Engineering 5 (2019) 607–608

Contents lists available at ScienceDirect

Engineering

journal homepage: www.elsevier.com/locate/eng

News & Highlights

Space Trash Removal

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March 2019 saw the culmination of the RemoveDEBRIS satellite mission, which demonstrated a set of technologies that could one day help address the problem of space trash. This burgeoning collection of debris in low Earth orbit is inching toward a crisis that threatens to make the region of space within 2000 km of the Earth's surface very difficult to use.

The US Department of Defense estimates that there are some 500 000 pieces of debris, or space trash, in low Earth orbit, including about 23 000 objects larger than a grapefruit that the agency tracks with ground-based instruments [1]. As rocket launches continue and the number of satellites placed in orbit grows, the chance that these objects could collide—and thereby create even more debris in a dangerous cascade effect known as the Kessler syndrome [2]—is putting current, new, and replacement satellite deployments at risk.

The world's major space agencies agree that orbital debris is a serious issue. Studies by the Inter-Agency Space Debris Coordination Committee indicate that mitigating the creation of new debris is critical to the future of orbital missions, as is the removal of debris already in place [3]. Another study by the US National Aeronautics and Space Administration (NASA) concluded that five to ten of the largest debris objects—dead satellites ranging in size from a refrigerator to a city bus—would have to be removed every year just to stabilize the growth in space debris [4].

However, only a small number of pieces of debris have ever been removed from orbit, due to challenges both technical and economic in nature. "There's actually a handful of ideas that make sense for how to go up and remove space debris," but not much interest to date in funding missions, said Brian Weeden, the director of program planning for the Secure World Foundation, a Broomfield, Colorado-based organization focused on promoting peaceful and sustainable uses of outer space.

The European Space Agency (ESA) has put the most effort into developing and testing active debris removal technologies as part of a larger program called Clean Space that the European Commission has funded since 2012. "Europe is a little more forward thinking on these sorts of environmental issues," Weeden said.

RemoveDEBRIS was sponsored by the European Commission and is its most notable active debris removal project so far. Other active removal technologies being evaluated by the ESA include a satellite bearing a robotic arm that can grab onto debris and drag it into a lower orbit where it will burn up in the atmosphere and a satellite-mounted conical net that opens up and clamps down on derelict satellites [5,6]. Other space agencies are exploring the use of ground-based lasers to ablate the leading edges of defunct satellites and other debris, causing the objects to slow down and re-enter the atmosphere [7].

The RemoveDEBRIS spacecraft was designed and built by an international consortium of aerospace companies and research institutions, including Airbus, Surrey Satellite Technology, Ltd., CSEM (Switzerland), Inria (France), ISIS (the Netherlands), Stellenbosch University (South Africa), and the Surrey Space Centre at the University of Surrey (United Kingdom), which led the project. Ferried to the International Space Station (ISS) aboard a SpaceX Falcon 9 rocket in April 2018, the 100-kilogram RemoveDEBRIS experiment platform (Fig. 1) was designed to test four decidedly nautical-sounding debris-removal technologies: a net, a navigation system, a harpoon, and a drag sail [8].

In June 2018, the Canadarm2 robotic arm on the ISS positioned the RemoveDEBRIS mission into orbit. Three months later, RemoveDEBRIS released a shoebox-sized satellite. This "cubesat" drifted outward 7 m and inflated a set of sails in order to increase its overall size to one-meter across. RemoveDEBRIS then shot out a five-meter-diameter net that encapsulated the cubesat [9]. Over the next months, the net slowly increased the drag of the cubesat, dropping it into the Earth's atmosphere where it burned up in March 2019.

Fig. 1. The RemoveDEBRIS satellite, the largest ever deployed from the ISS, is moved into an airlock by NASA astronaut Ricky Arnold. The satellite successfully completed three out of its four missions to test technologies for removing debris from orbit. Credit: NASA/NanoRacks.

https://doi.org/10.1016/j.eng.2019.07.010

RemoveDEBRIS then released another cubesat in December 2018 and closely tracked the spinning object through space with an onboard, vision-based navigation system consisting of a set of two-dimensional cameras and three-dimensional lidar technology [10]. This test demonstrated that the navigation system could be used in future missions to track debris in space in order to target it for removal.

For the third stage of its mission, which occurred in February 2019, RemoveDEBRIS released a ping-pong paddle-sized aluminum target supported by a carbon-fiber boom deployed by the satellite. The satellite then fired a pen-sized titanium harpoon into the target at 20 $m \cdot s^{-1}$ and reeled it back in (Fig. 2) [10].

One month later, the RemoveDEBRIS spacecraft deployed its paper-thin, polyester sheet drag sail [10]. The hypothesis was that the 10 m^2 sail would catch residual air molecules at the satellite's 400 km altitude, ultimately slowing the satellite down and accelerating its descent into the Earth's atmosphere. Due to design constraints, the sail was unfurled on the one side of the spacecraft that was out of view of its onboard cameras. Observations from the ground indicate that the spacecraft's orbital trajectory has not changed significantly, and its solar panels are still receiving full sunlight, suggesting that the sail likely did not fully deploy. So, for now, the result of the last experiment remains uncertain.

Regardless, Guglielmo Aglietti, director of the Surrey Space Centre, said the mission was successful on multiple fronts. "As for the technical aspects, we have demonstrated that these methods can work in space," he said. "The behavior of anything in space is a bit different from what you get on the ground, so for us to see how certain things actually behaved in orbit was an important learning exercise and will contribute to designing the next missions."

Another accomplishment of the mission was increased public awareness of the space debris issue. "This is important," Aglietti said, "because at the end of the day if missions to clean space are to be funded through governments or national space agencies, having favorable public opinion clearly will help."

And while most of the RemoveDEBRIS demonstrations worked, they were somewhat limited, Weeden said. "There is still quite a long way to go," he said. "I would hope that other governments—China, Japan, Russia, and the United States—will fund their own technology demonstrations to further this sort of research."

There also remains the possibility that the space debris problem could be tackled—perhaps in part—commercially. Some of the RemoveDEBRIS industrial partners are looking into making a business out of this, Aglietti said.

"Airbus is examining options relating to active debris removal, including techniques in addition to those proven in the RemoveDEBRIS project," said Alexander Hall, a mission systems engineer for Airbus, in an e-mail. "A decision is currently being made as to whether active debris removal is a viable commercial business model, specifically in relation to the increasing number of mega constellations entering into service."

Meanwhile, with the outcome of the drag sail experiment pending, RemoveDEBRIS has ironically become—at least for the time being—another piece of space trash.

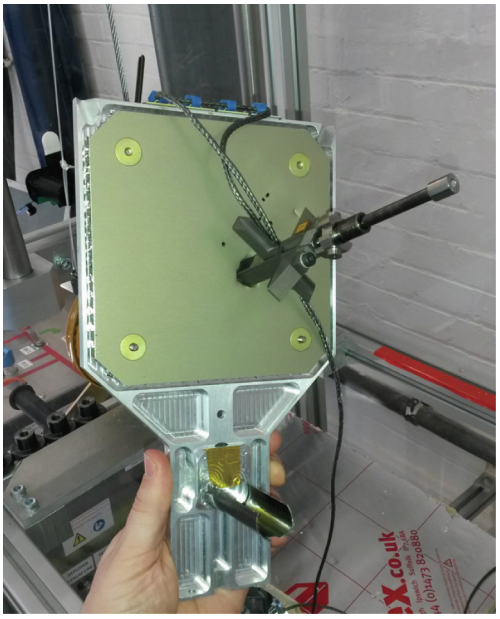

Fig. 2. The RemoveDEBRIS satellite's "space harpoon" was designed to skewer and reel in pieces of orbiting space junk. Here, during a ground-based test, the harpoon's design was tested on an aluminum ping-pong paddle-like panel similar to the one used in the orbital test mission. Credit: Airbus/The RemoveDEBRIS Consortium.

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