Market innovations would greatly benefit America's space policy.

Regulation on the Final Frontier

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THE TRAGIC LOSS OF THE SPACE SHUTTLE *Columbia* last February reintroduced into America's consciousness the question of why we send humans into space. But until the accident, most people did not know that *Columbia* was in orbit and even fewer people cared why. Could it be that manned space flight lacks much public relevance? Instead, it is unmanned space activities like television broadcasting, paging services, cell phones, navigation, and weather monitoring that affect our day-in, day-out lives. Their estimated market size has grown to over $270 billion annually — an expenditure far greater than the $11 billion budget for human flight.

Government regulation of commercial space has kept pace with that growth. As in markets for other goods and services, regulation of space exploitation is appropriate in some cases but much less so in others. As policy analysts both inside and outside NASA contemplate the direction of the shuttle program in the wake of the *Columbia* tragedy, they would do well to consider the broad field of space policy instead of focusing exclusively on shuttle operations and safety.

SPACE TRANSPORTATION

The nation's space transportation infrastructure consists of both government-owned resources (the space shuttles) and privately owned resources (conventional unmanned rockets known as "expendable launch vehicles" or ELVs). Despite the attention accorded *Columbia,* the shuttle is not the usual mode of space access. It flies only three or four times each year because of regulatory legislation enacted after the 1986 loss of its sister ship *Challenger.*

The legislation permits use of shuttles only for activities that require humans. In particular, the law prohibits shuttle launches of most satellites, including the plethora of spacecraft providing everyday services such as telecommunications, earth observations and mapping, weather forecasting, and navigation, as well as almost every satellite NASA operates for scientific studies of comets, planets, and other space phenomena. All of those spacecraft fly on ELVs.

The shuttles When the shuttle does fly, it is operated by United Space Alliance (USA), a joint venture of Lockheed Martin Corporation and the Boeing Company. NASA contracted with USA in 1996 for private sector management and operations — the contract was a congressionally mandated first step toward an attempt to increase industry involvement in the shuttle program.

The contract shifted many shuttle-related civil servant positions to USA to streamline shuttle operations and replace an aging civil service workforce that was rapidly nearing retirement. Because the government still owns the shuttle system, however, NASA is in charge of deciding when to upgrade the shuttles and how much maintenance they require. That places USA in the awkward position of being responsible for managing an asset but not having authority for its quality. Critics of USA have asked whether *Columbia*'s fate was related to lax safety procedures, but other observers point out that USA adheres to NASA-specified safety protocols.

The Commercial Space Act of 1998 requires further study of full-fledged privatization of the shuttle program — that is, the possibility of private ownership, not just operation. The Act intends "to restore NASA's research focus and to promote the fullest possible commercial use of space." An in-depth 2001 NASA internal assessment of privatizing additional shuttle management duties affirmed advantages of industry involvement. But one of the most respected trade journals, *Aviation Week and Space Technology*, expressed some incredulity about such plans in its December 12, 1998 issue. The magazine noted

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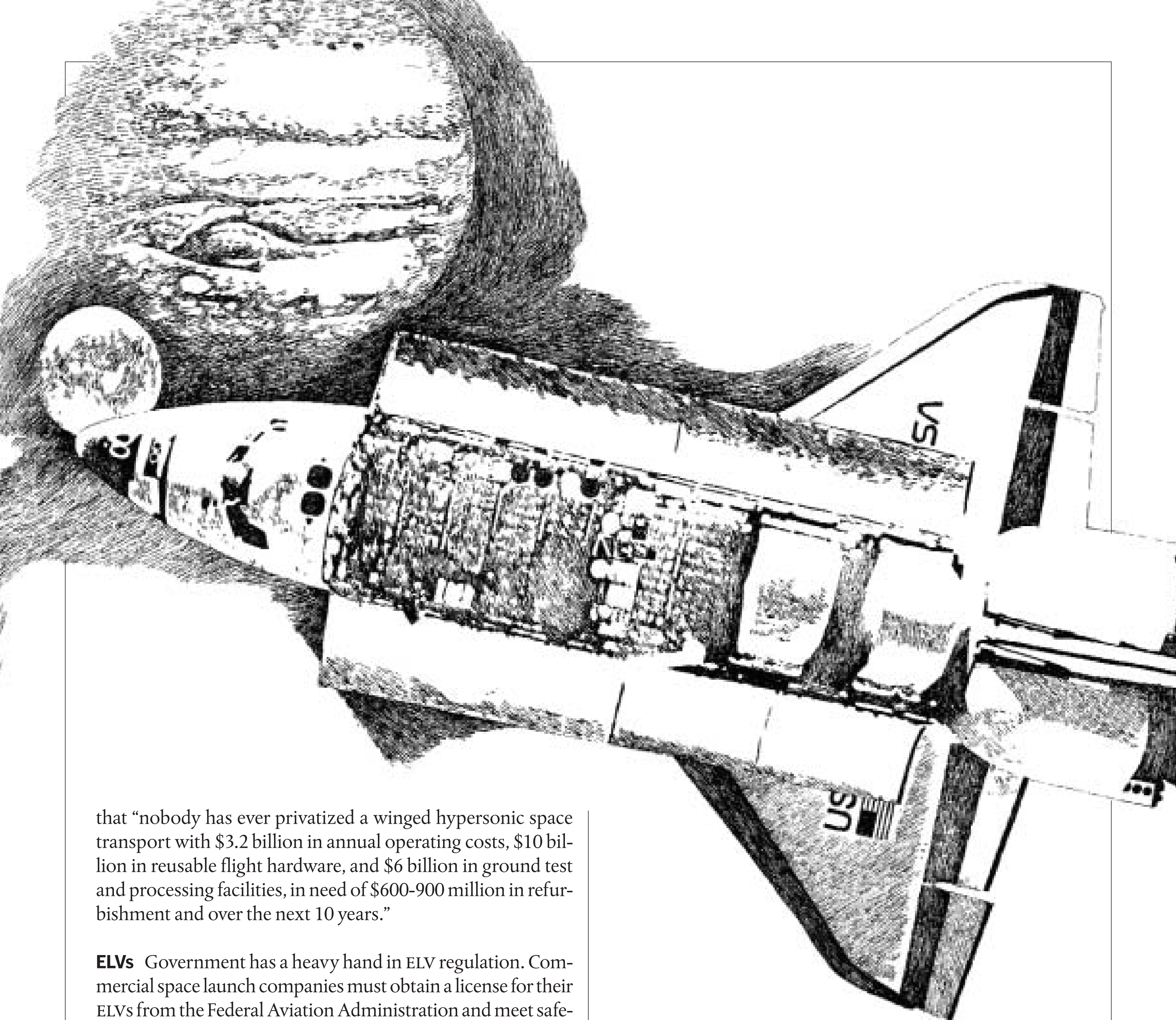

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that "nobody has ever privatized a winged hypersonic space transport with $3.2 billion in annual operating costs, $10 billion in reusable flight hardware, and $6 billion in ground test and processing facilities, in need of $600-900 million in refurbishment and over the next 10 years."

ELVs Government has a heavy hand in ELV regulation. Commercial space launch companies must obtain a license for their ELVs from the Federal Aviation Administration and meet safety requirements set by the U.S. Air Force, which operates government launch pads and associated facilities.

As part of that regulation, private ELV firms are required to carry insurance. One of the risks they face is the chance of harming third parties if an ELV malfunctions over populated areas during ascent. Under the Commercial Space Launch Act of 1988, government shares third-party liability to relieve private industry of potentially catastrophic claims. The government will pay third-party claims for amounts in excess of a base amount and up to a statutory ceiling. The base amount is typically around $100 million to $180 million; the FAA licensing process sets the base amount according to the agency's estimate of the maximum probable third party loss projected for the ELV used given its size, past record of launch success, and other measures of reliability. The Act specifies that the base amount is not to exceed the lesser of $500 million or the maximum amount of launch insurance available on the world market at reasonable cost. The Act initially set the upper limit at $1.5 billion and required that it be adjusted each year for inflation. In 2002, it was roughly $2.3 billion.

Effects The patchwork of shuttle and ELV regulatory policy often tends to work at cross-purposes. When the shuttle first began operations in 1981, its flight rate was high — in part because it quite frequently launched commercial satellites at heavily subsidized prices. NASA set those prices well below actual shuttle operating costs and well below the cost of using ELVs. Mounting criticism of shuttle pricing policy by the General Accounting Office and the commercial ELV industry was attenuated by the prohibition on shuttle launch of most satellites after the *Challenger* accident.

Without the satellite business, the shuttle flight rate dropped precipitously. In part to remedy the loss of business suffered by the ELV industry during the shuttle subsidies, Congress established an innovative launch voucher demonstration program.

The program issued vouchers to university and other researchers who had NASA grants to build small satellites for scientific studies. The researchers could use vouchers to purchase an ELV of their choice and sized "just right" for the payload.

As review of shuttle policy gets underway post-*Columbia*, some proponents of the shuttles advocate reconsideration of the ban on shuttle satellite launches. They expect the shuttle system to return to routine operations and suggest that properly set user fees could do a better job at sorting out if and when it makes sense to use the shuttle for launching satellites. Their argument has merit, as it may be that new and innovative satellite designs could make use of the unique capabilities of the shuttle. Provided that fees properly accounted for the extra costs of human involvement, access to the shuttle could unleash new satellite services. Certainly if NASA, in conforming with the 1998 Act, continues to pursue the possibility of private ownership of the shuttle fleet, a private owner will want the opportunity to attract as large a market as makes sense.

Too safe? In conjunction with review of shuttle policy, ELV insurance regulation also may merit overhaul. ELVs to date have an impeccably safe launch record. Safety does not equate with a successful launch, of course, as numerous launches go awry; but to date, there has been no harm to people. However, an impeccable safety record could mean that the safety provisions are, at the margin, too safe and perhaps too expensive. Safety officers view as heretical any suggestion that additional launch risk may be worth taking, even though other sectors of the transportation industry — aviation, autos, trains — routinely impose third-party costs.

Another prominent concern is that the safety regulations may discourage innovation in new flight hardware because it has to undergo extensive testing to meet qualifications. Because the world launch market includes ELVs supplied by France, Russia, and China, U.S. launch companies could be at a competitive disadvantage if they are subject to overly stringent government oversight. Controversy also surrounds whether fees charged ELVs to use the launch ranges are allocated commensurately between the government and industry. Foremost at the moment is how the cost burden should be distributed between government and the private sector to pay for desperately needed upgrades and modernization at launch facilities.

The legislative provision for ELV launch indemnification by government expires in 2004. Launch companies seek extension of the policy by arguing that the financial backing is critical to their ability to compete against foreign launch suppliers. Critics ask why taxpayers should underwrite space transportation and note that even in the case of the commercial nuclear power industry (often cited by ELV suppliers as precedent-setting), government has significantly reduced its level of indemnification from initial amounts provided by the Price-Anderson Act. (See "Determining the Price of Price-Anderson," Winter 2002.) Now, the insurance burden falls more squarely on industry.

Another possible disadvantage of the current ELV indemnification policy is that it may blunt industry's incentives to invest in improving safety. If the industry shared more fully in providing its own insurance coverage, the incentives might be stronger. The FAA has recently studied possible alternative insurance arrangements that could pave the way. One option is for industry to set up its own trust fund or captive insurance pool, with each company paying in funds over some period of time. Another option is use of catastrophe bonds that have evolved for managing risks of unusual events such as earthquakes, flooding, and crop losses from severe weather. Those options might provide a better balance of the safety and risk tradeoff. Other attractive advantages could accrue to industry. For instance, interest on a trust fund or pool can be returned to the firms, firms themselves either manage or have a say in how the fund is managed, and periodically after any obligations are fulfilled, assets can be returned to firms.

ACTIVITIES IN SPACE

Once in space, satellites require government-allocated access to orbital locations and electromagnetic spectrum for communications with the ground and, in some cases, other satellites. Extensive regulations also affect other characteristics of satellite operations, most notably rules governing the new commercial market for earth observations.

Spectrum and orbit allocation Economists and engineers have long studied the inefficiency of spectrum regulation. The inefficiency stems largely from the problem of centralized administrative practices by which government decides who, what, and when — who can use spectrum, what frequency and bandwidth are available, and when new technologies qualify for licensing. In the absence of a more market-like approach, spectrum allocations may not go to their highest-valued users. Research has also shown that government-managed spectrum allocation biases innovation toward wasteful use of the spectrum, particularly by incumbent users who have an allocation and little incentive to economize on it.

Wholly analogous problems arise with government allocation of orbital locations. The preferred orbit for most telecommunications satellites is 22,300 miles above the equator. Here in this "geostationary" orbit, the satellite moves in sync with the earth, which permits uninterrupted relay of signals between locations on earth (in any other orbit, the satellite is out of sync and not in constant "view" of relay points on earth). But satellites communicating on the same government-assigned frequencies need to be spatially separated along the orbit by a hundred miles or more to minimize signal interference. So, the joint allocation problem of a frequency assignment and a parking spot in the geostationary orbit has long been a source of contention among competing satellite companies. As in the case of spectrum allocation, researchers have found that the orbital allocations have not always gone to highest-valued users and that innovation in telecommunications satellites tends to disregard the scarcity value of those non-priced resources.

Some precedent for reforming the allocation procedures was set in the 1990s when the Federal Communications Commission implemented public auctions for a few frequencies of keen interest to terrestrial telecommunications services. By 1997, auctions had brought in over $22 billion and more important, according to the *Economic Report of the President* for that year, the auctions got spectrum "quickly into the hands of service providers" and "rapidly promoted the use of innovative, advanced telecommunications technologies throughout the economy." Last year, the courts took exception with some rules the FCC uses to implement the auctions, but the courts did not question auctions themselves as a useful allocation tool. Extending auctions to spectrum and orbital locations for the satellite industry could bring mutual gain — greater assurance that the highest-valued users gain access and a stream of revenues for the federal treasury.

Earth-observing satellites Satellites used for observing the earth — as distinguished from providing telecommunications — snap photos of the planet and take sensor readings about the atmosphere and other environmental conditions. Earth-observations satellites assist in a long list of activities including environmental monitoring, land-use planning, responding to natural disasters such as flooding, assessing crop yields, controlling pests, managing agricultural irrigation, and exploring for oil, gas, and minerals. The satellites supply photos of cities, airfields, and other infrastructure that are prominent in the news media as part of war coverage and cover a host of other geographically large-scale events such as hurricanes, earthquakes, and forest fires. The photos are useful when the synoptic view accorded from space illustrates the scale and scope of those events or when accessing the event by conventional means (on foot, by car, by airplane) is difficult or impossible.

Earth-observing satellites — also referred to as land remote-sensing satellites— orbit just a few hundred miles above earth in non-geostationary orbits. Here among these "low earth orbit" spacecraft, neither spectrum nor orbital allocation is contentious because the congestion problem besetting geostationary satellites has yet to arise. Low earth orbit operation is far from a freely functioning, unregulated market, however, because of other forms of government oversight.

NASA launched the first non-military earth-observing satellite in 1972. After more than a decade of government operation, the 1984 Land Remote Sensing Commercialization Act transferred the program from government operation to a joint venture of RCA and Hughes Aircraft Company. The reasoning behind the transfer was based on arguments similar to those for the private operation of the shuttle: NASA should be restricted to research and not be involved in routine operation of infrastructure.

The industry-run observation program suffered severe financial losses for a variety of reasons. Government specified the prices that the new company could charge and controlled other sales terms involved in product marketing. Even worse for the new company, much of the supporting market infrastructure was not yet in place for fully commercially exploiting earth-observation data. There were too few people trained to process and interpret the information. Severe limits plagued existing hardware and software capability, including, at that time, no Internet or Pentium chips for fast and easy data transmission and processing. (The experience of a large-scale farmer who ordered imagery of his fields to time pesticide application illustrates the challenge the new company faced. To speed delivery, the company shipped the mailing tube containing the photo first by air, then used a courier on rollerblades to get the photo to the farmer's office. Despite best efforts, the package arrived a few days too late for practical use).

Eventually, the financial loss was so high that the company folded. Stakeholders — including the science community, which uses the data for research, and the aerospace and photo interpretation industries — successfully lobbied government to take back the program and continue its operation under government auspices. In response, Congress enacted the 1992 Land Remote Sensing Policy Act to return the program to the government — this time, to NASA and the Department of Defense. Later, the Defense Department would drop out of the program and NASA and the Department of Interior would manage it.

In the meantime, a private firm was petitioning for government permission to launch and operate its own earth-observing satellites to produce images of the planet based on commercial specifications. By this time, more of the complementary architecture such as increasingly high-speed Internet connections was in place to support a commercial market. The 1992 Act specified that the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), which had experience operating weather satellites, would regulate any future private market. NOAA granted the first license in 1993. Three companies now operate commercial satellites.

Operations and pricing Among the most controversial operating parameters specified by the commercial license is the spatial resolution, or level of detail, with which the satellite can see the earth. Only military reconnaissance satellites are allowed to have the keenest eye. In the interest of national security, the Department of Defense and the Department of State review commercial license applications. The agencies also review commercial operations to control the flow of information during periods of international crisis and to fulfill unspecified foreign policy obligations that might require the United States to share imagery with other countries.

Resolution is an influential factor in the market value of the images of earth. Just a few years ago, the government limited commercial resolution to one meter (that is, it can distinguish objects of roughly one meter or larger on a side). Industry pressure and competition from foreign commercial earth-observing satellites operating at better resolution led NOAA to relax the limit. At present, the highest spatial resolution supplied by a U.S. commercial earth-observation satellite is 0.61 meters. But market pressure for even finer resolution continues — a company has recently requested a license for a quarter-meter resolution. At that scale, additional issues arise — like citizens' right to privacy in their backyards.

As in the case of shuttle pricing, government is heavily influential in earth-observation pricing. Until 2000, regulations mandated that commercial "unenhanced data" (that is, minimally processed film or signals) be offered at identical prices to all customers. This was the case whether they were government agencies (for example, the Department of Agriculture uses imagery to monitor the status of crops in the United States and overseas), commercial customers (for example, oil companies use earth-observation data to plan geologic exploration), university researchers (who often work with imagery to research new algorithms for interpreting the imagery), or NGOs (for instance, international environmental organizations use imagery to monitor a variety of environmental and habitat conditions).

In 2000, NOAA partially relaxed its oversight of pricing to allow industry greater market flexibility — but the agency still reviews prices. Now, companies can differentially price products provided their commercial system has received no government funding for development, fabrication, launch, or operations costs. Allowing a company to charge a fully commercial price to oil companies and a discount price to, say, university researchers or new customers by way of "introductory offers" may improve the faltering profitability of the earth-observations market.

Integrating public and private sector activities Much like the predictable problem of the government-owned shuttle competing with the ELV industry, so too does the government earth-observing satellite system compete with the private satellite industry. The supply of imagery by government at low prices crowds out some commercial sales, though the effect is tempered somewhat because the government products are at much grosser resolution.

In response to this dilemma, and as the government satellites have aged, Congress has asked NASA to solicit industry bids to build, operate, and own the next-generation government system (government would contract to buy imagery from the system). The rationale for building a new government system, instead of relying solely on a privately financed and operated system, is based on a strong conviction of many legislators and the successful lobbying of earth-observation scientists. The supporters assert that continuing the collection of over 20 years of observations using the original technical characteristics of the government system would enable development of a consistent time series of information about earth (particularly about trends in climate change). Information collected from new or differently configured satellites would interrupt the time series.

In 1999, NASA issued a request for industry proposals for the satellite system to continue the supply of government data. In 2001, NASA awarded funding for design studies; funding for actual construction is expected this year. The bidders are allowed to design their satellites to meet commercial demand but, at the same time, include additional sensors and other instruments to provide imagery that conforms to the government specifications. Because the government will substantially underwrite the system, NOAA would be allowed to restrict somewhat the company's commercial practices (most notably, in applying the nondiscriminatory pricing policy).

Observers have characterized the development of earth observations policy as a series of experiments and learning by trial and error. Unfortunately and despite progressively more favorable regulatory policy, the red ink in the industry persists. A recent National Academy of Sciences study attributes weak demand to, among other problems, a continued shortage of trained analysts and failure of the industry to fully demonstrate cost effectiveness of the information compared with other sources (aerial photos, traditional ground-based data collection). The intimate link with government also persists. Government continues as the biggest customer, and sometimes the monopoly buyer, of commercial images. During the recent conflict in Afghanistan, the government purchased exclusive rights to commercial images of that country for national security and military operations. During Operation Iraqi Freedom, the government purchased significant quantities of imagery although it did not choose to obtain exclusive rights to the data.

SPACE DEBRIS

After getting to space and operating there, the management of space debris generated during those activities arises as a third area of government regulatory policy. Much like increased attention to practices of recycling, demanufacturing, hazardous waste management, and other procedures for cleaning up on earth, so too is space debris increasingly prominent as a concern of regulators.

Launch and operation of space missions routinely generate debris ranging from used rockets and derelict satellites to discarded lens caps, nuts and bolts, and particulates from propellant fuels. In the early days of the space program, naturally occurring micrometeoroids were the sole debris-related concern. But now, manmade debris has proliferated even though its accumulation is somewhat moderated by natural orbital decay (atmospheric drag eventually leads debris to reenter earth's atmosphere and wholly or partially burn up during reentry). Hundreds of thousands of pieces of litter now orbit in space. Engineers estimate that more than half the objects in low-earth orbits could still be there in 50 years, and 85 percent of those objects would still be in orbit after 100 years.

Space debris can be lethal to operating spacecraft. A marble-sized piece of metal is as destructive as a hand grenade in that it can easily penetrate a two-inch-thick metal wall. Even pinhead-sized particles in space orbit at six miles per second. Collisions with paint chips have gouged the outer panes of shuttle windshields and the surfaces of the shuttle's thermal tiles typically display evidence of being hit.

The inclination of policymakers has been to criticize debris generation and argue that the desirable amount is "zero." The NASA Authorization Act of 1991 states that a goal of U.S. space policy is to conduct activities "in a manner that does not increase the amount of orbital debris." But toeing this line may be inappropriately costly. Debris is a byproduct of activities that provide benefits — satellite telecommunications that enhance the quality of life, earth observations to protect the environment as well as enhance national security, and interplanetary exploration and scientific investigation that augment understanding of planets, comets, and other space phenomena. Unless some amount of debris is deemed tolerable, space activities would have to end — after all, debris can be generated merely by the accidental collision of a single spacecraft with naturally existing micrometeoroids.

Moreover, controlling the amount of debris is not free because resources are required for debris mitigation. By permitting some debris, money not spent on excessive control of debris can be spent on other space-related research, exploration, or other activities. The expense of debris depends in part on the probability of a debris hit and the cost of replacing the affected spacecraft. By way of illustrating the costs for a geostationary telecommunications satellite, if replacement cost is approximated by original cost (adjusted for inflation), then the probability-weighted expected loss is around $500,000 (multiplying replacement cost of about $500 million by the engineering estimates of the probability of about 0.001 for debris damage during the lifetime of the satellite). For the Hubble Space Telescope, the expected loss would be around $20 million. A private company may use insurance to cover on-orbit, debris-induced losses. In operating the space telescope and other government spacecraft, the government is self-insured for debris-related loss.

The actual expense of debris exceeds this expected loss calculation, however, because additional losses arise from an externality attributable to the technology of debris proliferation. Collisions of debris and spacecraft beget so-called cascading amounts of debris that, in turn, increase the probability of impact for other spacecraft. The cascade effect means that decisions based on private costs alone may shortchange the rest of society.

Because private and social losses diverge, a potential appropriate role for government could be to put in place reasonable incentives for additional debris mitigation. Debris reduction activities are numerous: designing and operating spacecraft to reduce their potential to break up or explode, venting excess propellant, using lanyards to secure external components, boosting geostationary satellites into "disposal" orbits, recycling in the form of capturing and reusing spacecraft and components, and shielding spacecraft to reduce their likelihood of colliding with debris and producing cascading debris. Policy encouraging spacecraft operators to choose which of those options makes economic sense for their system could go far in cost-effective debris mitigation. Generally speaking, a command-and-control approach — currently favored by government — is less desirable. Dictating a single strategy or technological practice is usually the most expensive approach, especially because of large differences in the costs of compliance among small and large payloads and launch vehicles and between manned and unmanned activities.

Instead of mandatory controls, financially based incentives make sense as a strategy that fosters mitigation at low cost. Government could levy penalties for debris generation potential (unpainted vehicles would get a discount, as would spacecraft with lanyards attached to releasable external components that tend to get lost in space). Or policymakers could implement a deposit-refund scheme whereby deposits are made upon launch and later refunded in whole or in part after post-mission disposal of space structures. Post-mission disposal occurs when components are boosted to disposal orbits, excess propellant is vented, or spent rocket bodies are de-orbited (that is, maneuvered to burn up during reentry into earth's atmosphere). Another option is issuance of permits to generate a specified amount of debris. Permits could be tradable among companies and between government and industry, thus allowing all parties to comply flexibly with overall debris-reduction goals. Or a bond market could be set up with bond redemption upon proof of compliance with overall debris reduction objectives (similar to insurance but specifically linked to debris mitigation). Deposit-refund and performance bonds encourage self-policing in order to secure refunds or obtain lower premiums. Under any of the schemes, some revenue could be allocated to a trust fund for compensating activities affected by debris. And under those schemes, the overarching goal is to economically control debris without unnecessarily increasing the cost of accessing and operating in space.

CONCLUSION

Perhaps it is characteristic of any new frontier that a patchwork of public policy for governance and policing emerges on an as-needed basis. Such has been the evolution of space policy. In large part, it has been a story of adjudicating squatter's rights — that is, government was first in space some 50 years ago by way of Sputnik and Apollo, and now the problem is how best to accommodate and even promote the keen interest of industry in markets for space launch, telecommunications, and earth observations.

Policymaking has also been insular — another problem on an isolated frontier. Seldom have space legislators and regulators taken into account lessons learned from other policy experiences, be they the ills of price regulation, government competition, or command-and-control management.

In June 2000, President Bush asked the National Security Council and the White House Office of Science and Technology Policy to begin a review of national space policies including those pertaining to space transportation and earth observation. The reviewers do not start with a clean slate, but if they are willing to entertain new perspectives like market-based approaches and fully appreciate the legacy of innovative policy regulation, the space future looks bright. R

READINGS

- *Commercial Earth Observations Satellites,* edited by John C. Baker, Kevin M. O'Connell, and Ray A. Williamson. Santa Monica, Calif.: RAND Corp., 2001.
- *Economics and Technology in U.S. Space Policy,* edited by Molly K. Macauley. Washington, D.C.: Resources for the Future, 1986.
- "Out of Space? Regulation and Technical Change in Communications Satellites," by Molly K. Macauley. *American Economic Review,* Vol. 76, No. 2 (May 1986).
- *Preservation of Space for Near-Earth Generations,* edited by John A. Simpson. Cambridge, Mass.: Cambridge University Press, 1994.
- *Space Politics and Policy,* edited by Eligar Sadeh. Boston, Mass.: Kluwer Academic Publishers, 2002.