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Servicing satellites in space

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DARPA, NASA, and other agencies are looking at how robotic on-orbit servicing could extend the lives of satellites in space, although making such missions a reality will not be easy. Technology and cost are not the only challenges—liability, regulatory, and other issues also come into play. But despite all the complexities, many nations are showing interest in this area, and several demonstration programs are now moving forward.

Servicing satellites

by Marc Selinger
Contributing writer

U.S. governments agencies and private firms often spend hundreds of millions of dollars building and launching a single satellite. Yet for the most part, when that satellite stops working, it becomes space junk, even if some components remain functional.

In the past few decades, spacefaring nations have made several attempts to fix nonworking satellites. The most dramatic were the space shuttle crew repairs of the Hubble Space Telescope (HST). With the shuttle now retired, the U.S. and other governments have several programs under way to develop unmanned systems for servicing satellites. Chief among these is Phoenix, an effort by DARPA to salvage a retired communications spacecraft.

Satellite equipment such as an imaging sensor or a communications payload often "continues to be operational even after the satellite has run out of propellant needed to maintain its orbit," says William Ostrove, an aerospace/defense analyst at Forecast International. "If a government agency or private company could extend the life of that satellite for a few more years for a fraction of the cost of a new satellite, it could benefit them drastically."

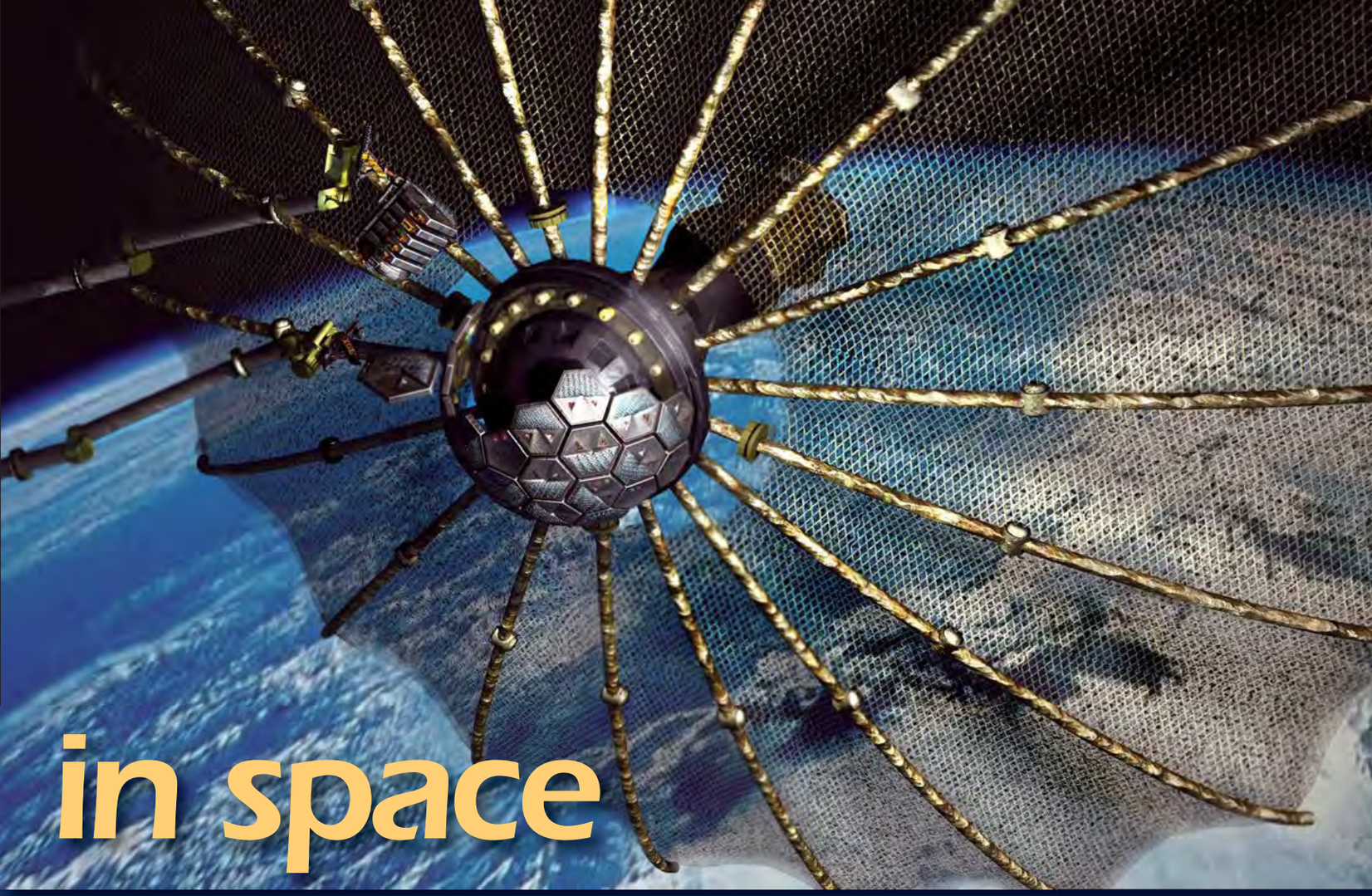
Proponents of on-orbit servicing say the urgency and value of such missions is growing, as space is increasingly crowded with nonworking manmade objects.

"A more refined consciousness of the need to reduce, reuse, and recycle here on Earth drives towards a similar awareness of these needs beyond our planet," NASA wrote in its *On-Orbit Satellite Servicing Study*, a 2010 report that captures work performed in response to a congressionally mandated study. "The proliferation of abandoned satellites poses known hazards to newer members of the constellation, and may occupy unique and economically valuable orbital real estate that could be recycled for other uses."

Risks and challenges

"Despite this interest, there is still a long way to go in developing this technology," Ostrove tells *Aerospace America*. Whether on-orbit servicing can take off remains unclear, as it faces a host of financial, legal, and technological challenges.

"It's very new and risky, and the space



in space

DARPA rendering of Phoenix.

industry tends to be conservative when it comes to adopting new technology," notes Ostrove. "Costs are another concern. They need to be kept low enough so that it will pay off to extend a satellite's life rather than launch a new one.…As with any new technology, it's hard to project costs this early in its development."

On the legal front, as the U.S. works with other spacefaring nations, it will have to address potential issues of international liability if its activities create debris that harms another satellite, according to Henry Hertzfeld, professor of space policy and international affairs at George Washington University. These liability and indemnification issues could be especially thorny if the damaged spacecraft belongs to another country and if private U.S. firms are in a partnership with the U.S. government. Current plans for future DARPA and NASA missions include such partnerships.

With on-orbit servicing, says Hertzfeld, "there's a risk that something can go wrong, and it opens up the possibility of interfering with operations in space—of our own or of others' spacecraft or equipment." Such legal and regulatory issues "can be solved, but haven't been," he says.

If countries can overcome these challenges, they still face the risk that such technology will be perceived by others as a potential weapon, even if the developers have no intention of using it for aggressive or harmful purposes. Hertzfeld cautions that "openness, transparency, notification, and understanding" are needed to "defuse that feeling and that worry" and avoid sparking an international incident.

Past efforts

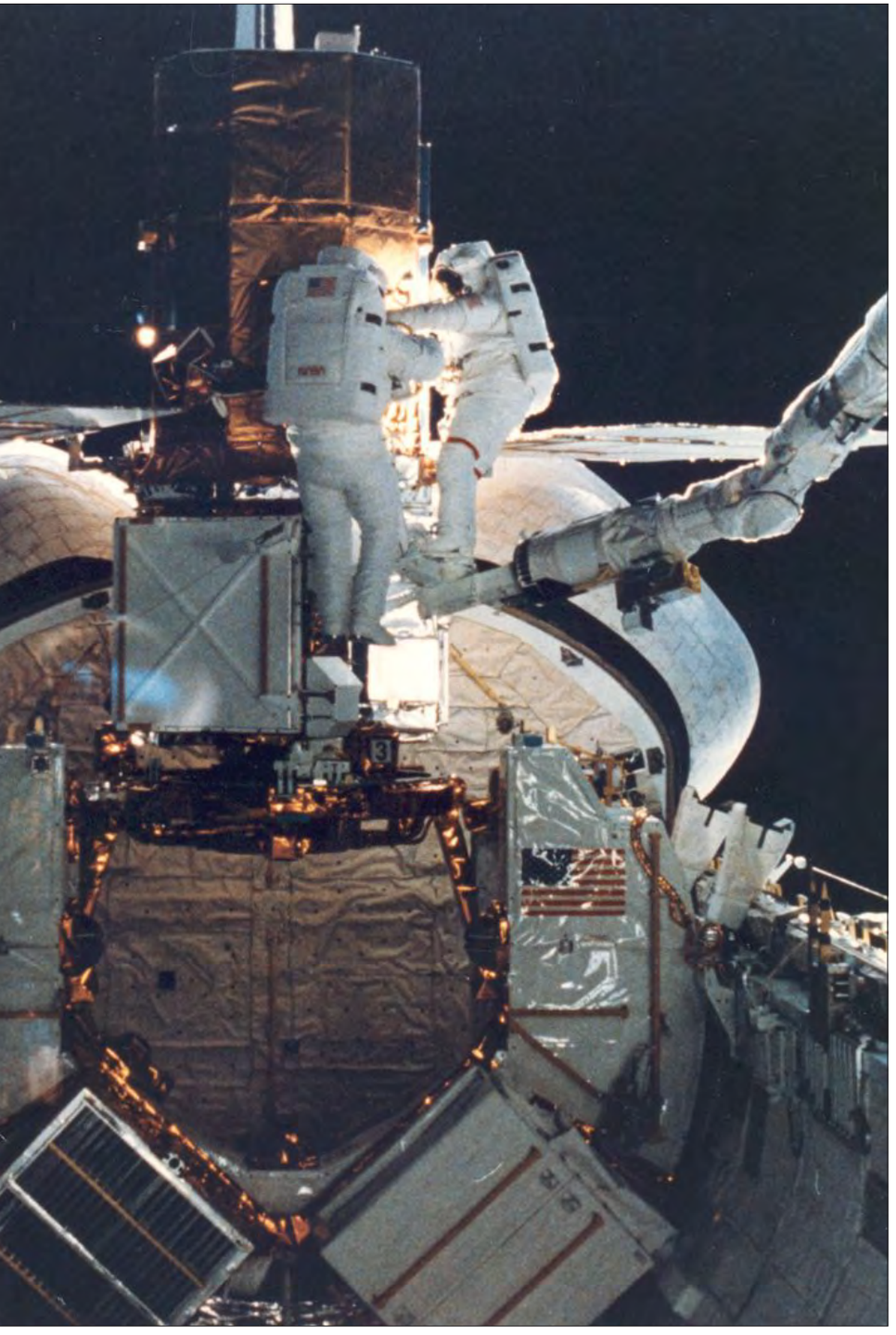
Soon after the U.S. began launching satellites in the late 1950s, it began laying the groundwork for extending their lives beyond their retirement dates. According to NASA, the Gemini program in the mid-1960s demonstrated a technology vital for satellite servicing: the ability of a manned spacecraft to rendezvous and dock with another vehicle in space. In the 1970s, a Skylab space station crew successfully performed the first on-orbit repair when it fixed a failing thermal shield on the NASA-operated facility.

In the mid-1980s, a shuttle mission repaired an ailing satellite for the first time.

The Challenger orbiter captured the Solar Maximum Mission, replaced failed parts in its attitude control system, and then redeployed it so it could continue studying solar phenomena. Another orbiter, Discovery, returned two errant satellites to Earth for refurbishing and relaunch.

Satellite servicing achieved further triumphs in the 1990s and early 2000s. The shuttle program flew five repair and upgrade missions to the HST. On-orbit construction and maintenance of the ISS became a reality. And during DARPA's Orbital Express mission in 2007, the unmanned ASTRO (autonomous space transport robotic operations) vehicle refueled and repaired a prototype modular NEXTSat (NEXT-generation serviceable satellite) in LEO.

On STS-41, mission specialists George Nelson and James van Hoften repaired the captured Solar Maximum Mission satellite.



"During its roughly four-month mission, Orbital Express provided confirmation that key technologies needed for satellite servicing are now in place," NASA says.

DARPA's Phoenix

Building on these earlier efforts, DARPA's Phoenix program aims to show it can recycle part of a defunct communications satellite in space. By 2016, the program hopes to conduct an unmanned mission to robotically remove a disk-shaped antenna, or aperture, from a nonworking satellite in a 'graveyard' or disposal orbit near GEO, which is about 22,000 miles above Earth. DARPA would then reuse the antenna to create a 'new' communications satellite.

"Today's ground-based robotics systems allow surgeons to perform telesurgery on a patient thousands of miles away, and advanced remote imaging systems used for offshore drilling view the ocean floor thousands of feet underwater," states DARPA. "These types of capabilities, if reengineered for zero gravity, high vacuum, and harsh radiation, could be used in space to allow the repurposing of valuable antennas from retired GEO satellites."

The Phoenix demonstration will kick off by launching anywhere from 10 to 50 'satlets,' small spacecraft similar to nanosatellites, as a hosted payload on a commercial satellite launch. Several different satlet prototypes no bigger than a computer laptop are in development. Designers are also working on a payload orbital delivery system (PODS) that will safely house the satlets aboard the rocket.

Launched separately will be a servicer satellite equipped with two 6-ft-long robotic arms. The servicer will capture the satlets from the PODS, place them on its 'tool belt,' remove the antenna from a nonworking satellite, and integrate the satlets with the antenna. The satlets will power and control the reborn space system, tentatively called 'ApSat.'

DARPA is reviewing retired satellites that it could 'harvest' for the demonstration and has identified about 140 candidates from the U.S. and other countries, says David Barnhart, program manager for DARPA's Tactical Technology Office. Before the agency proceeds with a mission for a

particular satellite, it intends to seek permission from the spacecraft's owner.

DARPA plans to spend about $180 million on Phoenix from FY12 to FY15, expressing confidence that it will be able to minimize the impact of defense budget cuts. If the program succeeds, in-space servicing could ultimately revive multiple retired satellites, creating a 'farm' of recycled spacecraft. DARPA believes that recycling several satellites would cost a fraction of sending up new ones.

Phoenix is a "modest effort we are attempting, to essentially increase the return on investments for DOD space missions and find a way to really change the economics so that, ultimately, we can lower the cost of space systems," Barnhart says.

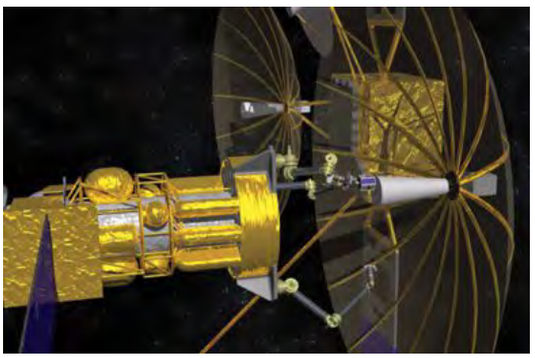
The prime integrator for Phoenix is the Naval Research Lab. For the servicer, the program will use an existing satellite bus developed by ATK, and robotic arms built by MacDonald, Dettwiler and Associates (MDA). The host of other tools now being designed include small cameras to see the mission in real time, and grippers to grasp and control the satlets and harvested aperture. A significant challenge will be severing the antenna from its host satellite while minimizing debris that could jeopardize the mission or endanger other spacecraft.

"Almost all of [the apertures] are tied [to the host satellite] via a boom of some sort—some structural element," Barnhart states. Severing parts from these will not be as easy as the team once thought, he notes, "primarily because many of the booms are carbon fiber, they're not metal, and they flex whenever you attempt to cut."

Another major challenge is that the exact condition of the decommissioned satellite will not be known until the servicer reaches it. And the Phoenix mission will not have people at the construction site, as the Hubble missions did, to handle any surprises that arise.

"If any of the [thermal] blankets are loose, or if an antenna guide wire is not intact, then Phoenix must be flexible enough to create maneuver and operations scenarios to deal with the situation in real time," Barnhart says. "Design-flexible tools and operations are key to the program's goals."

Although DARPA is busy with all these technological tasks, the agency insists it is also addressing the full range of relevant legal, policy, and regulatory issues. For example, to promote greater discussion and acceptance of responsible on-orbit servicing, it sponsored a one-day international conference, Fostering Sustainable Satellite Servicing, in June 2012 in Arlington, Virginia. DARPA described the event as "an open and honest discussion on nontechnical aspects of the new field of 'servicing' in space." The conference drew more than 130 attendees from the international space community and featured speakers from the U.S. and abroad.



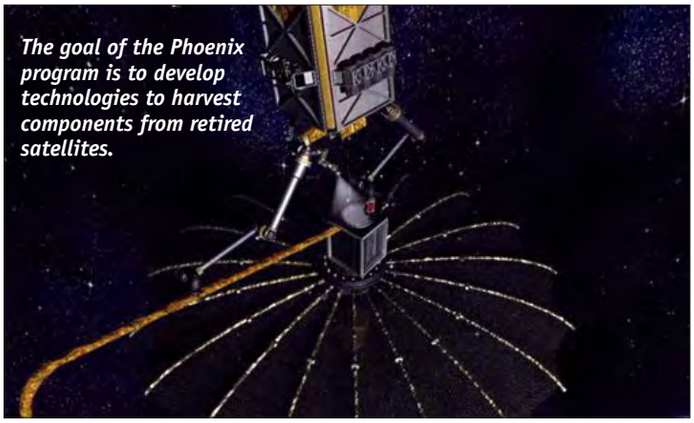
A servicer would attach a satlet to an antenna from a defunct communications satellite. Credit: DARPA.

"We're pursuing a technical demonstration….At the same time, we need the right policies and regulations in place to enable the program's successful transition" to a permanent capability, Barnhart says. "Both elements are critical."

Restore

NASA also has its eye on servicing GEO satellites, but instead of reincarnating them, it wants to make them last longer. In a January request for information, the agency asked for industry feedback on the possibility of forming a government-commercial partnership, called Restore, to demonstrate on-orbit servicing for these spacecraft.

In ground tests, a robot practices robotic refueling missions on mock satellites. Credit: NASA.



The goal of the Phoenix program is to develop technologies to harvest components from retired satellites.

"Such a capability would potentially provide life-extension servicing over a range of candidate client satellites," NASA says. Activities could include "remote survey, relocation, refueling, repair, and component replacement."

If NASA leaders give the go-ahead to pursue a full-fledged flight program, a servicing satellite could be ready for launch as early as 2017, according to Benjamin Reed, deputy project manager of the agency's Satellite Servicing Capabilities Office at NASA Goddard. For funding, however, Restore is in the running with other compelling programs, Reed acknowledges.

"As with all program new starts, we are subject to any number of external forces out of our control. Regardless, we'll have the technology ready when given the green light from NASA planners," Reed explains. "There are lots of important things that NASA's doing. This is but one of many."

The Restore spacecraft (right) services a "client" satellite. Credit: NASA.

For example, the agency is developing and testing technologies to prepare for a potential Restore flight program. With the Canadian Space Agency (CSA), NASA demonstrated the ability to robotically refuel satellites that were not designed to be serviced in space. During the Robotic Refueling Mission test, which occurred in LEO aboard the ISS in January, controllers at NASA Johnson used the station's two-armed Dextre robot to cut wire and remove seals covering a fuel receptacle on a box-shaped mock satellite; next, a nozzle tool with an integrated hose transferred fuel-like fluid to the receptacle, which was then resealed.

Upcoming tests aboard the station could demonstrate the ability to replenish a satellite's coolant robotically, says Reed. Equipment to prepare for the exercise was launched aboard a Japanese unmanned resupply spacecraft, H-II Transfer Vehicle 4, this August.

If Restore becomes a flight program, the leading industry participant will serve "not as a prime contractor, but as a partner who would co-invest with the government." Together these partners would create a mission to demonstrate on-orbit servicing, Reed says. The goal is to stimulate the rise of a "domestic, competitive satellite-servicing industry" to routinely maintain on-orbit satellites for both government and nongovernment customers.

The GEO environment

More than 400 commercial and government satellites in GEO are potential candidates for servicing. "We want to prove to the world that it can be done out in GEO," says Reed. "The advantage of GEO, of course, is that there's a whole slew of satellites all parked right next to each other. You don't get that in LEO," he notes.

Although NASA is developing new manned spacecraft, astronaut missions outside a space vehicle are not currently an option in GEO because of high radiation levels. "The radiation environment in LEO is manageable," Reed explains. "Ditto for the Moon. But in between, at GEO, the radiation level is significantly higher—so much so that technology doesn't presently exist to allow humans to remain on station for the time necessary to perform a servicing mission. Of course, robots don't have such constraints. We are designing the electronics to be able to withstand that environment, so they can stay out there for years and years."

Although astronauts could operate mechanical arms from inside a spacecraft—an approach NASA refers to as "man in a can"—the agency concluded it would cost less to keep people on the ground.

International efforts

The U.S. does not have a monopoly on satellite-servicing ambitions. The CSA and MDA are conducting ground tests of a new mechanical arm to see if it could be used to capture a satellite floating in space, according to Jean Claude Piedboeuf, CSA's acting director general for space exploration. "We are not planning to fly it right now," says Piedboeuf of this Next-Generation Canadarm. "It's something we are considering." The device is the newest version of the Canadarm that was deployed on the shuttle and is currently in use on the ISS.

The German Aerospace Center (DLR) plans to launch a robotic spacecraft called DEOS (German Orbital Servicing Mission) in 2018. DEOS will rendezvous with and capture an ailing spacecraft in LEO for one of three potential missions: deorbit the defective satellite so it can burn up as it reenters Earth's atmosphere, put it in a satellite graveyard in space, or prolong its on-orbit life if it can be repaired or refueled.

A mock satellite is kept in a temporary location aboard the ISS before it is moved to an external platform for a robotic refueling test. Credit: NASA.

EADS Astrium, the project's prime contractor, says it expects to brief DLR on the results of the current program definition phase, roughly in late October.

"To a large extent, DEOS is reliant on technologies that have not yet been tested for space operations," the company says. "In the definition phase, therefore, initial prototypes of the key technologies will be developed, so that subsequent realization of the project can progress swiftly." A