Distributed Storage-Generation Grid
Richard E. Smalley's Vision
For U.S. Energy Independence

Recommendations to the Technology Innovation Program
National Institute of Standards and Technology
U.S. Department of Commerce

Submitted by:
The Richard E. Smalley Institute for Nanoscale Science and Technology at Rice University

In partnership with:
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Introduction

Area of Critical National Need:

The country is in need of a new electrical grid that is predicated upon local storage of energy that would make it possible to get most of its electrical power from clean renewable sources, like wind and solar. This requires the ability to locally store enough energy, from a combination of centralized and distributed power generation facilities, that provides for sufficient uninterruptable power supply and consumption. In addition, the new grid must also be capable of efficiently transferring electricity thousands of miles, enabling the country to primarily transport energy as electrical power, and not as mass (fossil fuels.) The ultimate implementation of this vision, established by the late Nobel Prize Winner, Dr. Richard E. Smalley, has the very real potential of making our country truly energy independent, while hardening its energy infrastructure against both the threat of terrorist attack and massive power outages caused by natural disasters.

Transformational Results:

The sun is a nuclear reactor that has been going strong for billions of years. Without doing anything, we enjoy the effect of 165,000 terawatts of sunlight hitting the Earth every moment of every day. Although there are alternative solar technologies to consider, the obvious way to implement massive solar energy cheaply is with photovoltaics that are as cheap as paint to install, allowing for the creation of both localized-distributed as well as centralized production of solar energy. Ultimately, the use of novel advanced transmission lines could efficiently transfer enough electrical power from centralized solar farms capable of supplying the entire country's demand for energy. Furthermore, imagine that mid-century, nanotechnologies, new materials, and possible new physics required for the advancements of solar technology, will also enable the creation of local storage units for electrical energy that are about the size of a washing machine. The units would store 100 or more kilowatt-hours, which is enough to run a typical house for 24-48 hours, and provide a buffer to the grid's energy fluctuations. Real-time pricing for individual electrical power usage would give each customer the incentive to buy a unit that could absorb power during the evening, when energy is cheapest, for use during the day while selling excess stored power back to the grid during peak demand periods.

Societal Challenge:

For our economic prosperity, the United States of America must provide the technology and expertise that will generate enough clean, cheap, renewable energy for all the people on this planet to have an acceptable standard of living. To give the 10 billion people expected to be on Earth by 2050 the level of energy prosperity we in the developed world are used to, a couple of kilowatt-hours per person, we would need to generate 60 terawatts for the planet. That's the equivalent of 900 million barrels of oil per day! If we do not solve the global energy problem, our country's future is destined to include ongoing war, increased acts of terrorism, and possibly a permanent collapse of the Nation's economy.

Maps to Administration Guidance

Large National Problem – Warrants Government Attention – Not Being Addressed

There is ample evidence that both elected and agency officials have recognized the critical problems that the country faces as a result of an inadequate electrical grid. Moreover, in the time since Richard Smalley and his team developed the vision of the Distributed Storage-Generation Grid (the Store-Gen Grid), the world has begun to recognize that demand for energy has begun to outstrip our ability to add energy capacity – whether through conventional electricity or transportation fuel, both of which depend primarily on fossil fuel.

For example, more than once, President George W. Bush has stated our need to move on from our dependence on oil:

> Keeping America competitive requires affordable energy. And here we have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world. The best way to break this addiction is through technology. Since 2001, we have spent nearly $10 billion to develop cleaner, cheaper, and more reliable alternative energy sources -- and we are on the threshold of incredible advances.
>
> *President George W. Bush*
> *January 31, 2006*

President Bush's comments relate directly to the ***Store-Gen Grid*** because the latter ***promises to increase efficiencies, and will provide ways to integrate into the system any and all useful energy sources that we bring online to fill ever-growing demand.*** These sources will certainly continue to include oil and natural gas, plus clean coal, and will likely include thermal and photovoltaic solar power, wind power, advanced nuclear power, fuel cells and biomass technologies. Looking more specifically at the grid, the Department of Energy has for several years pointed urgently to our need to improve the electrical infrastructure. The following points out some of the reasoning for moving toward distributed generation, which in turn requires a better grid:

> Concerns about national security policies and the need to secure the electric system from threats of terrorism and extreme weather events are affecting the future of America's electric system. A small number of very large generating plants are inherently more vulnerable than a large number of smaller, widely distributed plants.[1]

The President's Council of Advisors on Science and Technology approaches this concept from the point of view of electricity demand:

> The Nation must proceed with the development of the 21st Century electricity grid. As the Nation's electrical transmission and distribution system is reinvented

[1] "Grid 2030" - A National Vision for Electricity's Second 100 Years. Based on the Results of the National Electric System Vision Meeting, Washington, DC, April 2-3, 2003. Published July 2003 by the United States Department of Energy, Office of Electric Transmission and Distribution. p 12.

> and expanded in response to changing needs and growing demand, an opportunity exists to incorporate highly efficient superconducting technology into the generation, transmission, and end-use phases of the electrical system.[2]

While Rick Smalley's Store-Gen Grid concept recommends cabling based on carbon nanotubes, rather than low-temperature superconductors, the point is the same: we need better infrastructure, and it has to come from new technology. Yet with all of this high-level attention to energy and the grid, funding for scientific investigation related to the grid has been slender or nonexistent. For example, in 2005, just when Rice University was starting to accelerate its research into the Armchair Quantum Wire (AQW, which promises to provide a high-strength, high-conductivity material with quantum improvements over conventional technology), the funding agency canceled the multi-million-dollar commitment to that project. (Please see cancellation documentation, included in Appendix A.)

Opportunity to Excel

Within the environment of concern there is an emerging opportunity:

> There are several promising technologies on the horizon that could help modernize and expand the Nation's electric delivery system, relieve transmission congestion, and address other problems in system planning and operations. These include advanced conductors made from new composite materials and high temperature superconducting materials, advanced electric storage systems such as flow batteries or flywheels, distributed intelligence and smart controls, power electronics devices for AC-DC conversion and other purposes, and distributed energy resources including on-site generation and demand management.[3]

The Store-Gen Grid concept, illustrated in Appendix B, maps directly to the PCAST recommendations:

> Industry will be investing billions of dollars over the next several decades to replace electric power equipment. The economic life of this new equipment will last 40 years or more, so this turnover of the nation's capital stock of electric power assets needs to include the latest technologies to ensure clean, efficient, reliable, secure, and affordable electricity for generations to come. An expanded research, development, and deployment effort is paramount.[4]

And:

> It is becoming increasingly difficult to site new conventional overhead transmission lines, particularly in urban and suburban areas experiencing the greatest load growth. Resolving this siting dilemma, by a) deploying power electronic solutions that allow more power flow through existing transmission

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[2] "Report on Energy Efficiency: Findings and Recommendations, from the President's Council of Advisors on Science and Technology," February 18, 2003 (PCAST 2003), p 7.

[3] "Grid 2030," p iv.

[4] Ibid, p v.

assets and b) developing new low impact grid solutions that are respectful of land use concerns, is crucial to meeting the nation's electricity needs.[5]

Again, the Store-Gen Grid shows the way toward solving these clearly recognized problems. Armchair Quantum Wire-based cabling, if successful, will overwhelmingly address the transmission issue, and an intelligent and robust grid will enable ever more green and friendly generation technologies.

Need for Public Funding

It has been widely noted that the combined Research and Development budgets for the entire utility sector of the United States sum up to a lower number than R&D for the pet food industry. More soberly, "Cost cutting measures [by utility companies] have included steep reductions in research and development expenditures."[6] Clearly, the country cannot afford to wait for private industry – whether regulated or otherwise – to lead the way in investing in new technologies to make the paradigm-shifting solutions that we need. Alarmingly, in a time when the country needs to invest more in research for improving our approach to energy, our government investments in that area have declined.[7]

Some of the attributes that "Grid 2030" calls for:

> Desirable properties of new material for electricity conductors include greater current-carrying capacity, lower electrical resistance, lighter weight, greater controllability, and lower cost.
>
> [National Electricity Backbone needs to provide customers with] "continental" access to electricity supplies, no matter where they or their suppliers are located.
>
> Expanded use of advanced electricity storage devices address supply-demand imbalances caused by weather conditions and other factors.
>
> A modernized national electrical grid will facilitate the delivery of electricity from renewable technologies such as wind, hydro, and geothermal that have to be located where the resources are located, which is often remote from load centers.[8]

These assertions all support the recommendations of the Store-Gen Grid, and along with it the need for government funding to make it happen.

Moreover, the country truly needs a thorough energy revolution in order to navigate a future that includes supply/demand disruptions and the emergence of the vast populations of developing world into the middle class. As we well know, energy is not simply a national issue.

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[5] Ibid.

[6] Ibid, p 13.

[7] "...while the challenges looming in the energy future of the United States and the world have been growing in recent years – or at least growing more apparent – expenditures on R&D have been declining. In the United States, this has been the case in both the public and private sectors. [The same is true] in most other industrialized countries, with the conspicuous exception of Japan." Report to the President on Federal Energy Research and Development for the Challenges of the Twenty-First Century – 2003, p 11.

[8] "Grid 2030," pp 14, 19, 20 & 21

> …by far the largest part of the future growth of world energy use is expected to take place in the currently less developed countries of Asia, Africa, and Latin America. Today, with nearly 80 percent of the world's population, these countries still account for only a third of the energy use. But if recent trends continue (the "business as usual" energy future), they will pass the industrialized countries in total energy use (and in carbon dioxide emissions) between 2020 and 2030, and their growth will be the primary driver of a doubling in global energy use between 1995 and 2030 and a quadrupling between 1995 and 2100.[9]

The same Federal Energy Research and Development report cited above lists ten goals of energy-technology improvements, four of which are:

- lower the monetary costs of supplying energy;
- lower its effective costs still further by increasing the efficiency of its end uses;
- increase the productivity of U.S. manufacturing;
- increase U.S. exports of high-technology energy-supply and energy-end-use products and know-how

The Store-Gen Grid and improved transmission technologies address ALL of these points.

Justification for Government Attention

Magnitude and Nature of Problem

Virtually all productive human activities depend on utilization of energy in one form or another, and the more advanced the society, the more energy needed and the higher the productivity.

According to estimates from the International Energy Agency, global energy use totaled 14 Terawatts in 2003, and using modest growth modeling will increase to 30 to 60 Terawatts in 2050. With demand for oil and gas already outstripping our ability to pump it out of the ground, this means that we need find ways to produce – and save – tens of Terawatts of energy, and we need to do it now.

Reduced to its essentials, any power system consists of three main parts: Generation, Transmission and Storage. As liquid energy supplies diminish, we will have to move energy around more and more as electrons, instead of mass. This will put even more pressure on the grid. The state of our electrical energy distribution infrastructure is already critical, as witnessed by significant power outages from Texas through Ohio due to hurricanes this fall.

The current state of our electrical energy distribution infrastructure is exceedingly poor. Massive electrical blackouts in the US in 1965, 1977, 1996 and 2003 have highlighted the existence of the problem. In response to these spectacular failures, agencies ranging from the North American Electric Reliability Council to the Department of Energy have made clear calls for revitalization of the national power grid and for an increase in use of

[9] Report to the President on Federal Energy Research and Development for the Challenges of the Twenty-First Century – 2003, p 8 of Executive Summary

distributed power generation. During the last forty years, maintenance and development of transmission facilities has lagged significantly behind the need for electrical power, and actual annual investment in the distribution infrastructure has been steadily declining.[10]

> There is growing evidence that the U.S. transmission system is in urgent need of modernization. The system has become congested because growth in electricity demand and investment in new generation facilities have not been matched by investment in new transmission facilities. Transmission problems have been compounded by the incomplete transition to fair and efficient competitive wholesale electricity markets. Because the existing transmission system was not designed to meet present demand, daily transmission constraints or "bottlenecks" increase electricity costs to consumers and increase the risk of blackouts.[11]

Societal Challenges Unmet

Nobel Laureate Richard Smalley addressed the question of what are the top concerns for humanity globally in his presentation to the Materials research Society in December 2004, as published in the MRS Bulletin Volume 30, June 2005. Listing the top ten societal challenges in priority order, it is clear that energy leads the list, and is critical for the solution of most or all of the other challenges, ranging from water to food and environment, poverty and terrorism and war, disease and education, democracy and population growth.

Without belaboring his arguments, it is clear that with adequate sources of ***CLEAN, WIDESPREAD AVAILABLE and INEXPENSIVE*** energy, we may be able to solve the most pressing problems of humanity. Conversely, without such energy, we will be unlikely to solve these problems.[12] For the far term (50 years) solar power will be the ultimate solution (discounting fusion, which has failed to show real promise as a viable alternative) and we will need a way to transmit massive amounts of electrical energy around the earth, and as way to store it. A distributed energy infrastructure will enable all persons on earth to participate in the new energy system for the world.

We will not, however, meet these challenges without conducting more basic research into the solutions.

Evidence of Commitment

Who are the stakeholders in a Store-Gen Grid concept? The challenge of rejuvenating the electrical energy distribution infrastructure will necessarily bring together participants from many arenas.

- The utility providers will be seeking private investment, but this investment will come over many years.
- The likely proposers for the near-term investment in technologies needed now include small technology-development corporations, and technology-development

[10] Franklin, Joshua J, "Upgrading the national power grid: electric companies need an economic incentive to invest in new technology," *Rutgers Computer & Technology Law Journal - September 22, 2004*
[11] Ibid.
[12] MRS Bulletin, Volume 30, June 2005

groups in larger corporations, academic research labs, privately-operated research and development companies, and government labs.

Which of these stakeholders needs funding critically? These groups all will compete for the scarce funding made available because funding for development of these technologies is very poorly supported at this time. The lack of support is particularly apparent now, as government and private industries cut back their investment in response to the present economic difficulties in the US and throughout the world. In spite of the global economic difficulties, it is clear that one foundational enabler of future productivity in the US is revitalization of our electrical energy distribution infrastructure; and it is equally clear that a bold initiative from NIST can have tremendous impact in this critical area.

Essentials for TIP Funding

Stimulates National Scientific Frontiers

Fundamental advances in power technologies have been made during the last decade. Some of these advances have been demonstrated in practical energy-related products, while some require considerable basic research for their implementation. Practically: Clean coal technologies have been demonstrated and multiple approaches for creating biofuels are entering the production phase. Plug-in hybrid cars will be coming out for the consumer within a few years, if not sooner.

In the basic research arena, but with clear practical prospects, there has literally been a revolution in carbon nanotube technology relating to electrical power. Carbon nanotubes have been shown as effective elements of new photovoltaic systems where they can provide an excellent transparent electrode for polymer photovoltaic cells. Other demonstrated technologies involving carbon nanotubes include one in which fuel cell electrodes have been improved by the incorporation of carbon nanotubes such that they provide higher power output and promise a substantially longer fuel cell life. Other technologies apply carbon nanotubes to lithium-ion batteries and increase the battery energy storage capacities and extend battery life. Within the last two years, new varieties of very-high-energy-density supercapacitors have been developed based on carbon nanotube electrodes. Supercapacitors are promising especially for high-value applications, and although they are unlikely to emerge as a solution for widespread energy storage in, for example, large industrial or household-size applications, they again show the implications of carbon nanotube technology for electrical energy solutions in general.

A potentially revolutionary development is the carbon-nanotube quantum wire. Originally proposed by Nobel-prizewinner Prof. Rick Smalley, the quantum wire consists of identical carbon nanotubes spun into a long fiber. Dr. Smalley's predictions are that this structure will conduct electricity substantially better, and weigh much less than present-day transmission wire materials. If successful in production and application, ***this material could allow a massive increase in the capacity and effectiveness of the national grid simply by replacing the conducting wires***. While this development is clearly at the research stage, it is the kind of breakthrough technology that could have a profound effect in the rejuvenation of the national electrical grid.

We can now see some of the outlines of the elements needed for a revitalization of our national electrical energy distribution and utilization, but a huge national effort is needed to sew these elements together into a truly effective infrastructure.

Meets Unmet Need

Nationally, we really have no choice about bringing our electrical energy transmission and distribution infrastructure up to par. It is abundantly clear that during the next century we will become ever more dependent upon the grid. The infrastructure as we know it was built during the last fifty years, and it will almost certainly require a comparable time to reconstruct it. Perhaps because of the long-term nature of this project, we have nationally lost sight of its urgency – even though the symptoms mount with each successive year. Any delay in starting serious work on this problem will further decrease the productivity and economic competitiveness of the country, and will increase the likelihood of broader, more crippling power outages in the future. ***Fortunately, however, we now have the opportunity to invest in new enabling technologies that will contribute significantly to meeting the challenges we face.***

Delivers Potential Transformation

As mentioned earlier, a power system consists of three main parts: Generation, Transmission and Storage. If we reduce energy to its smallest fungible element – the electron – then we can find ways to establish and tap into a global pool of electrons in as economic a way as possible. This approach would yield efficiencies – market and technical – that would drive down the cost and drive up the conservation of energy in ways that are simply unavailable to us today, because we are still primarily moving energy around in bulk, as coal, oil or gas. ***The Store-Gen Grid also gives us major flexibility in bringing new energy sources online as quickly as possible, whenever and wherever they make sense.***

This approach is not, however, available to us at all until we can move electrons around, across vast distances, with minimal power loss or disruption. This is why it is important to fund research into improvements in the actual transmission material.

Looking at a near-term example of the problem: in wind power, we have access to a major source of energy, but are currently hampered by a lack of infrastructure to move electricity from the wind farm to the city. The Wind Corridor, which stretches through the middle of the continent from Canada through Texas, has enough harnessable energy to make a significant dent in the country's power needs, but even moving the electricity from the panhandle of Texas to Dallas will require a multi-billion-dollar investment from both private and public sources, and will be feasible only because the distance to be spanned is just a few hundred miles. To make a real difference, we need to supply power from Midwest wind farms, for example, to the power-hungry Northeast. However, using conventional technology, at an average power loss of 8% for every 200 miles of transmission, we would lose about 44% of the generated electricity to move it from Des Moines, Iowa to New York City.

The most promising alternative energy source of all – Solar – is making substantial progress in efficiency, driving upwards from the typical 8-10% photovoltaic conversion from sunlight to electricity, which was normal for the lower-cost versions of the late

1990s, toward 30 and 40% for technology that is now under development. Solar thermal is also an emerging technology that is in use now in Spain and elsewhere.

As mentioned earlier, the technologies for storing energy are also making substantial progress, so **the remaining weak link is transmission.**

Recent DOE investments in research show evidence that the agency, on one hand, is working toward an understanding of distributed power systems, but on the other hand, is not seeing the need for improvements in the grid wiring itself. For example, of the $50 million budgeted for FY 2008-2012 to research ways to improve the grid and reduce peak-period demand, NONE of the named projects mentions efforts to improve cabling.[13] While the projects launched in this funding round are important, none goes to the heart of the most pressing need in US energy infrastructure: the actual transmission and distribution cable.

The store-gen grid, enabled by improved transmission, would be transformative for the US in other ways that are both familiar and critical:

- Infrastructure robustness
- Economic development
    - High-wage jobs
    - Improved balance of payments
    - Sale of technology
- Energy independence
    - Move away from being a net importer of energy.

In short, we propose research into areas that play to the country's strengths in science and innovation, yet push the boundaries of our knowledge and improve our opportunities to solve the problems that face the world.

[13] DOE Selects Projects for up to $50 Million of Federal Funding to Modernize the Nation's Electricity Grid, from DOE Website, April 21, 2008

APPENDIX A:

Documents showing the cancellation of funding through NASA for AQW research

OMB Approval No. 2700-0042

AMENDMENT OF SOLICITATION/ MODIFICATION OF CONTRACT	1. CONTRACT ID CODE	PAGE OF PAGES
		1 | 1

2. AMENDMENT/MODIFICATION NO.	3. EFFECTIVE DATE	4. REQUISITION/PURCHASE REQ. NO.	5. PROJECT NO. *(If applicable)*
Mod 4	See Block 16C	N/A	N/A

6. ISSUED BY CODE	7. ADMINISTERED BY *(If other than Item 6)* CODE
NASA LYNDON B. JOHNSON SPACE CENTER Attn: Julie Karr/BH2 2101 NASA Parkway Houston, TX 77058	See Block 6

8. NAME AND ADDRESS OF CONTRACTOR *(No., street, county, State, and ZIP Code)*
Rice University
Attn : Nancy Nisbett
6100 Main Street – MS16
Houston, TX 77005-1892

CODE		FACILITY CODE
(x)	9A. AMENDMENT OF SOLICITATION NO.	9B. DATED *(SEE ITEM 11)*
X	10A. MODIFICATION OF CONTRACT/ORDER NO. NNJ05HB73C	10B. DATED *(SEE ITEM 13)* 4/7/05

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.
Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended, by one of the following methods:

(a) By completing Items 8 and 15, and returning ☐ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided each telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPRIATION DATA *(If required)*

13. THIS ITEM APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS, IT MODIFIES THE CONTRACT/ORDER NO. AS DESCRIBED IN ITEM 14.(x)

(x)	
	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: (Specify authority) THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NO. IN ITEM 10A.
	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES (such as changes in paying office, appropriation date, etc.) SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
X	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF: Mutual Agreement of the Parties
	d. OTHER *(Specify type of modification and authority)*

E. IMPORTANT: Contractor ☐ is not, ☒ is required to sign this document and return 3 copies to the issuing office.

14. description of amendment/modification *(Organized by UCF section headings, including solicitation/contract subject matter where feasible.)*

See Page 2.

Except as provided herein, all terms and conditions of the document referenced in Item 9A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER *(Type or print)*		16A. NAME AND TITLE OF CONTRACTING OFFICER *(Type or print)*	
Nancy L. Nisbett, Director, OSR		Robert Kolb, Contracting Officer	
15B. CONTRACTOR/OFFEROR [signature] *(Signature of person authorized to sign)*	15C. DATE SIGNED 11/7/05	16B. UNITED STATES OF AMERICA BY *(Signature of Contracting Officer)*	16C. DATE SIGNED

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National Aeronautics and
Space Administration
Headquarters
Washington, DC 20546-0001

October 27, 2005

Reply to Attn of: Exploration Systems Mission Directorate

TO: Johnson Space Center
Attn: BA/Debra L. Johnson, Procurement Officer

FROM: Associate Administrator for Exploration Systems Mission Directorate

SUBJECT: Cancellation of Selected BAA Contracts

At the request of the Administrator, the Exploration Systems Architecture Study (ESAS) team has recently developed a new plan for lunar exploration, and identified technology investment priorities to support the mission architecture.

The highest priority ESAS recommendations are near-term technology investments that will support accelerated development of the Crew Exploration Vehicle, the Robotic Lunar Exploration Program, and human sortie missions to the moon during the next decade. The ESAS team assessed current technology development projects in the Exploration Systems Research and Technology (ESR&T) program against these new priorities. As a result, some of the extramural contracts awarded in FY05 under the Human and Robotic Technology Broad Agency Announcement (BAA) must now be cancelled because they are no longer aligned with the Exploration Systems Mission Directorate priorities as defined by the ESAS.

Effective October 31, 2005, selected BAA contracts managed by your Center are to be cancelled. These contracts are listed in the attached table. Please notify the contractors of the pending cancellations as soon as possible.

To minimize costs, the contracts will be reduced in scope to eliminate all remaining work subsequent to October 31, 2005. If the contracts have any uncosted carryover funding from FY05, this should be used first to cover closeout costs. Contracts without sufficient carryover funding may be provided up to two months of FY06 funding to bring all work to an orderly close no later than November 30, 2005. During November, the contractors will prepare a final report that summarizes the work completed. The final report will be a required deliverable for all cancelled contracts.

We would like you to prepare an estimate of the costs for each contract to assist us in budget planning for FY06. This information should be submitted to Rhett Herrera, ESR&T Procurement Lead, by November 18, 2005.

Scott J. Horowitz

Attachment

cc: JSC/Gen. Howell

Selected BAA Contracts Managed by Johnson Space Center to be Cancelled by October 31, 2005

Control Number	Project Title	Primary Contractor	Contract Number
1106	Intelligent, On-Board Space Operation to Enable Lunar Access	The Charles Stark Draper Laboratory	NNJ05HB72C
2758	Quantum Conductors for Power and Propulsion	Rice University	NNJ04HB73C
3659	Magnetic Nozzle and Detachment Efficiency of the Plasma Plume	University of Texas, Austin	NNJ05HB77C
3905	Microchannel In Situ Propellant Production System	Battelle Memorial Institute	NNJ05HB58C

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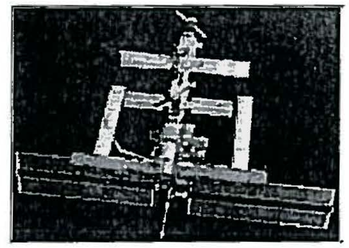
NASA tightens its belt, again

Projects face the chop in quest to put people back on the Moon.

Mark Peplow

NASA administrator Mike Griffin has confirmed speculation that even more of its science projects would be cut or delayed in an attempt to keep President Bush's 'vision for space' alive.



Some projects will be discontinued to help keep the International Space Station construction on track.

© *ISS*

On 3 November, Griffin told a US House Committee that NASA is US$3-5 billion short on funds to finish the space shuttle programme through to its retirement in 2010. Such shortfalls mean NASA has had to get its priorities in order and make some serious cuts to close part of this funding gap. To that end, Griffin unveiled a series of belt-tightening measures that will see key research programmes in life science and nuclear energy "discontinued, de-scoped or delayed".

The bad news isn't exactly a surprise. Griffin's testimony, given in his second appearance before the committee in four months, follows much speculation about how NASA would stretch its budget to cover the retirement of the shuttle, completion of the International Space Station (ISS), and its new vision to return astronauts to the Moon.

There have been a series of cut-backs in NASA projects over the past few years. Two planet-hunting projects, for example, were in May delayed until unspecified dates, and it was expected that many more missions would follow.

Key research programmes in life science and nuclear energy will be 'discontinued, de-scoped or delayed'.

"Focus is shifting from advancing technologies for long-term requirements, to directed research and maturing technologies for near-term use," Griffin told the panel.

This largely means funnelling money away from research programmes that are not immediately relevant to the three targets of space shuttle, ISS and Moon. The savings will help to accelerate development of the new Crew Exploration Vehicle (CEV), destined to replace the space shuttle as NASA's astronaut vehicle.

"There is simply not enough money in NASA's budget to carry out all the tasks it is undertaking and maintain the current schedule," said House Science Committee chairman Sherwood Boehlert (Rep, New York). "NASA has gotten in trouble repeatedly in the past by making promises that are beyond its financial means to fulfil," he added.

First things first

Griffin says that NASA's life-science research will focus on helping astronauts to make lunar sorties or safe trips in the CEV, whereas plans to develop better radiation shielding or life support systems for lengthy missions to Mars are on hold for now.

Technology research is also seeing a shift in priorities. For example, developing the methane and liquid-oxygen engines that the CEV needs to access the lunar surface must take priority over projects to investigate large-scale solar power or intelligent robotics, Griffin says.

The Prometheus project, which aims to use nuclear power in space, has also been cut back. The Jupiter Icy Moons Orbiter (JIMO) mission was once set to have nuclear-powered engines, but plans for that craft have been on ice since earlier this year. Griffin says that the other major use for nuclear power, to support long-duration stays on the Moon, will not be needed until after 2018. Consequently, most of the Prometheus' budget will now be spent on paying off the costs of cancelled contracts.

Happy birthday

Griffin confirmed that the construction of the ISS, which celebrated its fifth birthday this week, will be scaled down so that it can be completed before the shuttle retires. Plans for a Centrifuge Accommodation Module, which would carry a

NASA Internal Memo: NASA Realigns Research and Technology to Accelerate CEV/CLV

- 0

STATUS REPORT
Date Released: Friday, October 28, 2005
Source: NASA Office of Exploration Systems - Comments

From: Forehand, Lon (HQ-NC010)
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Sent: Friday, October 28, 2005 4:44 PM
To: Forehand, Lon (HQ-NC010)
Subject: NASA Realigns Research and Technology to Accelerate CEV/CLV

NASA has completed the Exploration Systems Architecture Study (ESAS), which outlines NASA's approach to implementing the Vision for Space Exploration. The Vision calls for the Agency to return the Space Shuttle to flight, complete the International Space Station, return to the Moon, and move on to the exploration of Mars and beyond. Based on ESAS recommendations, NASA has now laid out a detailed plan to support sustained human and robotic lunar exploration operations, for missions to the International Space Station, Moon, and Mars, and identify key technologies required to enable this exploration architecture. See the attached point paper for more details.

CEV and CLV development requirements now directly drive the content of ESMD's R&T components. This includes Exploration Systems Research and Technology (ESR&T), Human System Research and Technology (HSR&T), and Prometheus. Focus is shifted from advancing technologies for long-term requirements to directed research and maturing technologies for near-term use. As a result of these R&T requirements, ESMD is undertaking transitional activities within the ESR&T and HSR&T programs to suspend expenditures on specific R&T tasks that will not be continued in FY 2006. FY 2006 funding made available as a result of this transition will be redirected to Project Constellation to enable timely development of the CEV and CLV. Attached is Enclosure 2 which provides a detailed listing of the HSR&T and ESR&T reductions.

Also as part of the implementation of the ESAS recommendations, ESMD is reducing the size of the Exploration Systems organization at NASA Headquarters, designating Exploration program and project offices at NASA Centers, maximizing the use of uncovered capacity at NASA Centers, and realigning activities to other Mission Directorates, as necessary. NASA requires healthy Centers that fully utilize their unique strengths, and that work together to turn the Vision for Space Exploration into reality. Attached is Enclosure 1 which provides task distribution charts that outline the new roles and responsibilities for each NASA Center.

Let me know if you have questions.

Lon

Realignment of Research & Technology Funding to Accelerate Development of Crew Exploration Vehicle (CEV) and Crew Launch Vehicle (CLV) October 2005

NASA has completed the Exploration Systems Architecture Study (ESAS), which outlines NASA's approach to implementing the Vision for Space Exploration. The Vision calls for the Agency to return the Space Shuttle to flight, complete the International Space Station, return to the Moon, and move on to the exploration of Mars and beyond. Based on ESAS recommendations, NASA has now laid out a detailed plan to support sustained human and robotic lunar exploration operations, for missions to the International Space Station, Moon, and Mars, and identify key technologies required to enable this exploration architecture. This plan is a safe and sustainable approach that seeks

Funding for technologies applicable to lunar surface systems, such as in situ resource utilization (ISRU), are deferred and phased in only during the out years. Discontinued, descoped or delayed technology projects include nanomaterials, inflatable structures, large-scale solar power, intelligent robotic systems, in space assembly, Mars mission specific technologies, and electric propulsion. Transitional action is being taken now to discontinue plans for 80 tasks and activities, previously planned at $206 million in FY 2006, which do not directly support ESAS architecture or schedule requirements. These actions will yield $174 million in FY 2006 that will be applied towards accelerated development of CEV and CLV.

Realignment of ESR&T tasks is necessary not only to enable timely CEV development, but also to address the technology development priorities for lunar exploration. New technology development activities will be initiated beginning in FY 2006 and will be performed by NASA Centers. Major new work in ESR&T beginning in FY 2006 includes development of variable thrust rocket engines that use methane and liquid oxygen propellants, thermal protection system materials, and an auxiliary power system for the CLV.

Prometheus Nuclear Systems and Technology

Prior to the completion of the ESAS study, NASA was planning to restructure the Prometheus Nuclear Systems and Technology (PNS&T) program to prioritize NASA's nuclear technology development efforts to provide power on the surface of the Moon for a lunar outpost. ESAS results indicate that, given resource constraints, surface nuclear power systems to support potential long-duration stays on the Moon will not be required until after 2018. Nuclear propulsion will not be required until planning for Mars missions begins in earnest. The result of the findings is a total reformulation in the nuclear program, deferring all work until it is needed, yielding $76 million in FY 2006 to accelerate development of CEV and CLV.

Funding at these lower levels also assumed that remaining JIMO project activity was concluded at the Phase A Project Mission Systems Review milestone and that support for Prometheus by the DOE's Office of Naval Reactors will not continue. NASA has contacted the Office of Naval Reactors to initiate planning for termination actions on activities covered by the Memorandum of Understanding between NASA and DOE (National Nuclear Security Administration-Naval Reactors) regarding Civilian Space Nuclear Reactors. The bulk of the remaining FY 2005 and projected FY 2006 funds for this activity will be spent on termination costs.

NASA will continue a low level of funding of approximately $10 million a year for key, high-priority, nuclear system R&T issues, with longer-term plans to increase funding in the future, as the need for long duration lunar and Mars applications approaches.

Enclosure 1: NASA Center Roles and Responsibilities

ARC Task Distribution

Robotic Lunar Exploration Program (RLEP)

- Program Management
- Oversight of RLEP robotic missions (projects)

Crew Exploration Vehicle (CEV)

- Thermal Protection System Technology Development
- Integrated Systems Health Monitoring (ISHM) Oversight/Requirements Development
- Aero/Aero-Thermal database development team
- Analysis and Support

Crew Launch Vehicle (CLV)

- Expertise in Integrated Systems Health Monitoring (ISHM) including design and development phase health monitoring requirements analysis, CLV element fault detection algorithms development, and DDT&E and V&V tools development
- Support reliability assessment with Monte Carlo simulations
- Ascent Abort CFD Blast Analysis

Launch/Mission Systems

- Support DDT&E of multi-Center Command &Control systems, human-machine interaction requirements, mission control software development, project planning and management software systems,and documentation systems

Technology Development

- Support to various projects

Human Research

- Support to various projects

DFRC Task Distribution

Crew Exploration Vehicle (CEV)

- Abort testing
- Flight Test Support
- Independent Analysis

Launch/Mission Systems

(HLLV), Launch Systems, Mission Systems, Exploration Communication and Navigation Systems, and Extra Vehicular Activity (EVA) Projects

Crew Exploration Vehicle (CEV)

- Project Management
- Aero/Aero Thermal Database
- Low Impact Docking System (LIDS) Development
- GN&C joint development team
- Parachute Development
- Flight Test Execution
- Landing Systems
- Support to Lox/Methane Adv. Development Team
- Support to TPS Adv. Development Team
- Subsystems Management
- Analysis and Support

Mission Systems

- Project Management
- Development of capabilities and planning for mission operations, crew training, and the Mission Control Center for ESMD human space flight missions. Will be coordinated closely with SOMD as they will be responsible for operation of these vehicles.

JSC Task Distribution (cont)

Human Research

- Program Management
- Development of capabilities to maintain crew health and performance associated with exploration missions

EVA

- Project Management
- New Extravehicular Mobility Units (EMU) and related systems development required for the ESMD Extra Vehicular Activity (EVA)

Commercial Crew/Cargo

- Program Management
- New cargo and crew transport capabilities procurement and management for International Space Station (ISS) and human exploration needs
- Develop new ways of doing business with the emerging commercial space sector

Crew Launch Vehicle (CLV)

- Flight operations support to CLV including lead of First Stage Recovery System modification activities, Upper Stage RCS development and certification testing, and Abort Certification for all phases of CLV flight.
- Support Separation Certification for all phases of CLV flight, CLV reliability and safety assessments including launch site function, CLV Mission Operations Planning to the Operations Integration organization, and Avionics Simulation development

Technology Development

- Support to various projects

KSC Task Distribution

Launch Systems

- Project Management
- Ground systems required for processing and launching Constellation's space vehicles, including ground support equipment, Launch Control Center,and facility design and development. Will be coordinated closely with SOMD as they will be responsible for operation of these vehicles.
- Lead DDT&E and testing of ground processing, launch and recovery systems
- Launch and landing operations planning, C&C systems, common avionics, mechanisms and advanced propulsion systems across elements; test operations execution, ground and launch control software development and range safety integration

Crew Exploration Vehicle (CEV)

- Ground Operations and launch processing support, Prime Contractor Insight, Independent Analysis

Crew Launch Vehicle (CLV)

- Ground operations support to the CLV including leading GSE development and support facility modification activities and ensuring consideration of ground operations requirements during the design, development and test of all elements
- Avionics Simulations Support.

Technology Development

- Support DDT&E of propellant test and delivery systems, ground engine checkout facility simulation and analysis, engine and launch facility planning and development

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Enclosure 2: Realignment of Research & Technology Funding to Accelerate Development of Crew Exploration Vehicle (CEV) and Crew Launch Vehicle (CLV) October 2005

Summary

	FY 2006 Changes ($Millions)
Net Reduction to ESRT Available for Constellation Systems	-174
Net ESRT Content Reduction	-206
Total Value of Contracts and Projects Cancelled (FY 06)*	-265
Programmatic Adjustments	59
Termination Costs	32
*Note of explanation: In FY06, the total value of the BAA contracts and intramural projects that will be cancelled is $265M, as is shown as the sum of the totals of the two worksheets. The $206M in the Op Plan is a net result which includes other ESAS related programmatic adjustments that were subtracted from the $265M in savings from the cancelled projects.	

ESRT Broad Agency Announcement Projects Recommended for Terminiation: 51 Projects

ESRT Project Title	FY 2006 Changes ($Millions)
Automated Technology Assessment & Intelligence	-1.8
Thermoelectric Nanowire Composites for Energy Efficient Refrigeration and Power Generation in Space Applications	-1.3
A Model of Options and Costs for Reliable Autonomy	-1.2
Autonomous Walking Inspection and Maintenance Robot	-5.1
Modular, Multifunctional, Reconfigurable SuperBot	-6.3
Integrated System Health Management for Intelligent Modular Systems	-8.2
Wide Area Prospecting Using Supervised Autonomous Robot	-3.3
Team-Centered Virtual Interactive Presence for Adaptive Autonomy	-2.2
End-to-End Mission Modeling and Simulation Environment	-3.2
Intelligent Self-Situational Awareness for Exploration	-1.9
Dependable, Real-Time and Embedded Space Software	-3.0
Verification and Validation for Autonomous Systems	-2.9
Coordinated Multisource Maintenance on Demand	-3.3
Model-Centric Safety Critical JAVA for Exploration	-3.1
Thermal Protection System & Heat Resistant Structures	-9.3
Hydrogen Peroxide Based High Density Regenerative Fuel Cells	-1.4
Space Communications Testbed	-6.1
Low Cost Electrically Scanning Array (LCESA)	-3.2
Small Aperture Multiband Microwave Array Receiver	-2.7
Reconfigurable Intelligent Internet Protocols for Space Communication Networks	-1.0
600-Kw High Thrust Hall Thruster System	-6.6
Solar Electric Propulsion Direct Drive Demonstrator	-3.5
High Voltage/Temperature Electronics for Space Exploration	-3.1
Ultra-High Specific Power Density Solar Blanket	-2.2
MW-Class MPD Electric Propulsion System Demonstration	-3.0
Ultra-Lightweight Flexible Thin-Film Monolithically-Integrated CIGS-Based PV Modules for Space	-2.1
Adaptive Point-of-Load DC-to-DC Converter (APOL)	-4.6
RAD6000 System-on-a-Chip Microcontroller	-3.1
High Orbit Spacecraft Testbed Technology Demonstrator	-5.6
Fault-Aware, Modular, Reconfigurable Space Processor	-3.7
Quantum Conductors for Power & Propulsion	-2.4
Magnetic Nozzle and Detachment Efficiency of the Plasma Plume	-1.4
Intelligent, On-Board Space Operation to Enable Lunar Access	-7.0
Microchannel In Situ Propellant Production System	-2.9
Next Generation Wiring Materials	-2.8
Global Technology Discovery & Database Development & Support	-2.0
ACM Docking System for In-Space Assembly	-2.9
Ultralightweight Inflatable Ballutes for Return to Earth from the Moon (UITFB)	-3.0
Continuous ultrasonic process for dispersion of Nanofibers and Nanotubes in Polymer	-0.7
Campaign Methodology: Exploration-Driven Architectures	-1.3
Automated Assembly & Reconfiguration of Future Large-Scale Space Systems	-6.9
Precision Landing and Hazard Avoidance Technology Demonstration	-7.0
Deployable Skirt System (DSS) for Aero-assist Systems	-8.4
Self-Cleaning Anti-Contamination Coatings for NASA Applications	-1.7
Mitigation of Dust and Electrostatic Accumulation for Human and Robotic Systems for Lunar and Martian Missions	-3.2
Fully Integrated Scaleable, Modular Two Fluid Propulsion and Power Module for Sustainable Architecture	-1.3
Stretched Lens Array SquareRigger Tech. Maturation	-3.5
SmallTug: Miniature Cislunar Flight Experiment	-4.0
Planetary Geospatial Exploitation Toolkit	-1.3
Low-Power and Low-Complexity Video Compression for Deep Space & Sensing Applications	-1.3
Critical Thrust Chamber Demonstration for a Revolutionary Ultra-High Thrust Range Cryogenic Space Engine (HUTR TCA)	-2.0
Total	-174.8

Comments (beta)

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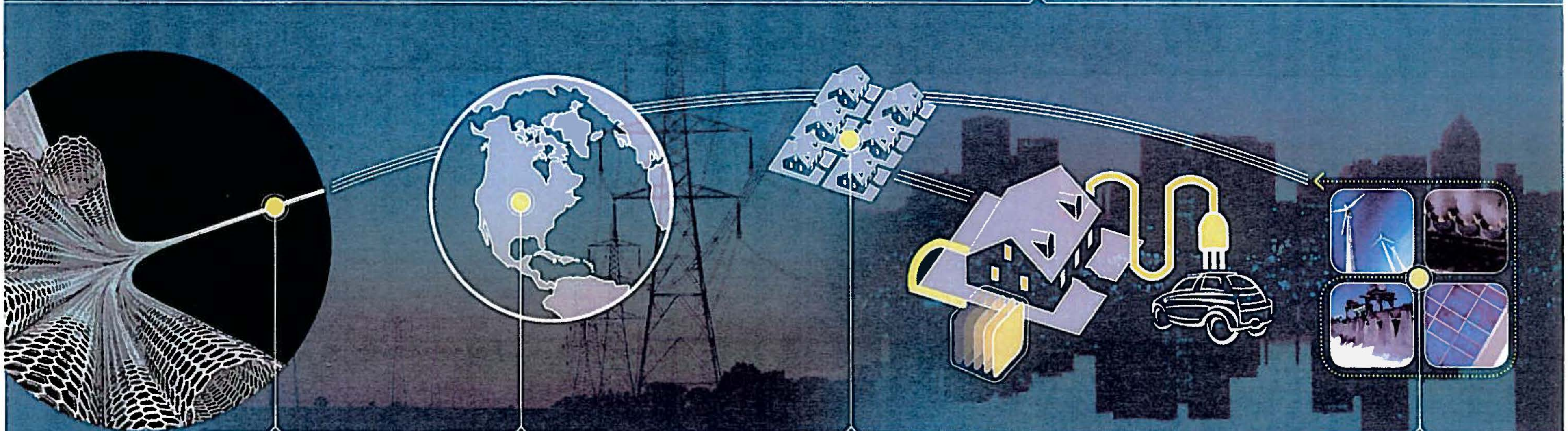
THE RICHARD E. SMALLEY INSTITUTE FOR NANOSCALE SCIENCE AND TECHNOLOGY – ENERGY VISION

The Distributed Storage-Generation Grid:
One World Energy Scheme for 2050

Energy will be transported as electricity over wire, rather than by transport of mass (coal, oil, gas)



Single Walled Carbon Nanotube (SWNT) fibres are spun into **quantum wires**, to re-wire the grid.

Vast electrical power grid
- Continental scale
- Interconnect asynchronous "local" storage and generation sites
- System continually innovated by free enterprise

"Local"
- house, block, community, business, town, ...
- Local storage: batteries, flywheels, hydrogen fuel cells, supercapacitors, etc.
- Local optimization: days of storage capacity, quality of local power

Local generation
- Solar, geothermal, wind, etc.
- "Buy low, sell high" to electrical power grid

THE BENEFITS OF THE QUANTUM WIRE:

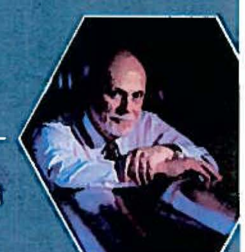
Expected Features
- 10x Copper Conductivity
- 6x Lighter
- Stronger Than Steel
- Zero Thermal Expansion

Key Grid Benefits
- Reduced Power Loss
- Low-to-No Sag
- Lightweight
- Higher Current-Carrying Capacity

SWNT Technology Benefits
- Type Specific
- High Purity
- Low Cost
- Scalable Processing

THE WORLD OF THE GRID:

Global grid
- Robust
- Massive primary power input to grid via HV DC lines.
- New input from vast solar farms in deserts, wind, NIMBY nuclear, clean coal, stranded gas, wave, hydro, biomass, space-based solar..."Everybody Plays"
- Ethanol / Methanol / Hydrogen are transportation fuels
- Transition technology – Plug-in Hybrids



Rick Smalley's vision of a global energy network.

RICE UNIVERSITY