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UAV sector faces sweeping changes
On-orbit servicing: The new focus

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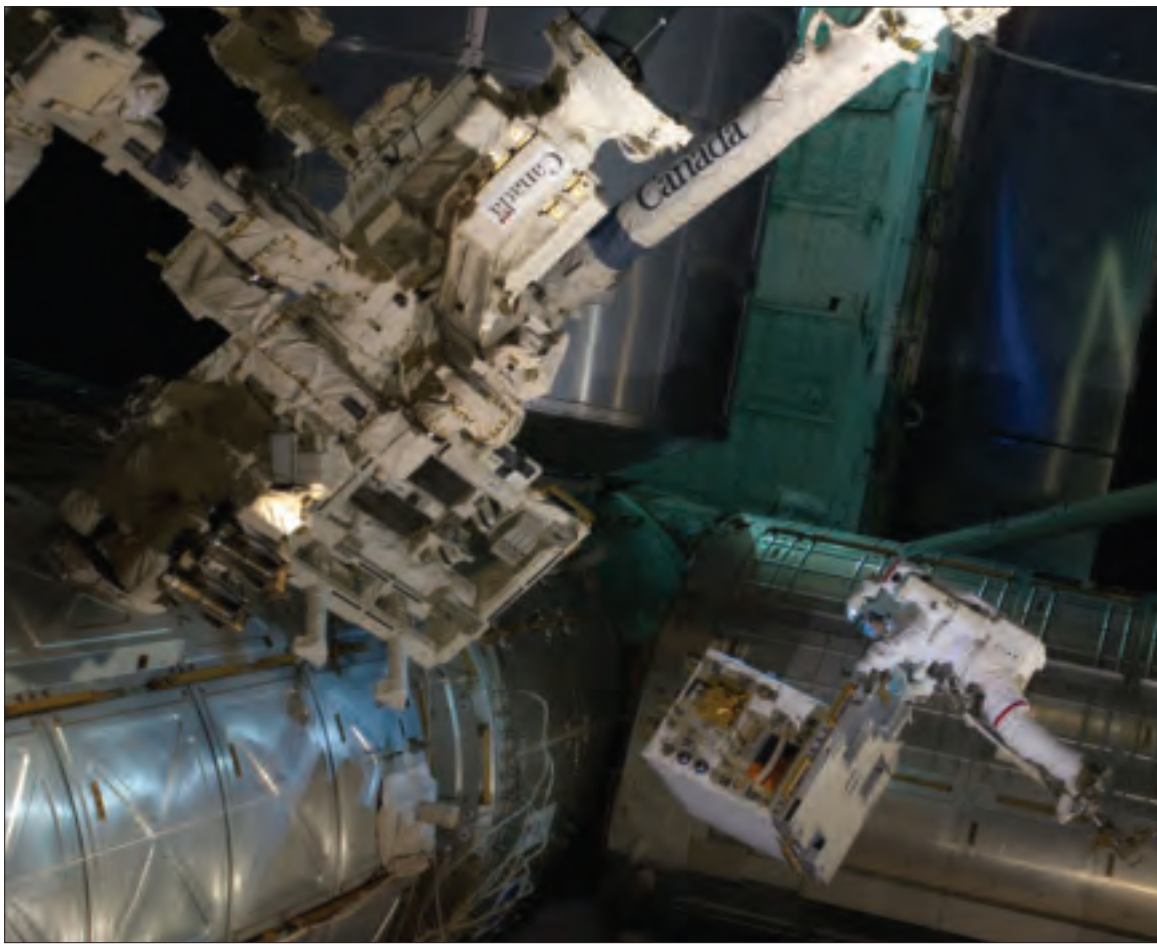
On-orbit servicing

From the moment the first operational satellite went into orbit, the user community began looking for ways to keep their initial investment viable beyond the life expectancy set by the manufacturer. Even more important, they wanted a way to recover a satellite that failed to reach its designated orbit, failed to deploy solar panels or antennas, or malfunctioned in other ways.

However, the concept of on-orbit satellite servicing—from refueling to component replacement—has faced serious obstacles, from the first platform design to the difficult tasks of locating, identifying, approaching, and 'snagging' a target satellite to actually performing on-orbit maintenance-level tasks never envisioned.

"We've been involved in satellite servicing since the late 1970s. In those days, some satellites were designed to take ad-



On July 12, 2011, spacewalking astronauts Mike Fossum and Ron Garan successfully transferred the RRM module from the Atlantis cargo bay to a temporary platform on the international space station's Dextre robot. Image credit: NASA.

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The new focus

Concepts for on-orbit satellite repair and maintenance have been progressing, along with the tools and technologies for carrying them out. Despite the complexity and high costs, companies are moving forward to pursue these capabilities. Their development is potentially quite profitable, say proponents, and could bring significant savings for users, investors, and insurers.

vantage of two things: first, the space shuttle being able to grab onto the Solar Max, for example, with a robotic arm; and second, astronauts being able to then go out and change out modules to restore the health and full operational capability of the satellite," Frank J. Cepollina, associate director of the Satellite Servicing Capabilities Office (SSCO) at NASA Goddard, tells *Aerospace America*. "That was first done in 1984.

"We did it with a variety of other satellites in the following years, including an emergency repair of the Compton Gamma Ray Observatory before it was ever released from the shuttle. Those all required various forms of tools that we gave the astronauts. And all those tools evolved as a function of being able to tell the astronauts they did not have to expend as much energy and muscle, because they had microprocessors and power systems to do the work. Instead, they needed to expend intellectual insight into the operation of those tools."

Until the shuttle was retired in mid-2011, leaving the U.S. with no way to send astronauts to perform hands-on satellite repairs and maintenance in LEO, the tools used for such efforts continued to evolve.

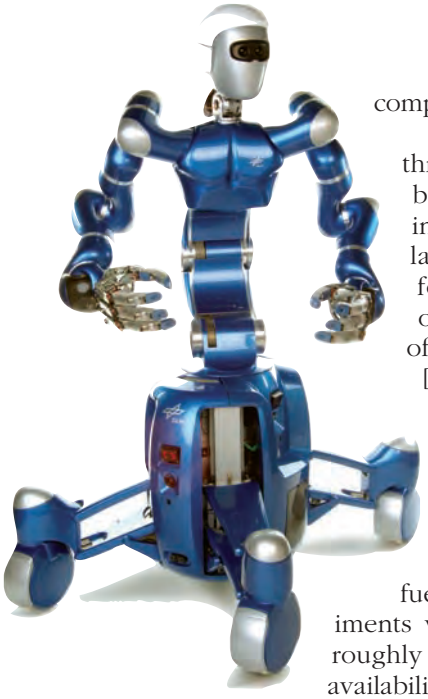
"That was especially true with the Hubble repair missions—five of them from 1993 through 2009. By the time we were doing the fifth mission, the tools had evolved to the point where they had become semi-autonomous. We did eight days' worth of work in five days on that final Hubble mission, thanks to ever-evolving robotic capability on the tools," Cepollina adds.

"And now that continues with the robotic refueling mission—RRM—where the tools basically have evolved from that last Hubble mission to our experiments aboard the ISS in 2011. And now ground control robotics operators at JSC [NASA Johnson] are watching their monitors here on Earth and operating these tools in space."

Remote experiments

The RRM uses robotic tools to work with a 1-m^3 module outfitted with typical satellite ports, interfaces, connectors, even thermal insulation blankets used to maintain the proper temperatures to protect sensitive

by J.R. Wilson
Contributing writer



Justin, the German Space Agency's humanoid robot, will be aiding development of DEOS, the Deutsche orbital servicing mission.

components for optimum performance. "What we are doing is going through the exercises, in a telerobotic fashion, of refueling, changing gas ports, cutting MLI [multilayer insulation] blankets, and so forth. We've already started some of those...and will start another set of tasks from July through October [2012]," Cepollina says.

"The robotic operators will be on the ground, with vision systems on our individual tools, to validate that we can repair and refuel satellites that were never designed to be repaired or refueled in space. That series of experiments will last about 14 to 18 months, roughly through mid-2013, subject to ISS availability schedules."

NASA's RRM project also builds on Orbital Express, a 2007 joint effort by DARPA and NASA Marshall, using spacecraft specially built by Boeing Integrated Defense Systems and Ball Aerospace & Technologies. Boeing's ASTRO (autonomous space transport robotic operations) servicing satellite was launched into the same orbit as Ball's NEXTSat (next-generation satellite), a prototype modular spacecraft designed to dock with and be serviced by the ASTRO.

Other players, other concepts

NASA's is not the only satellite servicing concept in development. Some believe this area may become a major business opportunity for decades to come. Among the international players are the German Space Agency (DLR), with its government-sponsored Deutsche Orbital Servicing Mission (DEOS), and Canada's MDA (MacDonald, Dettwiler and Associates), which is taking a purely commercial approach for its Space Infrastructure Services unit.

ViviSat uses ATK's Mission Extension Vehicle to safely connect to an orbiting satellite to provide attitude and propulsion capabilities without disrupting the client satellite's operation.

MDA and its anchor customer, Intelsat General, the world's largest commercial satellite fleet operator, declined requests to be interviewed. But ViviSat, the leading U.S. commercial competitor, went into considerable detail about its plans for servicing satellites in geosynchronous Earth orbit.

A joint venture of Alliant Techsystems (ATK) and U.S. Space, ViviSat was created in 2011. The business plan promotes "satellite life extension ser-vices, [to] change the way satellite operators make decisions by giving them better performance, higher return, and more flexibility in deploying capital and timing of assets."

"The time is right for this," says retired Air Force Maj. Gen. Craig Weston, president and CEO of both ViviSat and U.S. Space. He is speaking of ViviSat's plan to provide on-orbit servicing to both commercial and government customers. ATK's role draws on its years of experience with robotics and precursor technologies, while U.S. Space provides management expertise and financing.

Gradual approach for ViviSat

While agreeing that the Hubble repairs provided both foundation and proof of need for on-orbit servicing, ViviSat and NASA have significant differences of opinion—and approach.

"ATK has been looking at satellite servicing since 2007 and trying to determine the best way to enter the market, what the technology risk is, and what the future is. We decided we needed to take a low-risk marketing entry position to establish the market in a sort of crawl-walk-run mentality," says Tom Wilson, vice president and general manager of ATK Spacecraft Systems and Services. "And that is the thinking that went into the design of our mission extension vehicle, which is based on proven technology that has been flown many times.

"That, we believe, will establish the marketplace, and the feedback we have gotten from both commercial and government markets is that it is a low-risk approach. We do have visions of doing refueling and robotic repair in the future, but we are perfectly happy to let the government take the risk on that now, which is what DARPA is doing in terms of robotic repair or morph-

ing in space, and NASA's emphasis on refueling using robotic arms. Those have not been flown in orbit and are more complex, but we are partnering with them to see those developed for future insertion into our fleet. In the meantime, we can get going with systems that are proven."

NASA's robotic emphasis

ViviSat's approach is to dock with a target satellite, then use its own onboard fuel, rockets, and electronics to handle the problems of aging or improper deployment in GEO. NASA, after a similar rendezvous and dock, instead is looking to refuel the target satellite and replace or repair its original components. This process, says Cepollina, is not limited to GEO but can be performed on spacecraft in any orbit.

While not mentioning ViviSat specifically, Cepollina says a piggyback approach, taking over rather than fixing the target satellite, "does not fulfill all the objectives of repair and replacement, but we are looking at all possibilities. I can't go into it any more than that, because it is part of the RFI [request for information] currently on the streets. We're looking for all kinds of different commercial ideas and partners."

However, he adds, "if you are going to have a repair truck in orbit, a level of sophistication I'm thinking about, you must have a broad robotic capability across the board—relocation, fueling, repair, replacement. And the robotic part is just as important as approach, rendezvous, and grapple."

In November 2011, NASA issued a new RFI "to gather market research to assist NASA in developing strategies for supporting the development and dissemination of on-orbit robotic servicing capabilities for existing and future spacecraft, particularly including strategies involving collaboration with private domestic entities that leverage the government's existing intellectual property, technological resources, and expertise in this area. NASA does not intend to establish a government-operated on-orbit satellite servicing capacity, but rather to foster the creation of a domestic capability which may meet both future government and nongovernment needs."

That RFI is the latest in SSCO's congressional mandate to advance the use of robotics in space.

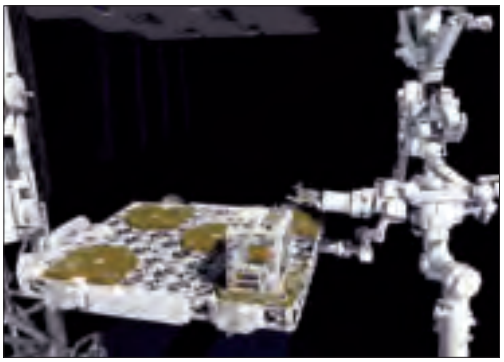
Current focus

NASA's near-term focus, building on Hubble repairs and the Orbital Express experiment, is on telerobotic and semiautonomous servicing of existing satellites.

"History taught us some very important, consequential lessons about the value of on-orbit servicing, such as that of the Hubble Space Telescope."

Frank J. Cepollina

"We broke that down into two areas: One is [to] approach, rendezvous with, and grapple systems never designed to be grappled (or even approached), and all the technologies to design meaningful experiments by which one could overcome" the lack of grapple fixtures on those satellites, Cepollina says. "Second is the ability to do the robotic manipulations on the spacecraft once it is captured—cut blankets and safety wires, remove ground-based installed fuel caps, connectors, and plugs.



In this artist's concept, the ISS's Canadian Dextre robot (right) approaches the RRM module (center, mounted to platform) with an RRM tool (above module). Image credit: NASA.

"So we're really evolving forward to a future where we will need to go to locations where humans currently are not present—such as GEO and L-1 orbits—and conduct repairs, in some cases adding new scientific instruments and capabilities. The objective is to push robotic maintenance technology forward as much and as fast as possible."

NASA's own statistics would seem to support ViviSat's focus on GEO, where Cepollina says nearly a quarter of the satellites have run out of fuel while still otherwise mission-viable, and another 20% or so were put into the wrong orbit or attitude.

"In the past decade, on average, 8.5 spacecraft a year have gotten into trouble because of contaminated fuel systems and were unable to fire their thrusters to maintain their orbits or orientations. And we have to be able to deal with these kinds of failures," he says.

Continuing evolution

Technological evolution is the key concept for NASA, which sees future developments

The Dextre robot transferred and installed the RRM module onto its permanent home on the international space station on September 2, 2011. RRM will remain on the station's ExPRESS Logistics Carrier-4 during its two-year window of operations. Image credit: NASA.

in satellite servicing as coming from a long history, moving from manned shuttle missions to a future in which robots do the job where astronauts cannot, or where humans and robots can work together.

"I see it as a natural evolution of space transportation, of humans operating in space, of our ability eventually to even do human/robotic surgery in space," Cepollina says. "Consider an astronaut who has been in space for six months and is still that far away from Earth, but needs an appendectomy. The astronaut could be operated on by an onboard robot, aided by a surgeon on Earth. Consider it part of our ability to take care of humans on long interplanetary trips."

ViviSat has no problem with NASA pursuing more advanced technologies—which even the agency acknowledges are years from operational use—but believes their own approach will more quickly respond to a current and immediate need.

"We believe there is a viable market today for life extension of satellites about to run out of propellant, and for a next generation of on-orbit servicing that will get into more complex operations, such as repair and removal of modules," Weston points out. "That's where the government taking the lead can buy down the risk much more rapidly than commercial industry can. So that's where DARPA and NASA can help commercial servicing take a leap forward, by accelerating the next phase of servicing."

As with most space programs, the same contractors often are on both 'teams.' MDA and the Canadian Space Agency, for example, are working closely with NASA on its ISS-based experiments, in which Canada's Dextre, a two-armed robotic telemanipulator, plays a crucial role. Elsewhere aboard the space station, DLR's humanoid robot Justin will be furthering the development of DEOS, which Germany hopes to have in operation in 2015.

"Both technically and financially, on-orbit servicing is disruptive; but being disruptive is not always bad, especially in space, if you can bring a new business concept to life."

Maj. Gen. Craig Weston (USAF, ret.)

A less optimistic view

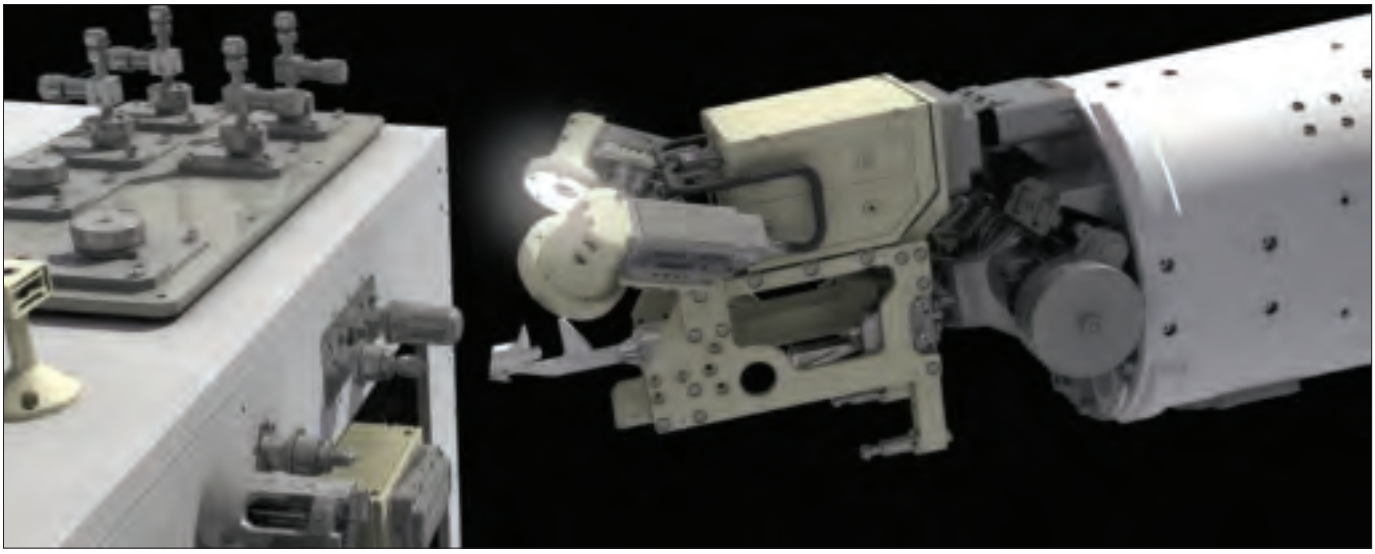
Even as those and other satellite servicing concepts move forward, however, not everyone believes they are practical, either as a commercial venture or as an option satellite manufacturers and launch service providers are likely to embrace.

The CEOs of Europe's Astrium Satellites and Thales Alenia Space and of the U.S.'s Orbital Sciences all have been quoted as saying the technology required is too complex and expensive for a commercial venture to be practical. Even if they can overcome those obstacles, MDA may face an unexpected problem with what previous comments by the company and Intelsat indicated would be a critical customer: the U.S. military.

DOD satellites are among the largest and most expensive in orbit, which made the possibility of extending their useful lives or recovering those lost or crippled by launch problems seem a certain proposition. However, at SATCON 2011 in November, Col. Michael Lakos, chief of the USAF Military Satellite Communications Systems Directorate, said the plan faces two major problems: Tight budgets and new satellite technologies.

Lakos told the conference it would be hard to convince DOD to support a new (and still experimental) program when existing programs are losing funding. That is especially true, he added, when the military's telecommunications satellites are being replaced by the new AEHF and Wideband Global Satcom system fleets, making servicing of existing satellites irrelevant.

Another threat to the commercial programs may be the NASA and DARPA efforts, which leave private industry hard pressed to compete. With a renewed emphasis on dealing with U.S. contractors, the Canadians could be shut out of future competitive bidding.



In this artist's concept, cameras light the way as an RRM tool approaches the RRM box to cut wire—one of the steps to accessing a satellite's triple-sealed fuel valve. Image credit: NASA.

Prospects for success

ViviSat officials, meanwhile, have said they will enter any competitions with a U.S.-based proposal that does not require extensive new R&D. But, they add, the success of their business will not depend on government contracts.

ViviSat also dismissed most of the other arguments against both the viability of a commercial venture and the approach the company is taking to on-orbit satellite servicing. Wilson, for example, says they have been working with GEO satellite manufacturers and operators, including the U.S. government, and have determined the designs of the spacecraft are such that "we can dock with about 80% of the more than 300 satellites up there now without difficulty. And that is more than enough to warrant this venture.

"We chose the backpack approach because the fill-and-drain valves and end caps were not designed to be taken off after 10 or 15 years in orbit," says Wilson. "And NASA is spending dollars to figure out that problem while we establish the marketplace with this docking-based system," he adds, responding to one of the major questions raised about the NASA approach.

All of the satellite servicing proponents also are working to gain the support of the insurance companies that serve the satellite industry. Saving a satellite that failed to achieve its proper orbit could save insurers billions of dollars in the next couple of decades. At the same time, industry officials have questioned the value of saving satellites with outdated technology.

"This is a tough financial investment market, so at this point a lot of satellite operators are trying to avoid new capital expenditures. One obvious way is to maintain existing satellites in orbit, even if they are technologically outdated," Weston replies. "There also is an emerging group of companies that acquire aging satellites and relocate them to serve underserved markets. In that case, a 70 or 80% solution, extended in its mission by a package such as ours, could be very valuable."

Looking ahead

Whether by 'grapple-and-repair' or 'dock-and-recover,' Cepollina believes on-orbit servicing is both an inevitable development—with future implications far beyond simply saving Earth-orbiting satellites—and one that ultimately will be up to private industry to advance and maintain.

"First and foremost, NASA is in the business of being the technology innovator to take us forward. But we're not in the commercial satellite business—nor should we be in the commercial satellite repair business. We're about demonstrating a technology to a point where it becomes extremely useful, and industry can step up and take over," he says.

"There are first-time things that are so risky and what I call venture-tech oriented that, in fact, somebody like NASA needs to take the lead. And that's what we're doing with RRM and other activities, whether human or robotic or a combination. And there are step-off points where there is important gain, and important commercialization potential, that would give the commercial community a belief that they can go up there, and do so in a way that will enable them to really profit from it."