FY02 Highlights

- Overview
- Architecture Concepts
- Exploration Hurdles
  - Space Transportation
  - Power
  - Crew Health and Safety
  - Human and Robotic Operations
  - Space Systems
- *Technology Planning*
- Leveraging and Partnering
- Future Direction

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Technology Planning

An integrated, sustained technology planning and investment program – addressing the exploration hurdles and traceable to major, NASA-wide scientific objectives – is pivotal.

FY02 Technology Planning Accomplishments:

- Updated Technology for the Human/Robotic Exploration and Development of Space (THREADS) Strategic Research & Technology Road Maps
  - Self-Sufficient Space Systems (new WBS element)
  - In Space Instruments and Sensors (new WBS element)
- Continued TITAN (THREADS Integrated Technology ANalysis) model development
- Conducted THREADS-Revolutionary Aerospace Technology Working Group (RATWG) FY 2002 Workshop
- Updated "Top 10" exploration technology funding priorities
- Identified and invested in aerospace technologies which may have high payoff value
  - FY02 seed investments
  - Revolutionary aerospace technologies
- Technology Needs Gap Analysis in progress
- Completed Human Capital Gap Analysis

Technology Planning –
THREADS Work Breakdown Structure

The THREADS* Work Breakdown Structure (WBS) is organized not along discipline lines—nor according to potential future missions or targets. Rather, the THREADS WBS is organized along broad, functional areas. It comprises three major topics: Systems Analysis, Integration and Planning; Enabling Research and Technology; and Technology Flight Demonstrations.

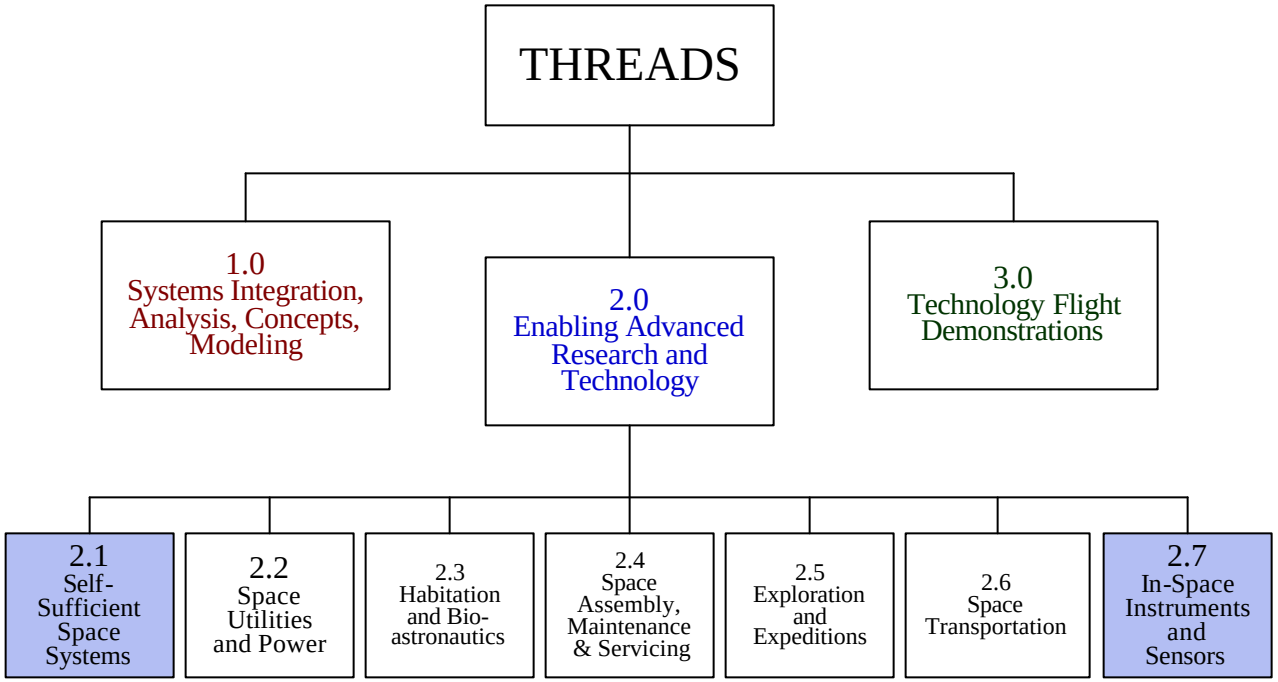
One of the major changes that emerged in FY2002 involved a restructuring of the THREADS road maps in order to better accommodate the expanding strategic space exploration goals and objectives of the Agency. This involved the addition of a new theme, "In Space Instruments and Sensors," and the reformulation of a previous theme ("Space Resources Development") to form a new them, "Self-Sufficient Space Systems." With FY2003, the THREADS WBS includes the following areas:

1.0 Systems Integration, Analysis, Concepts and Modeling
2.0 Enabling Advanced Research and Technology
- 2.1 Self-Sufficient Space Systems
- 2.2 Space Utilities and Power
- 2.3 Habitation and Bioastronautics
- 2.4 Space Assembly, Maintenance and Servicing
- 2.5 Exploration and Expeditions
- 2.6 Space Transportation
- 2.7 In Space Instruments and Sensors

3.0 Technology Flight Demonstrations

*THREADS: "Technology for Human/Robotic Exploration and Development of Space"

THREADS Work Breakdown Structure



- Intelligent Operations
- Advanced Space Platforms
- Control and Communications
- In-Situ Manufacturing
- In-Situ Resource Excavation
- In-Situ Resource Processing
- Surface Construction
- Consumable Storage and Distribution

- Detectors and Sensors
- Microwave Sensing
- Sub millimeter sensing
- Laser Sensing
- X-Ray & High-energy Sensing
- Telescope Systems
- In-space laboratories
- Instrument & Sensor Data Management

Technology Planning –
Strategic Research & Technology Road Map

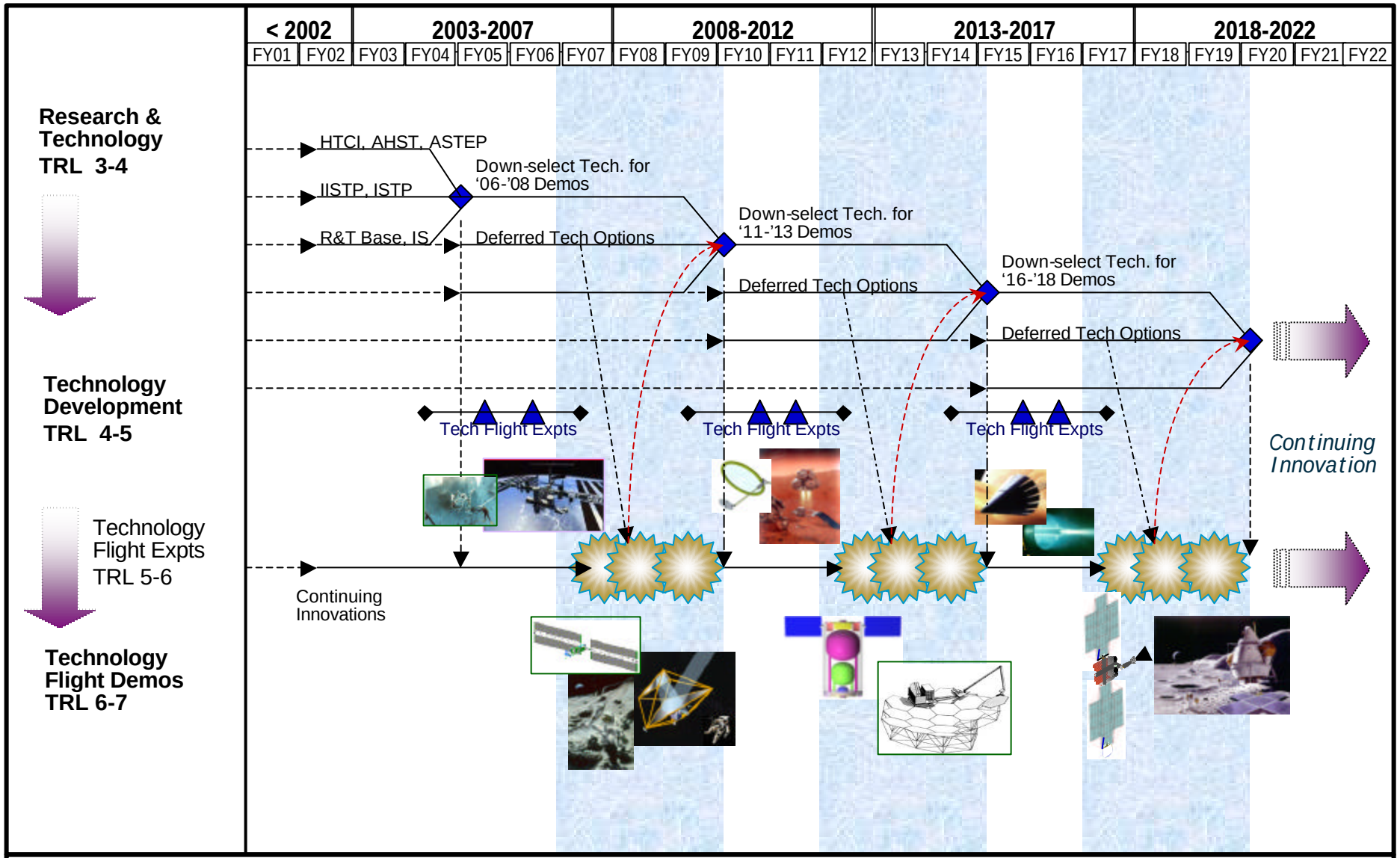
The THREADS* Strategic Research & Technology road maps consist of several elements, including the definition of a diverse set of important and clear technical challenges; the formulation of potential technological solutions to those challenges; the organization of those data according to a systematic, top-down WBS; and the identification of specific, quantifiable metrics that will allow Research & Technology investments to be guided and subsequent progress to be measured.

In addition, in order to allow notional budgets to be identified – and the "gap analysis" to be conducted based on the comparison of these notional budgets to actual and planned investments – a baseline timeframe for the accomplishment of the goals and objectives defined within THREADS is used. This timeline involves the regular – about once every 5 years – focusing of technology research and development to be focused through a hypothetical family of technology flight demonstrations. The first of which would occur approximately 6-7 years from the present date.

These "schedule of milestones" road maps provide a clear and consistent "clock" that allows the coordination and the integration of events and plans across the several themes and elements of the THREADS road maps.

*THREADS: "Technology for Human/Robotic Exploration and Development of Space"

Strategic Research & Technology Road Map



LEGEND

- Strategic Research and Technology Decision Point
- Major Technology Development Milestone
- Major Technology Flight Demonstration

*NOTE: Supporting resources includes other proposed augmentations for FY '02

Technology Planning –
TITAN Development Progress

The purpose of TITAN (THREADS Integrated Technology ANalysis) is to make possible high-level systems-technology analyses that include examination of various options for THREADS – including sensitivity studies involving various levels of possible future progress.

TITAN will provide a systematic modeling process to support the following THREADS systems goals:

- Optimize the investments made in technology for human/robotic exploration and development of space
- Gain insight in identifying advanced system and architecture concepts that can dramatically increase the safety and reliability – and reduce the cost – of ambitious future human exploration missions and campaigns beyond Earth orbit
- Establish a foundation of relationships with science, commercial, or international partners for future exploration studies, by identifying cross-cutting technologies that are synergistic with other interests

TITAN will serve as a single, high-level modeling tool that makes possible a range of analytical studies. Various parts/pieces might be added and/or adapted by various parties:

- Contributing to the “baseline” new model
- Making evolutionary changes/improvements over time
- Tailoring the model to examine specific cases, as desired

TITAN Development Progress

TITAN is a single, modular, multi-workbook modeling architecture, providing a crosscutting capability for technology investment studies, with applications for human exploration, science missions, and commercial space markets.

- Established TITAN **(THREADS Integrated Technology ANalysis)** Development Working Group
- Proposed user interface concepts and established top-level modeling structure
  - Each segment is a collection of workbooks; each subsegment performs unique function
  - Segment-unique output page resides inside segment model instead of user interface
  - Subsegment workbook would contain it's set of subsystem worksheets, which contain technology gearboxes
  - Orbit geometry will come from architecture level user
  - Menu of predefined mission scenarios, with elements & technologies, will be developed first (targeted to mission architecture users)
  - Selected technology toolbox data will be stored in "common block" format for use in all modules
- Developed several configuration modules for Space Solar Power infrastructure elements
- Space Solar Power Model is currently being restructured into the TITAN modular structure

Technology Planning –
THREADS-RATWG Workshop

In August 2002, THREADS* Team and RATWG** jointly hosted a major technology planning workshop. The purposes of the meeting, which involved more than 60 innovators from across NASA, industry and universities, was to examine the challenges of future human/robotic exploration – and to begin identification of prospective conceptual and technological approaches to meeting those challenges.

The workshop, which was held at NASA Headquarters, was organized into two major sections: a THREADS technology assessment activity, covering the first three days, and a RATWG brainstorming session on the fourth day. The THREADS section included several integrated plenary sessions and parallel breakout sessions. A variety of "catalytic presentations" were made during these sessions that highlighted a wide range of mission and technical issues associated with the future development of technology for human and robotic exploration and development of space. Many sessions address current state-of-the-art topics in technology and anticipated the scope of advances that might be made with adequate funding. Systems sessions reviewed and endorsed the overall road mapping process of the THREADS Team as well as details of modeling challenges for NEXT.

The THREADS-RATWG Workshop was a major step in updating the THREADS technology road maps for FY2002, and for conducting the annual technology gap analysis.

*THREADS: "Technology for Human/Robotic Exploration and Development of Space"
**RATWG: "Revolutionary Aerospace Technology Working Group"

THREADS-RATWG Workshop

- A THREADS-Revolutionary Aerospace Technology Working Group (RATWG) workshop was conducted to identify and assess innovative architectures, revolutionary concepts and technology needs, and opportunities for a wide range of prospective future exploration and commercial development of space activities
- Workshop Objectives:
  - Review of existing plans, road maps, and analyses
  - Generation of updates to the development plans, technology metrics and road maps
  - Identification of advanced concepts and high-risk/high-leverage research and technology
- The workshop was attended by government, industry, and academic representatives
- There were a total of 52 presentations on diverse technology subjects
- The working group sessions addressed current state-of-the-art in technology and advances that can be achieved with adequate funding
- The workshop identified and documented 54 issues to be considered for completing the technology road maps in preparation for performing the technology gap analysis

Technology Planning –
Top 10 Technology Area Funding Priorities

The "Top 10" technology areas for investment action do not reflect – and are not intended to reflect – all of the areas of importance to future human and robotic exploration and development of space. Rather, the list is an indicator of which areas now need additional investment. If an area – however important – is currently well-funded in comparison to the level of funding that is expected to be needed to achieve the goals and objectives of the THREADS road maps, then it will not appear on the annual list.

For example, past gap analysis efforts had identified in-space propulsion as an important area for additional investment. However, this has now been addressed by a previous new initiative – hence, it does not appear in the FY2002 "Top 10" list.

In addition, two crosscutting topics were identified for continuing emphasis:

- Systems Studies, Advanced Concepts, etc.
- Technology Flight Demonstrations

By pursuing new and refocused investments in these priority areas, needed progress toward the capabilities that can enable future ambitious, affordable, and safe missions of human/robotic space exploration and development.

Top 10 Technology Area Funding Priorities

- Advanced Power
- Biological Risk Mitigation
- Space Assembly, Maintenance & Servicing (Robotic, Extravehicular Activity)
- Aero-Braking/Assist/Entry
- Regenerative Life Support / Habitation Systems
- Surface Science & Mobility Systems
- Materials and Structures (Manufacturing)
- Cryogenic Propellant Depots
- Systems Studies, Advanced Concepts, etc.
- Technology Flight Demonstrations

Technology Planning –
Example Technology Seed Investments

The general goal in NEXT technology research investments is to test in a timely way specific concepts and/or technologies that appear to hold significant promise for future human/robotic space systems and architectures. The intent is to more-effectively integrate systems studies and the results of preliminary technology development efforts to better inform management decisions – including (in particular) decisions about additional technology investments. Some of the highlights of the FY2002 NEXT investments in these "technology seedlings" include the following:

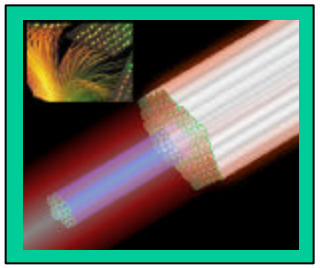
- *Plasma Sails* – which offer the potential to provide both propulsion as well as protection from solar particle events during long missions
- *Power Tile Technology* – in which a variety of new technologies, including multi-bandgap photovoltaics and thin-film concentrators, are integrated to make possible higher efficiencies and lower masses than have been achieved previously
- *Power Beaming Technology* – which may allow non-nuclear solution to the challenge of explored the permanently shadowed areas of the Moon, while advancing a technological foundation for (perhaps) someday delivering clean energy from space to markets on the Earth
- *50 kW Hall Thruster* – a first-of-a-kind test in the U.S. for the largest electric propulsion system of its type; which could be used to move large payloads cost-effectively from low-Earth orbit to beyond
- *High Voltage Thin Film Arrays* – which could reduce substantially the mass of very large area future photovoltaic arrays by reducing the mass of power management and distribution on these systems
- *2 kWe Brayton Testbed* – which examined the maturity of high-efficiency thermal conversion for solar and nuclear power systems
- *Entry, Descent, and Landing* – which tested concepts for precision landing of robotic and piloted missions on other worlds
- *Plasma Propulsion* – which may make possible omnivorous, high-efficiency propulsion to take humans anywhere in our Solar System
- *Wireless Systems* – which make systems more flexible and robust
- *All Terrain Mobility Systems* – for future robotic and human exploration of the Moon and the planets

Example Technology Seed Investments

NEXT manages a small investment portfolio for selected concepts and technologies to serve as seed money for future initiatives.

Plasma Sails

Power Tile Technology

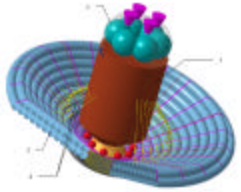


Power Beaming Technology

50 kW Hall Thruster

High Voltage Thin Film Solar Arrays

2 kWe Brayton Testbed



Advanced Entry, Descent, and Landing System Technologies

Plasma Propulsion

Wireless Systems

All Terrain Mobility Robotics Systems

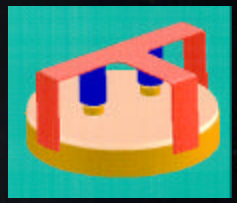
Technology Planning – Revolutionary Technology Candidates

The Revolutionary Aerospace Technology Working Group (RATWG) is responsible for investigating innovative technologies that can have a dramatic effect on future exploration missions. These technologies are intended to result in substantial increases in capability, significant increases in safety, and compelling reductions in cost. Since NEXT is familiar with the technology investments internal to NASA, RATWG's focus is external to the Agency; i.e., this group will identify new concepts and technologies, and determine what investments in advanced technologies are being made in other government agencies, universities, and commercial industry. Working with the THREADS team, the RATWG will highlight its findings to the NEXT and its teams/working groups so that additional steps can be taken (as appropriate) to infuse particular technology innovations into future systems concepts or architectures or fund a special study to further investigate the technology's value. When appropriate (i.e., following a review illustrating potential merits), the RATWG will work with the THREADS team to influence and exploit technology development.

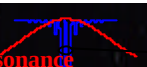
Candidate innovations in the RATWG data base include:

- Prioritized Technologies:
  - Reliable supply of high specific density energetics for long duration travel anyplace/anytime
  - Reliable affordable transportation (Earth-to-space, in-space)
  - High bandwidth optical communication with supportive relay stations
  - Materials – performance imbedded, hybrid-composites, nanotubes, smart structures with memory
  - Nano-miniaturization
  - Quantum computing, processing, and memory
  - Genomics for life sustenance under harsh space conditions
  - Mobility – seamless man-machine systems (flyers, surface, and subsurface)
- Concepts and Systems
  - Ultra-long life, modular, reconfigurable hardware; evolvable, self sufficient
- Architectures
  - Distributive, interactive networking; cooperative, evolvable, and capable of learning

Revolutionary Technology Candidates

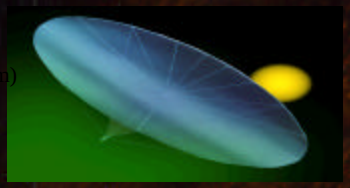


SPR Resonance
20 nm FWHM

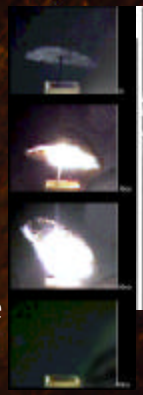


Bio-photonics

Miniature Scroll Pump on a Chip
(10's of grams, <1 watt)

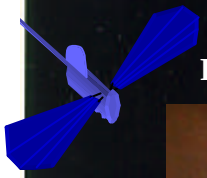


Interstellar Technology

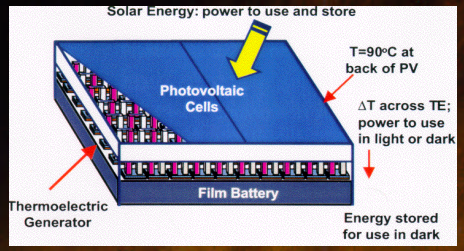


Microwave levitation

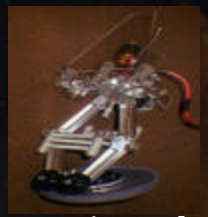
Liftoff of Carbon Sail under 10 kW Laser



Robo-Locust



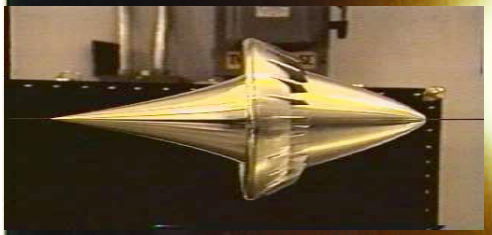
Power Tile: PV/ThermoPV-FilmBattery



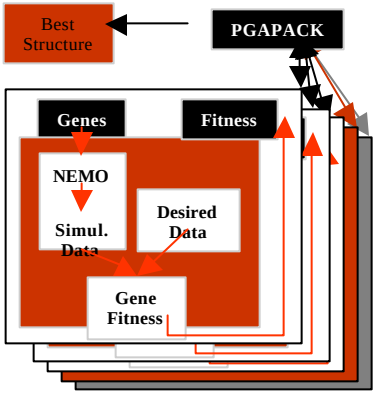
Hopping Robot

Genetically Engineered Nano and Microelectronic Structures

Web-Sensor



Laser Detonation Sailcraft



Software Package with Graphical User Interface

Input:
- Simulation Targets
- Platform parameters
- Interaction between PC and supercomputer

Output:
- Evolution development
- Evolution results
- Evolution statistics

Technology Planning –
Technology Needs Gap Analysis Example
Space Transportation Investment

A task was initiated to identify gaps between current space transportation technology investments and needed space transportation technology investments. This task was based on analysis of existing space transportation capabilities and technologies, technology development programs underway or in prospect, and exploration transportation requirements as presently understood. Technologies were characterized by maturity (Technology Readiness Level) and advancement degree of difficulty. Capabilities and technologies were then mapped to mission requirements within the NEXT Stepping Stone strategy and the road mapping framework developed by THREADS.

The results of the space transportation gap analysis showed that:

- Present space transportation technology is not capable of satisfying the full range of NEXT Design Reference Missions
- A number of competitive candidate technologies exist that show promise of satisfying all Design Reference Missions if developed successfully

The analysis identified a subset of low-technology readiness level technologies as suitable for priority investment to bring the competitive field up to sufficient technology readiness level to enable major investment decisions to be made. Also, the design reference missions themselves need to be developed to a higher level of detail to provide sufficient basis for narrowing the field of transportation technologies.

Technology Needs Gap Analysis Example

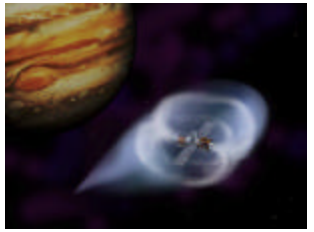
Space Transportation Investment

Scope

- Identify known exploration transportation requirements for Earth-to-orbit and In-Space missions
- Assess NASA Space Transportation investments against exploration requirements for Hypersonics, In-Space Propulsion, Nuclear Systems Initiative, and operational systems
- Identify Agency investment gaps for Exploration

Conclusions

- ***Space Launch Initiative:*** Investments partially close gap; primary gap lies in system requirements
- ***Hypersonics:*** No explicit requirements yet defined by NEXT
- ***In-Space Propulsion:*** Investments partially close gap; focused primarily on robotics; additional investments required.
- ***Nuclear Systems Initiative:*** Program formulating; concern investments will focus only on robotic requirements
- ***Revolutionary Research:*** Significant gaps; program terminated; long lead technologies are possibly being neglected



Recommendations

- Refine the fidelity of Design Reference Missions to allow for more detailed requirements generation
- Advocate for reinstatement of Revolutionary Research for Space Transportation

Technology Planning –
Human Capital Gap Analysis

As important as the need is to assure the readiness of exploration technologies through strategic investments, it is equally important to have available the skill sets and the human resources needed to develop these technologies.

The Human Capital Gap Analysis was performed in concert with the THREADS technology needs gap analysis to determine the skills and human resources needed to develop technologies in support of the NEXT stepping stone strategy.

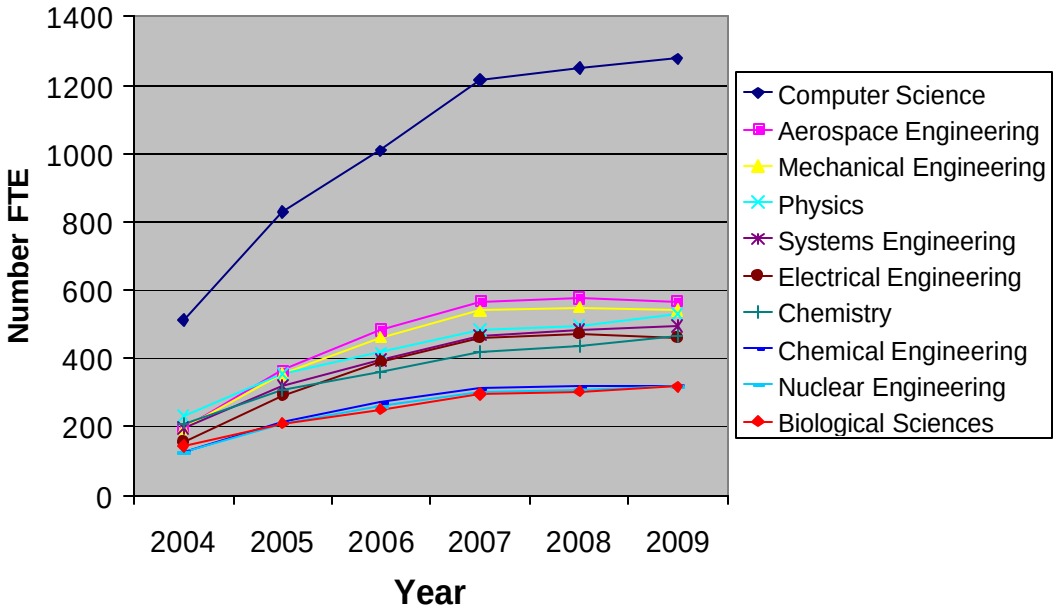
The chart below highlights the top ten disciplines required to accommodate THREADS technology development through FY2015. The numbers required are the actual full-time equivalents required each year.

With these data, one can cross reference the needs with the workforce, both internal and external of NASA, and predict the “gap” between the needed skills and the supply from universities and industry.

Human Capital Gap Analysis

- NEXT evaluated and documented the "top ten" required disciplines and NASA unique skill sets needed in support of a NASA educational scholarship
- This analysis included the estimates of full-time equivalents to accomplish forecasted technology development by fiscal year through FY2015 based on THREADS projections

Estimated Full Time Equivalents (FTEs) Required to Execute THREADS Technology Development Vision



NEXT has identified the disciplines of focus to fulfill the mission "*To inspire the next generation of explorers.*"

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