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Aeronautics and Space Engineering Board News

Welcome to the latest installment of the ASEB News! This newsletter will update you on ASEB events and activities, as well as policy items of interest to the aerospace community.

Inside this issue

Report Establishes Priorities in NASA's Space Technology Roadmaps

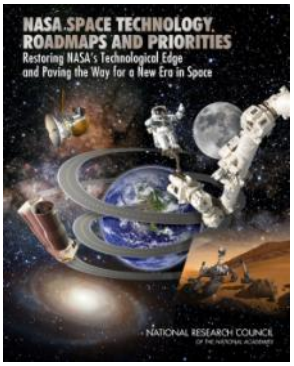
The ASEB has released a new report, *NASA Space Technology Roadmaps and Priorities: Restoring NASA's Technological Edge and Paving the Way for a New Era in Space*, a large undertaking that included the participation of 74 panel and committee members, 17 reviewers, and 17 NRC and Aerospace Corporation staff members. Study Chair Raymond Colladay briefed the report to NASA Administrator Charlie Bolden, Deputy Administrator Lori Garver, and (then) Associate Administrator Chris Scolese on January 26, 2012, the day of the report's release.

As noted in the ASEB Chair's column (see p. 2), the Roadmap report prioritizes the technologies that appear in 14 draft roadmaps produced by NASA. The scope of these roadmaps cover the full range of NASA space technologies and are organized as follows:

- Launch Propulsion Systems
- In-Space Propulsion Systems
- Space Power and Energy Storage Systems
- Robotics, Tele-Robotics, and Autonomous Systems
- Communication and Navigation Systems
- Human Health, Life Support and Habitation Systems
- Human Exploration Destination Systems
- Scientific Instruments, Observatories, and Sensor Systems
- Entry, Descent and Landing Systems
- Nanotechnology
- Modeling, Simulation, Information Technology, and Data Processing
- Materials, Structures, Mechanical Systems, and Manufacturing
- Ground and Launch Systems Processing
- Thermal Management Systems

The steering committee and six panels that conducted this study concluded that during the next 5 years NASA technology development efforts should focus on 16 high-priority technologies and their associated top technical challenges. These high-priority challenges and technologies were selected with input from the external technical community and are detailed in the tables shown on pages 9 and 10 of the newsletter. These priorities align with three main objectives of NASA's overall mission, defined by the steering committee as follows:

- Technology Objective A: Extend and sustain human activities beyond low Earth orbit.
- Technology Objective B: Explore the evolution of the solar system and the potential for life elsewhere using in situ measurements.



A copy of the Roadmap report can be purchased, or downloaded as a PDF document for free, from <http://www.nap.edu/catalog.php?record_id=13354>.

(Continued on page 9)

From the Chair

I am proud and humbled to assume the mantle of chair of the ASEB, stepping into the very large shoes that Ray Colladay wore for the last 6 years. I would be remiss if I did not acknowledge and sincerely thank Ray for the tremendous job he did in leading the ASEB in its various studies, its support to NASA and other high-tech organizations, and its standard of excellence in aeronautics and space engineering.

One of Ray's last tasks at the helm of the ASEB was to lead a demanding and complex study, which resulted in the report *NASA Space Technology Roadmaps and Priorities: Restoring NASA's Technological Edge and Paving the Way for a New Era in Space.* This study, which involved many members of our community, considered a set of 14 draft roadmaps produced by NASA that contained 320 Level 3 technologies. The scope of the draft roadmaps ranged from launch propulsion systems, space power and energy storage systems, robotics, and materials technologies to human health and habitation systems technologies. Panels with diverse expertise assessed the technology breakdown structure of the 14 roadmaps and concluded that 83 technologies were considered a high priority. The study's steering committee then evaluated those 83 technologies, and, by means of an organizing framework relating objectives, challenges, and individual technologies, the prioritization process across all roadmaps identified 7 or 8 technologies for each of three independent technology objectives, for a total of 16 unique technologies that the report recommends be emphasized over the next 5 years of the 5- to 30-year window of the technology roadmaps. The detailed report to NASA provided the benefits of the specific technologies and a prioritization list for the use of the agency and its chief technology officers.

About the time that the ASEB submitted its report to NASA, the Department of Defense was finalizing its new "Defense Strategic Guidance" and planning for the national security challenges of the future. While this topic may not seem connected to the mission of the ASEB, I am convinced there are important synergies related to the engineering programs and policies that the ASEB supports. I am reminded of a recent meeting with the Honorable Leon Panetta, the Secretary of Defense, where he expressed his commitment to make sure the DOD maintains the "technological superiority" that has always been the underpinning for our superior U.S. war-fighting capabilities. As an example of this commitment, the Secretary of Defense's office has tasked the Defense Science Board (DSB) to conduct a study of the emerging technologies that will enable the next generation of dominant military capabilities to be available by the 2030 timeframe. This study will identify promising technologies and, where possible, an experimentation roadmap to guide DOD research and development investments over the period of 2014-2020. The DSB study will also examine technology areas being pursued by other government agencies, like NASA, and significant technology advances outside the government, including the commercial sector. Clearly, the opportunity for synergies and overlaps between this DSB study and what the ASEB has done for NASA are great. The DSB study request mentions technology areas such as quantum computing, alternative energy sources, advanced materials, robotics, micro-electronics, and modeling and simulation—all of which were identified in our NASA technology roadmap study. Consequently, I plan to make sure that our efforts are a major input to the DSB initiative.

Finally, both the NASA roadmap report and the DOD strategic guidance raise the question: Where will we get the science technology engineering and mathematics (STEM) workforce for the future in the United States? This is a national problem that we have all recognized in numerous reports, studies, etc., over the last several years, if not longer. There are many excellent initiatives underway throughout the communities, throughout companies and organizations, and throughout government to address the STEM question. I hope to make this a priority topic of discussion in future ASEB meetings.

Lester L. Lyles
Chair, ASEB
thelylesgroup@earthlink.net

Former ASEB Chair Ray Colladay Receives Public Service Medal

Outgoing ASEB Chair Dr. Raymond Colladay (left) receives the NASA Exceptional Public Service Medal from NASA Administrator Bolden at the March 2012 NASA Advisory Council meeting.

The NASA plaque commendation reads: "For exemplary leadership, dedication, and commitment to NASA as a member of the NASA Advisory Council. Your contributions will benefit the Nation for generations to come."

ASEB Staff

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*Staff of other NRC Boards who are shared with ASEB

ASEB Calendar—Spring/Summer 2012

April 4-5, 2012	ASEB Meeting: Washington, DC.
April 19-20, 2012	Meeting to Review Proposals to the 2012 Ohio Third Frontier Innovation Platform Program: Irvine, CA.
May 7-9, 2012	Reusable Rocket Booster Systems Meeting : Washington, DC.
August 2-3, 2012	Aeronautics Research and Technology Roundtable Meeting 3: Washington, DC.

For updates to the ASEB calendar, please see http://www.national-academies.org/aseb.

Committee on Human Spaceflight Crew Operations

Frederick Gregory (Co-Chair)
Lohfeld Consulting Group, Inc.

Joseph H. Rothenberg (Co-Chair)
Swedish Space Corporation

Michael J. Cassutt
University of Southern California

Richard O.Covey
United Space Alliance, LLC (Retired)

Duane Deal
Stinger Ghaffarian Technologies, Inc.

Bonnie J. Dunbar
Seattle Museum of Flight, Dunbar International, LLC

William W. Hoover
Independent Consultant

Thomas D. Jones
Florida Institute of Human and Machine Cognition

Franklin D. Martin
Martin Consulting, Inc.

Henry McDonald
University of Tennessee at Chattanooga

Amy R. Pritchett
Georgia Institute of Technology

James D. Von Suskil
NRG, Texas

Richard N. Richards
Boeing Corporation (Retired)

ASEB Releases Report Assessing the Changing Role of Human Spaceflight Crew Operations

As the National Aeronautics and Space Administration (NASA) retires the space shuttle and shifts involvement in International Space Station (ISS) operations, changes in the role and requirements of NASA's Astronaut Corps will take place. On September 7, 2011, the Committee on Human Spaceflight Crew Operations released its report, *Preparing for the High Frontier: The Role and Training of NASA Astronauts in the Post-Space Shuttle Era*. Co-chaired by Frederick Gregory and Joseph Rothenberg, the committee considered three main questions at the request of NASA regarding the changes in the role and requirements in NASA's Astronaut Corps:

1. How should the role and size of the activities managed by the Johnson Space Center Flight Crew Operations Directorate change after space shuttle retirement and completion of the assembly of the International Space Station (ISS)?
2. What are the requirements of crew-related ground-based facilities after the space shuttle program ends?
3. Is the fleet of aircraft used for the training the Astronaut Corps a cost-effective means of preparing astronauts to meet the requirements of NASA's human spaceflight program? Are there more cost-effective means of meeting these training requirements?

A copy of the spaceflight crew operations report can be purchased, or downloaded as a PDF document for free, from <http://www.nap.edu/catalog.php?record_id=13227>.

The report did not consider whether the United States should continue human spaceflight or whether there are better alternatives to achieving the nation's goals without launching humans into space. Rather, the report assumed that U.S. human spaceflight would continue.

The report's conclusions and recommendations address the following topics:

- Increasing the factor of uncertainty used to determine minimum staffing requirements for the Astronaut Corps. The current 25 percent does not provide sufficient flexibility to meet the current flight manifest requirements reliably.
- Maintaining the NASA Flight Crew Operations Directorate as a national resource for U.S. human spaceflight experience and knowledge. The resource should be:
  1. Maintained to ensure appropriate staffing and training of the Astronaut Corps in support of the ISS manifest;
  2. Applied to the future development of NASA human spaceflight and exploration activities;
  3. Available to the emerging commercial industry and the FAA; and
  4. Applied to support authorized agreements with international partners.
- Evaluating future requirements of the Shuttle Engineering Simulator Dome.
- Retaining the capability and training facilities to conduct ISS mission-specific training after retirement of the space shuttle.
- Maintaining a spaceflight readiness training program.
- Retaining the T-38N fleet for spaceflight readiness training.
- Monitoring training methods and technologies in related fields to enhance astronaut selection and training.

In responding to the report, NASA announced its newest call for astronaut applicants in October 2011, and the second-highest number of applications was received by the agency (over 6,300).

The ASEB Convenes an Aeronautics Research and Technology Roundtable

The ASEB's Aeronautics Research and Technology Roundtable held its second meeting on February 21-22, 2012, in Washington, DC. The Roundtable convenes senior-most representatives from industry, universities, and NASA to define and explore critical issues related to NASA's aeronautics research agenda. Chaired by Boeing Chief Technology Officer John Tracy, the 25-member Roundtable includes a broad range of executives, entrepreneurs, and experts representing airframe and engine manufacturers, general aviation companies, academia, industry associations, and other federal agencies. The Roundtable meets several times a year and does not create any written reports or products. Its purpose is to facilitate candid dialogue among participants, foster greater partnership among the NASA-related aeronautics community, and, where appropriate, carry awareness of issues to the wider public.

NASA Associate Administrator for Aeronautics Jaiwon Shin (second from the right) talks to and receives input from the NRC's Aeronautics Research and Technology Roundtable. Roundtable chair John Tracy is at right.

NASA defined key issues for the Roundtable and posed the following questions to the Roundtable for the members to consider during their deliberations:

1. What are the technical competencies for sustained leadership?
2. What are the most important aviation risks and opportunities for research focus?
3. What research is most effectively accomplished by public-private partnerships?

The first day of the February Roundtable meeting consisted of sessions organized by sector: general aviation, commercial aviation, vertical lift, and unmanned aircraft systems (UAS). Each session featured several invited speakers and discussion periods. On the second day of the meeting, the Roundtable met in plenary session and reported on the results of the previous day's discussions. They also explored common threads among the sectors.

The next meeting of the Aeronautics Roundtable is scheduled for August 2-3, 2012, at the National Academies Keck Center in Washington, DC. For more information about the Roundtable, including information about upcoming meetings, please visit: <http://sites.nationalacademies.org/DEPS/ASEB/DEPS_061276>.

Roundtable member Dale Klapmeier (right) from Cirrus Aircraft providing input to the Roundtable's discussion.

Aeronautics Research and Technology Roundtable Members

John Tracy, Chair
The Boeing Company

Ella Atkins
University of Michigan

Interjit Chopra
University of Maryland

R. Scott Dann
General Atomics Aeronautics Systems

George Donohue
George Mason University

Alan Epstein
Pratt & Whitney

Catherine Ferrie
Bell Helicopter Textron

M.E. Rhett Flater
AHS International (retired)

Bruce Holmes
NextGen AeroSciences, LLC

Margaret Jenny
RTCA, Inc.

Ray Johnson
Lockheed Martin Corporation

Charles Keegan
Raytheon Technical Services Company

Dale Klapmeier
Cirrus Aircraft

Andrew Lacher
The MITRE Corporation

Robert Loewy (NAE)
Georgia Institute of Technology

Lourdes Maurice
FAA

Mark Miller
Sikorsky Aircraft Corporation

M. Granger Morgan (NAS)
Carnegie Mellon University

David Parekh
United Technologies Research Center

Steven Pennington
U.S. Air Force

Eli Reshotko (NAE)
Case Western Reserve (emeritus)

Thomas Romesser (NAE)
Northrop Grumman (retired)

Jeanne Rosario
General Electric Company

Jaiwon Shin
NASA

Edward Yarbrough
Honeywell International

Committee to Assess NASA's Flight Research Capabilities

Wesley L. Harris (Chair)
MIT

Mark Anderson
Boeing Research & Technology

Neil A. Armstrong
EDO Corporation

Edward J. Burnett
Lockheed Martin

Inderjit Chopra
University of Maryland

Richard S. Christiansen
Sierra Lobo, Inc.

Robert A. Cowart,
Gulfstream Aerospace Corp.

Timothy Lieuwen
Georgia Tech

Ronald F. Probstein
MIT

Eli Reshotko
Case Western Reserve University (emeritus)

Rogers E. Smith,
Independent Consultant

John Tylko
Aurora Flight Sciences

Randy Voland
ACENT Laboratories

Deborah DeMania Whitis
GE Aircraft Engines

New Report Assesses NASA's Flight Research Capabilities

The Committee to Assess NASA's Aeronautics Flight Research Capabilities delivered its report, *Recapturing NASA's Aeronautics Flight Research Capabilities*, to NASA in early March 2012, and the report was publicly released on March 15, 2012. The report's primary message is that NASA needs to resume flight research in order to restore balance to its aeronautics research program.

A copy of the flight research report can be purchased, or downloaded as a PDF document for free, from <http://www.nap.edu/catalog.php?record_id=13384>.

The report stresses the contributions of NASA's flight research programs to the demonstration and adoption of various aeronautics systems, including advanced flight control systems, de-icing devices, thrust-vectoring systems, wing fuselage drag reduction configurations, aircraft noise reduction, advanced transonic airfoil and winglet designs, and flight systems. The report describes three case studies to illustrate the current state of flight research at NASA: the Environmentally Responsible Aviation Program, supersonics, and hypersonics. The report contains several findings relative to making progress in flight research in these three areas. The report also discusses unmanned aircraft systems. Following the case studies and discussions, the report describes issues related to NASA's organization, collaboration, and communication and offers solutions.

The report contains five recommendations on how NASA can improve its flight research, including a recommendation that the agency initiate a series of programs with total budgets of $30 million-$50 million per vehicle over a 3-year period to demonstrate innovative aerospace technology in flight.

Recapturing NASA's Aeronautics Flight Research Capabilities concludes that the type and sophistication of flight research currently being conducted by NASA today is relatively low and that the agency's overall progress in aeronautics is severely constrained by its inability to actually advance its research projects to the flight research stage, a step that is vital to bridging the confidence gap. NASA has spent much effort protecting existing research projects conducted at low levels, but it has not been able to pursue most of these projects to flight research.

Committee Chair Wes Harris and members of the committee head to Capitol Hill to brief the report, March 2012.

Upcoming Projects

Human Spaceflight Study. A congressionally requested study to examine the value of human spaceflight has been discussed several times by the Board over the past year. Following an extended series of discussions with NASA, a statement of task was agreed upon earlier this year and recently approved by the NRC Governing Board. Funding for the actual study is not expected to arrive before May. However, NASA has made available some initiation funds which are currently being used to begin assembling nominations for the steering committee and panels that will conduct the study. The NRC's Committee on National Statistics will be partnering with the ASEB and SSB in overseeing this study. ***Suggestions for areas of membership, as well as names, can be sent to Sandra Graham at sgraham@nas.edu.*** Please provide as much information as possible about why you are nominating an individual. As the Board has discussed, this study addresses cultural and sociological issues, as well as technical and scientific questions, and the make-up of the committees and panels will be critical to its success.

Strategic Directions. The ASEB's parent division, the Division on Engineering and Physical Sciences, has been asked to conduct a comprehensive, agency-wide assessment of NASA's strategic direction. Staff from the ASEB and the SSB will be helping manage the study for the division. The NRC has begun forming a committee for this activity, and meetings will commence later this spring. A final report is expected in fall 2012.

This activity will be chaired by Dr. Albert Carnesdale. Dr. Carnesdale (NAE) is chancellor emeritus and professor at the University of California, Los Angeles (UCLA). He was chancellor of the university from 1997 through 2006 and now serves as professor of public policy and of mechanical and aerospace engineering. Prior to joining UCLA, he served at Harvard University for 23 years as the Lucius N. Littauer Professor of Public Policy and Administration, dean of the John F. Kennedy School of Government, and provost of the University. Dr. Carnesale is the author or co-author of six books and more than 100 articles on a wide range of subjects, including national security strategy, arms control, nuclear proliferation, the effects of technological change on foreign and defense policy, domestic and international energy issues, and higher education. Dr. Carnesale holds a B.M.E from the Cooper Union for the Advancement of Science and Art, an M.S. in mechanical engineering from Drexel University, and a Ph.D. in nuclear engineering from North Carolina State University.

A detailed description of work is below:

The National Research Council will appoint an ad hoc committee to assess whether the strategic direction of the National Aeronautics and Space Administration, as defined by the 2011 NASA strategic plan, remains viable and whether the agency's activities and organization efficiently and effectively support that direction in light of the potential for constrained budgets for the foreseeable future. In particular the committee will:

1. Consider the strategic direction of the agency as set forth most recently in 2011 NASA Strategic Plan and other relevant statements of space policy issued by the President of the United States.
2. Consider the goals for the agency set forth in the National Aeronautics and Space Act of 1958 (as amended) and the National Aeronautics and Space Administration Authorization Acts of 2005, 2008 and 2010.
3. Consider previous studies and reports relevant to this task.
4. Assess the relevance of NASA's strategic direction and goals to achieving national priorities.
5. Assess the viability of NASA's strategic direction and goals in the context of current budget expectations and stated programmatic priorities for the agency.
6. Discuss the appropriateness of the budgetary balance between NASA's various programs.
7. Examine NASA's organizational structure and identify changes that could improve the efficiency and effectiveness of the Agency's mission activities.
8. Recommend how NASA could establish and effectively communicate a common, unifying vision for NASA's strategic direction that encompasses NASA's varied missions.

Any recommendations made by the committee will be predicated on the assumption that NASA's out year budget profile will be constrained due to continuing deficit reduction.

Committee News

2012 Ohio Third Frontier Innovation Platform Program. Continuing the previous work of the National Academies for the State of Ohio, a committee was established to review grant proposal applications to the Innovation Platform Program (IPP) competition of the Ohio Third Frontier (OTF) Program for fiscal year 2012 to identify proposals that best meet the scientific, technical, and commercialization criteria of the award program. The IPP competition focuses on linking the development and innovation capabilities of an already-established innovation platform and all its resources at an Ohio college, university, or not-for-profit research institution to specific late-stage development and innovation needs of Ohio companies. This linkage must in turn lead to job creation and business opportunities in the state of Ohio through development and commercialization of new technologies, innovations, and products that will have beneficial long-term economic impacts for Ohio. The committee, chaired by T.S. Sudarshan, CEO of Materials Modification, Inc., will hold its first meeting in mid-April and represents a wide range of expertise and backgrounds across scientific, engineering, and biomedical fields. The committee expects to publicly release its report in June 2012.

Astrodynamics Standards. The NRC has formed a committee to assess the astrodynamics standards established by Air Force Space Command (AFSPC) and their effectiveness in meeting mission performance needs. The Joint Space Operations Center (JSpOC) uses astrodynamic algorithms to perform satellite orbit determination and prediction in order to maintain a catalog of over 20,000 objects, ranging from active satellites to tiny pieces of orbital debris. These standards were implemented to achieve interoperability between the JSpOC and the mission systems and to ensure mission performance. The committee has assessed current AFSPC astrodynamics standards, compared those to leading alternatives in the community, outlined options for using alternate standards, and examined issues related to cost and risk of different options. The study committee, a collaboration between the ASEB and the Board on Mathematical Sciences and their Applications, held its fourth and final meeting March 26-27, 2012, in Colorado Springs, CO, and is submitting its final report for review. The report will be delivered to the Air Force and made public in the summer.

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Members of the Astrodynamics committee deliberate at their fourth and final meeting, March 27, 2012, in Colorado Springs, CO.

Committee News, continued

(Cntinued from page 8)

Committee to Review and Assess a USAF Space Command Program to Develop a Reusable Booster System. Domestic launch capabilities are integral to ensuring that U.S. space assets are available and responsive to meet Air Force needs. Future launch requirements with necessary responsiveness, reliability, availability, efficiencies and affordability will likely need to transcend the current Evolved Expendable Launch Vehicle (EELV) construct. The Space and Missile Systems Center (SMC), in conjunction with the Air Force Research Laboratory (AFRL), has developed the concept of a Reusable Booster System (RBS) intended to significantly improve launch costs by reducing the amount of expendable hardware that must be produced, tested, and processed. A committee of 15 experts has been formed to examine the criteria and assumptions used in the formulation of current RBS plans, the modeling methodology used to frame the business case for an RBS capability, the technical maturity of key elements critical to RBS implementation, and the ability of current technology development plans to meet technical readiness milestones. In February, the first data-gathering meeting of the committee was held in Colorado Springs, home of the USAF Space Command. A second data-gathering meeting was held in March at the National Academies' Keck Center in Washington, DC, and a third meeting will be held there in May. The committee anticipates that its final report will be issued in September.

For more information about any of these committee activities, please visit the ASEB website at: <http://national-academies.org/aseb>.

Roadmap Report, continued

(continued from page 1)

Highest Priority Technologies

Technology Objective A Extend and sustain human activities beyond LEO	**Technology Objective B** Explore the evolution of the solar system and the potential for life elsewhere (in-situ measurements)	**Technology Objective C** Expand understanding of the Earth and the universe (remote measurements)
Radiation Mitigation for Human Spaceflight	**Guidance, Navigation, and Control**	**Optical Systems (Instruments and Sensors)**
Long-Duration Crew Health	**Solar Power Generation (Photovoltaic and Thermal)**	**High Contrast Imaging and Spectroscopy Technologies**
Environmental Control and Life Support System (ECLSS)	**Electric Propulsion**	**Detectors and Focal Planes**
Guidance, Navigation, and Control	**Fission Power Generation**	**Lightweight and Multifunctional Materials and Structures**
(Nuclear) Thermal Propulsion	**Entry, Descent, and Landing Thermal Protection Systems**	**Active Thermal Control of Cryogenic Systems**
Lightweight and Multifunctional Materials and Structures	**In-Situ Instruments and Sensors**	**Electric Propulsion**
Fission Power Generation	**Lightweight and Multifunctional Materials and Structures**	**Solar Power Generation (Photovoltaic and Thermal)**
EDL TPS	**Extreme Terrain Mobility**	

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Where's the report summary?

Looking for a more extended summary of one of our reports? On the report's page on the National Academies Press website (such as <http://www.nap.edu/catalog.php?record_id=12202>), scroll down a little bit to a section called "Free Resources." There, in a box titled "Download Free," you will see a link called "PDF Summary." Click the link to download the full summary in PDF format. Many reports also have a link here for a "Report in Brief", a one- or two-page summary of the report.

Where's the report?

Each of our reports is also available in its entirety in PDF format from the National Academies Press website. Each report highlighted in this newsletter has its corresponding NAP website listed (such as <http://www.nap.edu/catalog.php?record_id=12202>). On the report's page, click on the button that says "Download free PDF" and follow the instructions to download the full report.

You can browse or search the NAP website at <http://www.nap.edu> for other ASEB titles.

Roadmap Report, continued

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- Technology Objective C: Expand our understanding of Earth and the universe in which we live using remote measurements.

To ensure the validity of the study's results, the steering committee and study panels designed and executed a thorough deliberative process that began with the establishment of specific evaluation criteria for assessing each technology. The panels then used a quality function deployment (QFD) process to characterize and rank order each of the technologies under their purview. This led the panels to produce initial lists of top technical challenges and high-priority technologies for each roadmap. The steering committee then defined the three technology objectives, described above, to ensure balance across NASA's key mission areas. For each of these objectives, the steering committee then examined the panels' lists of top technical challenges and high-priority technologies to determine which ones were most important for NASA to begin during the next five years of the 20- to 30-year window of the roadmaps. During this final phase of the process of the process, the steering committee also considered affordability to ensure that identified NASA could afford to pursue the recommended set of highest priority technologies.

In addition to identifying the top technical challenges and highest priority technologies, the study made additional findings and recommendations related to maintaining and enhancing the effectiveness of NASA's investments in advanced space technology. These findings and recommendations address the following topics:

- Flight demonstration of Advanced Stirling Radioisotope Generators.
- Production of Plutonium-238.
- Flight testing and demonstration of cryogenic storage and handling technology.
- Use of disciplined system analysis for the ongoing management and decision support of the space technology portfolio.
- Managing the progression of technologies to higher technology readiness levels (TRLs) using a rigorous process to down select among competing technologies.
- Reestablishing a discipline-oriented technology base program that pursues both evolutionary and revolutionary advances.
- Cooperative development of new technologies with other organizations.
- Flight demonstrations and technology transition via collaboration between the Office of the Chief Technologist and NASA mission offices and outside partners.
- Importance of adequate research and testing facilities.
- Importance of program stability.
- Expanding industry access to NASA data.
- Collaborating with the U.S. commercial space industry in the development of precompetitive technologies of interest.
- Importance of crosscutting technologies, such as avionics and space weather beyond radiation effects.

Top Technical Challenges

Technology Objective A Extend and sustain human activities beyond LEO	**Technology Objective B** Explore the evolution of the solar system and the potential for life elsewhere (in-situ measurements)	**Technology Objective C** Expand understanding of the Earth and the universe (remote measurements)
Improved Access to Space	**Improved Access to Space**	**Improved Access to Space**
Space Radiation Health Effects	**Precision Landing**	**New Astronomical Telescopes**
Long Duration Health Effects	**Robotic Maneuvering**	**Lightweight Space Structures**
Long Duration ECLSS	**Life Detection**	**Increase Available Power**
Rapid Crew Transit	**High Power Electric Propulsion**	**Higher Data Rates**
Lightweight Space Structures	**Autonomous Rendezvous and Dock**	**High Power Electric Propulsion**
Increase Available Power	**Increase Available Power**	**Design Software**
Mass to Surface	**Mass to Surface**	**Structural Monitoring**
Precision Landing	**Lightweight Space Structures**	**Improved Flight Computers**
Autonomous Rendezvous and Dock	**Higher Data Rates**	**Cryogenic Storage and Transfer**

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Aeronautics and Space Engineering Board

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The ASEB's sister Board, the Space Studies Board (SSB), also publishes a newsletter; visit http://sites.nationalacademies.org/SSB/ssb_052298 to subscribe or to view past SSB newsletters. The ASEB's division, the Division on Engineering and Physical Sciences (DEPS), also publishes a newsletter; visit http://sites.nationalacademies.org/DEPS/DEPS_059299 to subscribe.

About the ASEB...

The Aeronautics and Space Engineering Board (ASEB) was established in 1967 "to focus talents and energies of the engineering community on significant aerospace policies and programs." In undertaking its responsibility, the ASEB oversees ad hoc committees that recommend priorities and procedures for achieving aerospace engineering objectives and offers a way to bring engineering and other related expertise to bear on aerospace issues of national importance.

The majority of ASEB studies originate with the National Aeronautics and Space Administration (NASA), particularly the Aeronautics Research Mission Directorate and the Human Exploration and Operations Mission Directorate. Some of these studies are requested by Congress in related legislation. ASEB also conducts proposal reviews for the State of Ohio's Third Millennium Program through the Ohio Department of Development and identifies experts to assist the Government Accountability Office in conducting its studies. The ASEB also has performed technical and policy studies for the Nuclear Regulatory Commission, the Defense Nuclear Agency, the Federal Aviation Administration, the National Science Foundation, the Defense Threat Reduction Agency, Air Force Space Command, the Air Force Office of Scientific Research, the National Oceanic and Atmospheric Administration, and others.