INTERNATIONAL
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Space Traffic Management

The IAF initiative

Status of Working Group #3.4.1

Future operations

Spacetugs, IOS, IOM, IOR

Speaker: Roberto Opromolla

Special Session

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Membership

WG#3.4.1

- 14 people
- 4 Continents
- 9 Countries

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Introduction – What is IOS?

The term **In-Orbit Servicing (IOS)** refers to a large variety of in-orbit operations involving physical contact or very close proximity motion between two or more space vehicles.

- **Supply of services** to already existing space assets (e.g., refueling, repair)
- **Assembly** of modular parts into functional aggregate structures (e.g., future Lunar Gateway)
- **Fabrication** of components in space
- Use of **Spacetugs** for orbit correction, relocation, debris removal

IOS is strictly linked to other STM aspects, e.g., debris removal, human in orbit operations, space surveillance.

Economic impact of commercial IOS

The execution of IOS missions has the potential to provide several benefits to customers, e.g.,

- volumes and launch costs reduction;
- preservation or improvement of satellite performance,
- possibility to ensure a sustainable use of outer space.

Several recent market studies have highlighted that IOS is projected to become a **multi-billion-dollar market** driven by the continuous growth of LEO and GEO commercial activity.

SERVICE NAME
Life extension Station keeping
Refuelling
Deorbiting
Salvage & recycling
Relocation (incl. Deployment)
Robotic manipulation (Orbital replacement units, P/L maintenance and repair, inspection, satellite upgrade)
In-orbit-assembly
In-orbit-manufacturing

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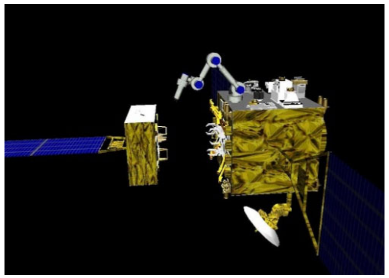
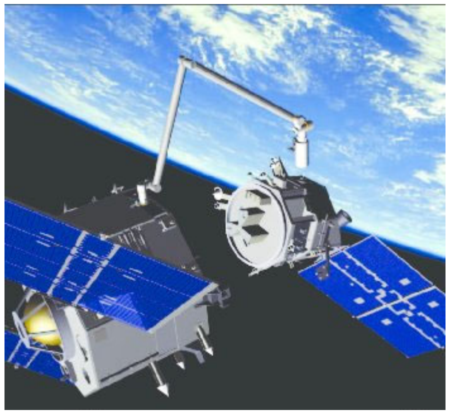
IOS technology: state of the art

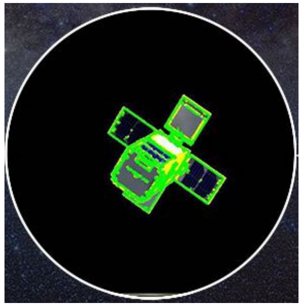
ROTEX (DLR) 1993



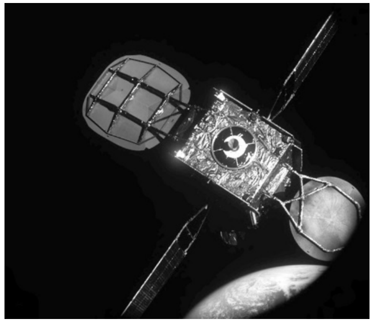
ETS-VII experiment
(JAXA) 1997



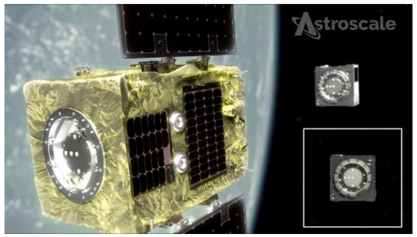
Orbital Express Advanced Technology
(DARPA) 2007



RemoveDebris
(SSTL) 2018



MEV-1 and MEV-2
(Northrop Grumman)
2019, 2020



Elsa-D
(Astroscale) 2021

- **Mission Robotic Vehicle, Northrop Grumman (2024)**
- **Clear Space 1, ESA (2025)**

IOS technology: open challenges

Autonomous Guidance, Navigation and Control (GNC)

- Guidance → design of safe trajectories for monitoring/approaching/capturing, CAM planning.
- Navigation → ensure algorithmic robustness against illumination conditions and fast relative dynamics.
- Control → capability to deal with highly non-linear multi-body dynamics (e.g., attitude control of the stack).

Modularity

- Definition of standard payloads and interconnectors/interfaces (e.g., fluidic, electrical, mechanical).
- Design challenges to avoid introducing additional structural mass which can negatively impact the total life-cycle cost of a spacecraft and its scientific return.

Propulsion systems

- Transfer of propellant and other consumables.
- Identification of most convenient solution depending on mission requirements.

Other aspects

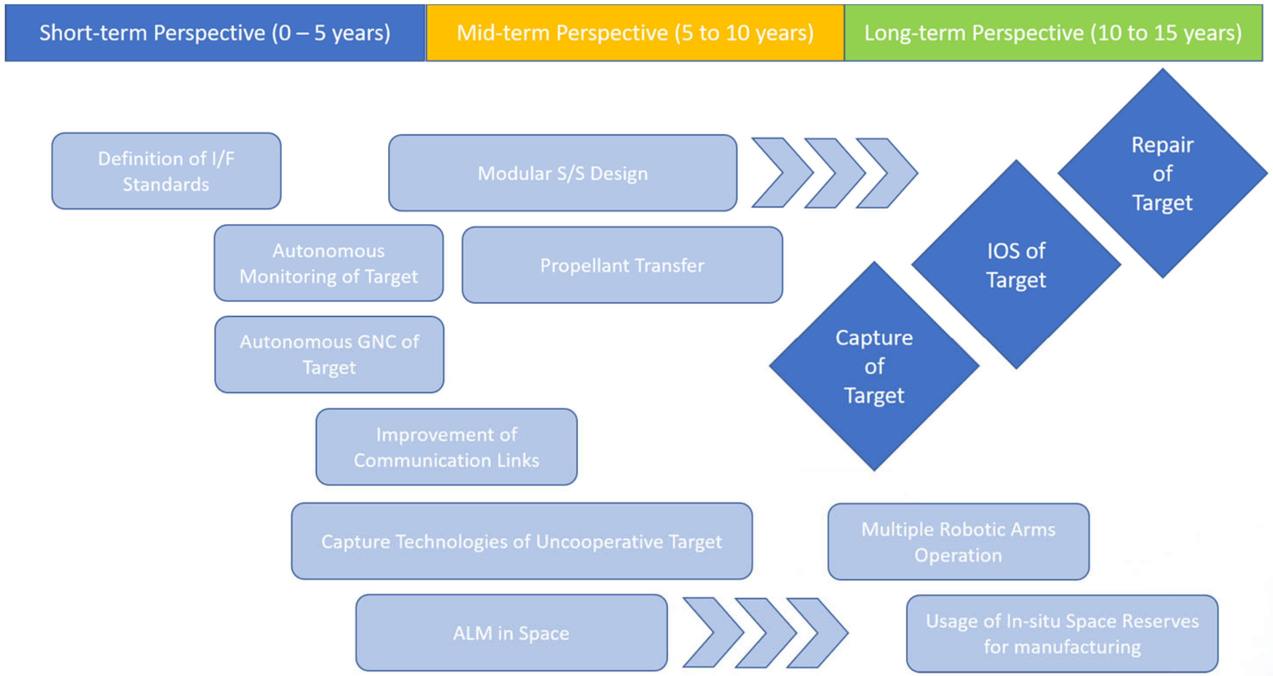
- Improvement in communications infrastructures to support IOS operations in real time.
- Low gravity effect on 3D printing capabilities.

Next steps and recommendations

- Definition of standards and the execution of missions to demonstrate critical technological advancements are expected as a <u>short-term result</u>.

- Technology consolidation, including modular spacecraft design, is expected as a <u>mid-term result</u>.

- The possibility of servicing operations to become routine, the fabrication and assembly of aggregate structures also exploiting products manufactured in orbit is expected as a <u>long-term result</u>.



<u>Technology developments cannot be decoupled from the respective regulatory issues and coordination mechanisms to correctly place IOS into the global STM framework</u>.

Connecting @ll Space People