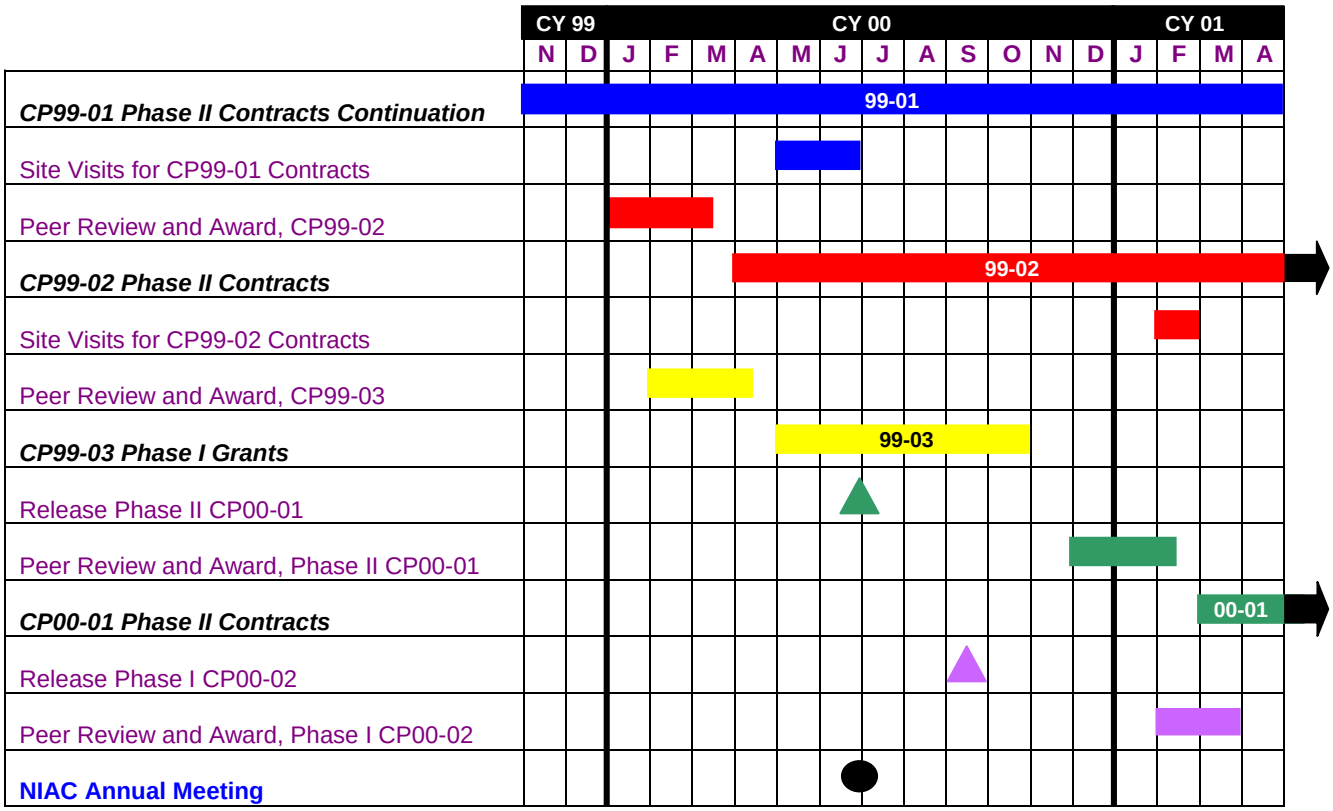


Figure 11. Key Activities during Third Contract Year

Advanced Concept Solicitation, Selection and Award

The peer review and award selection based on proposals received in response to Phase II Call CP99-02 and Phase I Call CP99-03 will be completed in the first quarter of the third contract year. Grant and contract start dates are anticipated in April and May 2000.

The next Phase II Call for Proposals will be sent to the PIs selected for CP99-03 within the first two months of their Phase I grant. The next Phase I Call for Proposals will be released Fall 2000. Publication of the Calls and distribution of general information about the NIAC will be achieved over the NIAC website. Direct web links from technical societies and NASA web pages will continue as methods to notify the community about NIAC. In addition, the NIAC distribution list and distribution lists provided by NASA will be used to notify interested persons about NIAC research opportunities.

Management of Awards

NIAC will continue to require all grant and contract recipients to submit monthly and final reports. In addition, all Phase II contractors will be required to submit an annual report at the completion of their first year of funded activity.

All Phase II contracts awarded under CP99-01 are required to host a site visit and to submit an annual report before the end of their first contract year. Site visits are tentatively scheduled during May 2000. Participants in the site visits will include the NIAC Director, experts in the technical field of the concept, and NASA representatives key to the eventual transition to long range NASA funding.

Communication with NASA, Other Federal Agencies and the Research Community

Since NIAC is a virtual institute, NIAC's principle method of communication with the technical community will be through the NIAC website. In addition, NIAC will utilize the NASA Technology Inventory Database to distribute information about NIAC projects.

In addition to contractually required reports to NASA, the NIAC Director will sustain a flow of information to the technical and management levels of NASA. These activities will encompass appropriate status reports and overviews plus technical meetings in specialized technical areas. In general, the visits to the NASA Centers and JPL will continue to include meetings with the Center Director, top management staff and technical groups related to current and future NIAC areas of emphasis. Visits to NASA HQ will be with Associate Administrators, Enterprise Representatives, Technical Theme Managers, the Chief Technologist and the Chief Scientist.

To maintain an understanding of NASA's current and future technical activities, the NIAC Director will participate in appropriate NASA steering committees, working groups and technical workshops sponsored by NASA and JPL. The director was appointed to the Office of Space Science "Space Technology Management and Operations Working Group" that meets quarterly and will attend the meetings in March, June, September, and December 2000. He will give an overview of the NIAC in the March meeting.

The NIAC Annual Meeting is scheduled for June 6-7, 2000 at NASA GSFC, and will showcase the current grants and contracts. A meeting with the NIAC Phase I Fellows will be scheduled in the early Fall 2000 if it will be useful to the progress of their Phase I grants.

In order to continue with a special encouragement to the Historic Black Colleges and Universities, Minority Institutions and Small Disadvantaged Businesses, the NIAC Director will schedule NIAC overviews and briefings at appropriate venues for these organizations.

By invitation, the NIAC Director will give NIAC status briefings to the National Research Council Boards.

NIAC will strengthen collaboration with advanced concepts programs in other federal agencies such as the Air Force Office of Scientific Research, Office of Naval Research, Defense Advanced Research Projects Agency, Army Research Office, DoD-Pentagon, National Reconnaissance Office, Department of Energy and the Federal Aviation Administration. This collaboration will be in the form of periodic cross-briefings in areas of mutual interest and may inspire additional proposals from contractors associated with these agencies.

NIAC will continue to encourage distribute information about NIAC activities in a variety of publication venues in science and engineering as well as popular science. NIAC Fellows will be encouraged to present papers in technical conferences and to publish in technical journals.

Oversight by USRA Management

The NIAC Science, Exploration and Technology Council will meet on June 8, 2000, to receive an overview of the status and plans of the NIAC. The Council will issue a report to USRA management and NASA on NIAC's operation and will offer suggestions for future activities.

APPENDIX A

Call for Proposals CP98-02 Phase I Grants

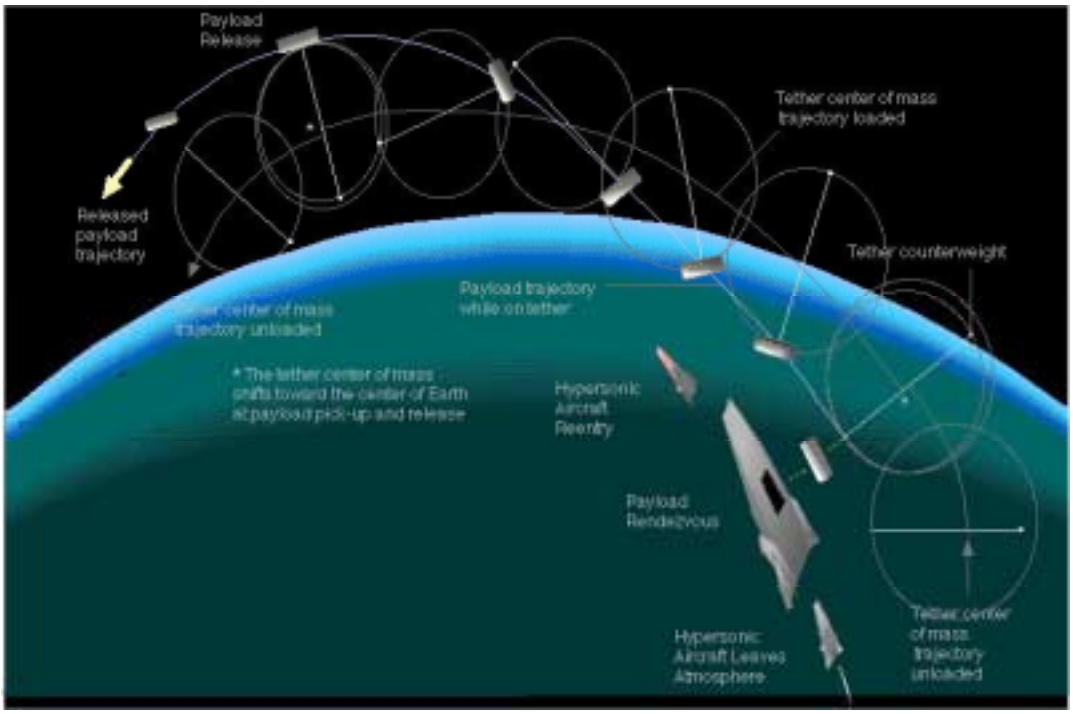
Thomas J. Bogar
McDonnell Douglas Corporation

"Hypersonic Airplane Space Tether Orbital Launch System"

The Hypersonic Airplane Space Tether Orbital Launch (HASTOL) system is an architecture for a low-cost satellite launch system designed to provide an additional order of magnitude reduction in the cost of transporting people and materials from Earth to Orbit (ETO) relative to rocket-powered SSTOs. This architecture for ETO transportation was chosen because it offers the best opportunity for practical industrialization space and the eventual colonization of the solar system. The system architecture consists of several elements: an air-breathing subsonic to hypersonic vehicle which transports the payload from the ground to some intermediate point, the details of which are the subject of an optimization study; a tether system which then transports the payload from the intermediate point to orbit; and a grapple system for transferring the payload from the hypersonic vehicle to the tether.

The system is revolutionary in that it minimizes, and perhaps even eliminates, the use of rockets for satellite launch, while limiting the design requirements for a reusable air-breathing hypersonic vehicle to Mach 10. The benefits which accrue from the eventual development of this system are a reusable "pipeline" from runways near the equator to Medium Earth Orbit (MEO). This proposal will directly support the NASA pillars for revolutionary technology leaps and low-cost space access.

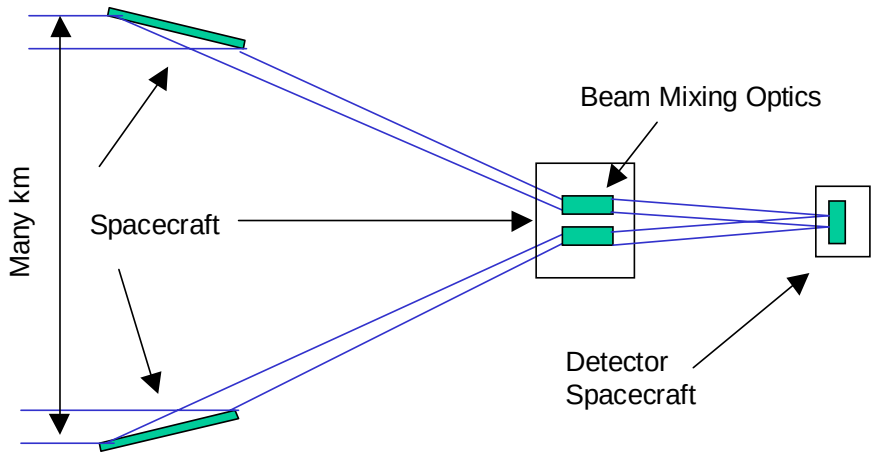
The HASTOL team consists of Boeing, Tethers Unlimited, Inc. (TUI), and the University of Maryland (UMd). Each member brings unique capabilities to the proposed effort. Boeing has experience and capability in the design of hypersonic vehicle concepts and has performed work for NASA in the area of advanced tether concepts. TUI has been awarded several contracts for the development of revolutionary tether concepts. UMd is a NASA-recognized center of excellence in hypersonics, and has worked with both Boeing and TUI on previous hypersonic vehicle and tether efforts.



Webster Cash
The University of Colorado

"X-Ray Interferometry: Ultimate Astronomical Imaging"

Imagine a telescope with resolution so fine it can image the even horizon of a black hole in a Quasar, resolve the disk of a star in another galaxy, or measure parallax to the Virgo Cluster. Imagine a telescope so sensitive it could detect an object no larger than an automobile at the center of our galaxy. Such is the promise of X-ray interferometry. Because of the short wavelength of X-rays, interferometric baselines can be much shorter and more practical than systems in the visible. Because some hot celestial sources are very compact and very bright, the X-ray is an ideal band for pushing imaging to its ultimate limitation (funding). We argue that the X-rays will naturally become the band of choice for high resolution imaging. We present a practical approach to X-ray interferometry. We propose to develop the concepts of X-ray interferometry by (a) looking for practical approaches that will allow us to push the concept as far as possible, and (b) demonstrating the feasibility in the laboratory.



Dean Spieth
Pioneer Astronautics

"Ultralight Solar Sails for Interstellar Travel"

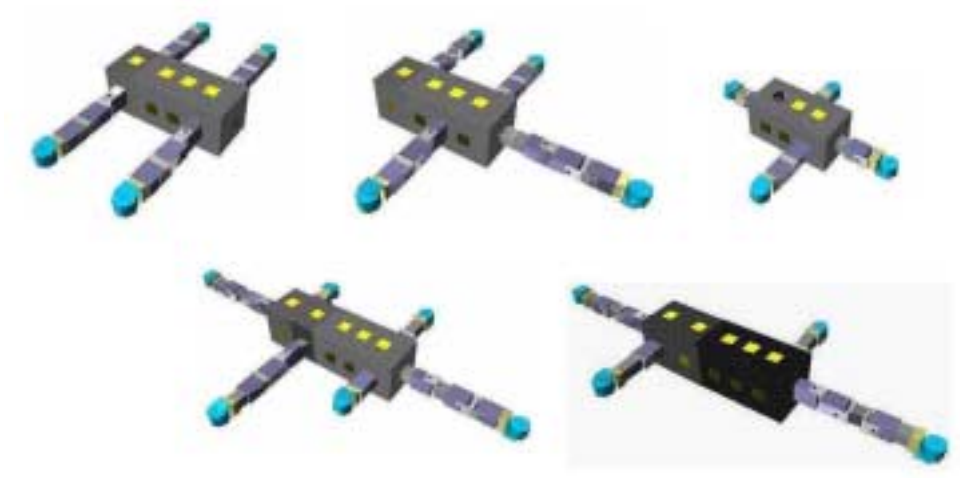
Solar sails offer unique promise for interstellar travel because their lack of need for rocket propellant frees them from the velocity limits imposed by the rocket equation. Conventional solar sails made of aluminized plastic films cannot reach velocities relevant for interstellar flight on the power of sunlight alone, however, as their thrust to mass ratio is too low to allow the attainment of high velocities before leaving the solar system. For this reason, alternative concepts have been advanced which involve pushing light sails with very high-powered lasers or other transmitting devices positioned within the solar system. Such schemes, which involve a host of very formidable technical challenges.

In this proposal, an alternative approach is advanced -- that of manufacturing ultralight perforated solar light sails, which operate without plastic backing. Based upon a preliminary analysis of the fundamental physics of such systems, we have found that they can achieve thrust to mass ratios in sunlight at 1 AU on the order of 10 m/s^2, and that if solar system departure is initiated at 0.1 AU, that terminal velocities on the order of 1% the speed of light can be achieved with no other source of energy than sunlight. The ability to achieve such high velocities with such a simple and relatively near-term system define it as a technology of extreme interest, enabling routine ultra-high speed interplanetary travel, and offering a first-generation capability for interstellar flights.

Shane Farritor
The University of Nebraska-Lincoln

"A Modular Robotic System for Surface Operations of Human Mars Exploration"

This proposal presents a study of a Mars Surface Modular Robotic System (MSMRS). Human exploration of Mars is planned for the 2010-2020 timeframe. Extensive use of robots would reduce costs and increase safety. A wide variety of tasks, requiring large variation in robot capabilities will be performed. Current robot technology may not be sufficient to accomplish all tasks required within the mission constraints. For example, large quantities of regolith may need to be manipulated for resource extraction, a task requiring bulldozer-like capabilities. Also, delicate scientific instruments may need to be deployed. Creating an individual robot for each class of tasks is not an efficient approach, especially since not all tasks can be foreseen.



The challenges of a human Mars mission may require revolutionary robotic solutions. The Mars Surface Modular Robotic System, a new approach to space robot design, is proposed as a possible solution. Here a robotic system, rather than an individual robot(s), is proposed. The system is based on a fundamentally modular design to efficiently address the unique challenges of the human Mars missions. The system consists of individual modules that can be assembled into many different robot configurations. With this system, robots can be dramatically reconfigured to perform dramatically different tasks. This approach, based on solid engineering principles, will allow the robot system to accomplish a wide variety of tasks, and will promote extreme reliability through adaptability.

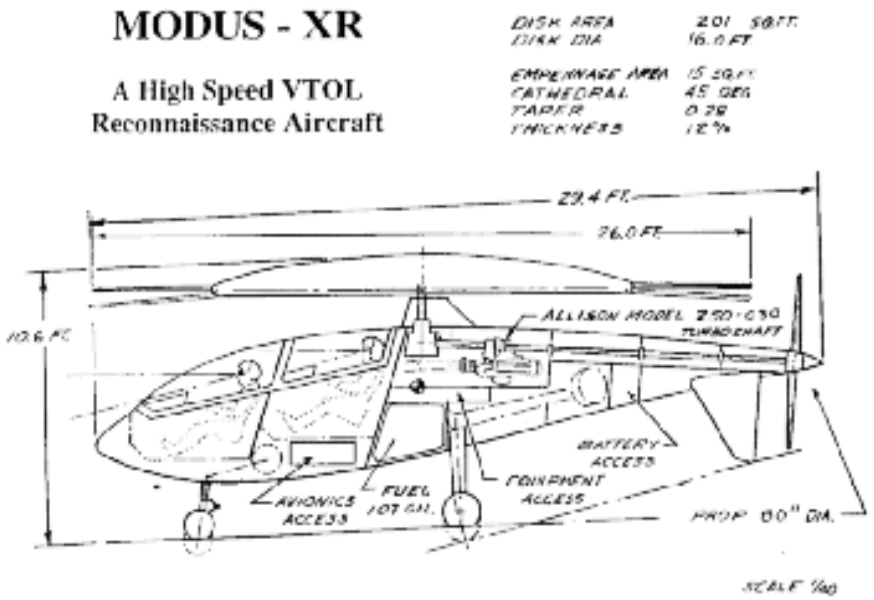
Such an adaptable and reliable system would have clear benefits to a human Mars mission. The Phase I study will explore the requirements and design of such a system. Important root tasks will be identified, and a modular system will be designed to accomplish these tasks. The adaptability and reliability of the proposed system will be demonstrated using detailed physical simulation and animation.

Carl Grant
Diversitech
"An Advanced Counter-Rotating Disk Wing Aircraft Concept"

The need for rapid response in military and civilian rescue and other emergency operations is paramount. Future emergency mission requirements, including rescue and special operations, have shown a critical need for higher cruise speeds that that possible with conventional rotorcraft. Helicopters have been the traditional vehicles for these missions because of their VTOL capabilities and ability to hover, but their response times have always been too long. As the U.S. Military is increasingly finding itself pushed into more and more expeditionary operations around the world, there is a great need for an aircraft that will supply both vertical take-off and landing with efficient long-range cruise – a feature the helicopter does not have. The proposed concept in this study contains the unique combination of efficient vertical take-off and landing capabilities of a helicopter with that of the high-speed cruise efficiencies of a fixed wing aircraft. The MODUS Verticraft design described in this study is capable of meeting these requirements.

In this study, the primary task will include the aerodynamic analysis of the disk plan-form including analysis of the disk and fuselage drag profiles for flight regimes from 150 to 500 knots at altitudes from 1000 to 15,000 feet MSL. This task will also involve an assessment of previous NASA study results on low aspect ratio airfoils. Selection of an optimum plan-form for use in the analysis of VTOL and cruise lift and vehicle stability and control dynamics for transition to hover from horizontal flight will made in order to conduct a preliminary analysis of these characteristics.

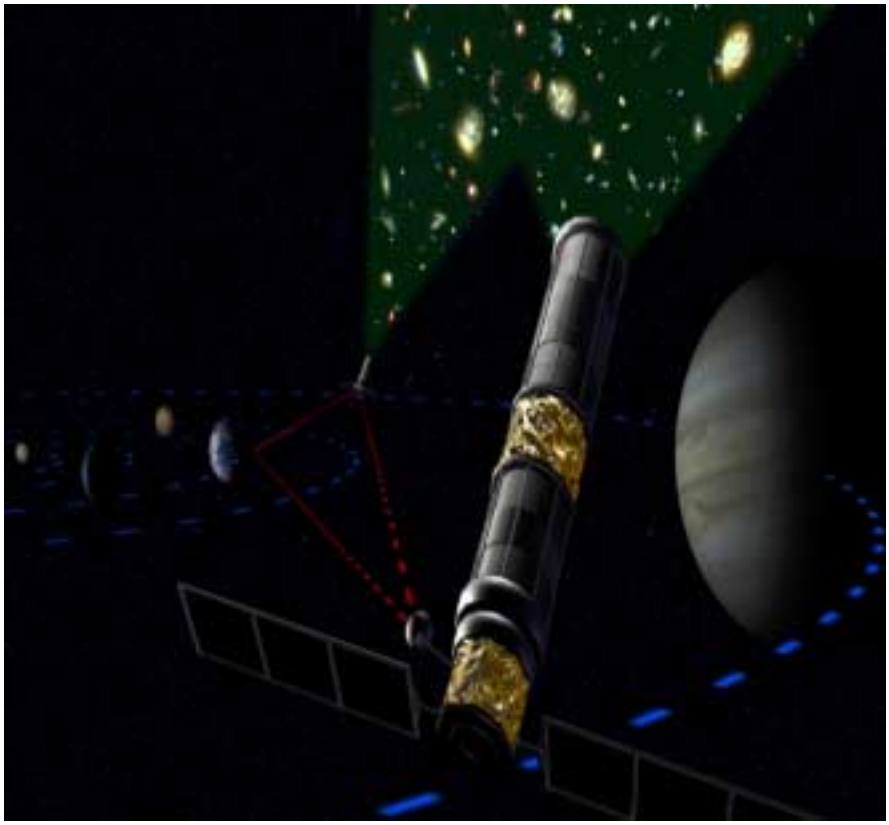
Labor and computer facility uses, plus associated engineering assessments of prior airfoil designs, and scientific analysis of vehicle aerodynamics, aeromechanics, structural integrity and stability are the main cost elements of the study.



Timothy L. Howard
SVS Systems, Inc.

"Planetary-Scale Astronomical Bench"

Currently there is intense interest in the astronomical community in developing spaceborne interferometers for high-accuracy astrometry and aperture synthesis. Although even current plans are technologically challenging, we believe that eventually ultra-long baseline aperture synthesis will be possible, and propose that a natural location for such a system already exists: the two Jovian Lagrange points at 60 degrees ahead of and behind Jupiter in its orbit. Receivers placed at these locations, nine astronomical units apart, would allow synthetic imaging at unprecedented resolution. In fact, there are a number of astronomical and space science applications that would benefit from this concept. Such a system would be comprised of one or more platforms placed at each of these points, robotically maintained and designed for extremely long life and extensibility. The two stations would work cooperatively and would be suitable for multiple types of astronomical and space exploration instruments. We propose to design the architecture for the Planetary-scale Astronomical Bench: a space mission to utilize the Jovian Lagrange points as the foundation of a permanent, large-scale observatory in space.

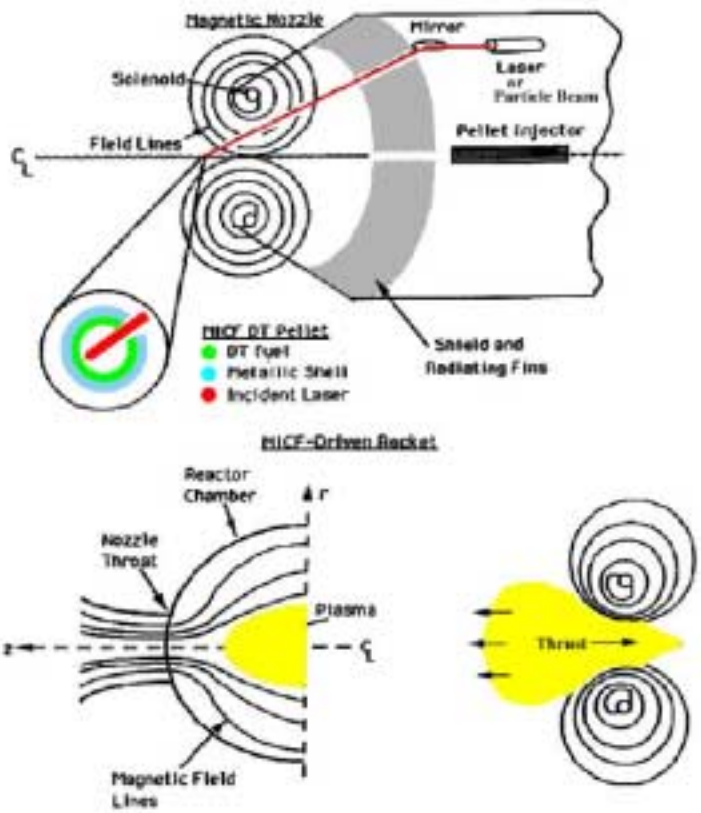


Terry Kammash
University of Michigan

"Antiproton-Driven, Magnetically Insulated Inertial Fusion (MICF) Propulsion System"

A fusion scheme that combines the favorable aspects of inertial and magnetic fusion into one is proposed as a potential space propulsion system that could open up the solar system and beyond to human exploration. The physical containment of the hot plasma is provided by a metal shell, while its thermal energy is insulated from this wall by a strong, self-generated magnetic field. The fusion nuclear reactions in this device can be triggered by a beam of antiprotons that enters the target through a hole and annihilates on the deuterium-tritium (DT) coated inner wall giving rise to the hot fusion plasma. In additional the thermally insulating the plasma, the magnetic field helps to contain the charged annihilation products and allows them to deposit their energy in the plasma to heat it to thermonuclear temperatures. In contrast to the conventional "implosion-type" inertial fusion, the input energy required to initiate the burn in MICF is relatively modest and that, in turn, means a very modest number of antiprotons. With the ongoing effort at NASA's Marshall Space Flight Center (MSFC) to develop an antiproton trap that can trap up to 10^{13} particles, it is quite feasible to experimentally validate the formation and dynamics of plasma in such a device in the near future. As a propulsion system, it is envisaged that MICF targets will be ignited by antiprotons at a pre-determined rate inside a burn chamber, and the reaction products exhausted through a magnetic nozzle to produce the desired thrust.

Preliminary analysis reveals that an MICF propulsion system is capable of producing specific impulses on the order of a million seconds. Such a capability makes not only the most distant planet in the solar system, but also the nearest star, reachable in a human's lifetime. In fact, it would allow an interstellar robotic exploration mission to 10,000 AU in less than 50 years.



Laurence E. LaForge
The Right Stuff of Tahoe, Inc.

"Architectures and Algorithms for Self-Healing Autonomous Spacecraft"

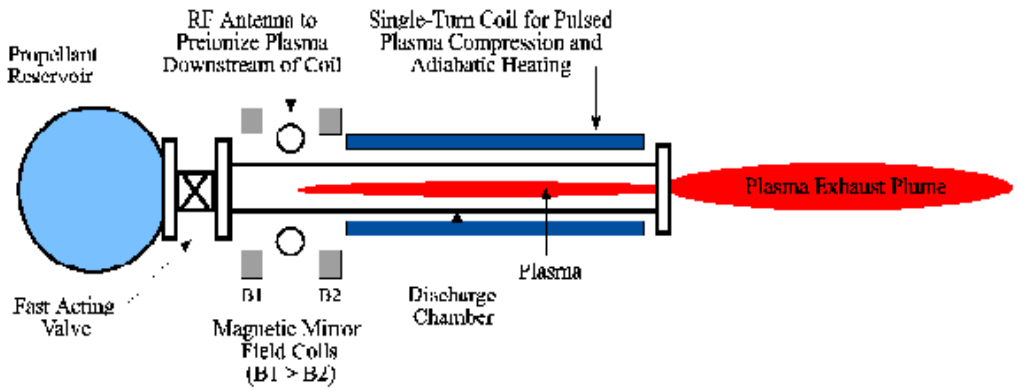
Imagine spacecraft whose missions last three times the human lifespan. Imagine spacecraft with the ability to decide where to explore, how to plan a trajectory, and which data to record. These autonomous spacecraft will require computational systems whose fault tolerance and performance are orders of magnitude better than presently possible. This challenge has been recognized by NASA's Dan Goldin as calling for revolutionary computations systems that depart radically from contemporary designs. We propose to develop a family of such systems, with emphasis on algorithms whereby the architecture heals itself. Highly autonomous spacecraft will require computations systems that tolerate a number of faults in proportion to the total number of components, hardware and software. This is orders of magnitude better than presently possible. To enable the combination of fault tolerance and performance, we envision a self-healing architecture. Self-healing architectures would naturally support fault tolerance, and are therefore amenable to scalable constructions. Self-healing architectures could be realized using a variety of technologies. The benefits of self-healing architectures extend to military and commercial applications. However, a self-healing architecture such as we prose has never been built, nor is it on the evolutionary horizon of the immediate decade. Our effort will identify properties for self-healing architectures that deliver at least 10^{15} operations per second per kilogram, and that tolerate a number of faults proportional to the number of components.

For Phase I, we propose to deliver a graphical, executable model of a highly fault tolerant, self-healing architecture prototype. The fidelity of this Phase I model with be sufficiently rich to demonstrate tolerance to a number of faults in proportion to the number of components. For Phase I, we foresee two major technical challenges: i) generalization and merging of results from configurations for fault tolerance, and ii) specification of a baseline programming model for a self-healing architecture. The next step would be to design and construct a self-healing architecture and attendant software. Looking to Phase II and beyond, realizing such an architecture will of necessity be multi-disciplinary, and will draw on the expertise of specialists in algorithms, testing, software engineering, circuits, power, packaging, radiation hardening, thermal and mechanical design, control, sensors, and mission planning.

Dr. Michael R. LaPointe
Horizon Technologies Development Group

"Primary Propulsion for Piloted Deep Space Exploration"

The piloted deep space exploration missions envisioned by the NASA Human Exploration and Development of Space initiative will require the development of advanced electric propulsion systems capable of providing high specific impulse for extended periods of operation. Current electric propulsion thrusters are well-suited for orbit maneuvering and robotic exploration, but at present they cannot provide the combination of specific impulse, lifetime, and efficiency required for piloted deep space missions.

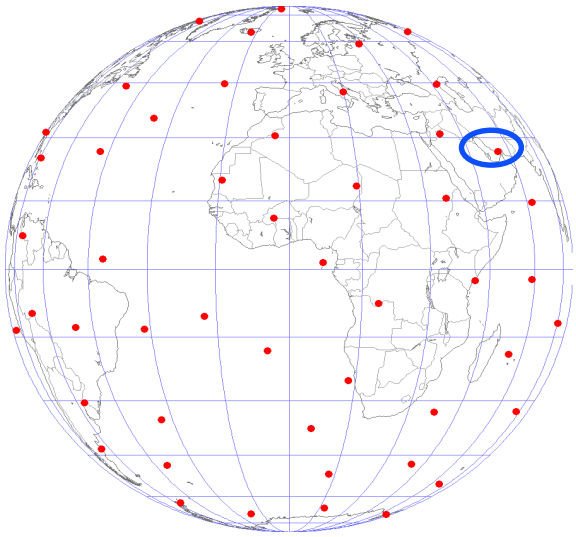


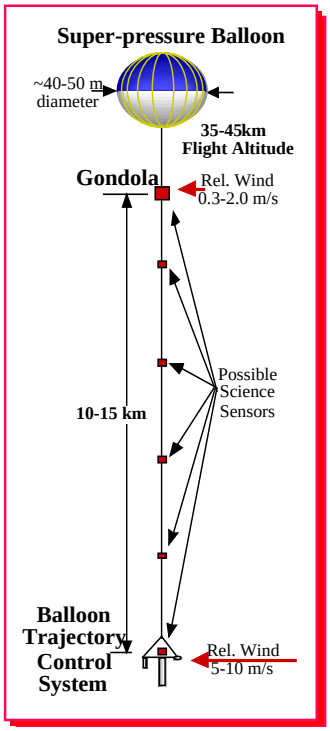
This proposal outlines a new concept for a high density, high temperature plasma thruster that can meet future deep space propulsion requirements. Efficient microwave pre-ionization of a gas propellant in tandem with rapid adiabatic compression is used to generate, heat and expel high-density plasma. The concept is electrodeless, and radial compression of the plasma by the magnetic field of the discharge coil mitigates material erosion to ensure long thruster lifetime. Because the heated plasma is free to flow along axial magnetic field lines during compression, a magnetic mirror located at the entrance to the discharge chamber is used to help direct the plasma flow out of the thruster. The thrust and specific impulse of the engine can be tailored for a given mission scenario through the selection of plasma density, compression coil discharge current, and compression repetition rate, making this an unique concept among the high power electric propulsion systems of the future.

Kerry T. Nock
Global Aerospace Corporation

"Global Constellation of Stratospheric Scientific Platforms"

Global Aerospace Corporation will be developing a revolutionary concept for a global constellation and network of perhaps hundreds of stratospheric superpressure balloons which can address major scientific questions relating to NASA's *Earth Science Mission* by globally measuring stratospheric gases, collecting data on atmospheric circulation, observing the Earth's surface, and detecting and monitoring environmental hazards. Such a system could replace satellites for making some environmental measurements.





The keys to this new concept are:

- Affordable, long-duration balloon systems
- Balloon trajectory control capability and
- A global communications infrastructure

In the nearly forty years since the launch of artificial satellites, there has been a shift away from making *in situ* measurements of the global environment to remote sensing from Earth orbiting spacecraft. Today, there may be reasons to challenge this remote sensing paradigm. In combination, (a) the advance of electronics, communications and balloon technologies, (b) the difficult of doing some remote sensing, and (c) the interest in simultaneous global measurements, argue for a re-evaluation of the current reliance on satellites for many global environmental measurements.

Total system cost for a constellation of stratospheric superpressure balloons may be quite competitive with or even lower than comparable spacecraft systems due tot he inherent high cost of getting to space. Indeed, a network of balloons will be less costly than a comparable network of spacecraft if the individual balloons have lifetimes measured on the order of years, thereby reducing the cost of replacement or refurbishment.

Developing technology for very long-duration and guided stratospheric balloons will enable an affordable global constellation of formation-flying, stratospheric platforms. The structure of the global constellation of balloons will be maintained by sophisticated trajectory control algorithms with inter-platform communication facilitated by the emerging global communications infrastructure. Global Aerospace Corporation will be developing this concept, exploring additional applications and benefits, and generating first order estimates of the cost of implementing such a revolutionary system.

Dr. Eric E. Rice
Orbital Technologies Corporation

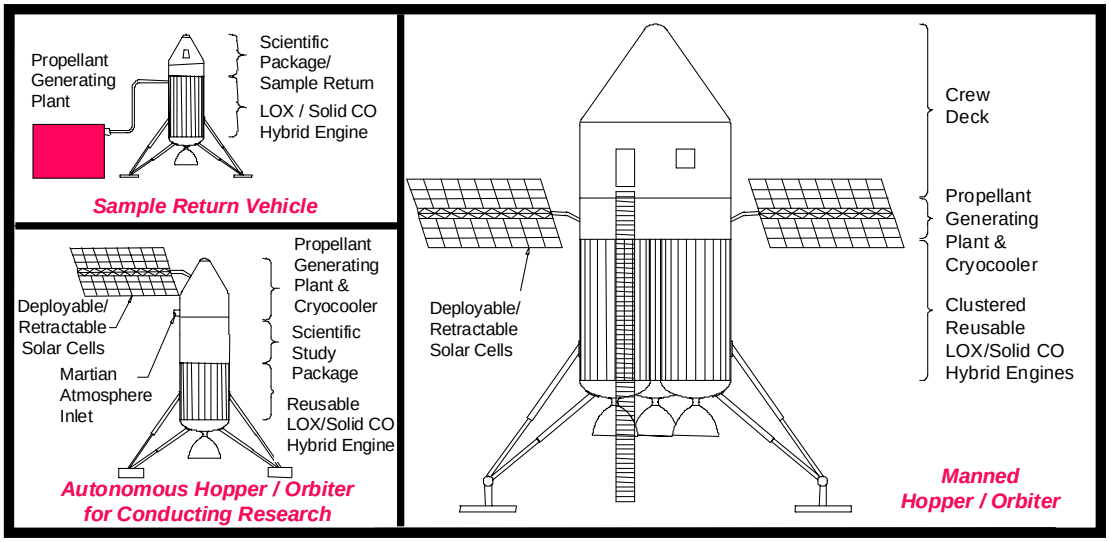
"Development of Lunar Ice Recovery System Architecture"

The presence and properties of ice in permanently shadowed depressions near the lunar poles will influence both the near- and long-term prospects for lunar and Mars exploration and development. Since the most recent data from Lunar Prospector indicate that ice is present in the polar regolith in significant quantities (up to 6 billion metric tons), it is important to understand how to extract it for beneficial use, as well as how to preserve it for scientific analysis. ORBITEC is proposing a complete lunar ice recovery system study. This study would develop an overall system architecture for lunar ice discovery, extraction and utilization. The major result of this study would be a comprehensive program plan for the verification, acquisition and use of lunar water ice. The Moon is an attractive source of resources for the development of near-Earth space because it is close to Earth, it has a small gravity field and most resources (e.g., oxygen, metals) can be readily found. The most significant problem with lunar development is the scarcity of fuel for spacecraft. Although oxygen is present in abundance in the minerals of the lunar regolith, no concentrated source of hydrogen was known with certainty to exist, prior tot he recent Lunar Prospector mission. If rocket fuel must be imported tot he Moon to launch payloads from the Moon, it is very difficult to devise a low-cost Moon-to-space transportation system. However, if both fuel and oxidizer can be obtained locally and relatively easily, a reusable transportation system that can reach Moon-orbit space at low cost may be feasible. This is the promise of lunar water. Water can easily be electrolyzed to produce hydrogen and oxygen, be liquefied and used as propellants. If developed as a supply of propellant, a myriad of other beneficial uses for lunar water could be developed, ranging from life support to construction materials. Two general classes of ice extraction processes can be considered for removal of lice and concentration of water. In the first class of processes, energy is transported into the shadowed regions, ice is processed in-situ, and water is transported out of the cold trap. Alternatively, ice-containing regolith can be mined in the cold trap, transported outside the cold trap, and the ice extracted in a location with abundant solar energy. The existence of water ice deposits on the Moon represents an extremely valuable resource for future lunar exploration and development.

Dr. Eric E. Rice
Orbital Technologies Corporation

"Advanced System Concept for Total ISRU-Based Propulsion and Power Systems for Unmanned and Manned Mars Exploration"

ORBITEC proposes to conceptualize systems and an architecture for producing and utilizing Mars-based ISRU fuel/oxidizer combinations from the atmosphere to support ground and flight propulsion and power systems. For ground systems, we include rovers and auxiliary power. For flight systems, we include Mars sample return vehicles, follow-on automated surface-to-surface and surface-to-orbit vehicles, and larger vehicles to support manned flight operations from surface-to-surface and surface-to-orbit locations.



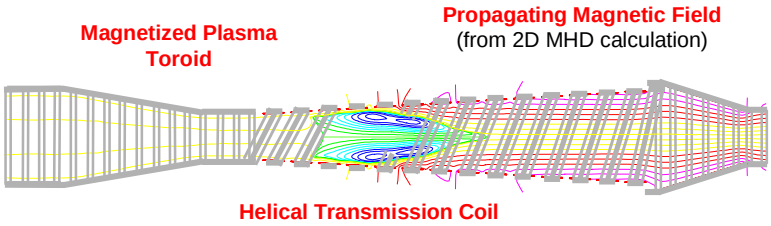
Solid CO/O_2-Based Hybrid Rocket Flight Vehicle Concepts

In Phase I we plan to accomplish a preliminary systems study which will provide the data needed to assess the benefits of our proposed approach compared to one of using all Earth-supplied propellants or using some other ISRU infrastructure (e.g., methane/oxygen). For the cost-effective human exploration of Mars, we will need to use in-situ resources that are available on Mars, such as: energy (solar), gases or liquids for life support, ground transportation, and flight to and from other surface locations, orbit and Earth; and materials for shielding, habitats and infrastructure. Probably the most cost-effective and easiest use of Martian resources is the atmosphere (95% CO_2). The CO_2 can be easily processed and converted to carbon monoxide or carbon and oxygen. ORBITEC proposes to conduct the necessary analysis and advanced concept analysis work that will support the knowledge base to allow us the ability to eventually reliably use these resources in the most effective and efficient manner. In this proposal, we are focusing on the innovative and revolutionary use of solid CO and C as fuels in hybrid rocket propulsion and power system applications. New advanced cryogenic hybrid rocket propulsion systems are proposed that will tremendously improve the performance of CO/O_2 or C/O_2 propulsion such that this is the best option for sample return missions, and follow-on unmanned and manned missions. The implementation of this architecture will also greatly support logistics and base operations by providing a reliable and simple way to store solar or nuclear generated energy in the form of chemical energy that can be used for ground transportation and power generators. ORBITEC has recently proven the concept as technically feasible by test firing a small-scale solid CO/O_2 hybrid! Dan Goldin was provided the test firing information and was impressed.

Dr. John Slough
MSNW

"Rapid Manned Mars Mission with a Propagating Magnetic Wave Plasma Accelerator"

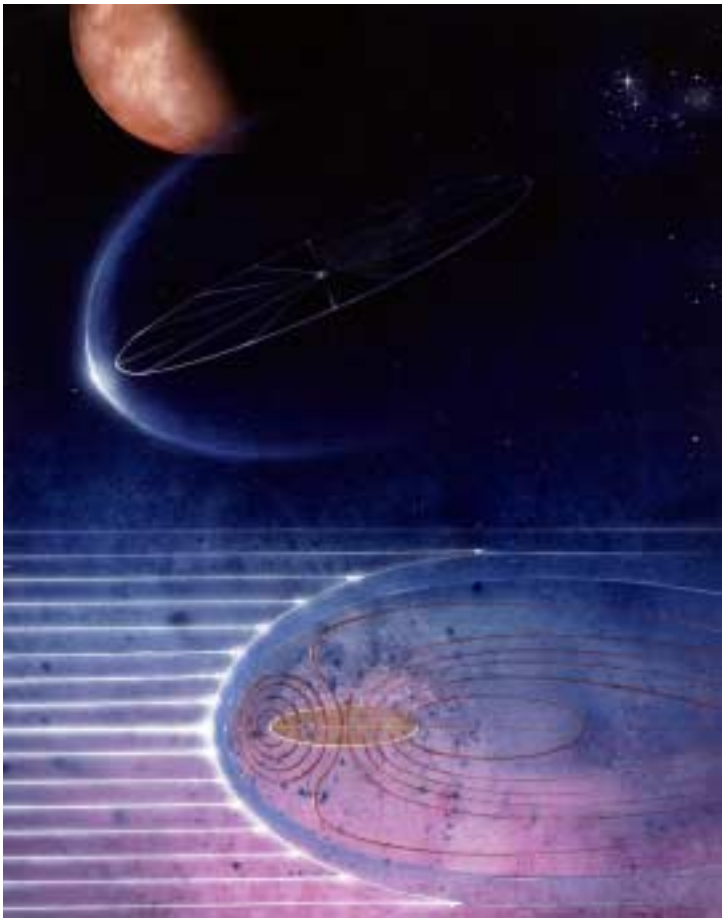
For man to venture forth into the solar system, a radically different propulsion system must be envisioned to make these deep space missions possible. The requirements for deep space exploration are two-fold. First, there must be a power source that employs a fuel with a very high specific energy. This fuel must also be available in sufficient quantity for long missions. It is recognized that nuclear fusion is one known source that can satisfy this requirement. Second, there must be an efficient method for converting this energy into the thrust and I_{sp} necessary for a fast mission. It is proposed here to solve this second problem. This is accomplished by employing a travelling magnetic wave accelerator to accelerate a magnetically self-confined plasmoid, commonly referred to as a Field Reversed Configuration (FRC). Since the FRC is magnetically isolated from the accelerator, there is no contact between the propellant (RFC) and the accelerator. The transfer of momentum to the FRC occurs through an electromagnetic interaction with the magnetic wave so that the exhaust velocity could, at least theoretically, approach the speed of light. In previous experiments carried out by the proposers, FRCs of near milligram mass accelerated to velocities of $2x10^5$ m/s in a single pulse. A novel inductive magnetized plasma source now being developed at MSNW will make it possible to produce FRCs at a very high pulse repetition rate. Using this plasma source, the acceleration scheme proposed here will allow for orders of magnitude increases in I_{sp} over conventional electric propulsion with efficiencies that approach unity. The physical requirements for the accelerator are quite modest. The magnetic fields employed are ~0.3 T and superconducting coils are not required. The concept appears simple enough that a proof of principle experiment could be initiated that would produce plasma mass exhaust velocities approaching 0.01c.



Parameter	First Stage	Final
System length	5 m	25 m
Plasma mass m_p :	0.2 mg D_2	(same)
Final plasma velocity:	$3x10^5$ m/sec	(I_{sp} = 30,000 s) $1x10^6$ m/s
Acceleration (Force):	$2x10^{10}$ m/s (4 kN)	(same)
Thrust Power (1 kHz rep)	9 MW	100 MW

Robert Zubrin
Pioneer Astronautics
"The Magnetic Sail"

The magnetic sail (or "magsail") is a concept that propels spacecraft by using the magnetic field generated by a loop of superconducting cable to deflect interplanetary or interstellar plasma winds. Assuming high temperature superconductors with the same current/mass ratio as existing low temperature superconductors, a magsail sailing on the solar wind at a radius of one astronautical unit can attain accelerations on the order of 0.01 m/s^2 -- much greater than that available from a conventional solar lightsail -- and also greater than the acceleration due to the Sun's gravitational attraction. A net tangential force or "lift" can also be generated. Lift to drag ratios of about 0.3 appear attainable. Using these forces, a magsail can transfer payloads to and from any two circular orbits in the solar system in a flight time without the expenditure of propellant. A magsail operating within the magnetosphere could be made to interact usefully with the Earth's magnetic poles to generate large amounts of thrust that can be used in a series of perigee kicks to drive a payload of several times the magsail's mass to interplanetary space in times scales of a few months.



APPENDIX B

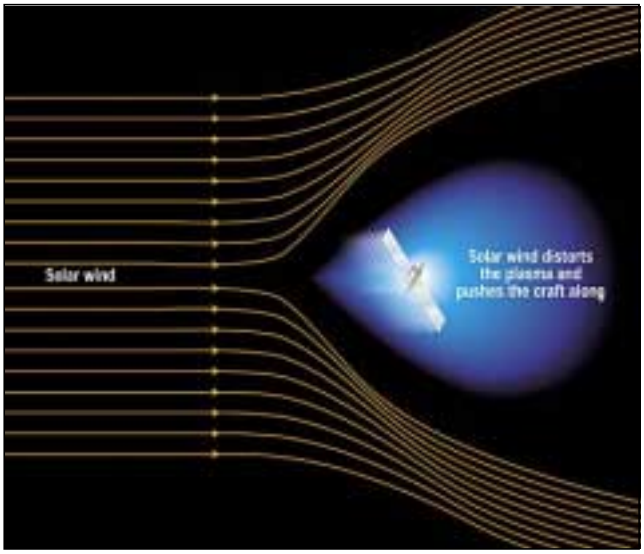
Call for Proposals CP99-01 Phase II Contracts

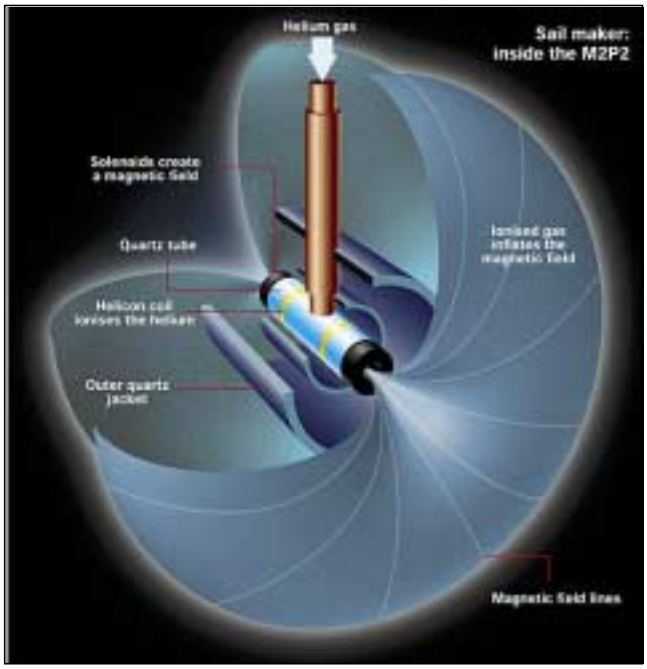
Robert M. Winglee
University of Washington

"Mini-Magnetospheric Plasma Propulsion"

The Mini-Magnetospheric Plasma Propulsion, M^2P^2, system provides a revolutionary means for spacecraft propulsion that can efficiently utilize the energy from space plasmas to accelerate payloads to much higher speeds than can be attained by present chemical oxidizing propulsion systems. The system utilizes an innovative configuration of existing technology based on well-established principles of plasma physics. It has the potential of feasibly providing cheap, fast propulsion that could power Interstellar Probe, as well as powering payloads that would be required for a manned mission to Mars. As such, the proposed work is for missions out of the solar system and between the planets.

The project is interdisciplinary involving space science, plasma engineering and aeronautics and space transportation, which are key components of NIAC's program. The M^2P^2 system utilizes low energy plasma to transport or inflate a magnetic field beyond the typical scale lengths that can be supported by a standard solenoid magnetic field coil. In space, the inflated magnetic field can be used to reflect high-speed (400 – 1000 km/s) solar wind particles and attain unprecedented acceleration for power input of only a few kW, which can be easily achieved by solar electric units. Our initial estimates for a minimum system can provide a typical thrust of about 3 Newton continuous (0.6 MW continuous power), with a specific impulse of 10^4 to 10^5 s) to produce an increase in speed of about 30 km/s in a period of 3 months. Proposed optimization could allow the development of a system that increases the acceleration with less expenditure of fuel so that a mission that could leave the solar system could become a reality.





Ilan Kroo
Stanford University

"Mesicopter: A Meso-Scale Flight Vehicle"

A team of researchers from Stanford University, SRI, and M-DOT Corporation propose to build the 'mesicopter', a centimeter-size electric helicopter, designed to stay airborne while carrying its own power supply. This device represents a revolutionary class of flight vehicles at an unprecedented size, and suggests a range of potential uses. The proposed work focuses on the development of mesicopters for atmospheric science, permitting in-situ measurements of meteorological phenomena such as downbursts and wind shear, and with unique capabilities for planetary atmospheric studies. Swarms of mesicopters could provide atmospheric scientists with information not obtainable using current techniques and could aid in the understanding of phenomena that play a critical role in aviation safety.

Better characterization of atmospheric phenomena on Mars and other simple sensing tasks may be feasible with these very low mass and low cost aerial micro-robots. The mesicopter will pioneer the application of new aerodynamic design concepts and novel fabrication techniques, including solid free-form fabrication and VLSI processing steps. These techniques may ultimately allow the mesicopter to be scaled down to millimeter dimensions. Significant challenges are anticipated in the areas of materials, battery technology, aerodynamics, control and testing. This proposal describes work for the first phase of the program in which initial designs and fabrication tests are used to evaluate the concept's feasibility. An outline of subsequent phases is also provided.

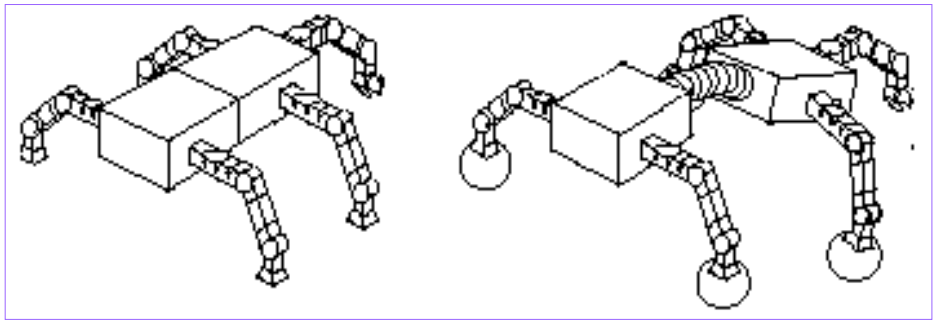
Steven Dubowsky
MIT

"Self-Transforming Robotic Planetary Explorers"

While the 1997 Sojourner mission was an outstanding technical feat, future robotic exploration systems will need to be far more capable. They will need to explore challenging planetary terrain, such as on Mars, with very limited human direction. To achieve this capability, major revolutionary breakthroughs in planetary robotic technology will be required. Here a new and potentially very important concept for robotic explorers is proposed. These are self-transforming planetary explorers – systems that are able to autonomously change their physical and software structure to meet the challenges of its environment and task. Such systems could dramatically enhance the ability of planetary explorers to survive and to successfully complete their mission objectives.

In the concept, the robotic systems would be constructed with reconfigurable elements, or modules. Based on sensor information and onboard models and analysis, the system would autonomously transform itself into the "best" configuration to meet the local challenges.

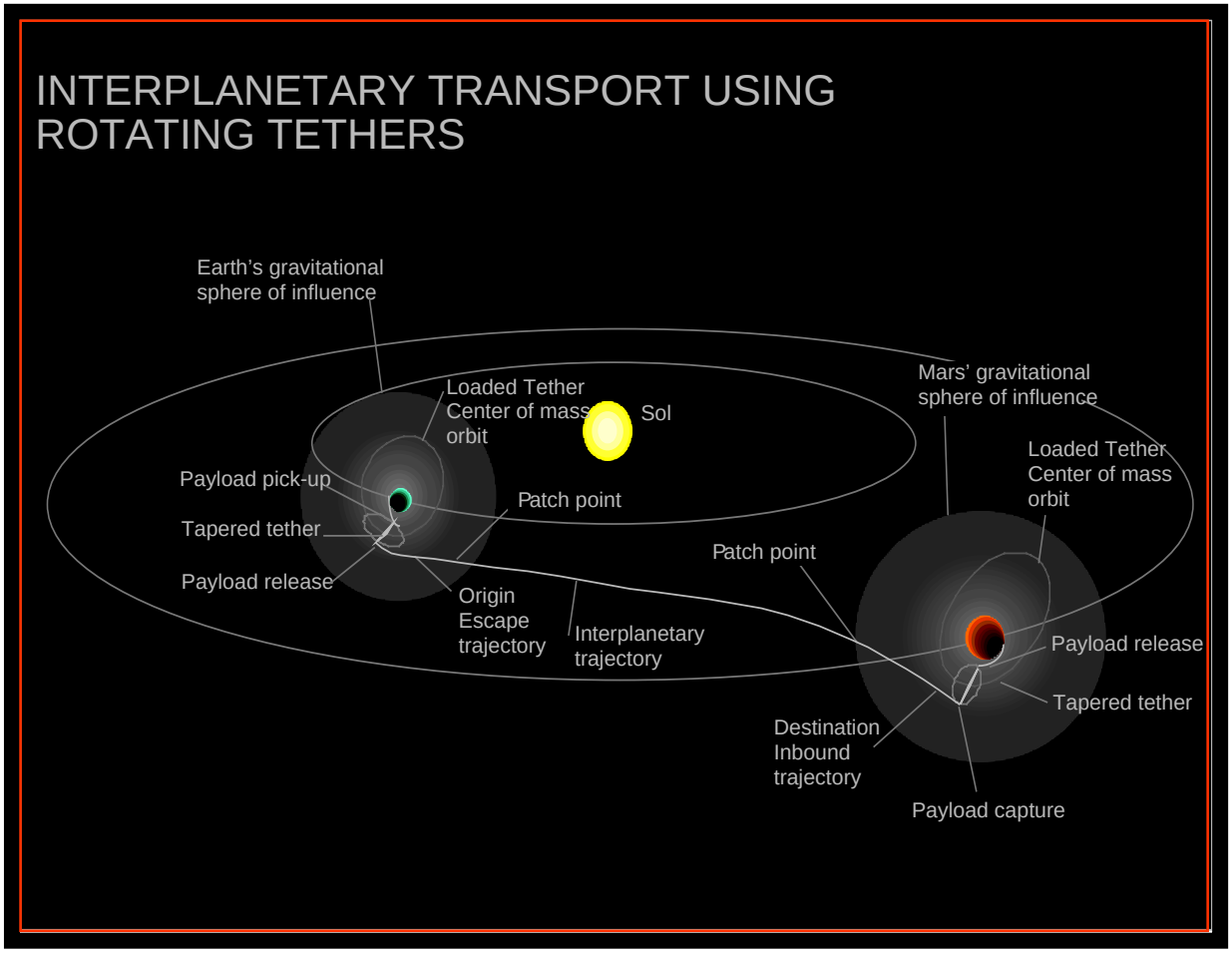
System configurations that could be self-constructed from the original basic system are called cognates. Realizing effective and practical self-transforming systems is difficult for a number of reasons. During this Phase I program, the feasibility of the concept will be studied. While the challenges associated with this study are substantial, so are the potential benefits. If the self-transformation concept can be practically applied, it could significantly impact future planetary exploration missions in the year 2010 and beyond.



Robert P. Hoyt
Tethers Unlimited, Inc.

"Cislunar Tether Transport System"

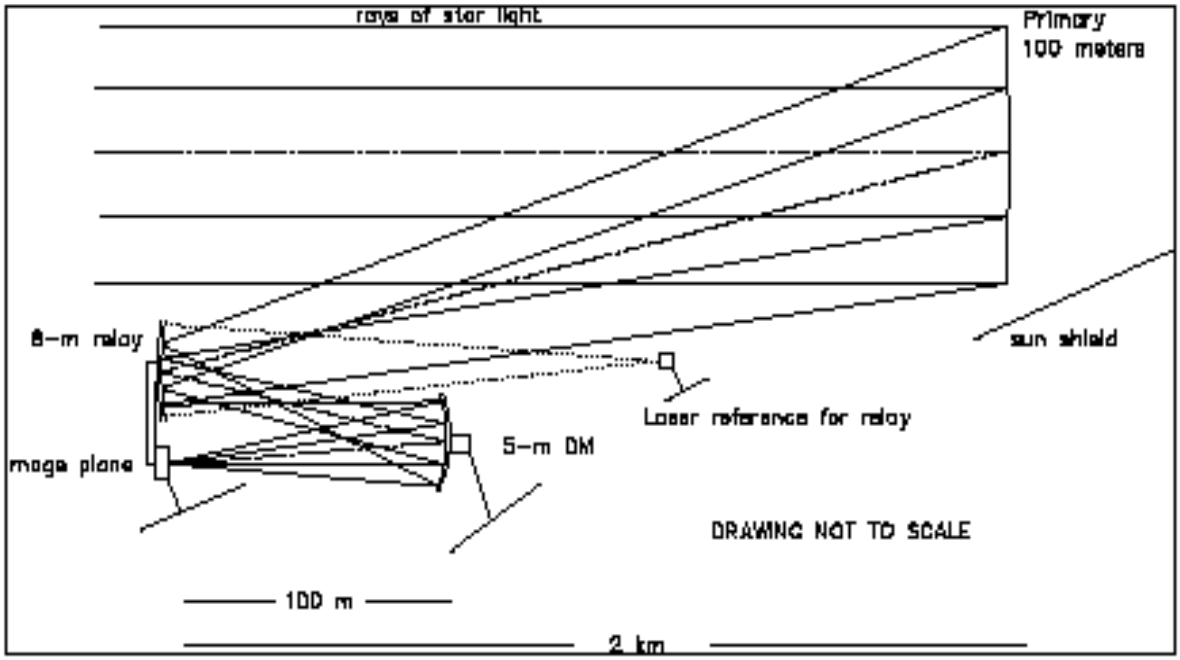
Systems composed of several rotating tethers in orbit can provide a means of transporting payloads and personnel between Low-Earth-Orbit and the lunar surface with little or no propellant required. The underlying concept is to build a reusable transport system that utilizes rotating tethers to throw payloads to the moon and to catch return payloads sent from the moon. By balancing the flow of mass to and from the moon, the total energy of the system can be conserved, eliminating the need for the large quantities of propellant required by rocket systems. Previous studies have shown the potential of tether systems for making LEO to GETO to LEO to Lunar travel affordable by greatly reducing the amount of propellant that must be launched into orbit.



Neville J. Woolf
University of Arizona, Steward Observatory

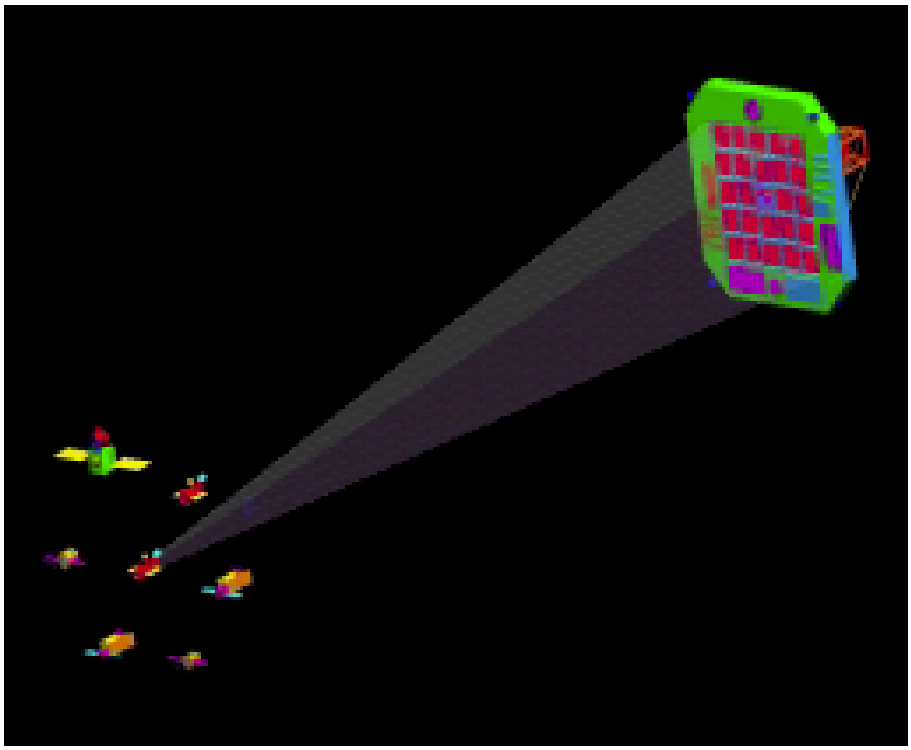
"Very Large Optics for the Study of Extrasolar Terrestrial Planets"

To evaluate habitability and to research for primitive life on Earth-like planets of other stars, telescopes in space with collecting areas of 10 m 2 to 1,000k000 m 2 are needed. We propose to study revolutionary solutions for reflecting telescope in this size range, going beyond technologies we are developing for adaptive secondary mirrors and for ultra-lightweight panels for the NGST. Ways will be explored to build very large lightweight mirrors and to correct their surface errors. As a specific example, we will study a 100 m reflector with a concave NGST-size secondary relay that images the primary onto a 5-m deformable tertiary. The primary, free-flying 2 km from the secondary would be assembled from 5-m flat segments made as reflecting membranes stretched across triangular frames. A 1/20 scale (5 m) image of the primary is formed on the deformable mirror, itself segmented, where panel deformation would be corrected. Scalloping of the segments would compensate the missing curvature of primary segments.



Paul Gorenstein
The Smithsonian Institute, Astrophysical Observatory

"An Ultra-High Throughput X-Ray Astronomy Observatory with A New Mission Architecture"

We propose a study of new mission architecture for an ultra high throughput x-ray astronomy observatory containing a 10 m aperture telescope and a set of detectors. It has potentially much better ratios of effective area to weight and cost than current approaches for the 1 m class AXAF, XMM and "next generation" 3 m class observatories. Instead of a single spacecraft that contains the telescope, the optical bench, and a fixed limited set of detectors in the new architecture, the telescope and an unlimited number of detectors are all on separate spacecraft. Their trajectories are in the same vicinity either in high Earth orbit or the L2 point. Usually, only one of the detectors is active. The active detector places and maintains itself at the telescope's focus by station keeping. Its distance and aspect sensors provide signals that drive electric propulsion engines on the detector spacecraft, which regulate its distance from the telescope to be precisely equal to the focal length.

Unlike current systems, detectors can be replaced and new ones added by launching a small spacecraft that will rendezvous with the others. To reduce its mass, the telescope has a segmented architecture and the segments are actively aligned. The study will identify the nature and magnitude of problems that need to be solved in order to develop a 10 m class X-ray astronomy observatory with these new architectures. The study will involve both analysis and laboratory measurements. The mission architecture is applicable to other observatories.