Prepared Statement delivered July 18, 2000
to the U.S. House of Representatives, Subcommittee on
Space and Aeronautics, Committee on Science

Dr. Molly K. Macauley, Senior Fellow
Resources for the Future
macauley@rff.org

Commercializing Space

Mr. Chairman and distinguished members of the subcommittee, thank you for inviting me to meet with you today. My name is Molly K. Macauley and I am a Senior Fellow at Resources for the Future, an independent, nonpartisan research organization established in 1952 to conduct independent analyses of issues concerned with natural resources and the environment. I emphasize that the views I present today are mine alone. Resources for the Future takes no institutional position on legislative, regulatory, judicial, or other public policy matters.

BACKGROUND

I am an economist and have been a member of the Resources for the Future staff since 1983. During that time, I have specialized in the analysis of space policy issues with a focus on economics. I have conducted research on space transportation and space transportation vouchers; economic incentive-based approaches, including auctions, for the allocation of the geostationary orbit and the electromagnetic spectrum; the management of space debris; the allocation of resources on space stations; the public and private value of remote sensing information; the roles of government and the private sector in commercial remote sensing; and the economic viability of satellite solar power for both terrestrial power generation and as a power plug in space for space-based activities. This research has taken the form of books, lectures, and published articles. My research is funded by grants from the National Aeronautics and Space Administration and by Resources for the Future.

Before offering specific comments, I would like to note that I am a space enthusiast insofar as I support public funding of space exploration activities for scientific and research gain. I also welcome space commercialization. I wish that the financial incentives under discussion today were the key to low-cost space transportation, space manufacturing, and other space-based businesses. However, using the federal income tax code to advance commercialization, as is the approach taken in some of the proposals, may not go very far in achieving this goal. I'd like to suggest some alternative steps to take if the goal is commercialization, and if the Congress decides that it is appropriate for the taxpayer to help underwrite this goal (that is, that some subsidy, however small or large, is acceptable public policy).

INTRODUCTION

I have been asked to speak today about four aspects of commercial space:

- Economic forces that drive the commercial space market
- Barriers to market entry
- Estimates of the economic payoffs of commercial space
- Relative merits of potential financial incentives to increase investment and competition

I have not been asked to address specific details of the legislative proposals for special tax treatment and loan guarantees for commercial space transportation and income tax exemptions for space manufacturing and certain other space-based services (HR3898; HR2289/S1239; S469; and HR4676). However, I would like to refer to these in my discussion of approaches that might be taken to spur commercial space activity.

I would also like to note that while commercial remote sensing activities are not the focus of the proposals, the subcommittee's actions during the past decade to support that industry have radically redirected remote sensing. The subcommittee has supported science data buys, innovative approaches to public and private partnerships through the National Aeronautic and Space Administration’s (NASA) Earth Observation and Commercialization Applications Program and Affiliated Research Center activities; and other collaboration between industry and government. These initiatives have helped to turn earth observations from an exclusively government -owned and -operated program to an industry with significant commercial promise, invention, and new markets. These approaches might be useful to support other commercial space activities and I will mention some of these.

WHY AND HOW SPACE MARKETS WORK:
ECONOMIC FORCES THAT DRIVE THE MARKET AND THE COST OF MARKET ENTRY

The first point I'd like to make is that although commercial development of many space technologies requires very large investments, the projects are well within the *capacity* of the private capital market.

Some highlights from a recent article in the business section of *The Washington Post* (11 June 2000) illustrate how these private markets work. The article refers to the biotechnology industry, but it could refer just as well to space businesses:

> *“It carries unique risks.”*
> *“There’s a sense that this industry really matters…. It’s developing products that can fundamentally impact our well-being.”*
> *“The majority of these companies have small capitalizations.”*
> *“Investors in this industry require not only time for research and knowledge, but also extraordinary patience – 10 to 15 years’ worth of patience – and a willingness to buy a bunch of companies that offset the ones that fail.”*
> *“The companies that have produced great earnings started their research 10 or 15 or 20 years ago.”*
> *“It can take a decade just to bring a product from concept to testing. Many don’t make it that far through the regulatory process. During this period, the*

company is not generating cash. It's consuming cash, and therefore its financial health is generally not improving. It's either staying the same or getting worse."[1]

These comments characterize the challenges in commercializing new technology:

- ♦ Long lead times for project development
- ♦ Long payback periods
- ♦ Large uncertainty or risk

However, despite these highly uncertain and distant returns, capital flows into pharmaceutical and biotechnology firms. It allows them to invest several billions annually in R&D on new drugs and other products and services.

A point that I will return to is also noted in these comments as the rationale for undertaking such investment—"the sense that this industry really matters... It's developing products that can fundamentally impact our well-being."

These challenges—long lead times, distant payback, and uncertainty and risk—characterize not only biotechnology, but also a host of other business, including space commercialization.

Much is also in the news about the capitalization of another frontier industry, that of the "dot.coms." Jeff Taylor, the CEO of monster.com, recently shared the following "New Math" at a breakfast meeting of technology experts. Table 1 below illustrates the capital that is flowing into this sector. The column headed "Market Cap" shows money going into the sector; the column headed "1999 Earnings" shows revenues and losses.

Table 1. The New Math

How the market values old vs. new

		Company	Year Founded	Market Cap*	1999 Earnings
Media	Old	Gannett	1906	18.5 billion	957 million
	New	Yahoo	1994	74 billion	143 million
Finance	Old	Paine Webber	1879	6.1 billion	629 million
	New	E-Trade	1996	5.2 billion	(54 million)
Retail	Old	Sears	1893	15 billion	1.5 billion
	New	Amazon.com	1994	18.5 billion	(720 million)
Transportation	Old	UAL	1929	3.5 billion	1.2 billion
	New	Priceline.com	1997	9.1 billion	(53 million)
Auction	Old	Southeby's	1778	952 million	33 million
	New	eBay	1995	19 billion	10.8 million

*Note: *as of May 17, 2000, 3pm.*
Source: Jeff Taylor, CEO, Monster.com, 19 June 2000.

[1] Fred Barbash, "'Moonshots' in Biotech Beg Patience," *The Washington Post*, 11 June 2000, H1, H5.

The point of these examples is that the private sector is clearly demonstrating its ability and willingness to finance a broad range of technology development, and, importantly, the negative returns in the far right column illustrate that these opportunities, like space commercialization activities, are not at all “sure bets.” Many dot.coms, as well as biotechnology companies, although well capitalized, are earning negative revenues. By the way, many are also forecasting continued poor earnings for years to come. In other words, like space businesses, they have long payback periods, long lead times for project development, and high uncertainty or risk. Yet the investment community is willing to finance them.

Some observers point out that many new businesses do not involve very large, up-front construction costs as might be required for space business. Yet the capital market also finances projects with large fixed costs, such as the construction of baseload electric generating units, chemical processing plants, oil refineries, and liquefied natural gas supertankers. And in the case of space, investors have funded the capital costs for manufacture, launch, and operation of communications satellites, and development costs for receivers, hardware, and software for using the Global Positioning Satellite System (GPS).

Taken together, this evidence strongly rejects the failure of capital markets as a rationale for government intervention in the commercialization of space. Although commercial development of many space technologies may require multi-million dollar investments, the projects are well within the capacity of the private capital market.

SOME ESTIMATES OF SPACE COMMERCE MARKETS

There seems to be no shortage of ideas for space businesses and, as importantly for today’s discussion, partners willing to invest in them. *Aviation Week and Space Technology* recently listed investments in space projects during May 1999 to May 2000 (see table 2). Some $10 billion was invested through private placements and sales of stock, and by companies including America Online, Microsoft, General Dynamics, General Motors, DaimlerChrysler, and Raytheon. The headline reads "*Iridium Debacle Leaves Investors Cautious But Undeterred,*" referring to the recent collapse of the Iridium satellite project, and the article quotes the chairman of SpaceVest: "A marketplace is starting to emerge… Nobody likes a financial catastrophe like Iridium but we'll live through it. You couldn't kill the space industry now if you wanted to."

Most of the investment listed in the table is in space-based communications, broadcasting, and earth observation. But other ideas --and corporate backers to finance them -- are also in the news. Just recently, for instance, plans have been announced for Lunacorp and Radio Shack's Moon Rover; satellite servicing by AeroAstro and Space Machine Advisors; and delivery of space (from Mir and the International Space Station) as a virtual experience via the Internet by MirCorp, SpaceHab and RSC Energia, and Dreamtime.

Table 2. Major Commercial Space Investment
May 1999 – May 2000

Company	Amount Raised	Investors
Hughes	$1.5 billion	America Online
Spaceway	$1.4 billion	Hughes
Astrolink	$1.3 billion	Lockheed Martin, Telespazio Liberty Media and TRW
ICO Global Comm.	$1.2 billion	Eagle River Investments
Echostar	$1 billion	Private placement
XM Satellite Radio	$865 million	Debt offering, public stock offerings, General Motors, Clear Channel, DirecTV, Columbia Capital
Sirius Satellite Radio	$700 million	Blackstone Group, DaimlerChrysler, Apollo Management, convertible subordinated notes, common stock offering
Thuraya	$600 million	Consortium of banks
Gilat	$400 million	Private notes offering, Microsoft
Loral Space	$400 million	Private sale of stock
Sky	$250 million	Liberty Media and others
Earthwatch	$199 million	Subordinated discount notes
Globalstar	$150 million	Convertible preferred stock
Final Analysis	$130 million	General Dynamics, Raytheon
Teledesic	$121 million	Abu Dhabi Investment Co.
OrbImage	$75 million	Private notes placement

Source: *Aviation Week and Space Technology*, 3 July 2000, p. S22.

Two other markets that are not in the news but that, according to many observers, may have potential are space power and space manufacturing.

A Power Plug in Space

For all types of space business, a limited resource is electric power in space. It seems possible, and appropriate, that the private sector could supply this service (in fact, the U.S. electricity industry began as an unregulated, private enterprise, with Wall Street financing Edison's pearl Street Station in Manhattan in 1882). Suppose there were a source of power – a space-based, investor-owned and operated "Potomac Electric Power Company" – supplying reliable and low cost electricity to activities in space. Preliminary estimates of the value of a unit of power in space are on the order of $2000 per watt. Launch costs figure prominently as a potential bottleneck, although not necessarily a show stopper, in the economic viability of a space power plant. Could the private sector build and operate a "power plug in space" and make money selling at this price? NASA is presently sponsoring several studies to shed some light on this question.

Manufacturing

In the heyday of excitement about the commercial potential of space -- during the mid 1980s -- aerospace companies and organizations specializing in forecasting the market for space businesses projected revenues of $30 to $40 billion for space manufacturing by the end of the century (the year 2000). Estimating such revenues is extremely speculative in many industries, not only space, but there is some information for a rough, back-of-the envelope estimate of the cost of space manufacturing. One of the most detailed estimates of the space manufacturing business included transportation costs to and from space, and in-space operating costs for one year of manufacturing a hypothetical product.[2] To fabricate one of a range of such hypothetical products, each with high value per unit weight, the total cost for manufacturing about one pound of product was $10 million or more. Transportation costs were about 90% of this cost, assuming use of the space shuttle to reach a space station orbit and to return the product to earth. The cost of power and other services made up the difference.

The investment cost is large for these businesses, and transportation costs are a sizeable fraction of the cost. Nonetheless, the required amounts *alone* are probably not a barrier to private sector financing. The cost is aligned with market capitalization in the businesses in tables 1 and 2.

USING FINANCIAL INCENTIVES

Although the capital markets seem *able* to finance development of space commerce, they seem less *willing* to do so in the case of some space activities. The businesses in table 2 are largely telecommunications, not space transportation or space manufacturing, for instance. This observation is suggestive for the legislative proposals under consideration today, as they focus on transportation and activities like manufacturing. Because the financial ability is there, but the interest seems lacking, the effect of tax incentives for these businesses could be something like leading a horse to water but failing to make him drink, even if in your opinion he is really thirsty. In other words, the proposed tax credits, loan guarantees, and tax and bond exemptions may have little effect if the barrier is not financial as much as it is *interest.*

Some other concerns with tax approaches include:

Losses. Tax exemptions for revenue earned in space may not make much difference if like much new industry, many space businesses initially operate at a loss, which they can carry forward, and thus have no tax liability for many years.

Propping up the wrong business model. For activities that generate taxable income, income tax exemptions under the "Zero Gravity, Zero Tax" bill could prop up otherwise unsuccessful projects for the proposed twenty-five year duration of the exemption. Loan guarantees may have the same undesirable effect. Investments might be made solely for the tax advantages yet the investments may simply not make sense and thus not lead to a viable industry. Although the proposals have "sunset" provisions, some space businesses may survive only because of the tax breaks rather than being robust on their own. For instance, the Omnibus Energy Act of several years ago allowed tax credits for investment in renewable energy. Investments in solar, geothermal, biomass, windfarms, and other energy technologies were made on the basis of the tax

---

[2] John E. Naugle, "A Manufacturer's View of Commercial Activity in Space," in Molly K. Macauley, ed., *Economics and Technology in U.S. Space Policy* (Washington, DC: Resources for the Future), 1983.

break rather than economic soundness of the technologies. When the tax preferences ended, the development of the industries was set back at least a decade. Subsidies as part of the business model are the wrong model.

Effect on the budget. To maintain the government's budget each year, taxpayers must make up the difference in tax revenue when credits, exemptions, and loan guarantees (when default occurs) reduce revenue that would otherwise flow to the public treasury.

Who bears the risk. In contrast with the risk that the private sector is taking in financing our "dot.com" industry, in which case the risk is borne by the investor rather than other taxpayers, supporting space commerce through the tax code forces all taxpayers to bear the risk in that industry. By forcing taxpayers to take the risk of space investment, the legislative proposals imply, from a public policy perspective, that space commerce is more desirable for the good of the country -- thus worth underwriting by the public at large -- than other activities that might be given similar tax breaks (for example, income tax exemption for investments in medical research, tax credits for investment in magnetic levitation (maglev) transportation development).

SOME ALTERNATIVE APPROACHES

I'd like to come back to why some potential space businesses do not seem to be attracting large amounts of capital. This outcome may not be a failure but a virtue of private markets. Investors decline to finance a project because they believe that there are more productive uses of their capital. In this case, the government reduces total social product if it intervenes to get the project financed. Intervention is desirable only if the government is better at "picking winners" than is the private sector.

Perhaps the experience of the commercial aviation industry is relevant. Some experts cite the role of government in that industry as a rationale for a similar role in space transportation and other businesses. For example, the government subsidized airmail; provided wind tunnels and other infrastructure and funded R&D; and enabled spin-offs from military programs to seed commercial aviation. Other analysts argue, however, that these actions did less to ignite commercial aviation markets than Lindbergh's flight across the Atlantic.[3]

Probably both perspectives have merit, and it was both government support and Lindbergh's flight, combined, importantly, with the initiatives and financial risk taking of the private sector, that underwrote the success of commercial aviation. In the case of space, government is following this precedent for support of commercial development. It is funding R&D infrastructure (for transportation testing, validation and verification of earth observation data, and other activities) and publicizing "spin-off" products, services, and processes that are now available for commercial adoption. The government has also indicated a willingness to be a customer of commercial space transportation and earth observation data. And, I've argued that the private sector seems to have ample capital and willingness to finance risky opportunities. Accordingly, what is missing in space business investment? Maybe it is the "Lindbergh spark."

If so, what might ignite the demand for business in space? To quote again from the news article cited at the beginning of these remarks, what is there to bring about "… *a sense that this industry*

---

[3] Nancy L. Rose, "The Government's Role in the Commercialization of New Technologies: Lessons for Space Policy," in Molly K. Macauley, ed., *Economics and Technology in U.S. Space Policy* (Washington, DC: Resources for the Future), 1983.

really matters…. It's developing products that can fundamentally impact our well-being." Some steps might be taken to make "being in space" more attractive for industry, particularly in enabling, encouraging, and facilitating space research for commercial purposes to generate a demand for using space (and in turn helping to create a market for space transportation). These approaches include:

- ♦Supporting a broad range of innovation through the general tax code
- ♦Auctioning space laboratory facilities and transportation
- ♦Offering prizes
- ♦Improving the market for people and ideas
    - --Establishing a high-level, industry-only Board of Directors
    - --Offering manufacturing extension centers and cooperative research extension services
    - --Chartering affiliated research centers
    - --Using the Small Business Innovation Research program
    - --Commercializing applications programs
    - --Purchasing from the private sector (buying data and services)

All of these government initiatives have been tried in various business settings, including, in some cases, some space activities. Each has worked well, although each has advantages and disadvantages. Let me briefly describe these options.

♦Supporting a broad range of innovation through the tax code[4]

Continuation of the tax credit for research and development in all industrial sectors, including space, fosters innovation and is probably easier to enact than preferences targeted specifically for space.[5] From a taxpayer perspective, the general R&D credit is attractively neutral in encouraging all types of research; it doesn't favor innovation in space at the expense of other types of technology development. Studies of the effectiveness of an R&D tax credit in promoting research have mixed results, although most of the evidence suggests that the credit can significantly increase R&D. Studies using data from the early 1990s showed additional R&D of about $1.75 per $1 of tax revenue foregone.

---

[4] The existing tax code provides for a host of tax credits falling largely, although not exhaustively, into two categories: (1) social assistance for welfare-to-work efforts, low-income housing, disabled access, and child, dependent, disabled, and elderly care; and (2) activities that may contribute to a larger public good such as helping the environment (renewable electricity production, nonconventional fuel source usage, electric vehicle usage). Based on these categories, the argument for providing tax credits for space-related activities is not clear, although as noted, there are credits for activities that fall outside of these rationale.

[5] The credit, known as the "Credit for Increasing Research Activities," was set to expire in June 1999. Some problems with such a credit are that investment is treated preferentially through expensing, so there is an incentive to "relabel" activities that would be undertaken anyway as "R&D." The credit also interacts with other tax provisions, such as the investment tax credit, depreciation, and capital gains. If plant and equipment investment is a major part of conducting R&D and plant and equipment are less expensive because of an investment tax credit, then a tax credit for R&D is less effective. Neither type of credit is relevant to a company unless it has positive tax liability. Carolyn Fischer offers good discussion of the credit (see Carolyn Fischer, "Empirical Evidence on the R&D Tax Credit" (Washington, DC: Resources for the Future), mimeo (available from the author at fischer@rff.org), 1995).

♦ Auctioning access to space laboratory facilities and transportation

One way to ascertain the value of space access and space-based location is through an auction. Auctions of rights to use publicly owned resources can allocate those resources efficiently, showing us what the market is willing to pay; suggesting the size of commercial markets; and perhaps indicating what the best role for government might be if it wants to help those markets to develop. The auctions by the Federal Communications Commission of rights to use parts of the electromagnetic spectrum are a notable example. By virtually all accounts, this has been an enormously successful use of market forces to promote innovative, advanced telecommunications technologies throughout the economy.[6]

Economists have long advocated auctions for commercial access to the space station.[7] If the public policy objective is to encourage space manufacturing, then capacity of the station (crew time, power, communications, and so forth) could be auctioned. If there is a deficit between operations and the auction revenue, the difference could be underwritten by government (again, this assumes that the policy goal is to support development of commercial space).[8] A similar approach could be used for auctioning shuttle capacity. Like the proposed tax-based approaches for space activity, taxpayers finance any deficit between actual costs and the auction revenue. However, by allocating existing resources, auctions of station and shuttle capacity effectively target the use of taxpayer funds if the goal is promoting space-based research or manufacturing. In addition, the effect of this policy on the federal budget is easier to evaluate than tax-based approaches.

♦ Offering prizes

Prizes have a long history of encouraging innovation. In the 1780s, the French Academy offered 100,000 francs to whoever could produce a soda alkali from sea salt; the competition successfully led to a process that became the basis of the modern chemical industry.[9] Today, the $500,000 Lemelson-MIT prize for American inventors seeks to foster new technology development. A familiar space industry example is the privately funded X-prize for the development of a suborbital space vehicle capable of carrying three people and reusable within two weeks of each flight.[10] In the spirit of financial incentives such as these, prizes could be offered for a host of other space-based industrial development, such as new materials processing, pharmaceutical products, or other specific products and services.

---

[6] Spectrum auctions have raised over $22 billion to date. Auctions need not be inconsistent with achieving important non-economic or public goods objectives associated with resource use, as the licenses can include, for example, designated public service obligations.

[7] John Ledyard and his colleagues at the California Institute of Technology have researched in depth the usefulness of auctions for station capacity. See John O. Ledyard, "The Economics of the Space Station," in Molly K. Macauley, ed., *Economics and Technology in U.S. Space Policy* (Washington, DC: Resources for the Future), 1983.

[8] NASA has recently posted a price schedule of fees for station capacity (see http://www.commercial.hq.nasa.gov/pricingstructure.htm). An auction may be a better approach than these posted prices because it is not clear that they have been set with much information about the prices the market is willing to bear.

[9] See Joel Mokyr, *The Lever of Riches* (New York: Oxford University Press), 1990.

[10] See http://www.xprize.org.

♦ **Improving the market for people and ideas**

There is no shortage of ideas for space commercialization, including radical innovation in space transportation, well-developed plans for space entertainment and tourism, and the beginnings of discussion of an investor-owned and -operated utility infrastructure (providing power and communications) as a backbone for space-based manufacturing and other activities. A problem is that these ideas are largely shared *within* the space community rather than with a broader community of interest. Some exceptions are that the conventional travel industry is now participating in discussions about space tourism, and recently, as I noted above, NASA has been including representatives from the energy industry in working groups on satellite solar power. In these cases, industry has brought marketing ideas, economic assessment, and pragmatic insights to the space vision. In the case of satellite solar power, this interaction has markedly influenced new engineering conceptions of system design.

Several existing mechanisms could be used to further the exchange of people and ideas – with the objective of getting industry "at the table" to share perspectives and in some cases, to fund incremental research and even commercial product development. These include:

<u>High-level commercial Board of Directors</u>: Because NASA is at present the gatekeeper for much commercial use of space, in that it governs shuttle access and station use, the agency should establish an industry-only, commercial advisory committee reporting directly to the NASA Administrator. The Board would provide the creative insights, hard questions, and financial reality of "what it takes" to achieve commercial success for activities in space. Members should be vice presidents or higher-ranking representatives from a cross-section of the nation's key industrial sectors and represent companies *not presently involved in space commerce.* Members could be drawn from companies in information technology and communications; energy; low-and high-tech manufacturing; pharmaceuticals and biotechnology; transportation; and travel, tourism and entertainment. The Board's task would be to consider in-depth the approaches being taken to space transportation, the international space station, and any other NASA activities with commercial relevance. The objectives would be to make NASA a more effective gateway to business in space by bringing to the agency a business mindset; identifying barriers and solutions to viable space commerce; and, importantly, being forward-looking and outward-reaching in communicating the opportunities of space to the rest of the business world, particularly those companies not yet involved in space activities.

<u>Manufacturing extension centers and cooperative research extension services:</u> Much like the agricultural and manufacturing extension centers, such centers and services could be established specifically for space-related, commercial industry development.

<u>Affiliated research centers</u>: NASA's Stennis Space Center sponsors an affiliated research center program. It establishes university-based centers expressly for doing small projects with industry partners and links the next generation of young people (in the university) with small businesses that are newcomers to the business potential of space.

<u>The Small Business Innovation Research program (SBIR)</u>: Some of America's most successful technology companies received support through small business grants in the Small Business Investment Company (SBIC) in the 1960s and more recently, the SBIR program while they were

still privately held entities.[11] These include Apple Computer, Chiron, Compaq, and Intel.[12] In addition to NASA's SBIR program, some fraction of SBIRs at various government agencies could be targeted specifically to space commerce activities (for example, at the Departments of Transportation, Agriculture, and Commerce).[13]

Commercialization applications programs: Commercialization applications programs, such as NASA's Earth Observation Commercialization Applications Program, involve co-funding by industry of small, exploratory commercial development projects. The advantage of co-funded programs is that by putting some resources at stake, industry partners have strong incentives to participate fully in the project.

Purchasing from the private sector (data, services): Government purchase of commercially provided earth observation data (a "Science Data Buy"), as encouraged by the 1998 Commercial Space Act (P.L. 105-303, section 107), is also a means of spurring space commercialization and at the same time, supplying government requirements. Data buys could be set up for research data generated by experiments in space manufacturing, for instance. In addition, commercial space companies could supply routine services such as communications and electric power to government space-based facilities. The draft *NASA 2000 Strategic Plan* calls for the agency's Human Exploration and Development of Space program to buy commercially provided communications by 2012-2025 and NASA could extend this goal to include power and other services.

CONCLUSION: OPENNESS TO NEW INFORMATION

Mr. Chairman and members of the subcommittee, thank you for the opportunity to speak today. I'd like to conclude my comments on a more philosophical note. Researchers on the history of science and innovation admit the complexity of understanding how to bring about technological diffusion to pave the way for successful commercialization. Among their observations is some conviction that what may be required for technological creativity is the right blend of accumulated knowledge of past generations and the ability to shed the stifling burden of past institutions. For instance, researchers note that this blend existed in "frontier" societies like the 19th century United States. They distinguish between the "dynamic forces of technology" and the

[11] SBIR grants have some disadvantages, however. Some research suggests that they encourage the substitution of federally financed R&D for R&D that the company might fund on its own, rather than increase the amount of R&D companies undertake (see Scott J. Wallsten, "The Effect of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program," *RAND Journal of Economics*, vol. 31, no. 1, Spring 2000).

[12] See Josh Lerner, "When Bureaucrats Meet Entrepreneurs: The Design of Effective 'Public Venture Capital' Programs," in Lewis M. Branscomb, Kenneth P. Morse, Michael J. Roberts, and Darin Boville, *Managing Technical Risk: Understanding Private Sector Decision Making on Early Stage Technology-based Projects* (Gaithersburg, MD: National Institute of Standards and Technology) NIST GCR 00-787, 2000. Charles Stein also discusses SBIR for small businesses in "A Sugar Daddy for Hungry Startups: Old Uncle Sam," *Fortune Small Business*, May/June, 2000,v. 10, no. 4, pp. 41-42.

[13] Already there is some space-related SBIR support by an industry partner in the form of discounted software access for companies participating in the program. Analytical Graphics, producer of the Satellite Took Kit software, offers discounts to companies participating in phase I of SBIR (see http://www.stk.com).

"conservative forces of ceremony and ritual."[14] Perhaps this characterizes the desirable relationship between a space program historically dominated by government and the emergence of commercial activity – NASA and the Department of Defense bring much expertise but are the "conservative forces of ceremony and ritual" that must blend with the dynamic forces of technology. I appreciate your willingness to catalyze the blend.

[14] See Mokyr, 1990.

Biography

Molly K. Macauley
Senior Fellow, Resources for the Future

Education: Ph.D., Johns Hopkins University, Economics
M.A., Johns Hopkins University, Economics
B.A., College of William and Mary, Economics

Dr. Molly K. Macauley is a Senior Fellow at Resources for the Future (RFF), a nonprofit, nonpartisan research institution in Washington, D.C. She is also an Adjunct Professor in the Department of Economics at Johns Hopkins University and at Hopkins' School of Advanced International Studies. At RFF she heads RFF's Space Economics Research Program.

For the past 9 years she has led the development of economic analysis for NASA's Earth Observations Commercialization Applications Program, and she participates in economics research on several other NASA projects, including programs at the Stennis Space Center and the Jet Propulsion Laboratory. She has received grants from the National Aeronautics and Space Administration, the U.S. Environmental Protection Agency, the National Institute of Standards and Technology, the Department of Energy, and RFF for her work. She has authored or co-authored two books and over thirty articles. In 1994, she was honored by the National Space Society as one of the "Top 25 Rising Stars" of the nation's space program. She has lectured extensively throughout the country on space economics, and is frequently called upon to give Congressional testimony on the space program and commercial space activities.

Her research focuses on economic and policy analysis of space technologies and programs, including studies of the appropriate role for government in its interaction with the private sector; performance measures for government and government/commercial joint activities; and the relationship between space technologies and other public regulation (for instance, the implications of remote sensing technologies for environmental regulation, monitoring, and compliance).

In addition, Macauley is on the Board of Directors of Women in Aerospace; she is President of the Board of Directors of the College of William and Mary's Thomas Jefferson Program in Public Policy; and she is a corresponding member of the International Academy of Astronautics. She was recently appointed to NASA's Space Science Advisory Board and to a special task force of the National Academy of Science's Space Studies Board focusing on remote sensing issues. She also serves as the Director of Academic Programs at RFF, involving the management of prizes awarded competitively under the Joseph Fisher Dissertation program; the administration of Gilbert White Fellowships for visiting scholars; and the management of RFF's public Wednesday Seminar Series. At Johns Hopkins, where she has taught for 9 years, she leads courses in microeconomics, public finance, and science and technology. Her classes include large undergraduate introductory courses, with over 250 students; upper class advanced courses; and graduate courses.