PATHFINDER

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GROUND-BASED LASERS IN SPACE OPERATIONS

Statistical estimates of space debris objects in Earth orbital environment: 29,000 objects >10 cm diameter; 750,000 objects from 1 cm to 10 cm diameter; 166 million objects from 1 mm to 1 cm diameter.

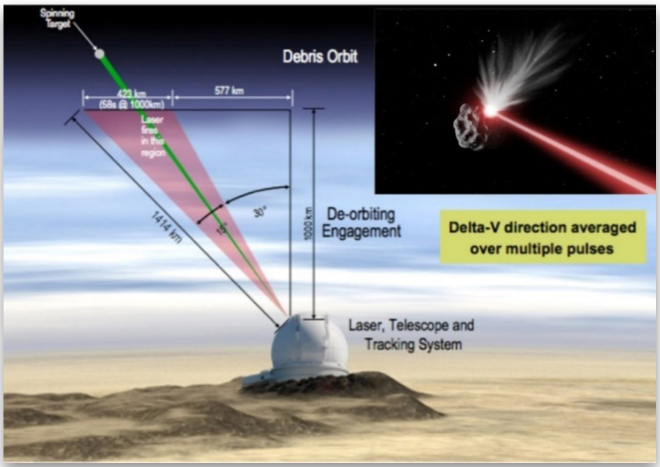
Space Debris by the Numbers, European Space Agency, 2017

For many people space remains a largely unexplored and empty final frontier but the current amount of space debris that encircles the Earth reflects that our own space 'backyard' is anything but empty. With the use of space-based systems increasing, there is an urgent need to clean-up the Earth's environs and this Pathfinder explores some of the recent innovations to achieve greater utility of space.

An increasing number of states are recognising that unhindered access to space and the protection and correct functioning of their space-based systems are critical to national security. A state's ability to control and influence activities in space through either terrestrial-based, ground-launched, or orbiting systems provides a significant advantage over an adversary's use of space.

Space traffic needs to be actively managed by the monitoring of uncontrolled space debris to limit the risk to orbiting space systems and to avoid orbital collisions. If debris is stable in preferred orbit location, satellites cannot be deployed into that orbital location which, in turn, adds to the overall congestion. In the past decade, protocols have been adopted to reduce the introduction of new debris into orbit.

A significant step towards mitigating the risks to Australian and allied space capabilities from space debris was made with the development of Australia's space situational awareness (SSA) capabilities. These capabilities include the ability to detect, locate, and track debris as the first step in addressing the problem of space debris. (*Pathfinder 273*, September 2016). The solution lies in developing the ability to remove the debris safely and economically.



Laser ablation of space debris by ground-based laser system.

Many countries are conducting research to develop innovative terrestrial and space-based solutions to reduce the quantity of orbital debris. One potential solution to this challenge is to employ a ground-based laser to detect and remove small space objects through a process known as 'laser ablation'. Laser ablation involves a skyward laser transmission of microwave energy that is powerful enough to melt and erode parts of the space debris, slowing its forward momentum. The thermal heating, by the laser, also breaks down the chemical bonds within the illuminated material and causes particles to be ejected from the object in the form of gas. The action of the separated gaseous matter being ejected from the object contributes to the deceleration of its momentum. With an adequate number of ablation events, the object could be slowed sufficiently to make it descend to a lower altitude orbit and when the object descends to an orbital height below about 200 km, it will be captured by Earth's gravity and burn up on re-entering the atmosphere. Initial research activities have focused on the laser ablation of very small orbiting debris, which only require the use of low-cost lasers using low levels of laser energy.

However, the use of lasers for space debris removal also presents a number of safety and security challenges.

The use of lasers for small object detection is preferred because the wavelength of the laser is shorter than the radio wavelengths used in radar systems, making it possible to combine the functions of small object detection, tracking and ablation into a single system. Laser ablation works by pointing and focusing a laser on an orbiting object when it is flying overhead; the energy that is focused on the object is at a maximum when it passes directly overhead at the closest point of approach to the laser ground site. The object has to be tracked in order to keep the laser energy pointed steadily at the moving object for a long enough period to generate enough heat for the illuminated material to breakdown. Maximum efficiency of the laser transmission is achieved when weather and atmospheric conditions are favourable and the orbiting object is not tumbling or reflective. With these conditions the object can be irradiated with adequate energy to cause material to breakdown and be ejected as gaseous matter.

However, uncontrolled domestic and scientific use of skyward-pointing lasers may inadvertently cause 'visual interference' and create a safety hazard for air and space activities. Aircraft and satellites might inadvertently fly through a laser emission. Microwave-energy lasers operate on frequencies that are not visible to the naked eye. Whilst the short time taken for a moving platform to cross a skyward pointing laser might not cause any damage, it could disrupt electro-optical sensors; while laser emissions in the visible spectrum might cause hazardous windscreen glare and/or flash blindness to aircrew.

The US Federal Aviation Administration (FAA) regulations for *Outdoor Laser Operations*, provide a good model for controlling laser operations based on priority being given to considerations of safety of aircrew and aviation operations. If the beam originates from below the FAA's minimum altitudes for controlled flight, the FAA stipulates that the laser operator must exercise due regard and is responsible for managing the hazards introduced into the airspace that are associated with the laser operation.

FAA airspace regulations aim to protect aircrew and systems operating in the navigable airspace up to 60,000 feet. Powerful lasers that, if pointed above the horizon can reach space, are being increasingly used for terrestrial purposes (eg science, communications, range finding). The US Department of Defense policy requires that the operation of all US Defense lasers be 'conducted in a safe and responsible manner to protect space systems, their effectiveness, and humans in space'. The Laser Clearinghouse is a division of the US Joint Space Operations Centre and is tasked to make predictive assessments, de-conflicting hazardous laser operations, and air and space missions. The deliberate pointing of a laser that can ablate or damage a space object needs to be assessed for the potential damage that spill-over radiation could potentially cause to space missions passing inline behind the target.

The Australian Civil Aviation Safety Authority (CASA) enforces similar regulatory requirements to those of the FAA. CASA centrally regulates the safe operation of lasers and high-intensity lights for the "protection of pilots against accidental laser beam strike" Accordingly, CASA requires laser operators to centrally register their laser activities with CASA.

In addition to this operational challenge, there are a number of strategic considerations that need to be taken into account in developing and fielding laser tracking and ablation systems. Countries with interests in space may view the development and utility of powerful laser systems for space debris removal as a potential threat to their space capabilities. A laser system that is employed for space debris removal should be designed for purpose and operated with transparent intent. Other countries need to have confidence that it is being used appropriately and for the benefit of the global space user community. This is normally achieved by using lasers with an energy level that is adequate to damage small-sized debris objects but which is safe for larger satellites and their on-board mission systems, and by sharing the results of the laser operation to support space object tracking.

As the space debris problem continues to increase, there will likely be more laser ablation systems operating in new locations around the world, increasing the probability of laser emissions spilling over. As air and space power continues to be used to respond to varied situations in different locations around the world, expeditionary units will be forced to share the air space with skyward pointing lasers.

Key Points

- *Changing the orbits of space debris will complicate space object tracking and require the space situational awareness mission to update object tracks, and orbital collision predictions more frequently.*
- *Using a ground-based laser to deliver kinetic effects on space debris represents a cross-domain activity that requires planners in multiple domains to be cognisant of collateral damage risks to other air and space activities.*
- *Although the laser direction and emission levels are controlled, it may cause interference or damage to objects passing through the beam in front of the object or in the beam spill-over behind it.*

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