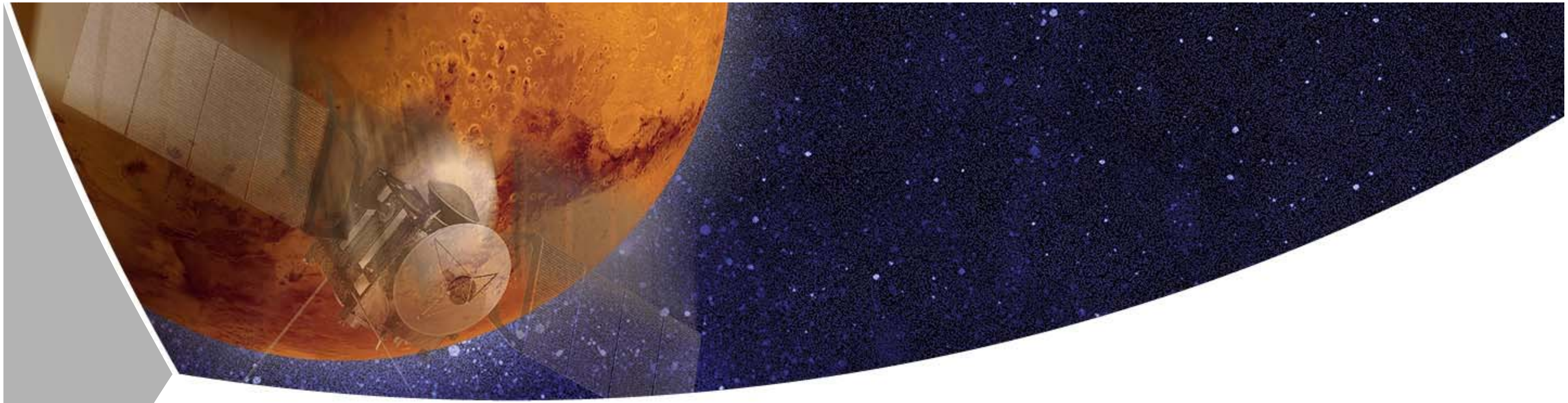


# Deutsche Orbitale Servicing Mission

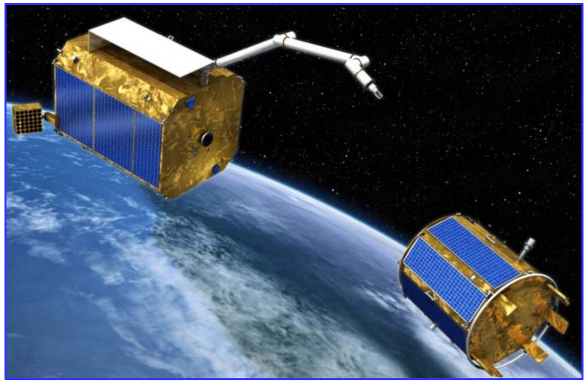
## The In-flight Technology Demonstration of German's Robotics Approach to Dispose Malfunctioned Satellites


**Thomas Wolf**

**Space-Administration of the German Aerospace Center (DLR)**

# Aspects to run through

Phase B study – On the way to a Preliminary System Design Definition



Research Team / Industrial Partners

DLR, STI, OHB SYSTEM, KAYSER-THREDE, JENOPTIK, iFR, vH&S, EADS astrium

- Introduction and Mission Statement
  - Mission Architecture and Operational Concept
    - Video Excitement
      - Conclusion

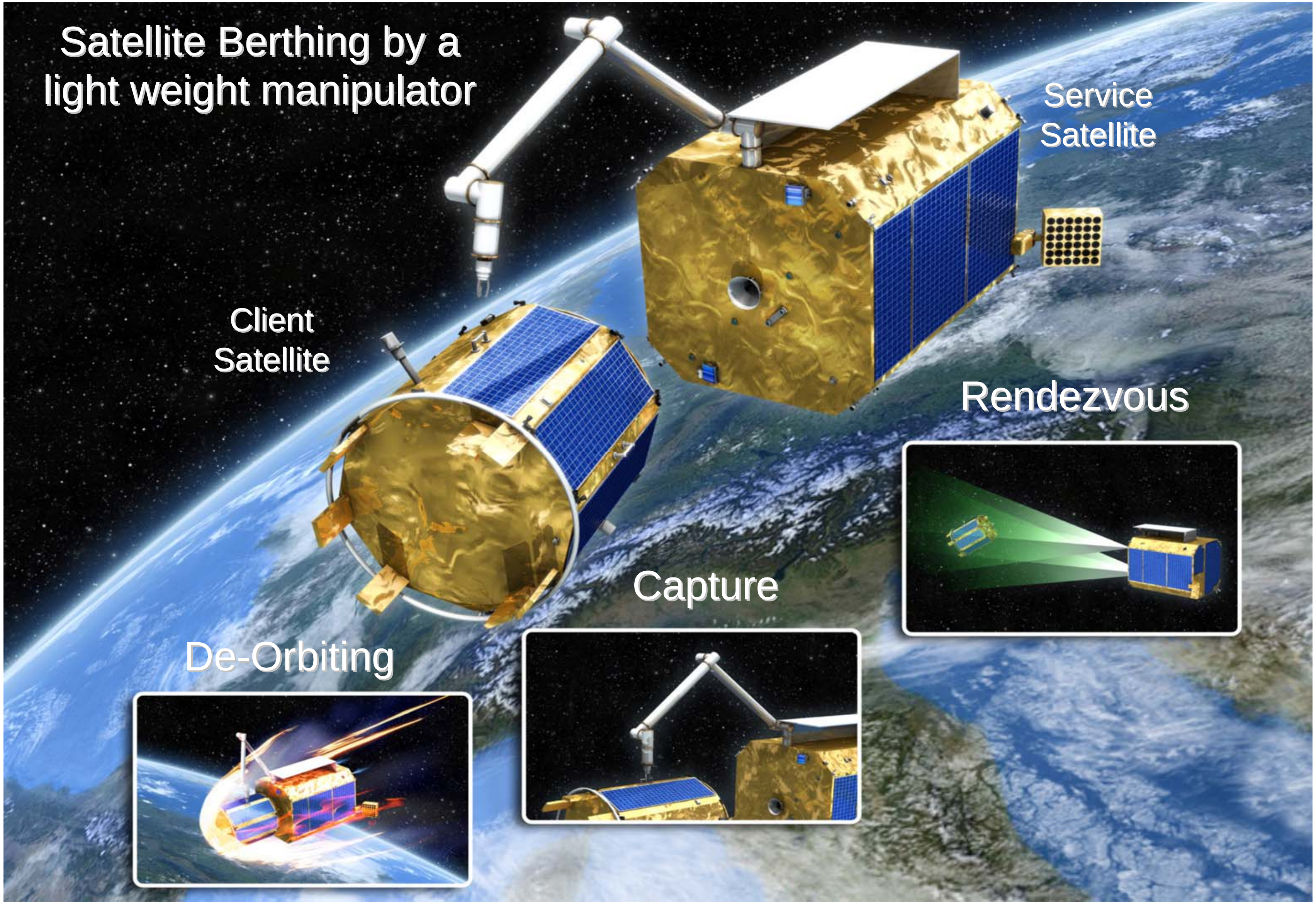
1) The DEOS project is performed on behalf of the Space Agency of the German Aerospace Center DLR funded by the Federal Ministry of Economy and Technology within the framework of Germany's National Space Program.

# Aspects on Saving and Securing Malfunctioned Satellites

- Nowadays **hundreds of satellites populate** the Earth **orbits**
- Although **satellites should** by definition [IADC] be able to **remove themselves** from their orbits, **many don't** because of a malfunction or lack of fuel.
- For *maintenance, repair or refueling* satellites must be captured in a safe and secure way avoiding any damage during the process.

- The **German approach** to serve, secure and de-orbit uncontrollable satellites is based on a robotic agent concept, a sufficient **servicing satellite equipped with at least one manipulator**.
- These aspects are of major interest within the scope of **DEOS** (**Deutsche Orbitale Servicing Mission**), Germany's on-orbit servicing satellite concept, to find and evaluate procedures and techniques for rendezvous, capture and de-orbiting of an uncontrollable satellite from its operational orbit

# Aspects on Saving and Securing Malfunctioned Satellites



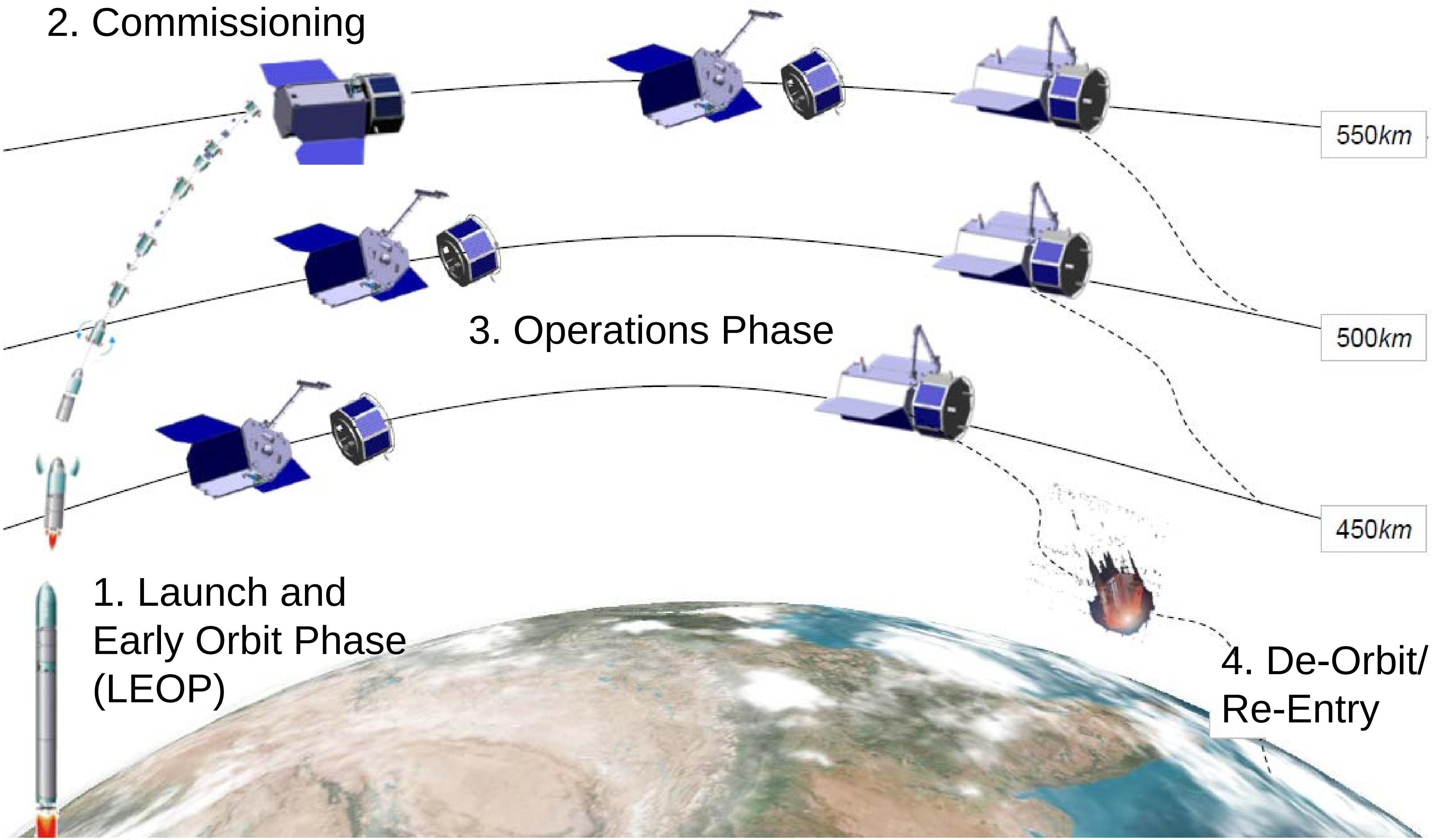
# The Mission Statement and his Objectives

1. **Capturing of a tumbling, non-cooperative satellite** using a manipulator mounted on a free flying service-satellite

2. **Demonstration of a servicing application**

3. **De-orbit of the captured satellite** within a pre-defined re-entry corridor

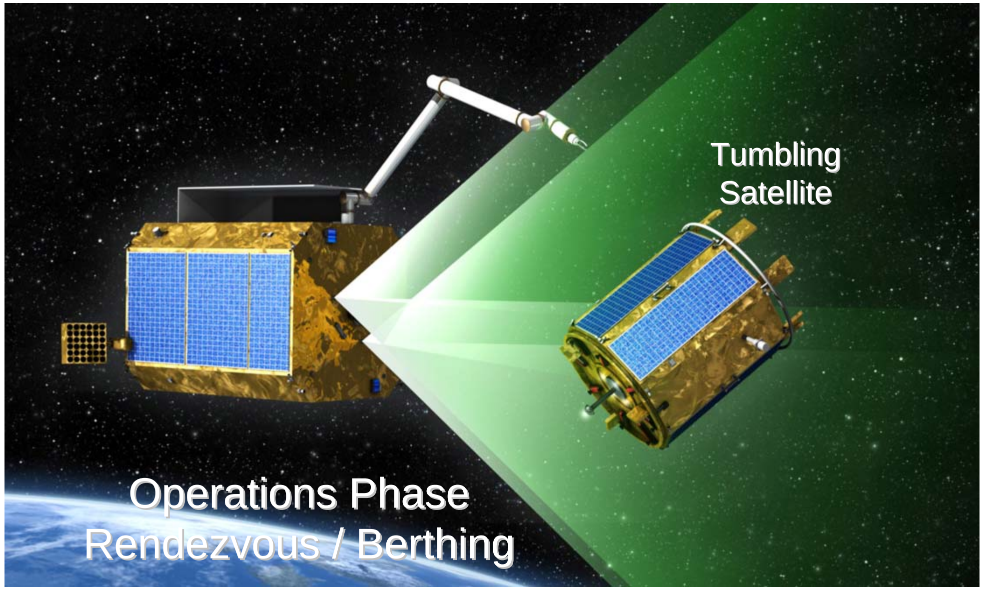
# The Operational Phases of the Mission

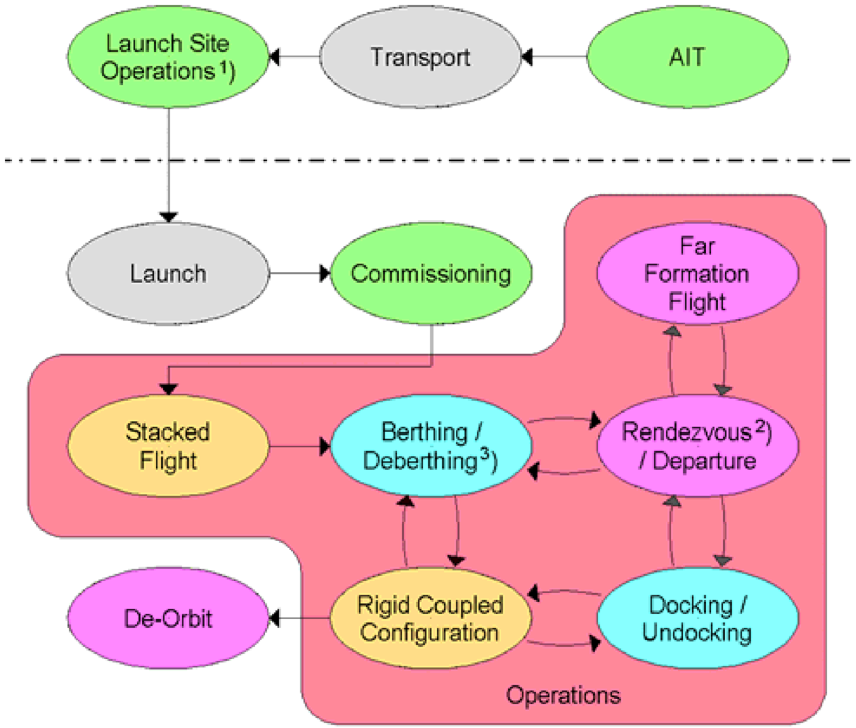


# The Operational Phases of the Mission

The Mission is divided into **four** standard **operational phases**:

- Launch and Early Orbit Phase (LEOP),
- Commissioning Phase,
- Operations Phase and
- De-Orbiting / Re-Entry Phase.



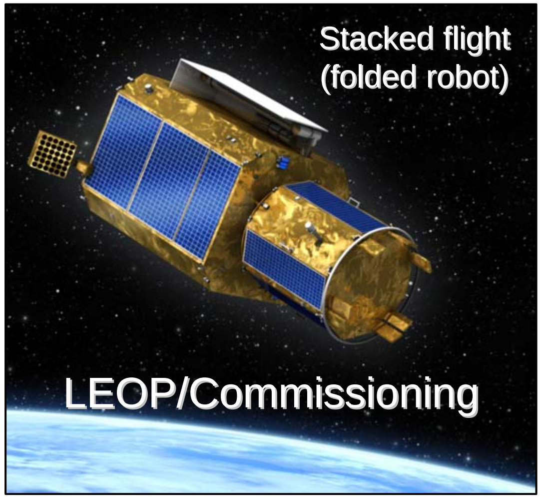




1 ) = Conditioning & Test, Installation on Launcher, Pre-Launch Preparation
2 ) = Phasing, Far Range Rendezvous, Close Range Rendezvous
3 ) = including Dynamically Coupled Configuration

# LEOP and Commissioning

- A *stack configuration* is chosen for launch
- Both satellites are *rigidly connected* to each other to inject both together into the initial orbit on one launcher

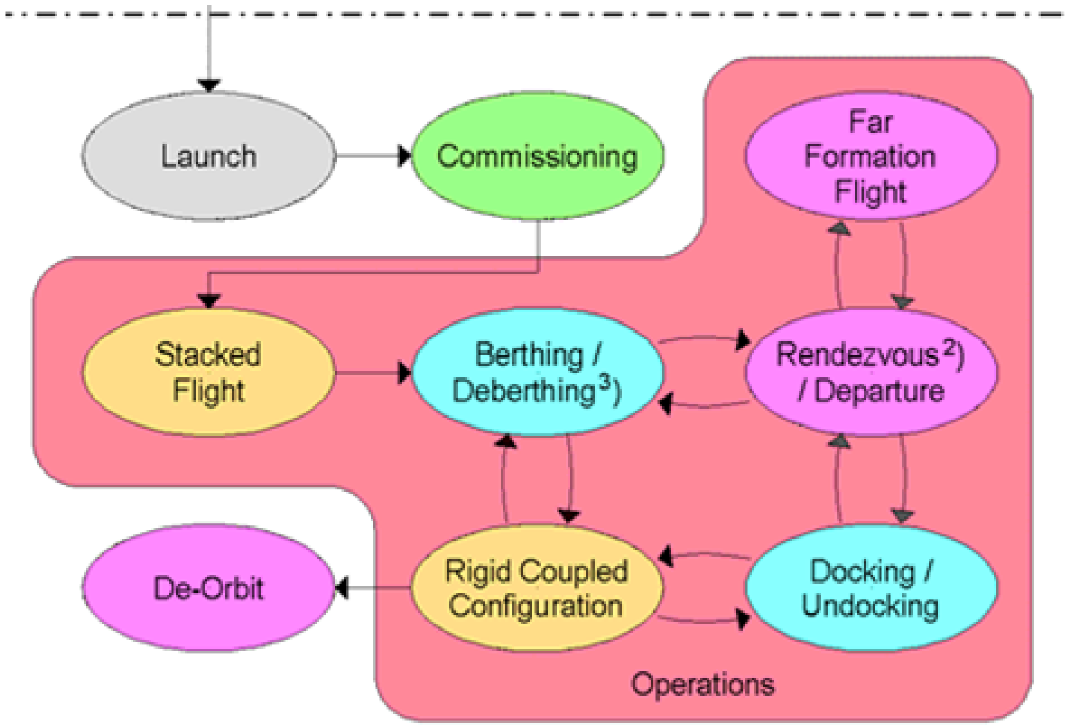
| Parameter | Values |
|---|---|
| Initial Orbit | **550 km** |
| Inclination | **85° … 90°** |
| Eccentricity | **0** |




- The *near polar inclination* offers variable illumination conditions over the life time for the planned complex demonstration program
- The Commissioning after LEOP *is conducted* in stacked configuration

# The Ambitioned Demonstration Program

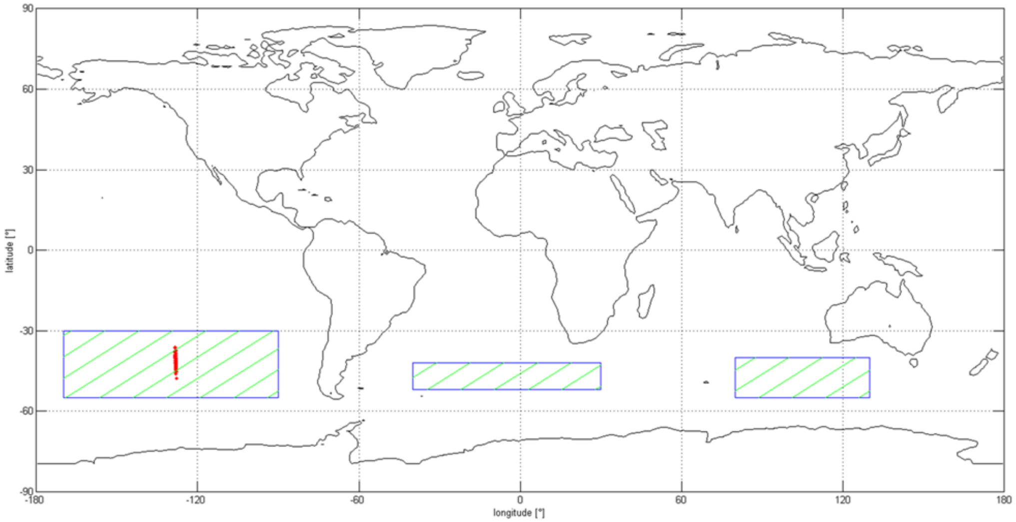
- During *De-Berthing* the Client shall be moved by the manipulator to a safe releasing position
- A departure maneuver moves the Servicer out of the close range of the Client
- The Servicer has to *find* and *navigate* towards the Client up to a *safe parking position*
- During *Berthing* the tumbling Client shall be grappled by the manipulator system

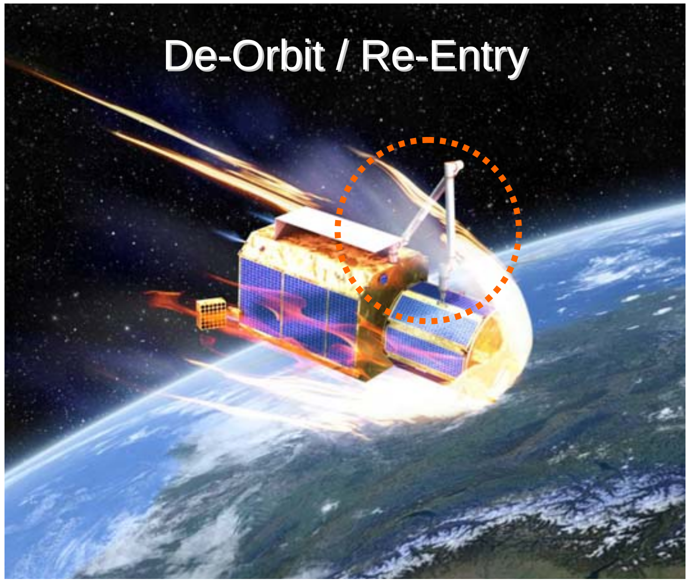



1) = Conditioning & Test, Installation on Launcher, Pre-Launch Preparation
2) = Phasing, Far Range Rendezvous, Close Range Rendezvous
3) = including Dynamically Coupled Configuration

## *De-Orbit / Re-Entry*

- a *re-entry corridor* shall be predefined to demonstrate controlled De-Orbiting
- at the beginning both spacecrafts shall be *rigidly coupled* using the manipulator system
- during re-entry spacecrafts shall *disintegrate* into smaller peaces which should *burn up* in the Earth atmosphere



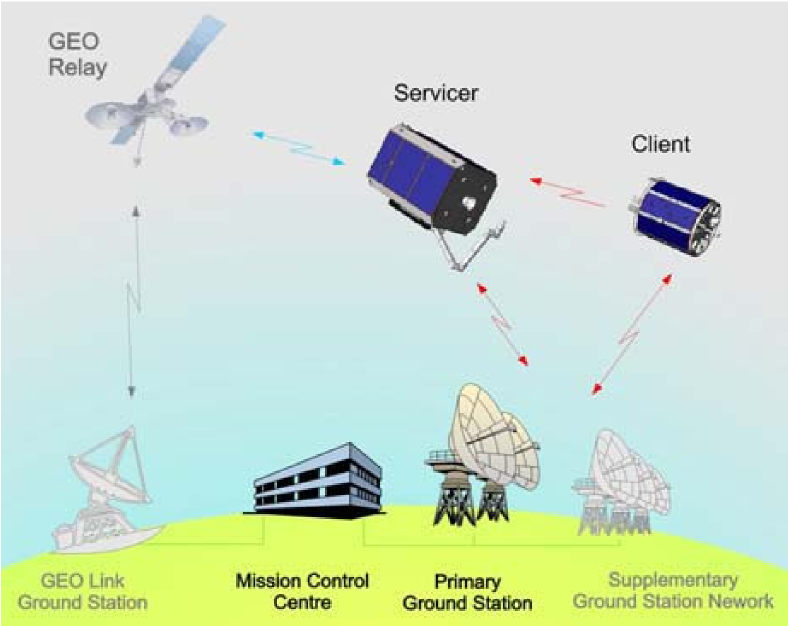



# The Mission Architecture and Operational Concept

**Servicer operations** will be planned and **initiated from ground** but shall be **performed autonomously** when ever possible.

Ground Control Modes

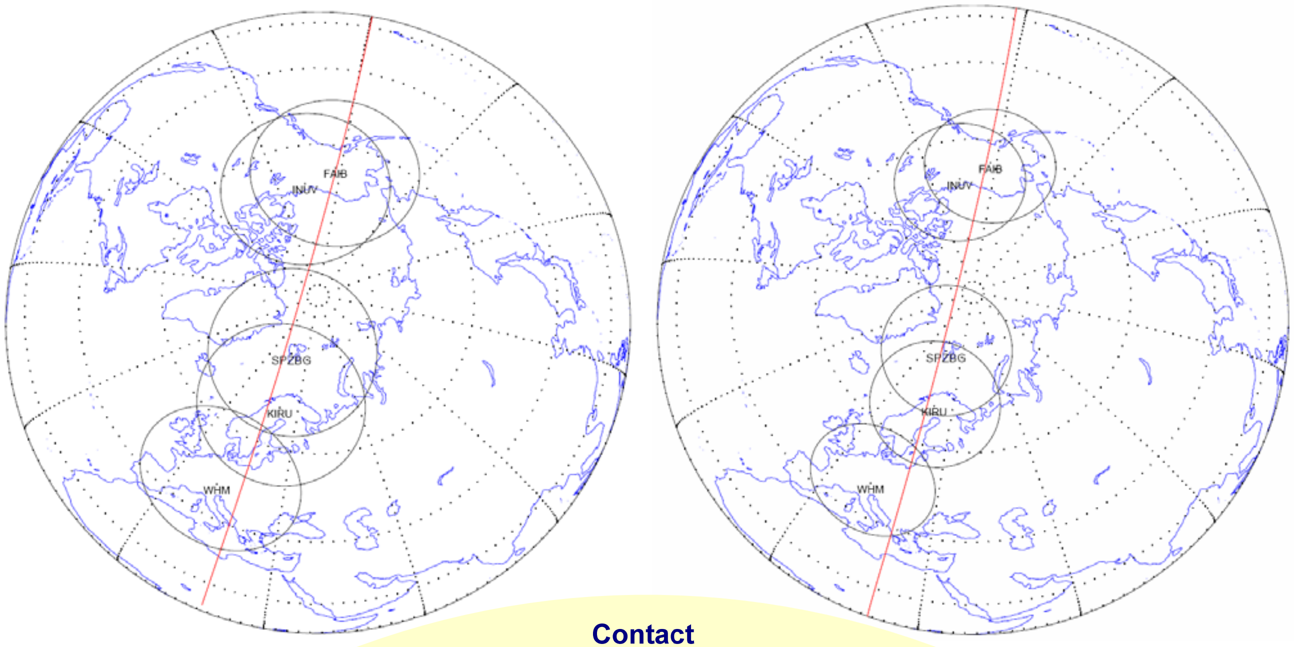
- *Passive ground control:* spacecraft operations are only monitored by the human operator on ground.
- *Active ground control* lets the human operator immediately command and control (**tele-operate**) the remote service-spacecraft / manipulator instead.

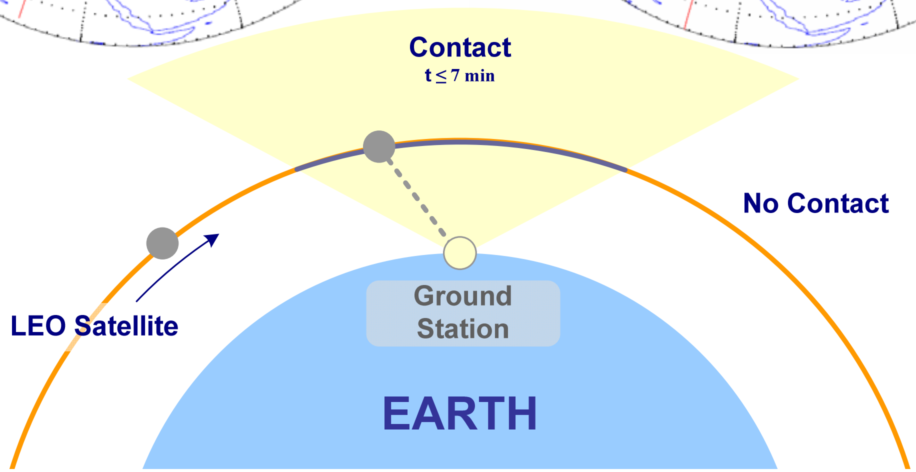



- **Satellite Links:** direct link (S-Band), GEO-Relay (Ka-Band), Inter-Satellite Link (S-Band)

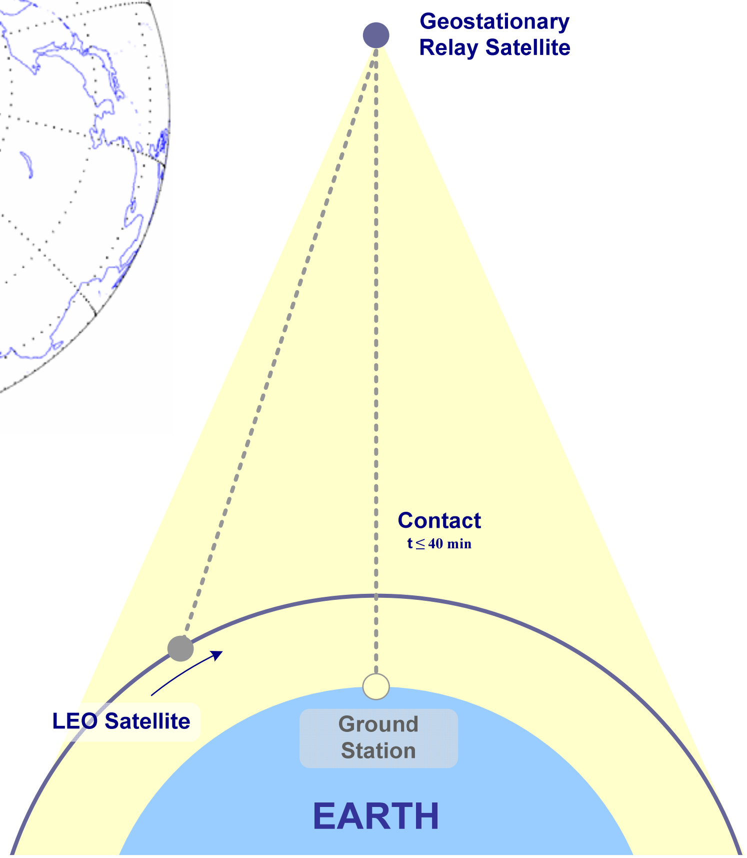
# Operational Aspects: Ground Control and Accessibility

## Ground Station Network

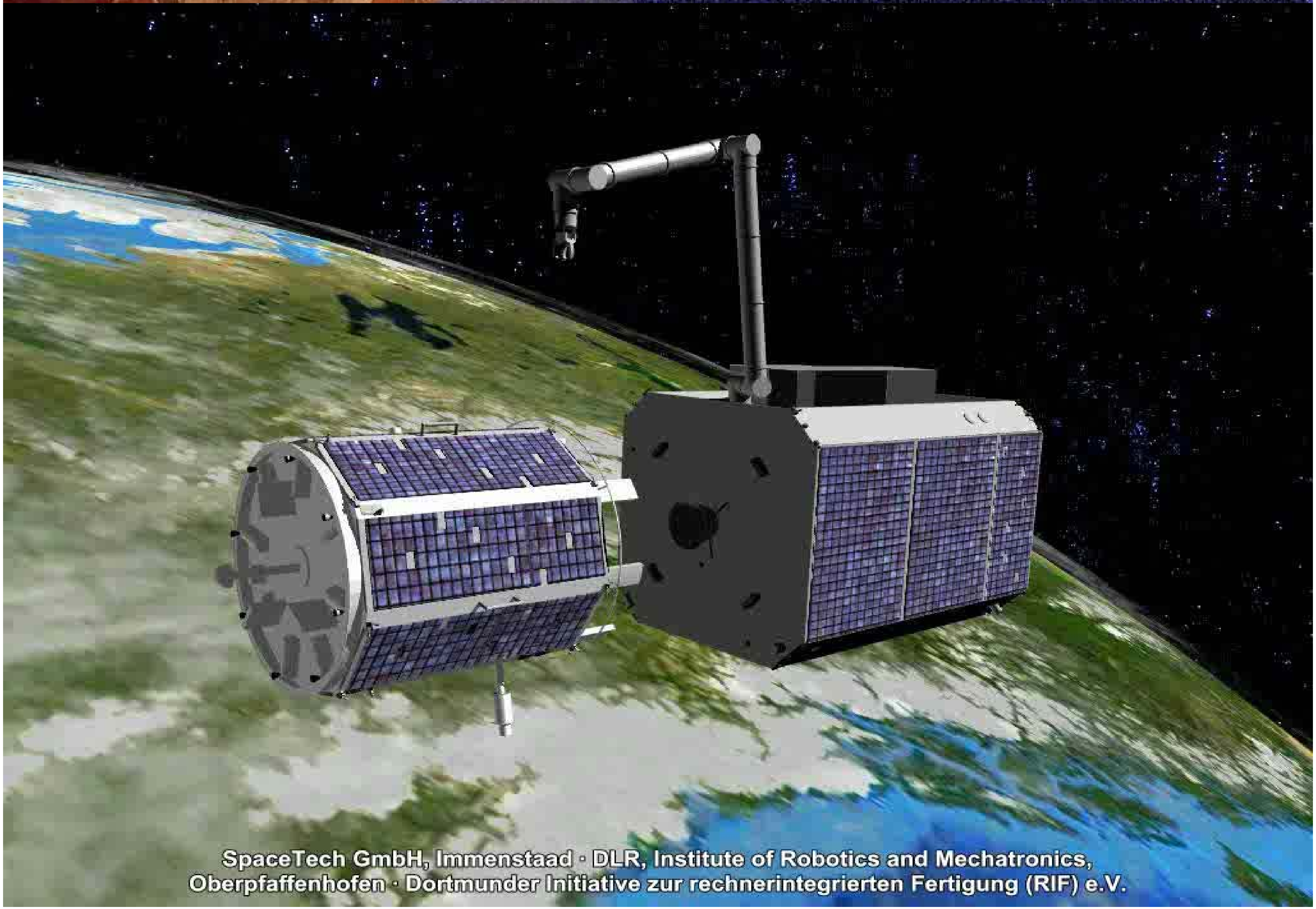


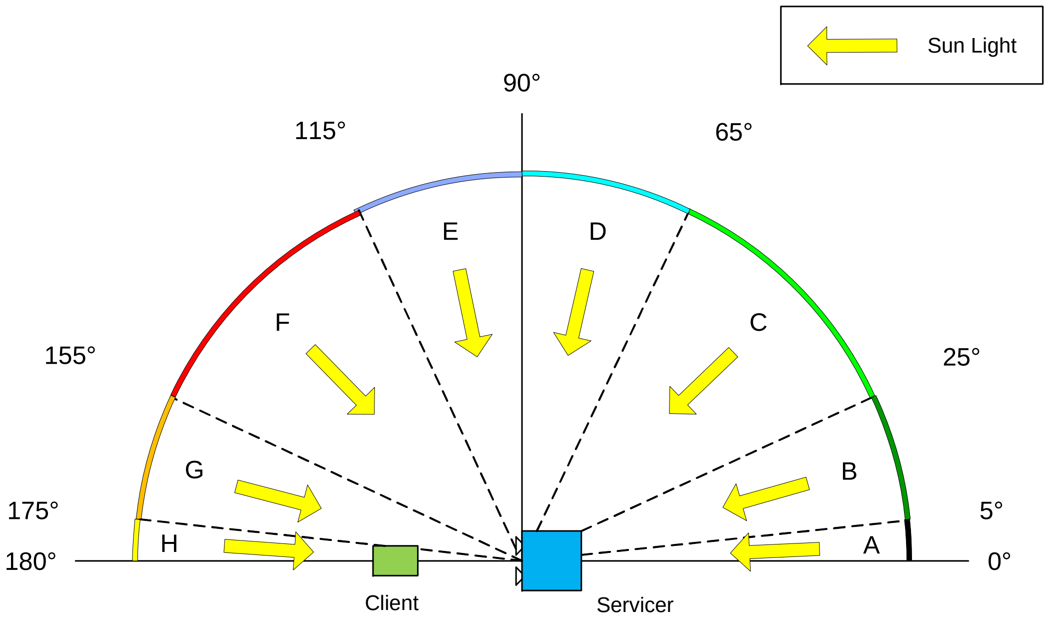

## Geo-Link (Ka-Band)

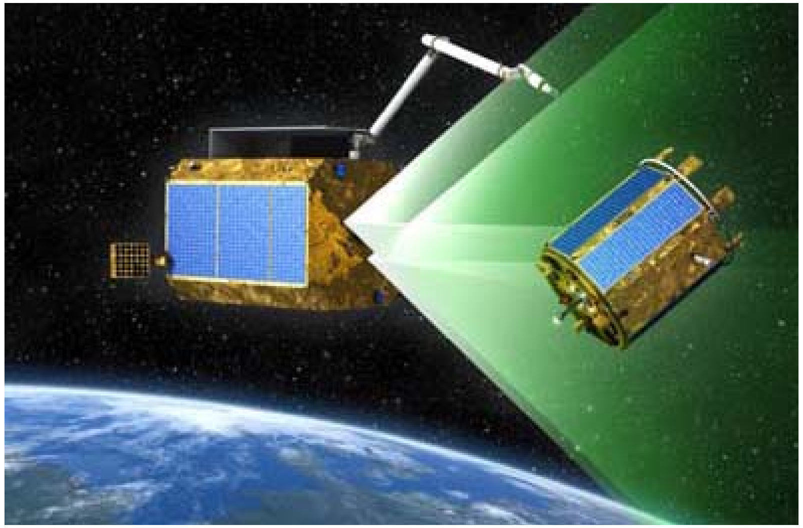


# Berthing: Grasping, Stabilization up to Rigidly Coupled



# Environmental Aspects: Sun Light and Illumination



Depending on the illumination conditions during pose estimation, final approach or berthing an additional target illumination might be required.

# Conclusion and Outlook

- The number of satellites orbiting the earth is rising constantly
- The DEOS system shall demonstrate and verify techniques to handle malfunctioned (non-cooperative, even tumbling) satellites
- DEOS approach explores a lot of mandatory techniques to be used to
  - avoid collisions of de-functional satellites
  - remove Space Debris similar to satellites
- Take into account that the gripper and manipulator are yet not designed to remove all kind of Space Debris (other solutions are needed)

- A successful demonstration of the technology would offer new applications in the field of On-Orbit-Servicing
  - Lifetime-Extension of Satellites

# Conclusion and Outlook

- The number of satellites orbiting around the Earth is increasing rapidly.
- Many of them will reach the end of their lifetime in near future. The Inter-Agency Space Debris Coordination Committee (IADC) requires self-removal
  - Satellites on/near the geostationary orbit have to lift themselves up to a higher altitude, the so-called graveyard orbit.
  - Satellites on low Earth orbits shall de-orbit to a lower altitude where atmospheric drag would cause it to re-entry within a defined timeframe (max. 25 years).
  - Although satellites should by definition be able to remove themselves from their orbits, but many don't because of a malfunction or lack of fuel.
- The DEOS system shall demonstrate and verify techniques to handle malfunctioned satellites
- DEOS approach explores a lot of mandatory techniques to be used to
  - avoid collisions of de-functional satellites
  - remove Space Debris similar to satellites
- Take into account that the gripper and manipulator are yet not designed to remove all kind of Space Debris (other solutions are needed)

# Programmatic Aspects and Funding

- The DEOS project is performed on behalf of the ***Space Agency*** of the German Aerospace Center DLR funded by the ***Federal Ministry of Economy and Technology*** within the framework of Germany's National Space Program. Taking a feasibility study of the DEOS mission and system concept into account, the program is on the way to explore and define the overall detailed mission and to develop a preliminary technical system design (ground & space segment) for mission preparation.
- Since January 2010 a preliminary Design Definition Phase (Phase B) is in progress performed by the space companies EADS Astrium GmbH, Kayser-Threde GmbH, OHB-System AG and SpacheTech GmbH.
- Technical support is given by DLR's Institute of Robotics and Mechatronics, Jena-Optronik GmbH, von Hoerner & Sulger (vH&S).

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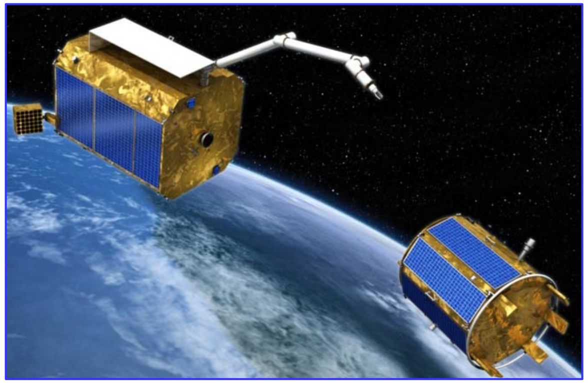


Research Team / Industrial Partners

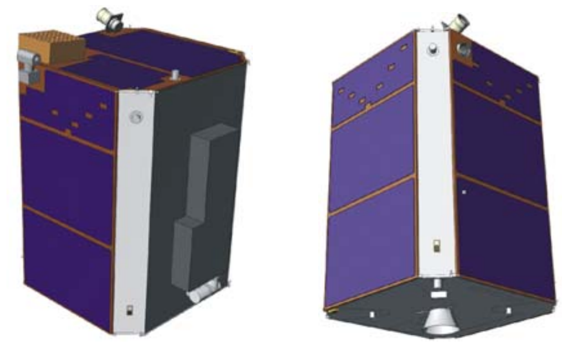
# Project Phasing according to ECSS

| MDR | | PRR | SRR | PDR | | CDR | | FRR | |
|---|---|---|---|---|---|---|---|---|---|

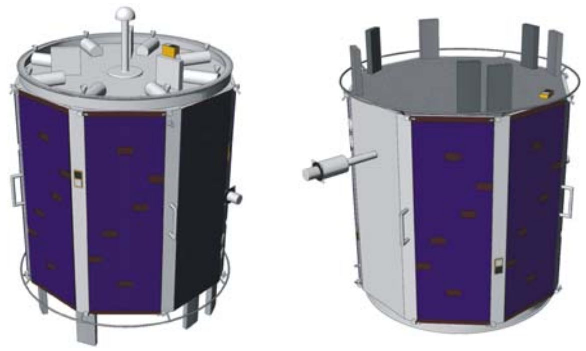
| PHASE 0 | PHASE A | PHASE B | PHASE C | PHASE D | PHASE E/F |
|---|---|---|---|---|---|
| Concept | Feasibility | Prel. Design | Development | Integration/Test | Mission |

- **Phase 0 “Concept”:** exploring different system and mission concepts
  - concerns the needs identification and the mission analysis
- **Phase A “Feasibility”:** finalizing the expression of needs and proposing solutions meeting the needs
  - estimating the technical and industrial feasibility
  - determine levels of uncertainty and risks
  - major interest: System Functional Specification
- **Phase B “Preliminary Design Definition“**:
  - a system technical requirements specification shall be established as a system *baseline* development and lower level elements technical requirements specifications;
  - the selected solution shall be evaluated and it shall have been demonstrated that it can meet the user, mission and technical requirements according with the schedule, the budget, the target cost and the organization requirements
  - major interest: System Technical Specification

# The Servicer Implementation

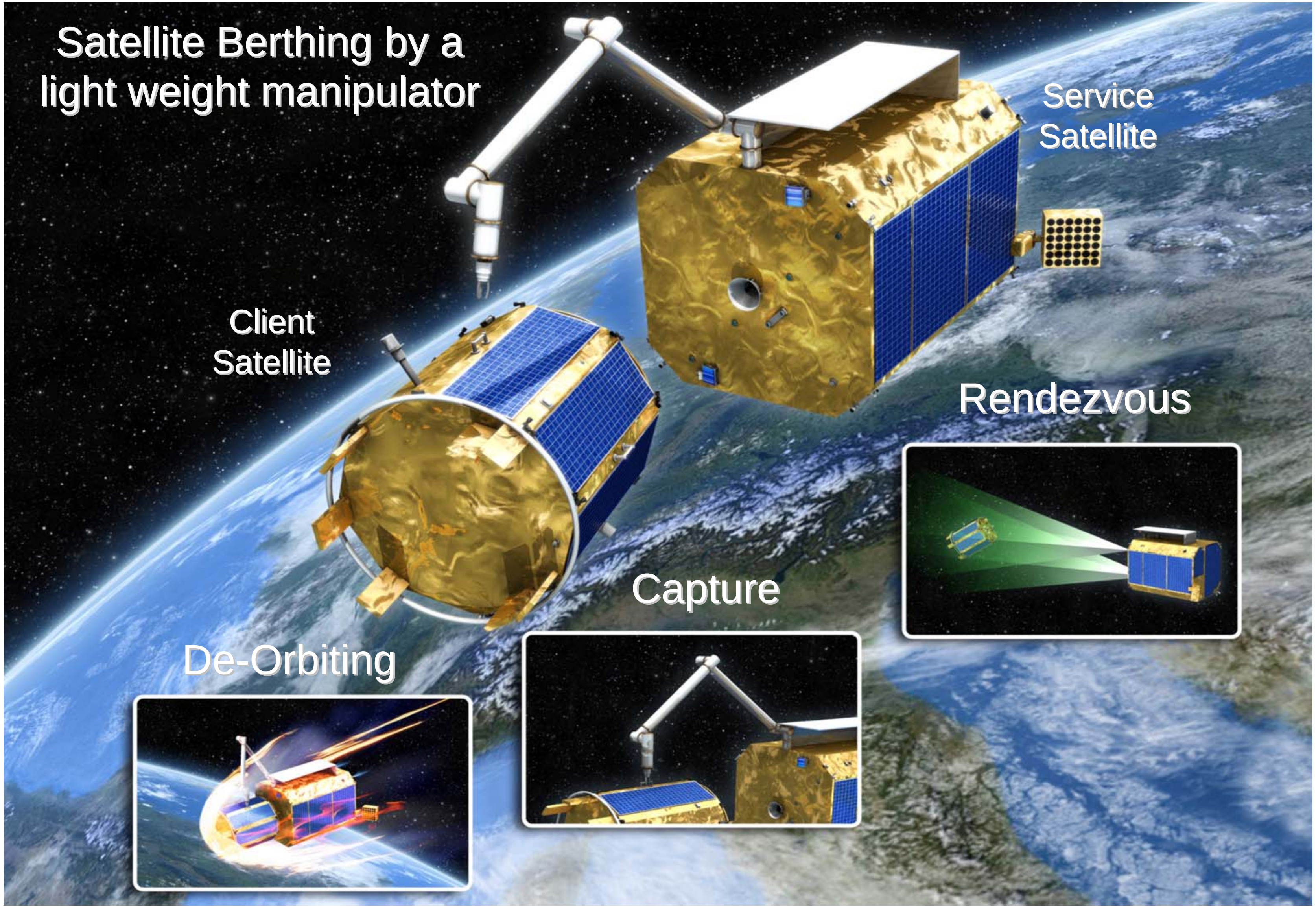
| | | | |
|---|---|---|---|
| **Abmessungen** | 2,6 x 1,7 x 1,8 $m^3$ |  | |
| **Trockenmasse** | 618 kg | | |
| **Treibstoff ($N_2$)** | 114 kg | | |
| **Gesamtmasse** | 732 kg | | |
| **Durchschnittliche Solargeneratorleistung** | 280 W ~ 700 W (Sonnen-/Bahnwinkel abhängig) | | |
| **Batteriekapazität** | 4 x 24 Ah | | |
| **Elektrischer Bus** | 26 ~ 33,6 V<br>unreguliert | | |
| **AOC Sensorik** | Position: GPS Empfänger<br>Lage: CESS, Sternsensor, Gyroskop, Magnetometer | | |
| **AOC Aktuatorik** | Magnetorquer, Kaltgasantrieb | | |
| **Fluglagen** | LVLH (geregelt, eingeschränkt geregelt) | | |
| **S-Band Uplink** | 2025 - 2110 MHz<br>BPSK<br>256 kbps, Omni-direktional | **S-Band Downlink** | 2200 - 2290 MHz<br>BPSK<br>4 Mbps, Omni-direktional<br>2 W (HF Leistung) |
| **S-Band ISL** | Separater Empfänger: 2200 – 2290 MHz, BPSK, 256 kbps, Omni-direktional | | |
| **Ka-Band Forward** | 23,175 GHz<br>256 kbps<br>Hochgewinnantenne (~2°) | **Ka-Band Return** | 27,475 GHz<br>4 Mbps<br>Hochgewinnantenne (~2°) |
| **Nutzlasten** | •Nutzlastkontrolleinheit (ICU)<br>•Kamerasystem zur Relativnavigation<br>•LIDAR zur Relativnavigation<br>•Manipulatorsystem, bestehend aus Armgelenke, Greifer, Stereokamera, Beleuchtung, Serieller Datenbus<br>•Aktiver Teil des kombinierten Andock- und Berthing-Mechanismus in-klusive Docking-Kamera<br>•Beleuchtung<br>•Ka-Band System zur Kommunikation mit einem GEO Relais-Satelliten | | |

# The Client Implementation



| | | | |
|---|---|---|---|
| **Abmessungen** | 1,9 x 1,3 x 1,3 $m^3$ | | |
| **Trockenmasse** | 268 kg | | |
| **Treibstoff** | $N_2$: 14,5 kg<br>Hydrazin: 126 kg | | |
| **Gesamtmasse** | 409 kg | | |
| **Durchschnittliche Solargeneratorleistun g** | 120 W ~ 240 W (Sonnen-/Bahnwinkel abhängig) | | |
| **Batteriekapazität** | 2 x 24 Ah | | |
| **Elektrischer Bus** | 26 ~ 33,6 V<br>unreguliert | | |
| **AOC Sensorik** | Position: GPS Empfänger<br>Lage: CESS, Gyroskop, Magnetometer | | |
| **AOC Aktuatorik** | Magnetorquer, Kaltgasantrieb (Lageregelung), Hydrazin-Antrieb (Bahnmanöver/Wie-der--ein-tritt) | | |
| **Fluglagen** | •LVLH<br>•Freitreibend (d.h. Lageregelung deaktiviert)<br>•Spin-stabilisiert mit einstellbarer Drehachse und Drehgeschwindigkeit<br>•Taumelnd, mit einstellbarer Taumelachse und Nutationswinkel | | |
| **S-Band Uplink** | 2025 - 2110 MHz<br>BPSK<br>256 kbps<br>Omni-direktional | **S-Band Downlink** | 2200 - 2290 MHz<br>BPSK<br>256 kbps<br>Omni-direktional<br>2 W HF Leistung |
| **Nutzlasten** | •Haltevorrichtungen zum Greifen durch den Servicer Manipulator-Greifer<br>•Passiver Teil des kombinierten Andock- und Berthing-Mechanismus in-klu-sive LED Pattern zur aktiven Unterstützung des Andockens durch den Servicer | | |

# The German Approach is based on a robotic Agent



# Environmental Aspects and Operational Orbit

| Parameter | Values | Comment |
|---|---|---|
| Initial Orbit | **600 km** | Stepwise decreased to ~ 400 km |
| Inclination | **85° … 90°** | For design purposes and concepts definition in Phase A 87° inclination was chosen as reference. |
| Eccentricity | **0** | Circular orbit |

- The *near polar inclination* offers variable illumination conditions over the life time for the planned complex demonstration program
- The *initial orbit altitude* will be decreased stepwise during the *one year* orbital lifetime in order to increase the operational complexity caused by reduced contact time to the communication network
- The *de-orbiting* and *re-entry* within a predefined re-entry corridor will be initiated from about ~ 400 km.
- At the beginning of the re-entry trajectory the spacecraft shall be *rigidly coupled* using the manipulator arm as mechanical fixture.
- During re-entry the spacecraft shall disintegrate into smaller peaces which then will *burn up* in the Earth atmosphere