Making space traffic running more smoothly: Laser technology for satellite identification and debris nudging

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Introduction

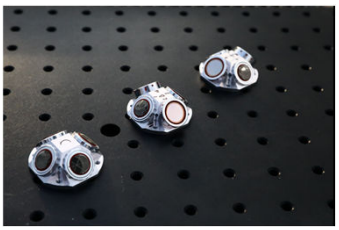
Laser-optical innovations offer the potential to facilitate space traffic management and to support efforts for space debris mitigation and remediation. This poster provides an overview of key applications: laser ranging for improved collision avoidance, satellite identification, and laser momentum transfer.

DLR Johannes Kepler Observatory for space debris research (Image: DLR)

Retroreflectors for satellite identification

Polarimetric satellite laser ranging (e.g., implemented at compact laser-optical ground stations such as the mini-SLR®) can simultaneously determine precise orbits and identify satellites equipped with retroreflectors.

Applications:
- Identification of satellites, e.g., after cluster launches
- Precise orbit determination
- Monitoring of decommissioned satellites



Left: CubeSat compatible, space-qualified retroreflector arrays (Image: DLR)
Right: Compact and transportable satellite laser ranging station mini-SLR® (Image: DLR)

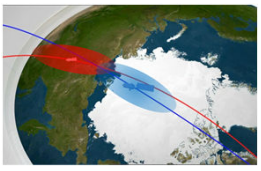
Laser-based Tracking for Reliable Collision Alerts

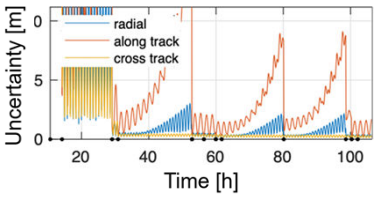
Laser-based tracking of space debris decreases the prediction uncertainty and false alert rate of collision warnings.

Technology specifications:

- Solid-state Nd:YAG lasers
- 50 W average power
- Nanosecond pulses
- 0.1 – 1 kHz pulse frequency
- λ = 532 / 1064 nm (green / infrared)

LEO satellite trace under twilight conditions (Composite image: DLR)





Left: Collision probability from covariance overlap (Image: ESA / DLR)
Right: Covariance evolution in laser tracking (Black dots: measurements, Image: TU Munich

Further reading:

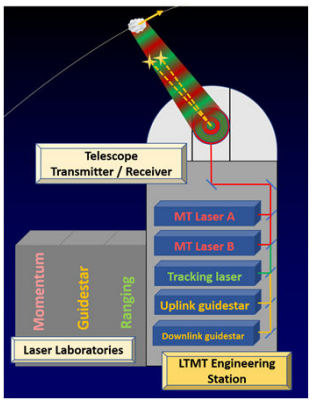
1. S. Scharring et al., LARAMOTIONS: a conceptual study on laser networks for near-term collision avoidance for space debris in the low Earth orbit, *Appl. Optics* **60**, 31 (2021).
2. N. Bartels et al., Space object identification via polarimetric satellite laser ranging. *Commun Eng* **1**, 5 (2022).
3. E. Cordelli et al., Ground-based laser momentum transfer concept for debris collision avoidance, *J. Space Saf. Eng.* **9**, 4 (2022).

Laser Momentum Transfer (LMT) to Space Debris

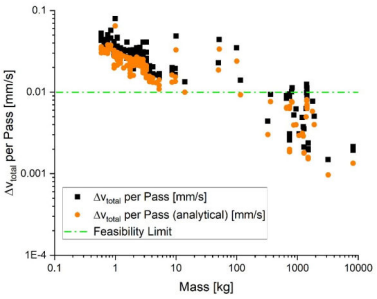
Laser-based momentum transfer to space debris by photon pressure can avoid collisions by shifting debris objects on their trajectory.

Laser specifications:
- High-power fiber lasers
- 2 beamlines, coupled
- 40 kW average power
- λ = 1070 nm
- Superior beam quality: $M^2 < 1.5$

Transmitter specifications:
- 2.5 m aperture
- Coudé path
- 300 adaptive mirror segments
- 2 laser guide stars
- 0.1” tracking precision
- 0.01” beam pointing precision



Hybrid station for laser tracking and momentum transfer (Image: DLR)



Simulations on velocity change from high-power laser irradiation (Image: DLR)

ESA LMT Studies

This work:
- LARAMOTIONS (conceptual), funded under contract no. 4000127148/19/D/CT

Ongoing:
- OMLET (“Orbit Maintenance via Laser Momentum Transfer”): Hybrid station, phase A/B1
- Adaptive optics
- In-orbit verification