ESA Perspectives on Electric Propulsion

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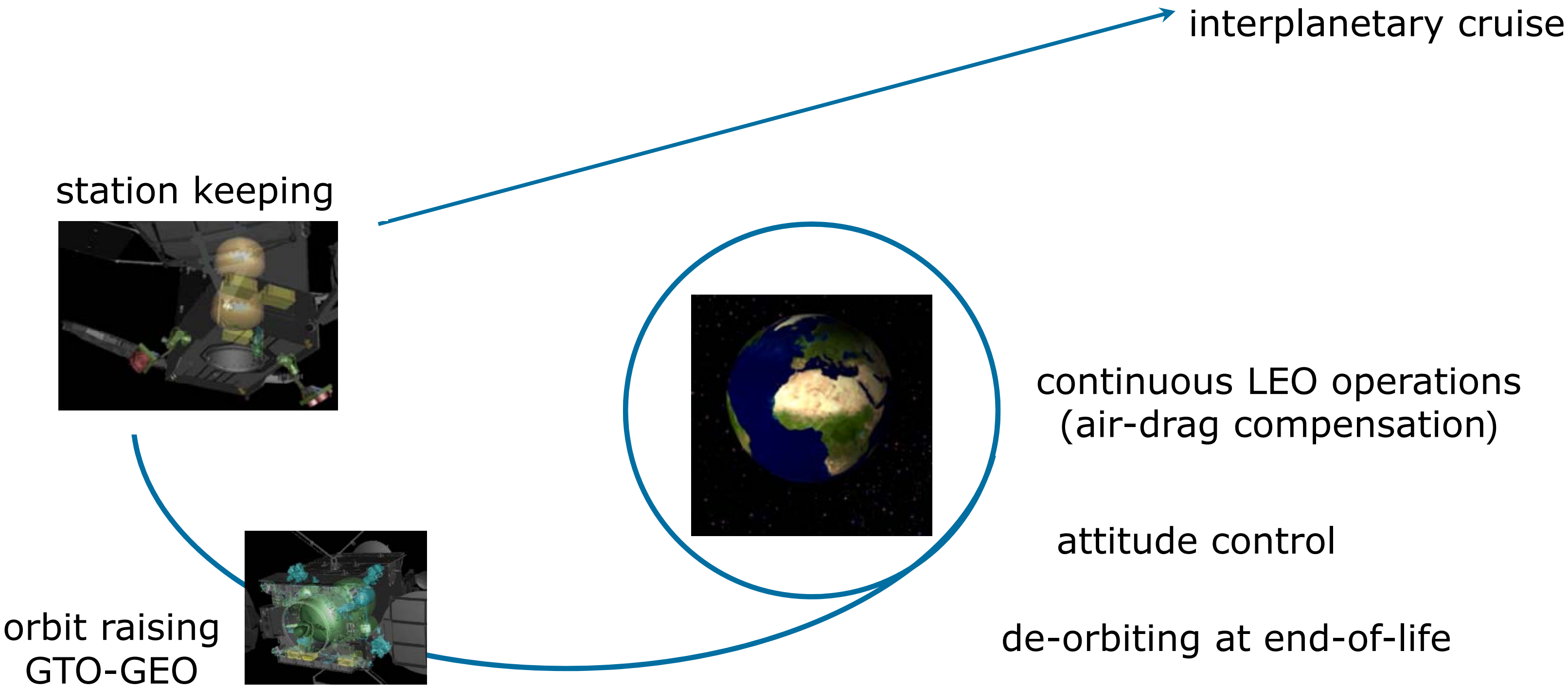
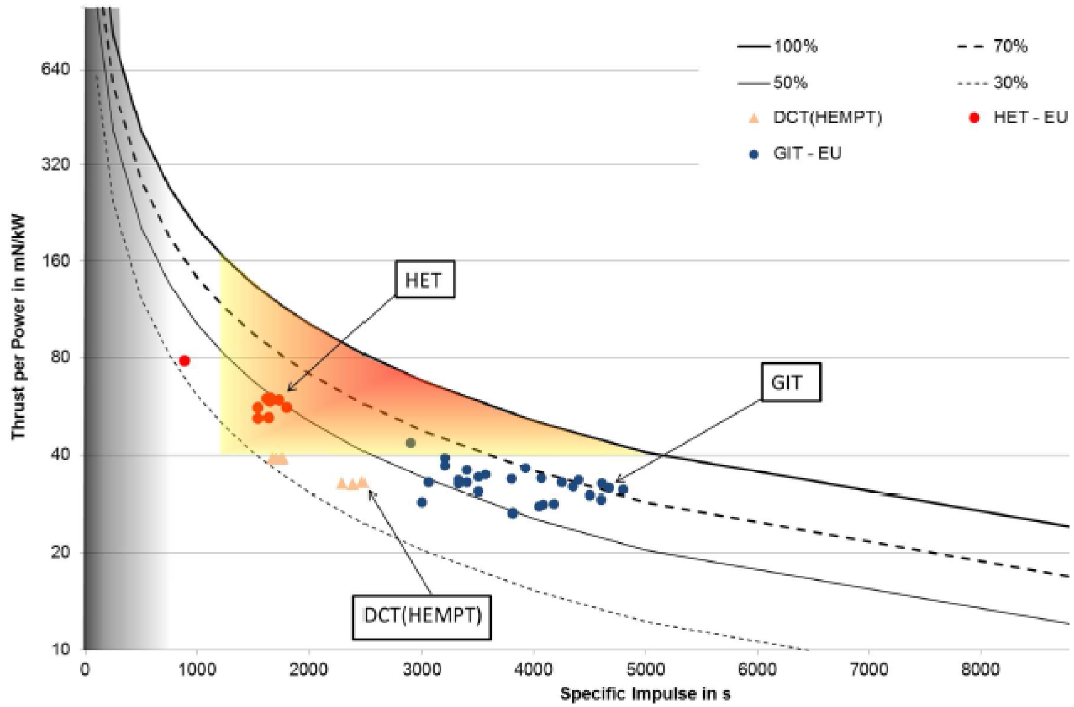
Electric Propulsion - Applications



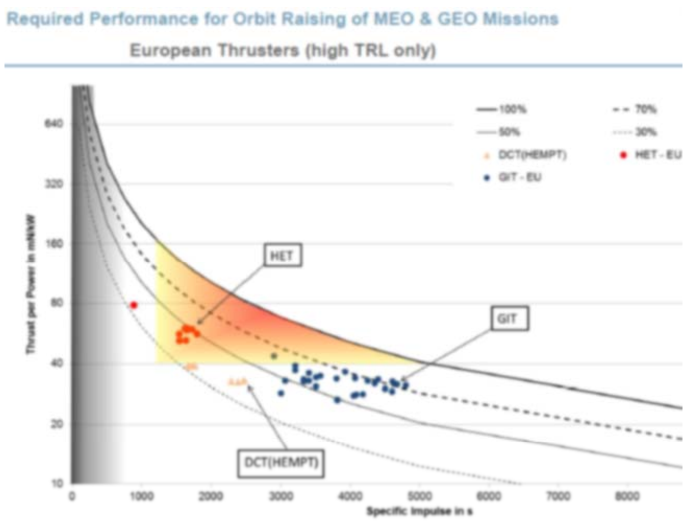
Electric Propulsion - Applications

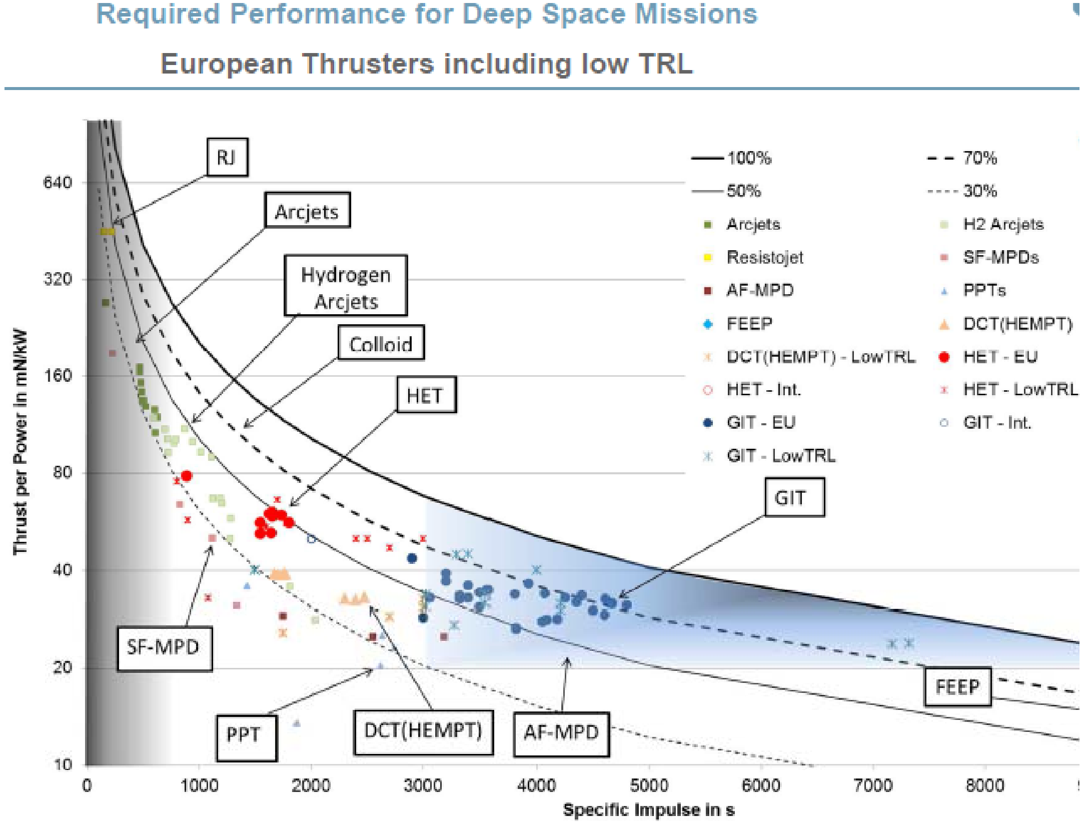
Required Performance for Orbit Raising of MEO & GEO Missions

European Thrusters (high TRL only)



Electric Propulsion - Applications





Electric Propulsion - Applications

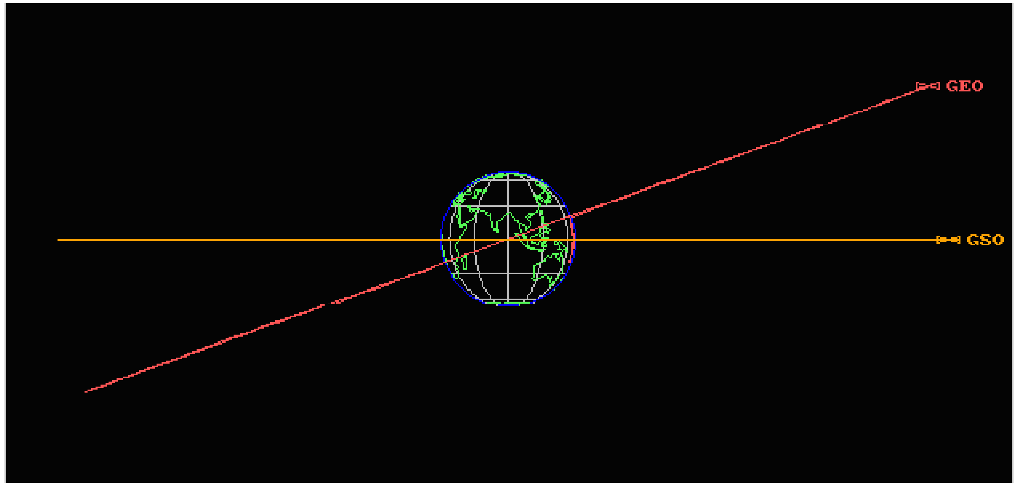
- EP is unlikely to ever completely replace chemical
  - Low thrust ≡ long manoeuvre durations
  - EP cannot be used to bring a spacecraft into space

- At present there are two principal applications for EP
  - **Commercial / GEO satellites**
    - Station-keeping (NSSK & EWSK)
    - Orbit raising
    - Orbital re-positioning and end-of-life disposal

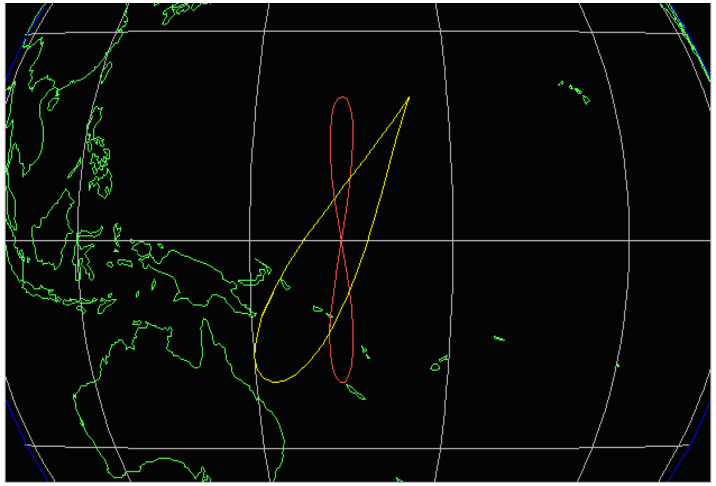
  - **Scientific satellites**
    - Near Earth science missions e.g. drag compensation at low altitude
    - Primary propulsion for deep space missions
    - Fine pointing/station-keeping

Telecommunication - NSSK

- Station-keeping propulsion is required to correct for orbital perturbations
  - Sun - gravitational and solar radiation pressure
  - Moon – gravitational
  - Earth oblateness



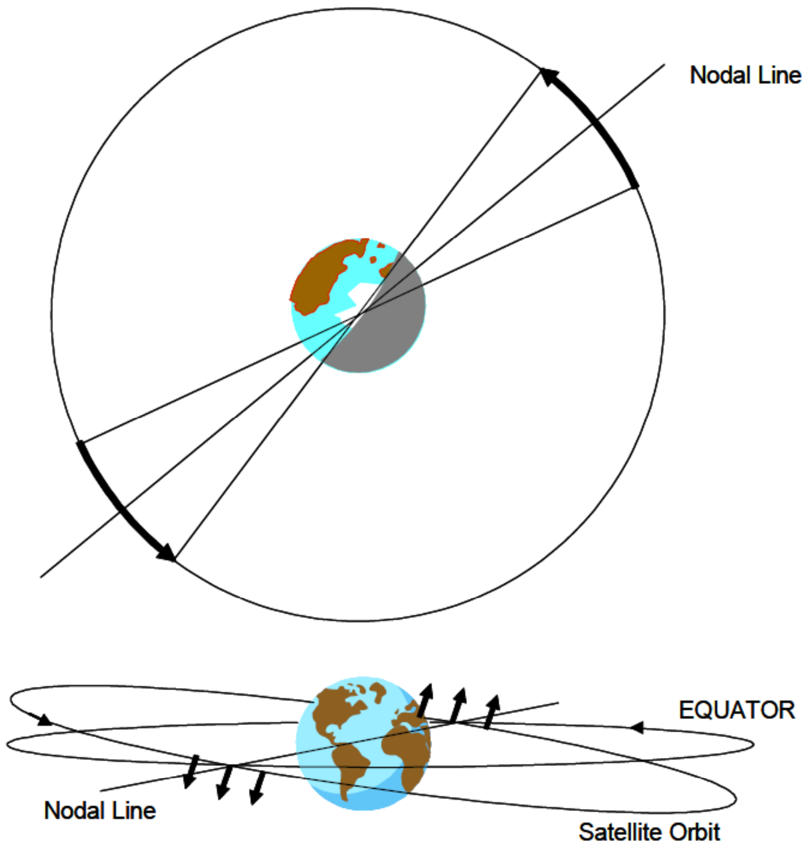
Geostationary Orbital Plane - side view



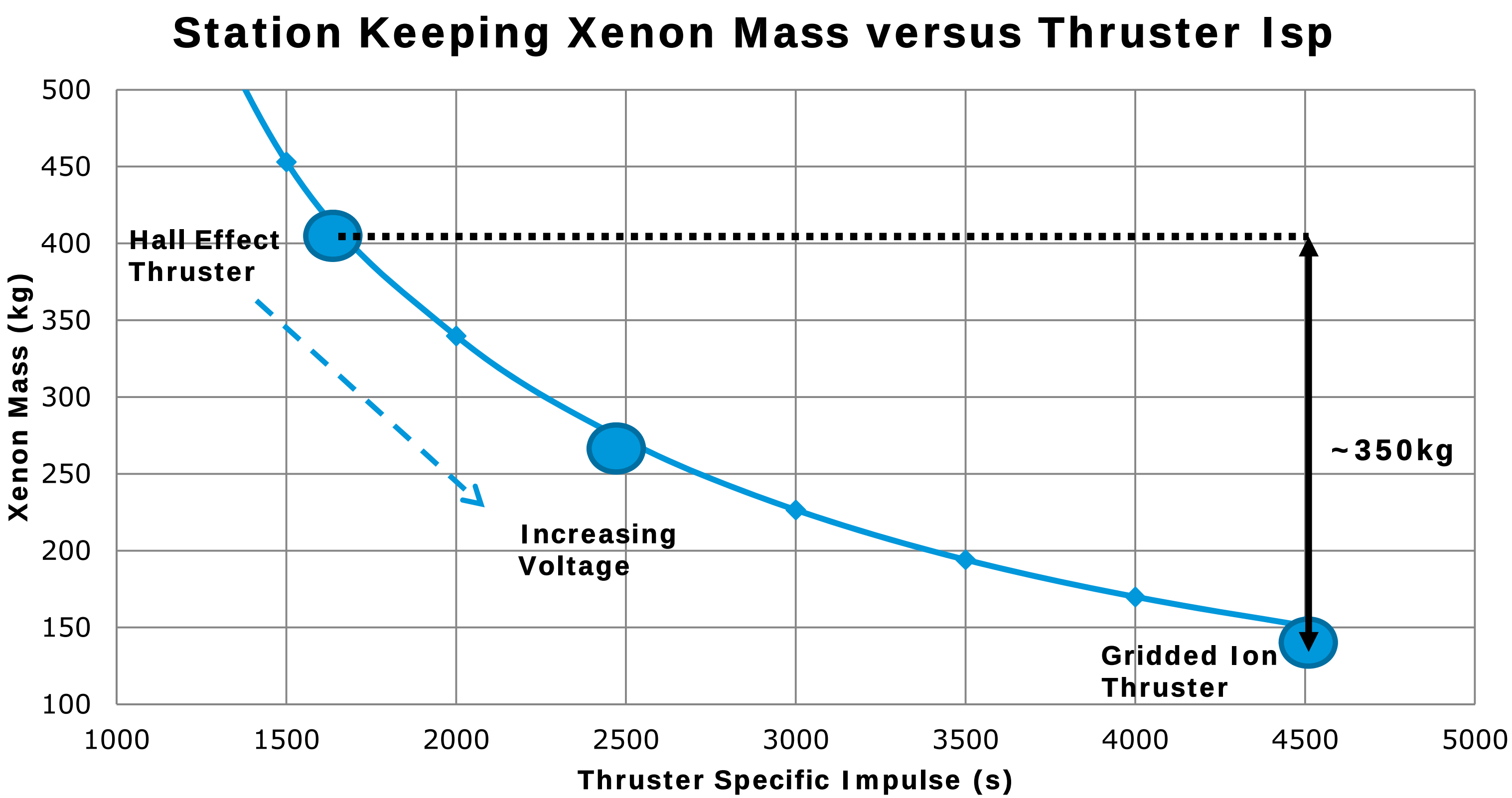
Ground Track

Telecommunication - NSSK

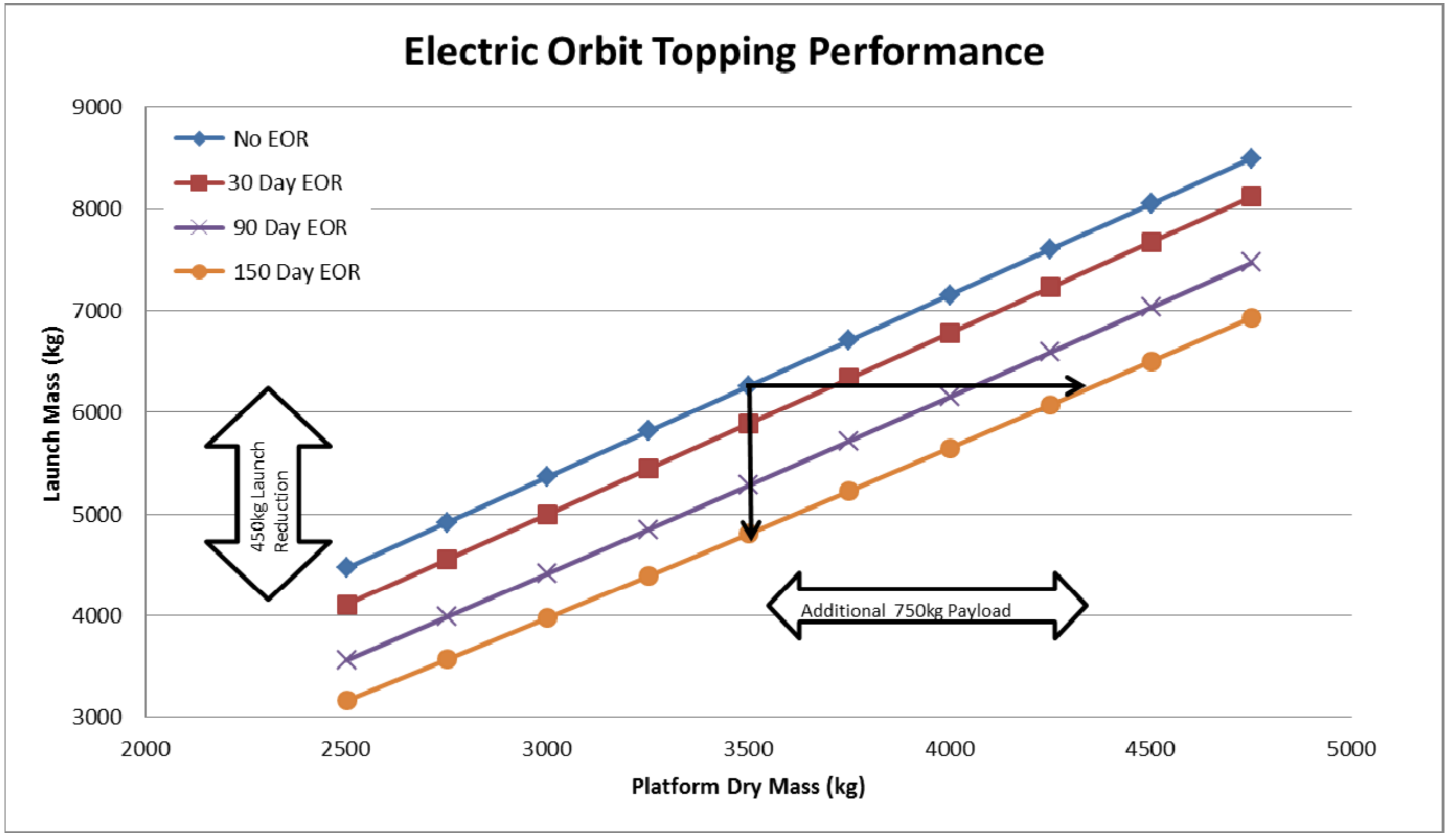
- If left uncorrected, these effects will increase the orbit inclination by up to 1° per year compared with a typical operational need to maintain inclination to within 0.05°
- Correction manoeuvres (station-keeping) performed around orbital nodes
- Thrusters fired in North direction and then in South direction on opposite side of orbit
- NSSK accounts for ~50ms^{-1} ΔV per year



Telecommunication - NSSK

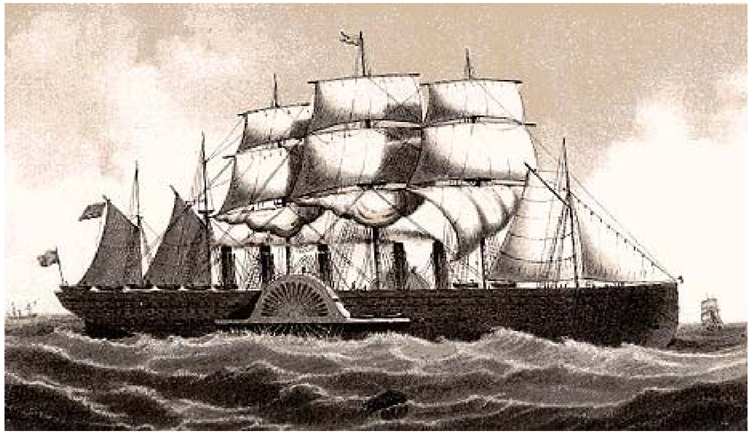


Telecommunication – Orbit Topping/Raising



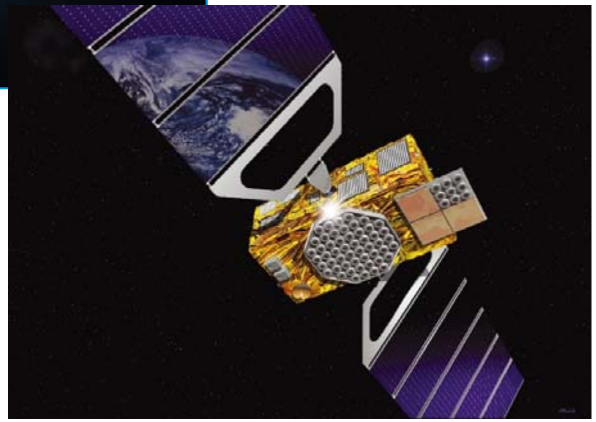
Telecommunication

- For thousands of years people relied on sail – they knew how to use it and understood its capabilities and drawbacks – ‘better the devil you know’
- Steam power offered a quantum leap in performance - but the systems were initially unproven and operators were nervous
- As a consequence hybrid ships – sail & steam - were built and used until confidence in steam systems increased to the point that business was confident enough to remove sails altogether – **EP is at this turning point**

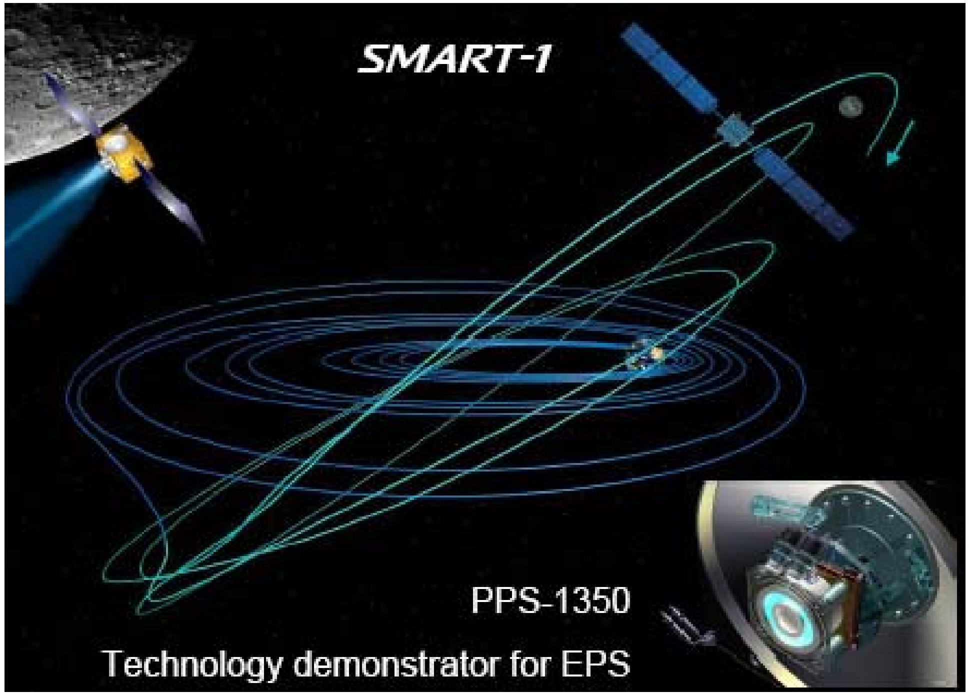


Navigation

- ESA is preparing the future replacement of GALILEO constellation and is targeting the possibility to increase the Galileo Payload capability without impacting the launch costs
- The increase in payload capability could be achieved by changing the launch injection strategy and by using EP to transfer the satellite to the target operational orbit.
- The use of EP might allow to use small launchers such as VEGA or place more spacecraft in the current SOYUZ and Ariane 5 launchers.
- GIE and HET subsystems are currently considered for the transfer by the selected Primes of Phase A/B1.



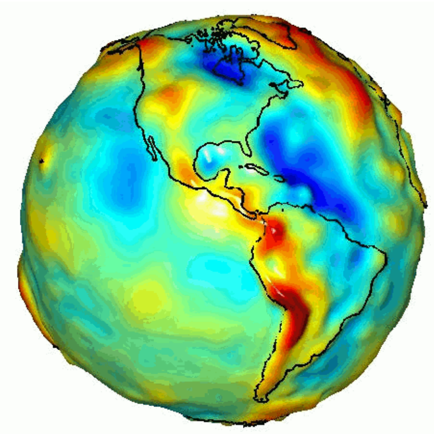
Science and Earth Observation – SMART1



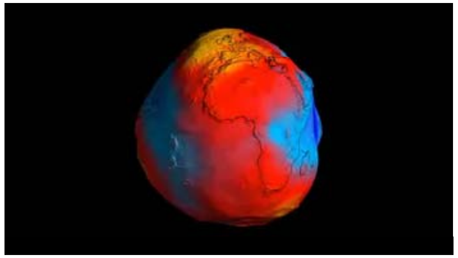
- Mass 370 kg, Size 1 m^3
- 1.9 kW solar power
- 1.5 kW HET (PPS®1350)
- 16 Months transfer to Moon
- 80 kg of Xe
- Launch: September 2003

Science and Earth Observation – GOCE

- Mass: 1050 kg
- Size: 5 m long, 1m² cross section
- 1.3 kW solar power
- Two 20 mN GIE (T5) for drag compensation
- Launch: March 2009

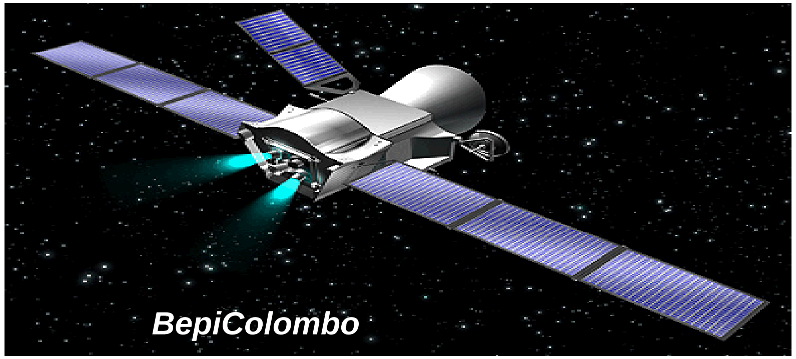


Computer model (exaggerated) of equipotential reference surface

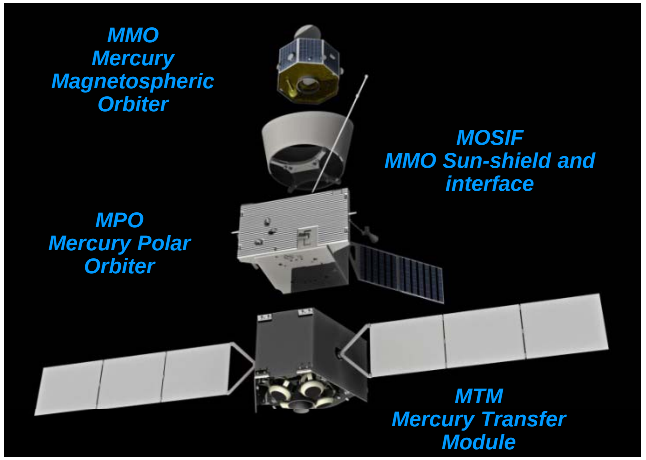


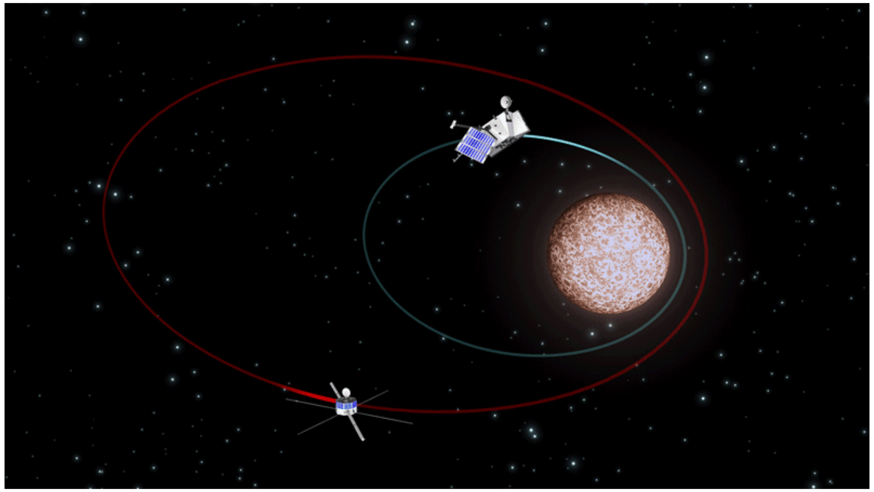
GOCE science data

Science and Earth Observation – BepiColombo



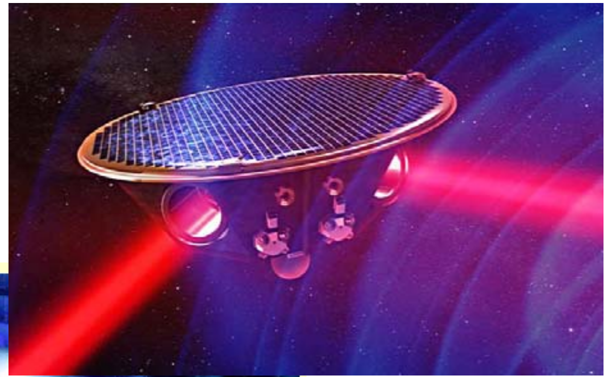
- Mass: 4100 kg
- 2 GIE (T6), 290 mN total thrust
- 7.5 years long transfer to Mercury using EP
- Launch: October 2018 (planned)

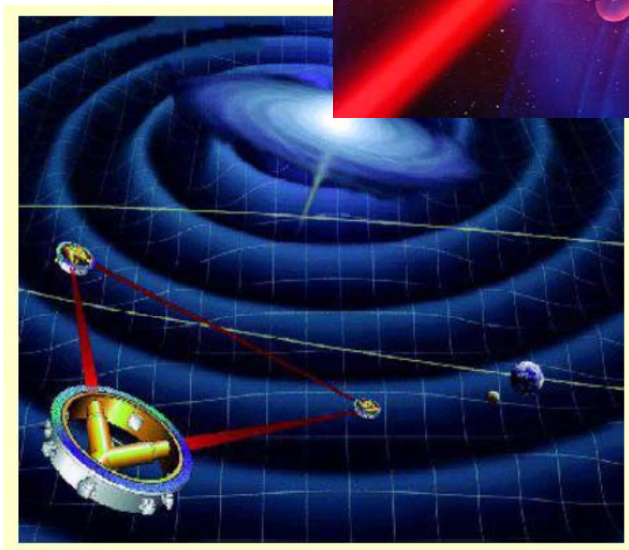




Science and Earth Observation – LISA

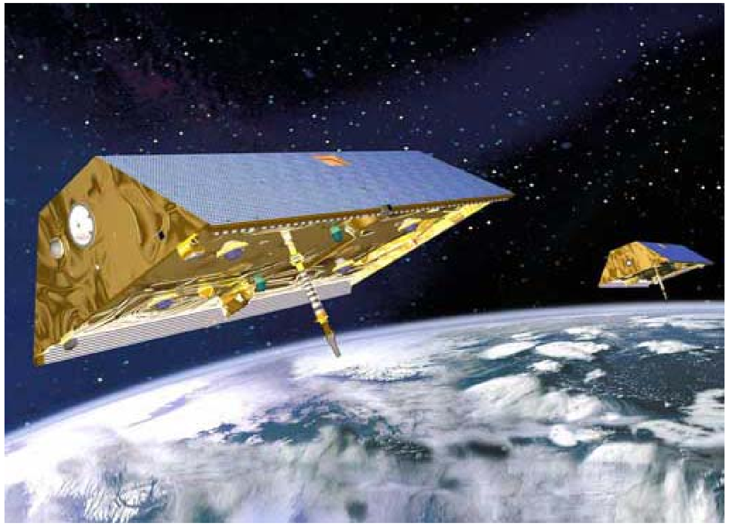
- Primary objective: detect and observe gravitational waves
- Mission success based on performance of sophisticated accelerometers working under drag-free conditions on each LISA spacecraft
- 3 clusters of four micro thrusters on each LISA spacecraft (~50 μN each)
- LISA Pathfinder technology demonstrator mission launched in December 2015





Science and Earth Observation – NGGM

- Follow-up mission of GOCE
- Primary objective: measure variations of Earth's gravity field over long time span (possible covering full solar cycle)
- Measurement technique: "Satellite-to-satellite tracking" (SST) in low Earth orbit
- Pair of satellites flying in loose formation to form "gravity sensor"

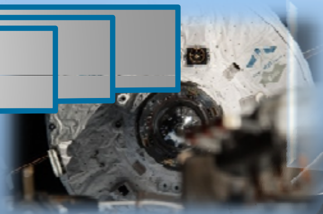


Electric Propulsion - Outlook

Exploration:

Application Area: Advanced Propulsion *(Priority for Space Council)*

Technology Subject: ***Electric Propulsion for High Capacity Cargo Transfer***



2020-2023

20-30kW Electric Propulsion System

High Capacity Cargo Transfer

Orbit Transfer / Raising Vehicle

2018-2019

20-30kW Thruster Testing Facilities

20-30kW System Components

Orbit Insertion & Maintenance

Large GEO S/C & Long duration operations around other planets

Rendezvous & Docking

2013-2017

Alternative Propellants

High Current Cathode Technology

5 kW Propulsion Systems

Electric Propulsion - Outlook

Commercial Applications:

Application Area: Telecom, Navigation

Technology Subject: ***Electric Propulsion for Orbiting, Deorbiting, Orbit Control***

2023 - ...

- Mass Savings and Mass Reduction
- Minimisation of Time-to-Orbit (mission scenarios)

Further Minimisations of Transponder to Orbit Cost

2018-2023

Commercial Exploitation

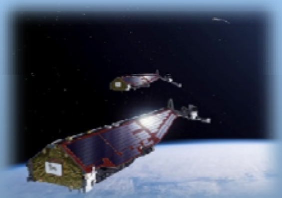
2013-2017

- Xenon market evolution and availability
- Electric Propulsion driven recurring and non-recurring prices for Design-to-Cost options
- Industrialisation and production chain
- 5 kW Propulsion Systems
- LEOP (Launch and Early Operations) Costs

Electric Propulsion - Outlook

EO and Mega Constellations:

Technology Subject: ***Electric Propulsion for Orbiting, Deorbiting, Orbit Control, Fine Attitude Control, Drag Compensation***



2020 - 2024

High Resolution from GEO (EO)

Next Generation Gravity Mission (EO)

2018-2020

Propulsion Subsystem:

- Low cost (constellation)
- Low Power Consumption (EO and Constellation)
- Light (EO and Constellation)
- High thrust controllability (EO)
- Manufacturing Capability(Constellation)

2013-2017

Alternative Propellants for Mini, Micro, Nano Satellites

Power

Micro/Mini Propulsion

Nano / Microsatellite Applications
Scientific Research, Technology, EO, Education, Military, Astronomy

Horizon 2020 Space Work Programme 2014 - EPIC

- Electric Propulsion has been identified as strategic technology by European actors
- European Commission has set up "In-space Electrical Propulsion and Station-Keeping" **S**trategic **R**esearch **C**luster (**SRC**) in Horizon 2020 to enable European leadership of European capabilities in electric propulsion at world level within 2020-2030
- **E**lectric **P**ropulsion **I**nnovation & **C**ompetitiveness (**EPIC**) project aims at providing integrated roadmap of activities and master plan for coordination and implementation through SRC
- EPIC **P**rogramme **S**upport **A**ctivity (**PSA**) coordinates activities within SRC, monitors evolution of works performed within SRC and supports commission on implementation
- PSA coordinator: ESA
- PSA partners: ASI (Italy), CDTI (Spain), CNES (France), DLR (Germany), Eurospace, SME4Space VZW, BELSPO (Belgium), UKSA (UK)

EPIC – Selected Operational Grants

- 6 **O**perational **G**rants (**OG**) selected with a total budget of ~28 M€
- 3 OGs have been awarded under COMPET-3-2016-a (Incremental Technologies)
  1. CHEOPS: focused on Hall effect thrusters
  2. HEMPT-NG: focused on HEMP thrusters
  3. GIESEPP: focused on gridded ion engines
- 3 OGs have been awarded under COMPET-3-2016-b (Disruptive Technologies)
  1. GaNOMIC: focused on a disruptive power converter
  2. HiperLoc-EP: focused on Electrospay Colloid Thrusters
  3. MINOTOR: focused on Electron Cyclotron Resonance Accelerator

http://epic-src.eu/

ESA Activities in the Field of Electric Propulsion

- Technical support to ESA project
- Coordination of R&D activities in the field of Electric Propulsion to prepare for future mission needs
- Coordination of numerical and experimental works in the field of plasma – spacecraft interactions induced by Electric propulsion with the aim to provide improved modelling tools
- Working group on "Standardization of Electric Propulsion Testing and Qualification" in order to achieve cost reduction by means of optimised production and verification programs
- Inter-laboratory comparison of Electric Propulsion Devices

ESA Propulsion Laboratory

- Located at ESTEC, The Netherlands
- The laboratory is focused on space propulsion
- EPL provides test services to the Propulsion and Aerothermodynamics division, which is responsible for R&D activities and support to projects in the areas of chemical propulsion, electric and advanced propulsion, and aerothermodynamics.
- ISO 17025 Accreditation
  - Thrust, mass flow and electrical power measurements
  - Electric, chemical and cold gas propulsion systems
- Flexible scope of Accreditation:
  - Force: 1 µN – 500 mN
  - Mass flow 1 µg/s – 300 mg/s
  - Power: 1 mW – 2 kW

Conclusion

- Electric Propulsion in Europe has been successfully used on missions for Telecom, Science and Earth Observation
- 5 kW engines will be used in the near term on telecommunication satellites for obit control and full or partial orbit transfer
- Navigation, Science (interplanetary missions) and Exploration (the Moon, Asteroids and Mars) will in the future also require 5 kW systems
- ESA is coordinating development of micro thrusters such as mini-ion engines, FEEPs, mini-Halls, etc. with capability to fulfil stringent Science and Earth Observation requirements
- Galileo 2nd Generation program is considering the use of electric propulsion to perform orbit raising from LEO/GTO to MEO
- In the future developments have to aim for longer lifetime, improved power-to-thrust ratio and higher specific impulse
- Thruster in the 10 to 20 kW range will have to be developed
- Constellations of satellites may make use of EP systems at very low cost, main application will be for end-of-life de-orbiting
- In the frame of the Horizon 2020, the EPIC project has been selected to improve the competitiveness of European actors in the field of electric propulsion