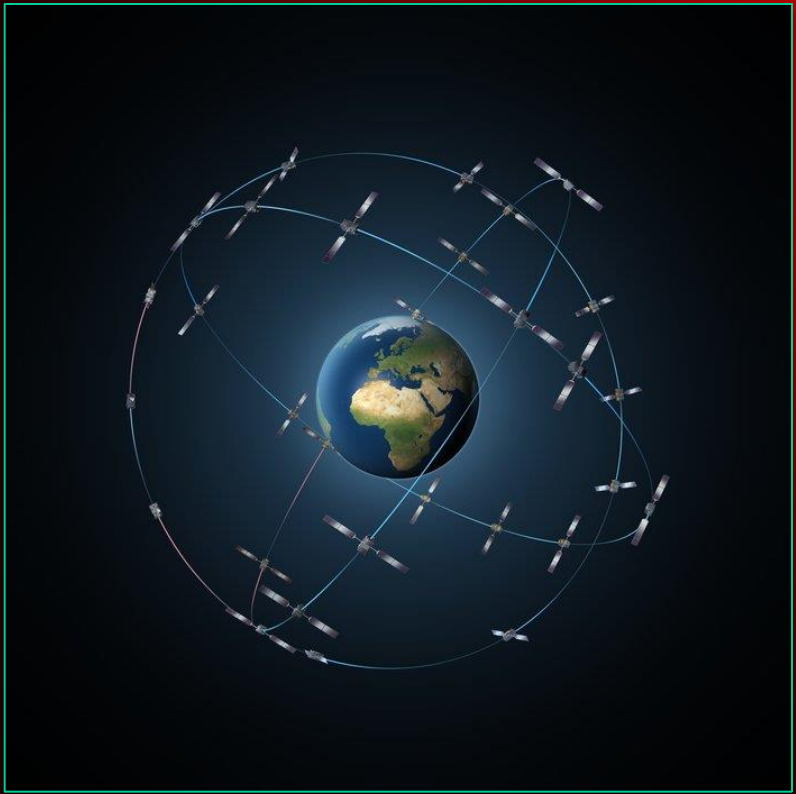
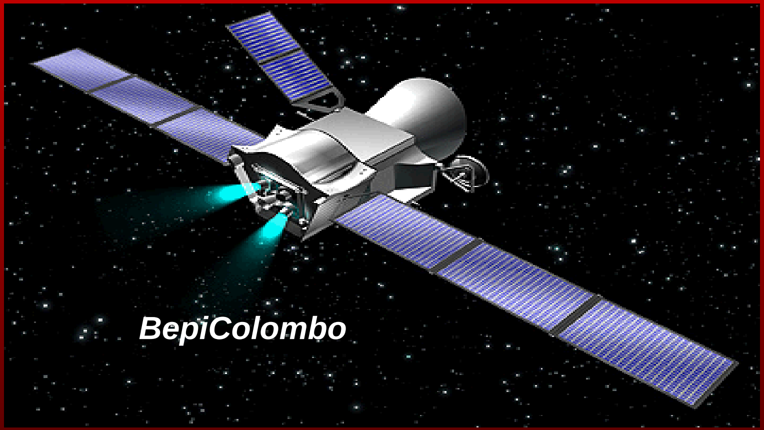
22 October 2015, UC3M, Leganés

'Present and Future of Space Electric Propulsion in Europe'





ESA

Presentation Overview

1. General Technology Overview

2. Applications
   2.1 Science and Earth Observation
   2.2 Commercial Spacecraft
   2.3 Exploration
   2.4 Navigation

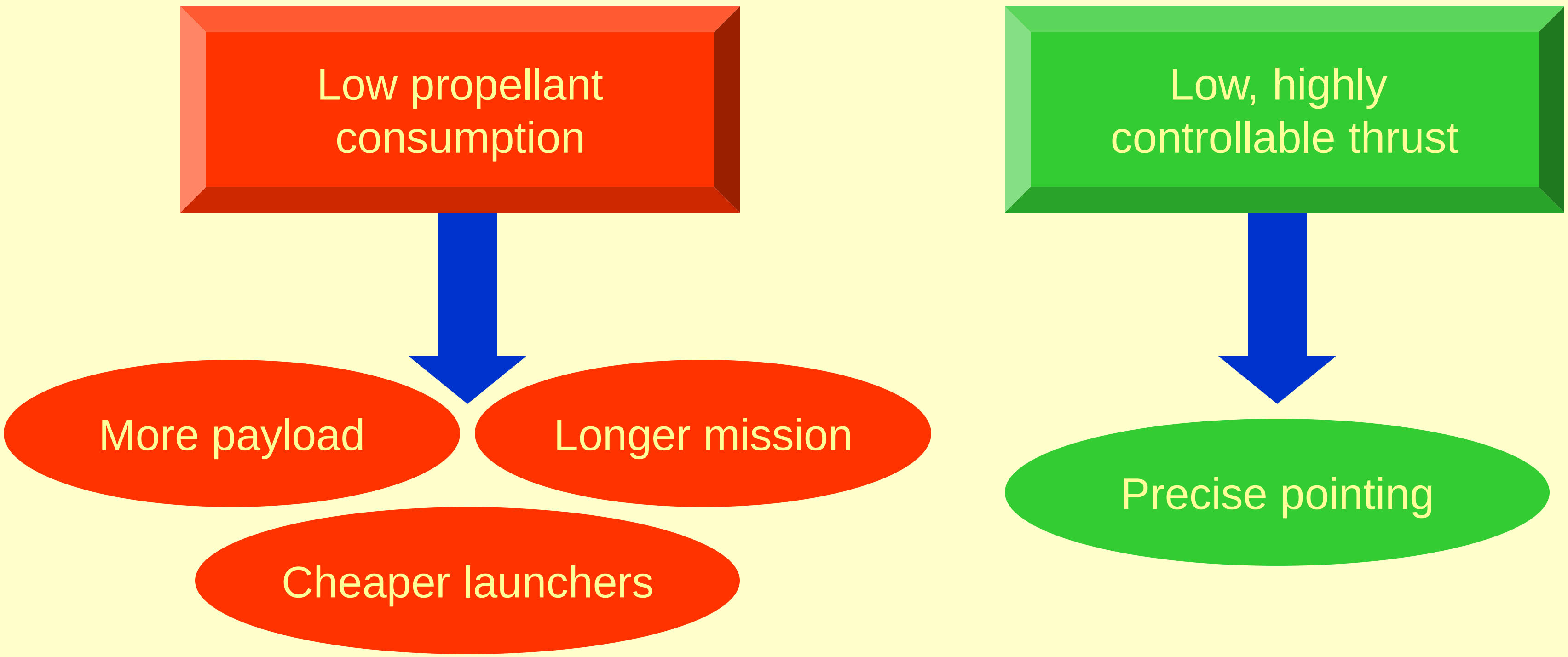
3. Important Technology Developments

4. ESA Propulsion Lab

5. H2020: EPIC

6. Conclusions

The most important advantages of electric propulsion with respect to conventional propulsion systems are:



Telecoms

Science

Earth Observation

Science

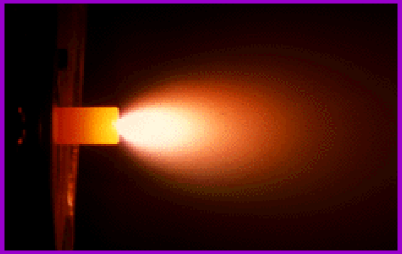
Earth Observation

Spacecraft Electric Propulsion (EP) technologies

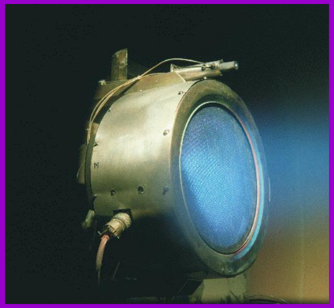
use electrical power to accelerate a propellant and, consequently, to apply a change of velocity to the spacecraft in a very efficient manner.

Depending on the process used to accelerate the propellant, electric propulsion thrusters are classified in:

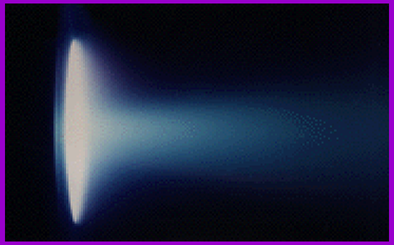
Electrothermal



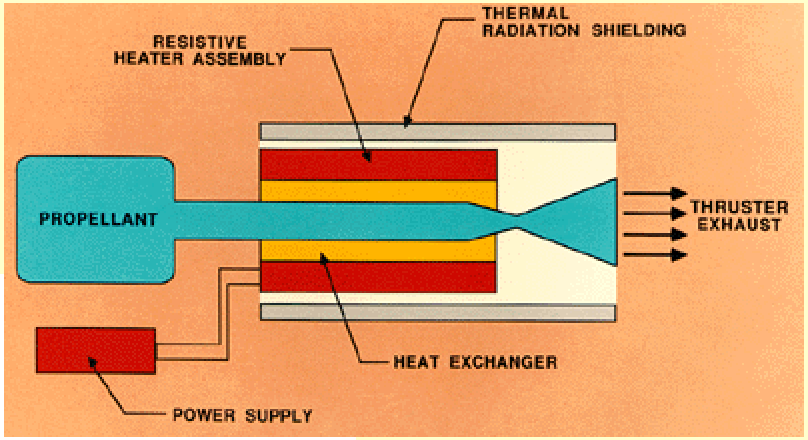
Electrostatic

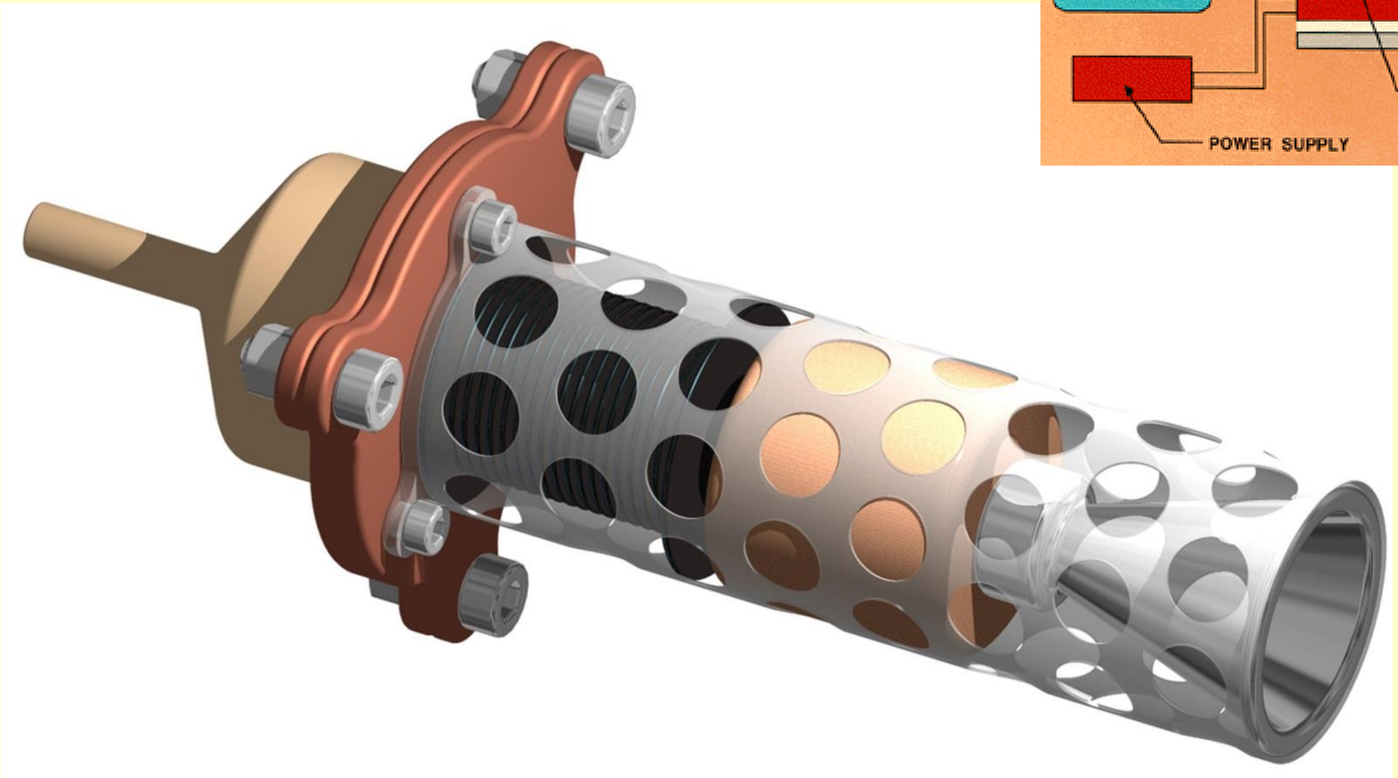


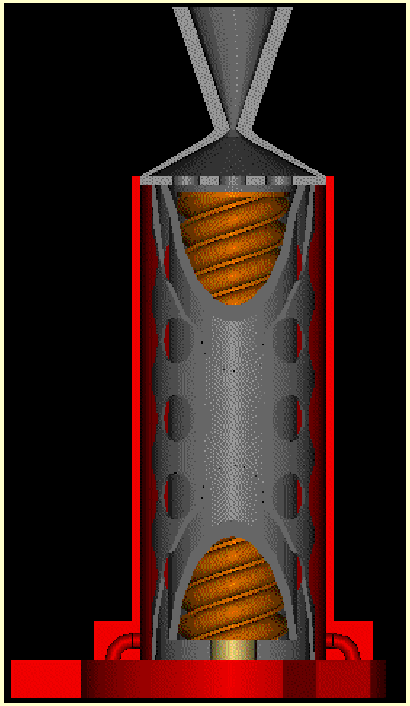
Electromagnetic



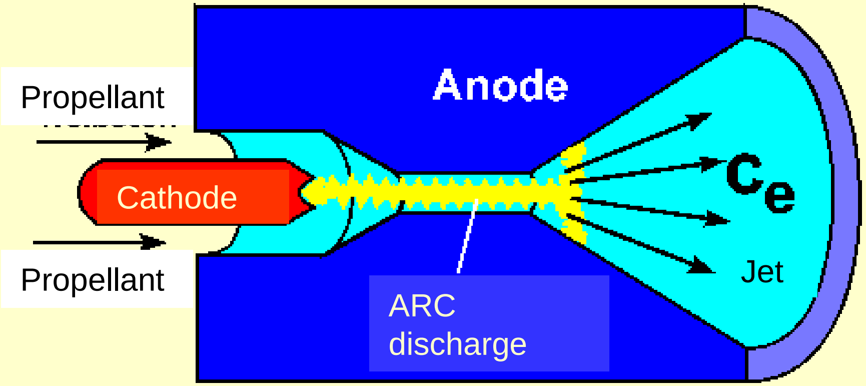
Resistojet

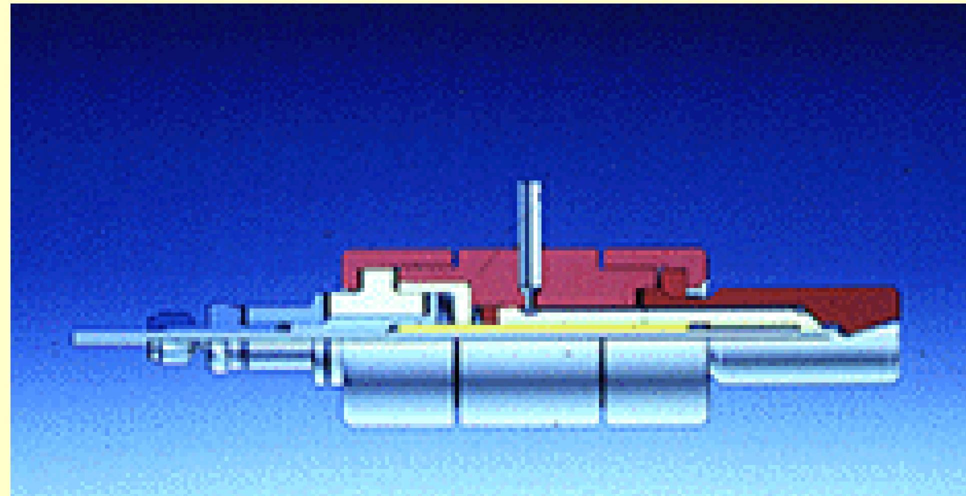

THERMAL
RADIATION SHIELDING
RESISTIVE
HEATER ASSEMBLY
PROPELLANT
THRUSTER
EXHAUST
HEAT EXCHANGER
POWER SUPPLY

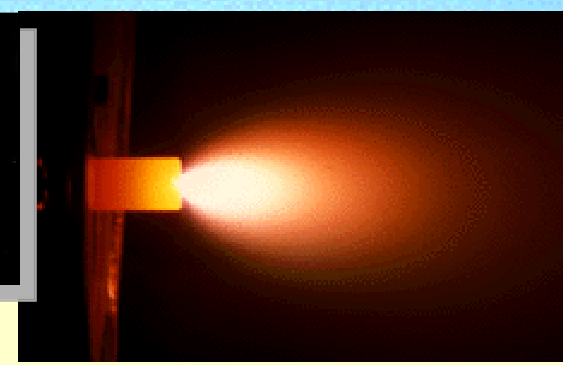


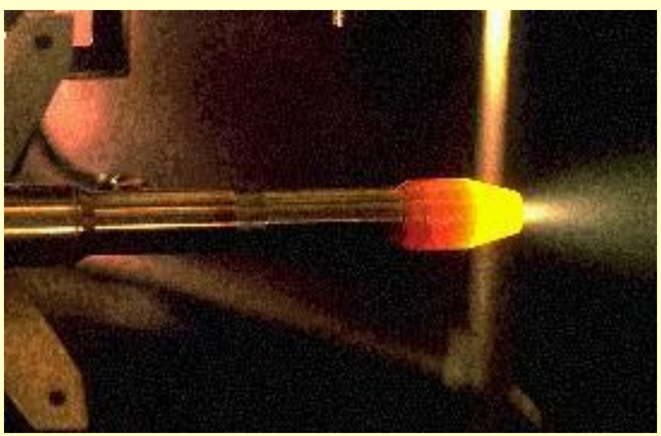


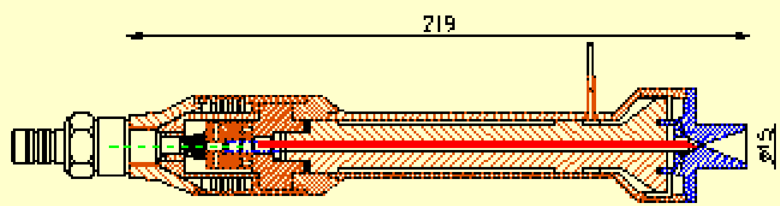
Arcjet


Propellant
Anode
Cathode
Propellant
ARC
discharge
Ce
Jet

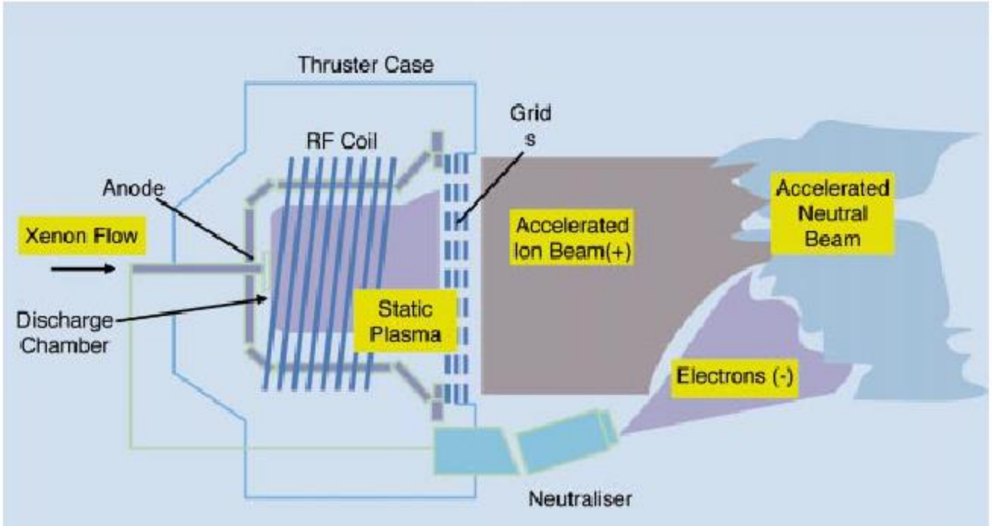




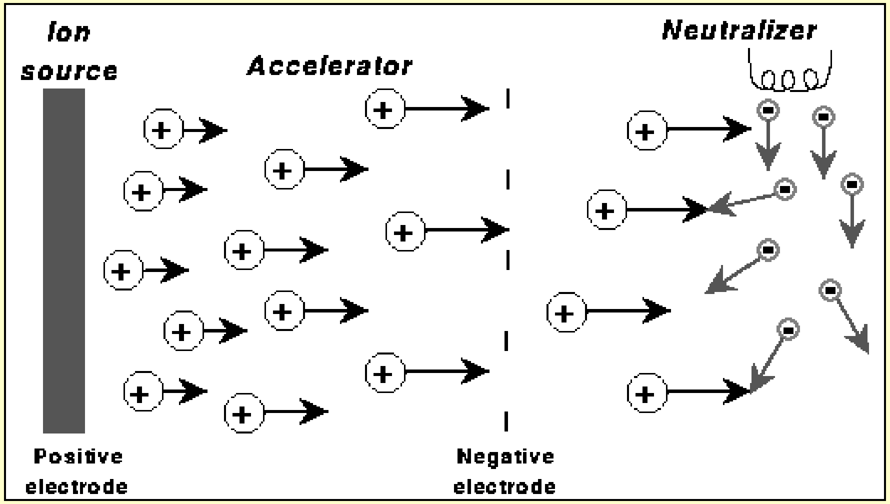


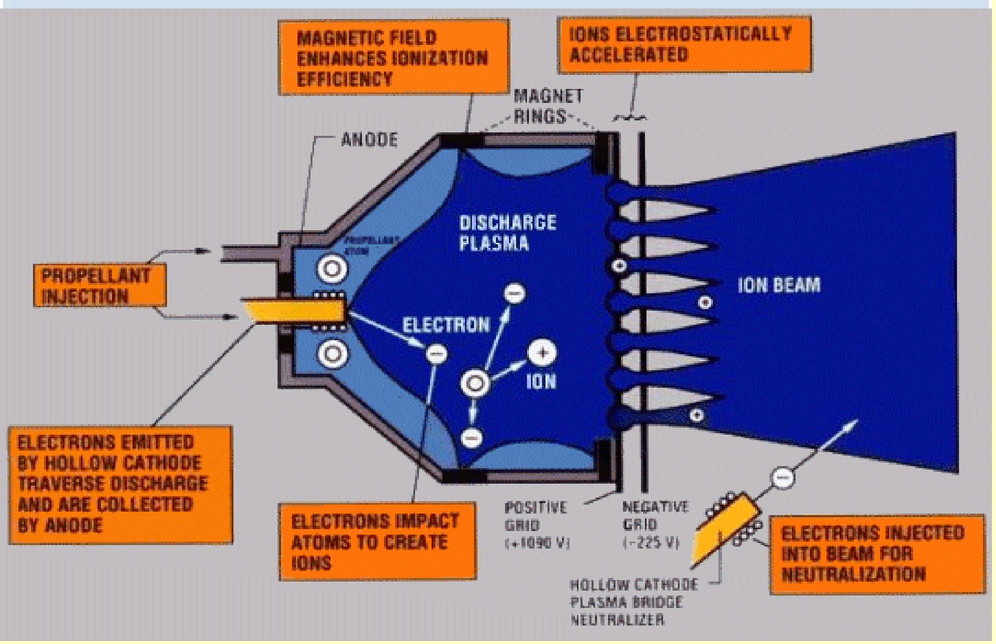

219

Gridded Ion Engines

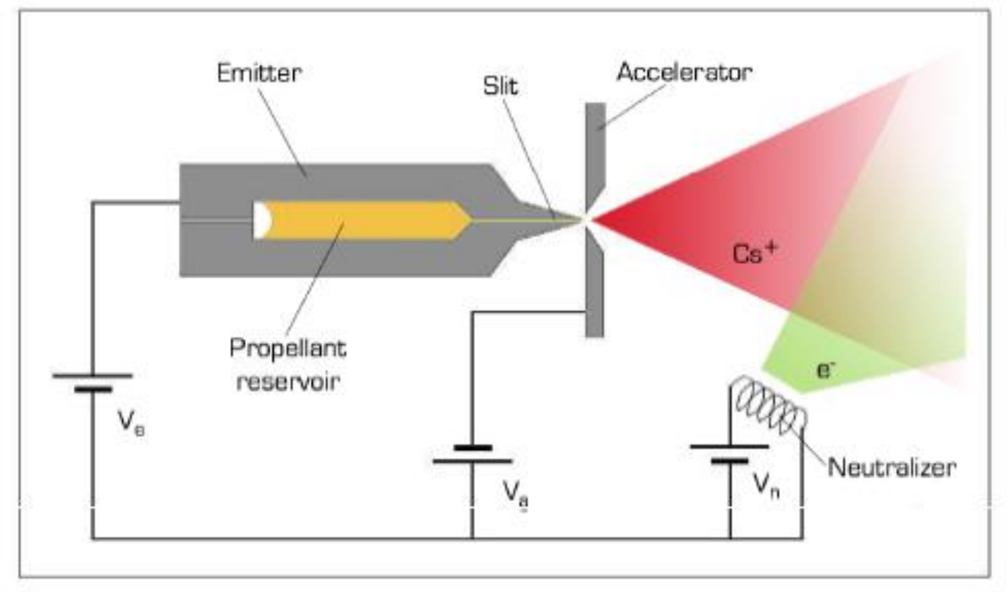


Radiofrequency Ionisation Thruster (RIT) Working Principle





Electron Bombardment Thruster Working Principle



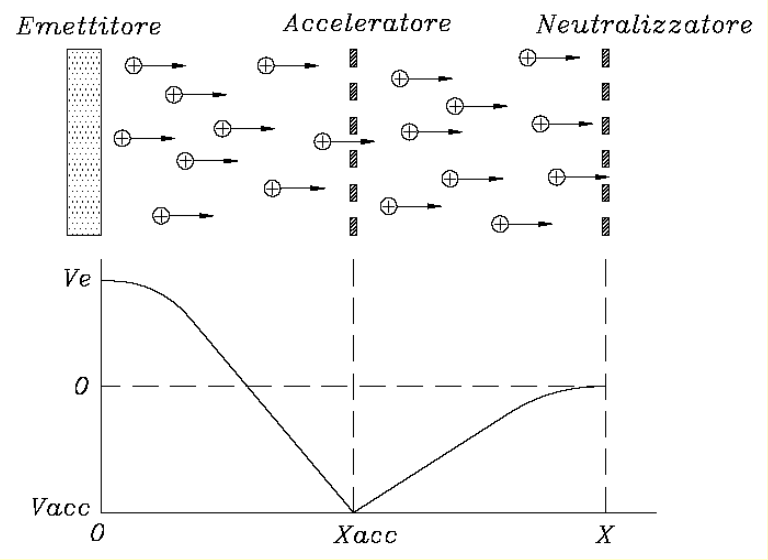
$$qV_e = \frac{1}{2} M v_e^2 \Rightarrow v_e = \sqrt{\frac{2qV_e}{M}}$$

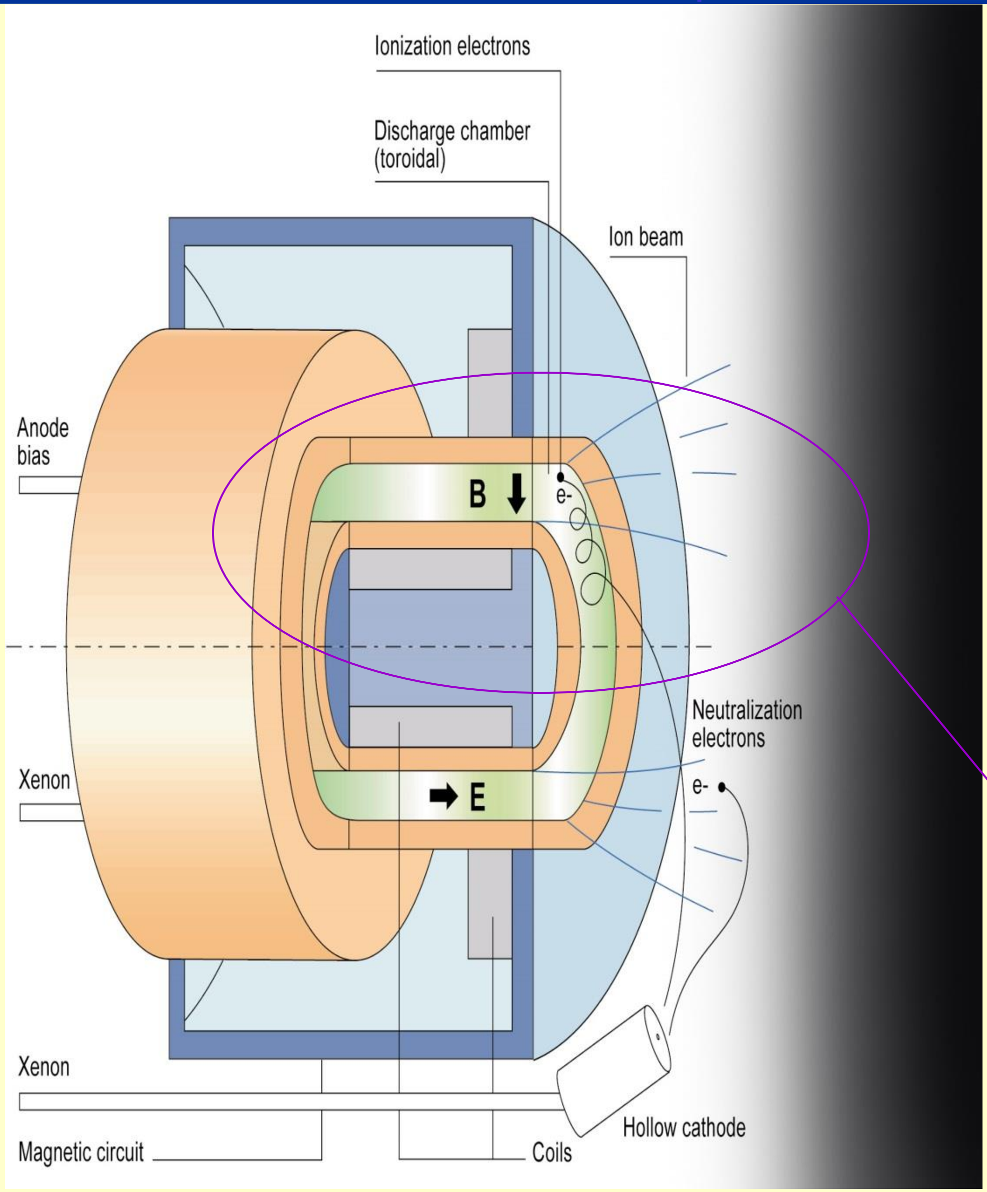
$$\dot{m}_i = \frac{MI_b}{q} \qquad I_b = I_e - I_a$$

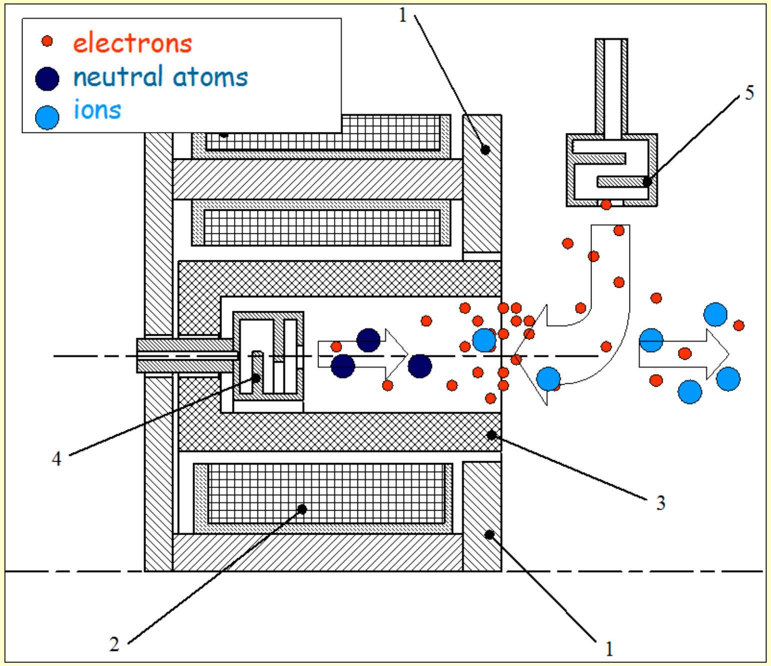
FEEP is an electrostatic type thruster:

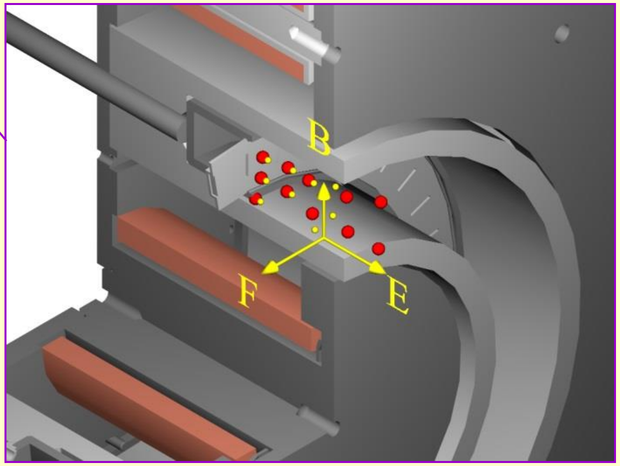
⇒ thrust is generated by ions accelerated by electric fields at high exhaust velocities;

⇒ electrons need to be emitted downstream in the same quantity for charge balancing.



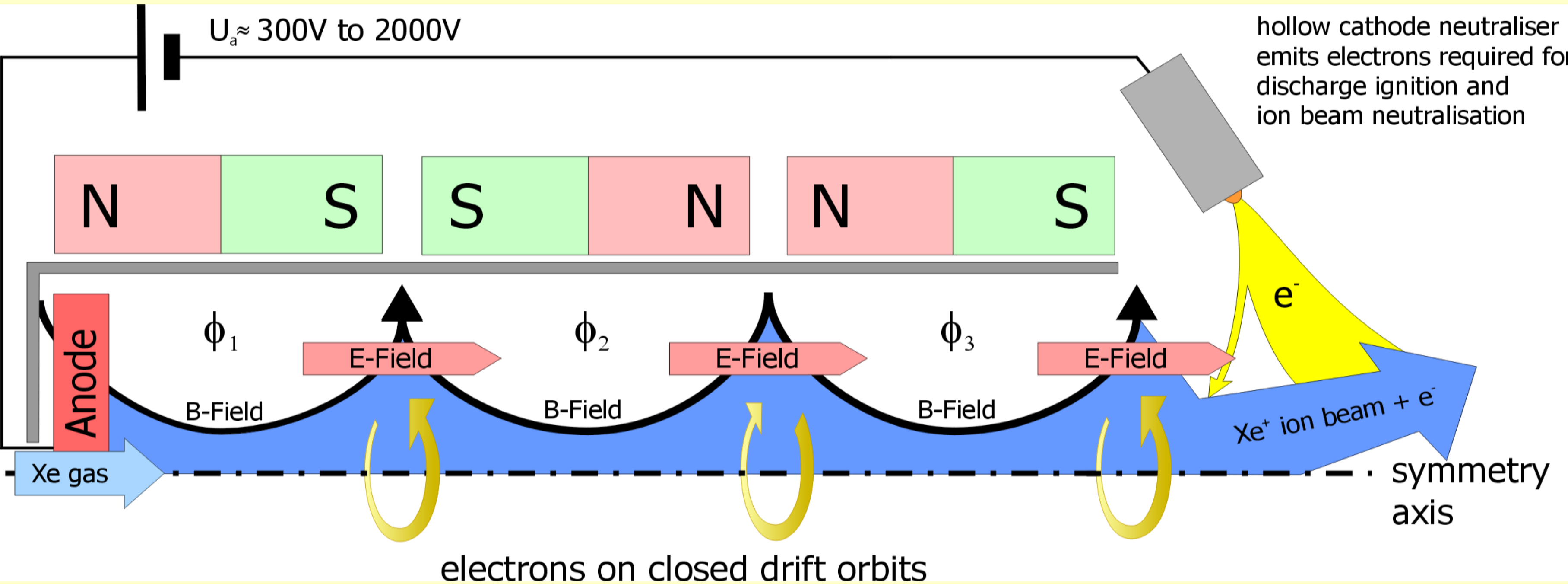

Ionization electrons
Discharge chamber
(toroidal)
Ion beam
Anode
bias
B
e-
E
Neutralization
electrons
e-
Xenon
Xenon
Magnetic circuit
Coils
Hollow cathode

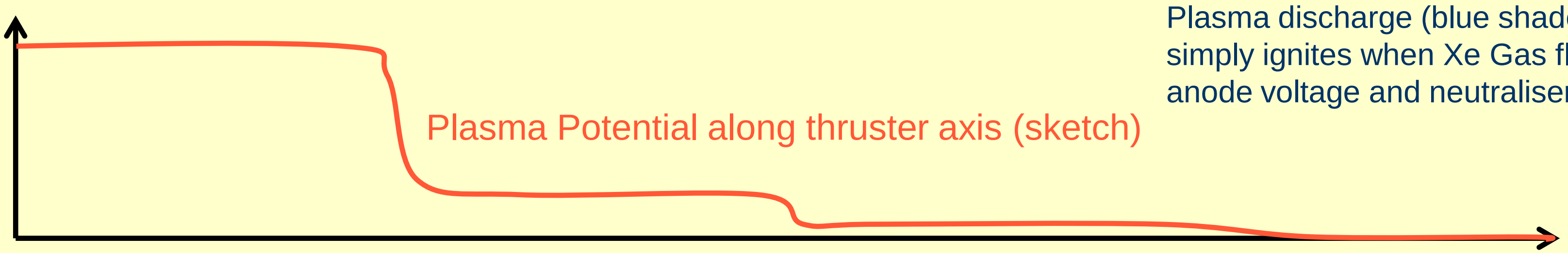

electrons
neutral atoms
ions
1
5
4
3
2
1


B
F
E

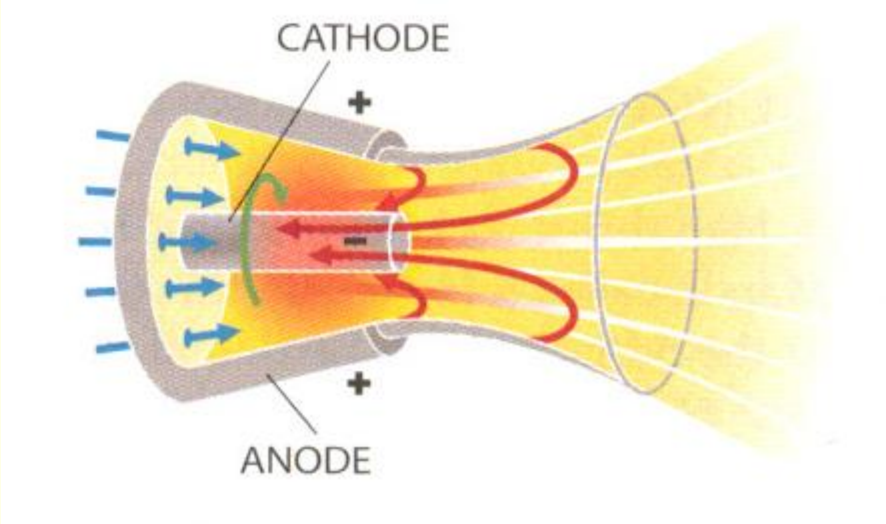
Highly Efficient Multistage Plasma (HEMP),

HEMP thruster

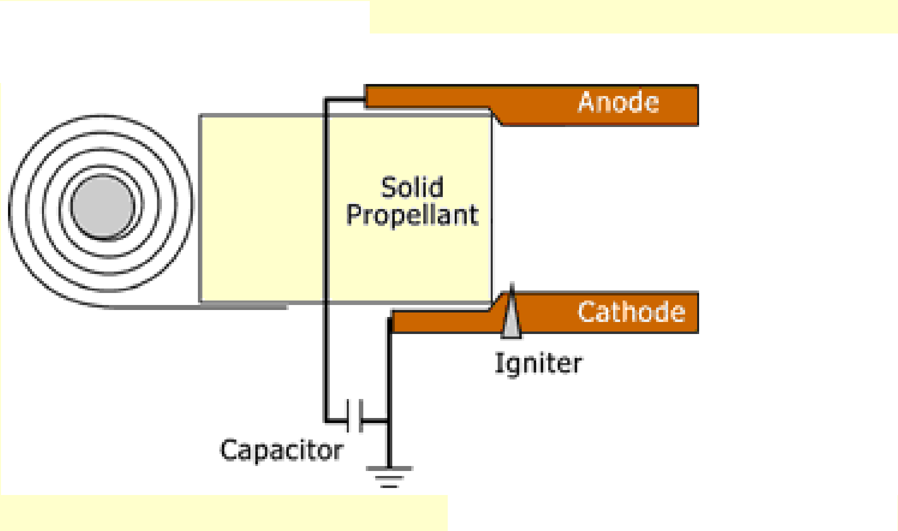




Plasma discharge (blue shaded area)
simply ignites when Xe Gas fl,
anode voltage and neutraliser are turned on.

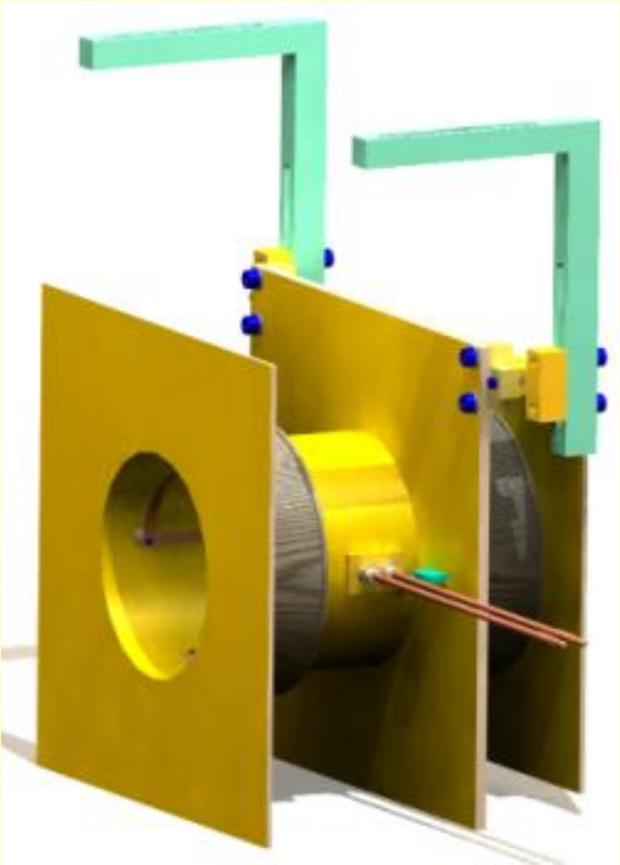


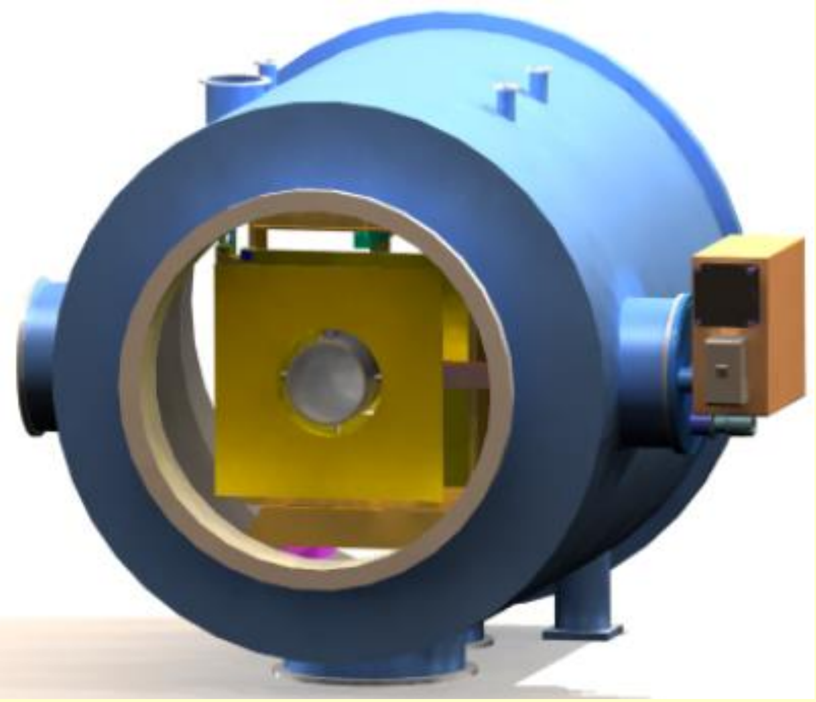
MPD Thrusters

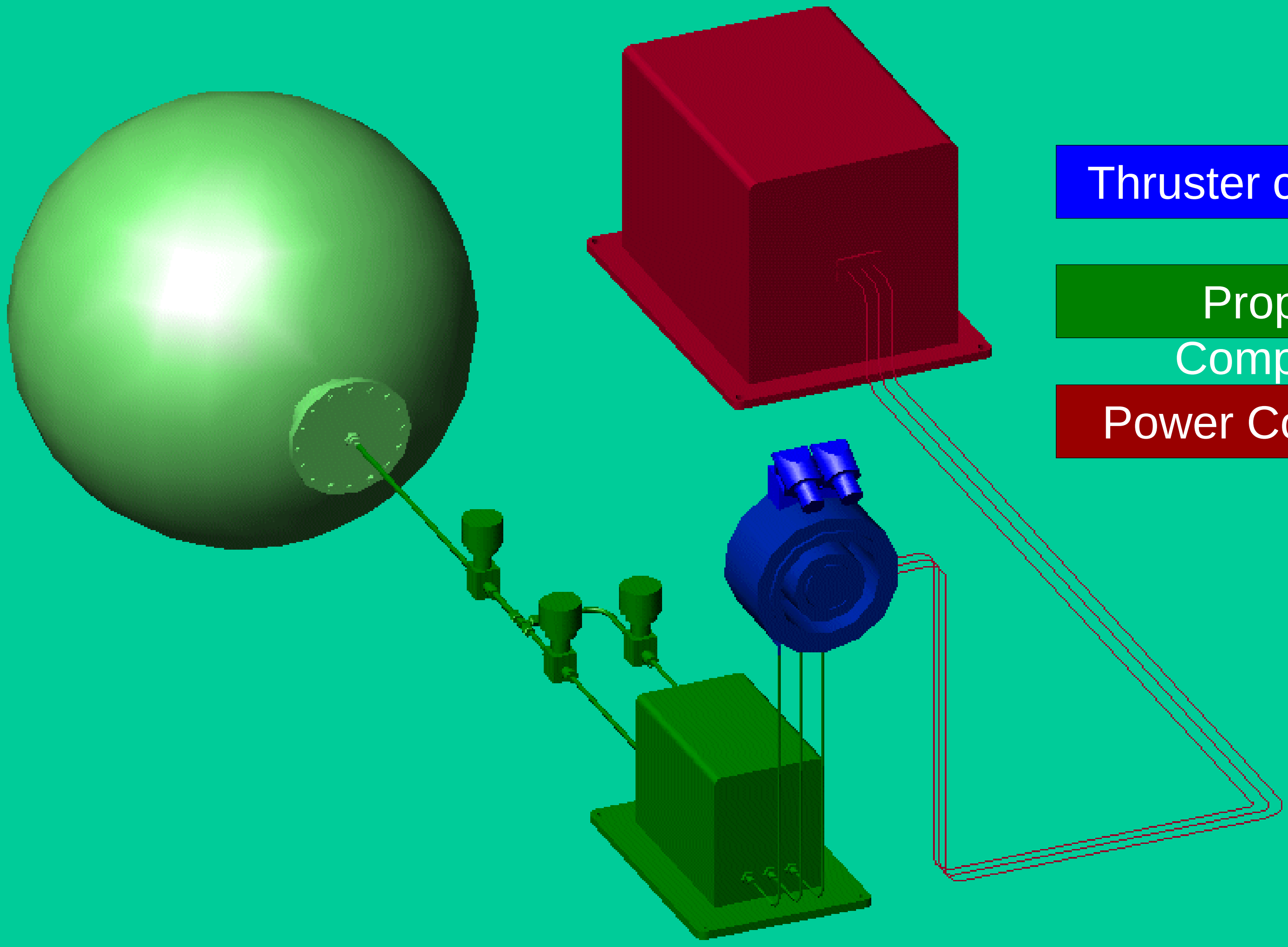


PPT Thrusters

Helicon Antenna Thruster







Thruster components

Propellant Components

Power Components

POWER ELECTRONICS

- Power Processing Unit
- Thruster Switching Unit
- Electrical Filter Unit (HET)
- Pulse Forming Network (MPD)

THRUSTER

- Thruster
- Other Components (cathode, neutraliser, grids, discharge chamber)

EP System

PERFORMANCE and LIFE QUALIFICATION TESTS

- Alignment Mechanism
- Electronics

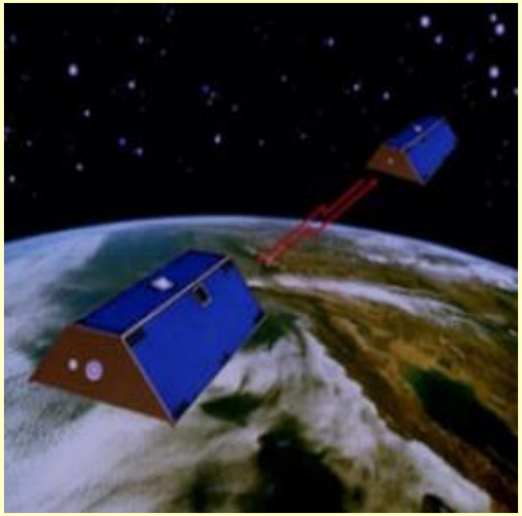
POINTING MECHANISM (optional)

- Propellant Tank
- Pressure Regulators
- Flow Controllers, Filters
- Valves

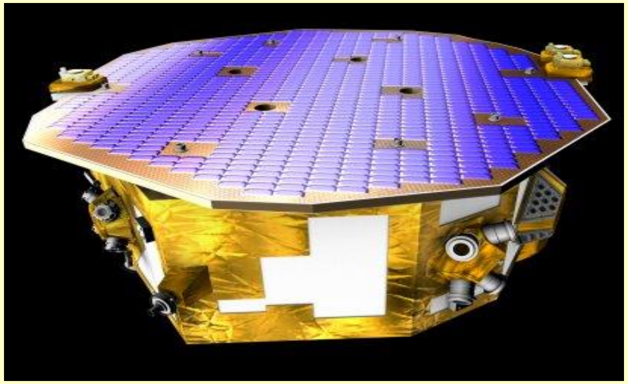
PROPELLANT SYSTEM

GOCE

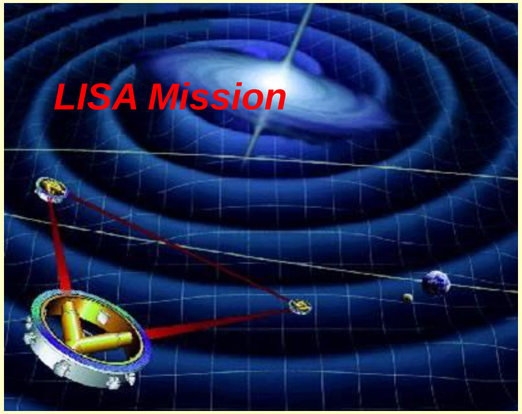
Smart-1



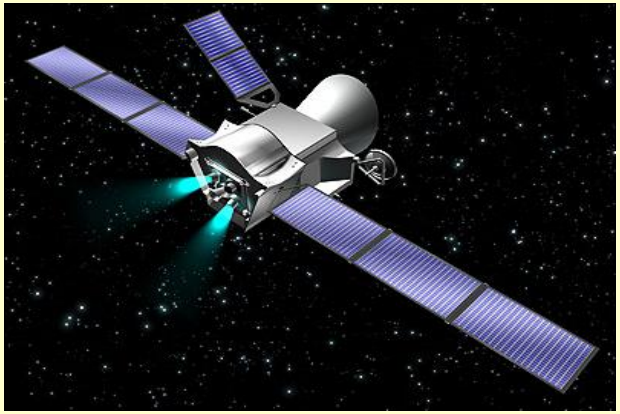
Post-GOCE



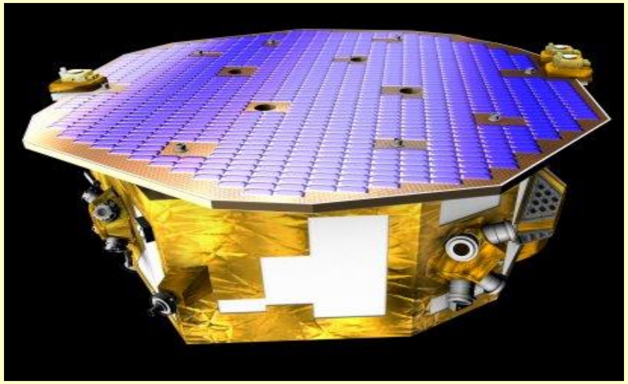
LISA Pathfinder Mission



LISA Mission

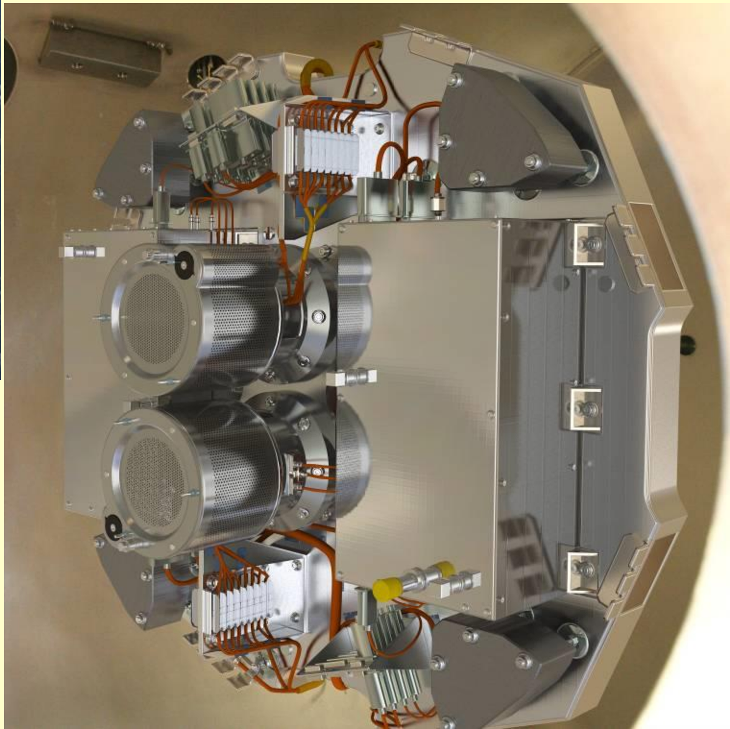


Bepi-Colombo

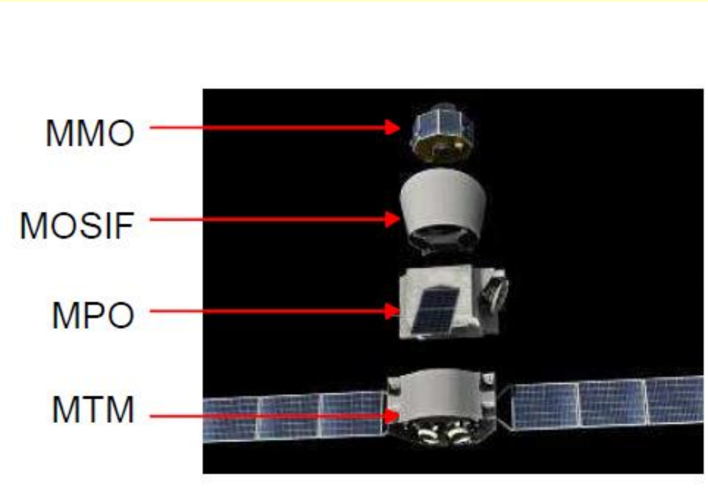


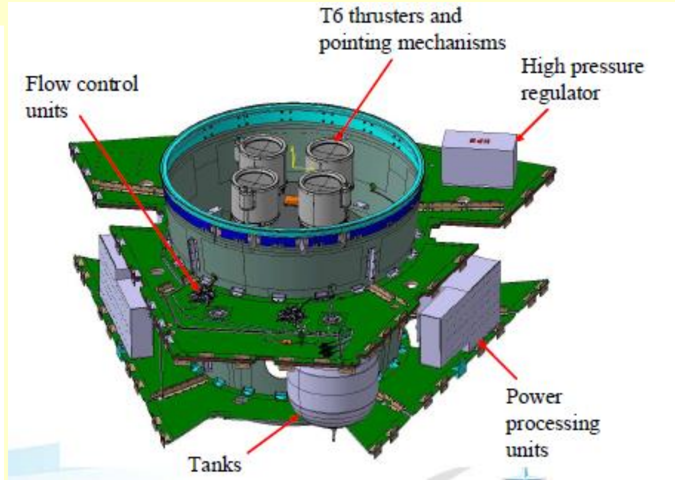
Previous and Current Missions

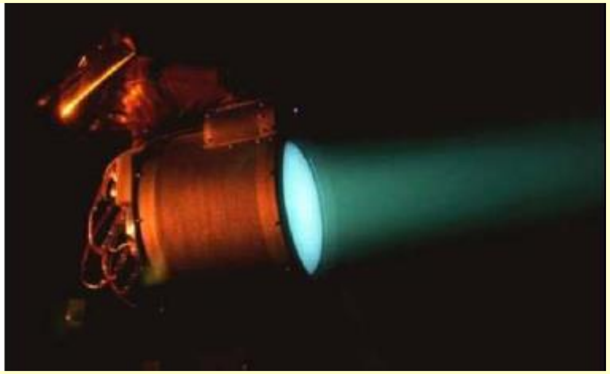
- Smart-1 reached the Moon ín 2006 using a PPS1350 Hall Effect thruster.
- Bepi Colombo will be launched in 2017 and will use four T6 Ion Engines for the cruise to Mercury.
- GOCE is using T5 Ion Engines to provide real-time drag compensation to allow high accuracy measurement of the Earths gravitational field.
- NGGM will improve the performance of GOCE. A flight formation mission.
- Lisa-pathfinder will demonstrate the use of microthrusters to compensate micro-Newton disturbance forces in a drag free control system.

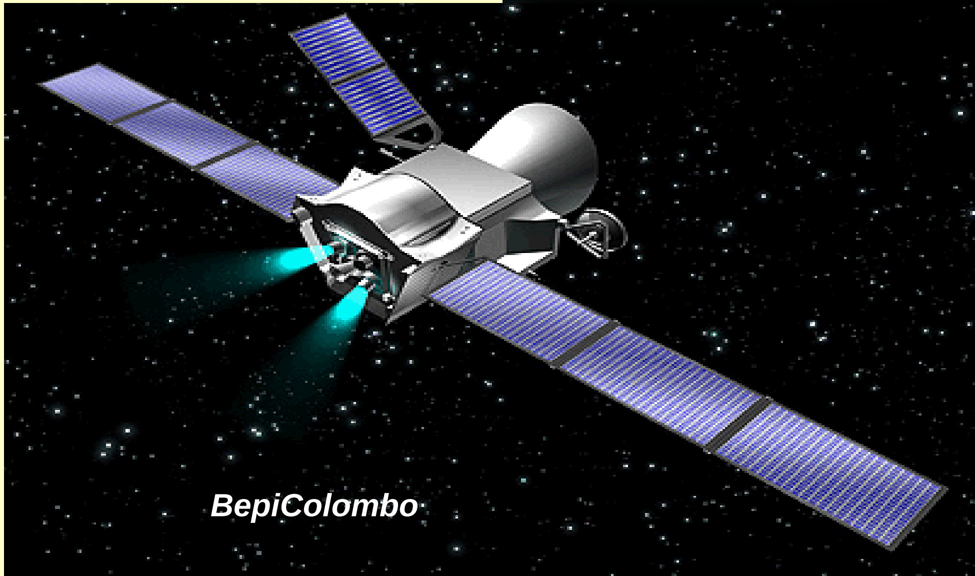


GOCE Spacecraft (concept)

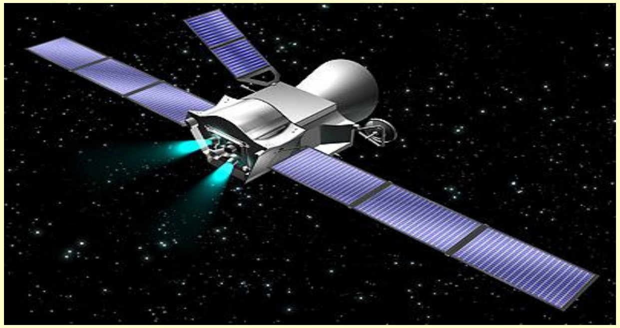

MMO
MOSIF
MPO
MTM

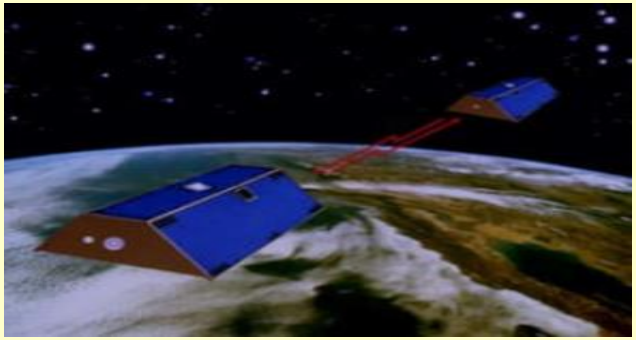

T6 thrusters and
pointing mechanisms
High pressure
regulator
Flow control
units
Power
processing
units
Tanks

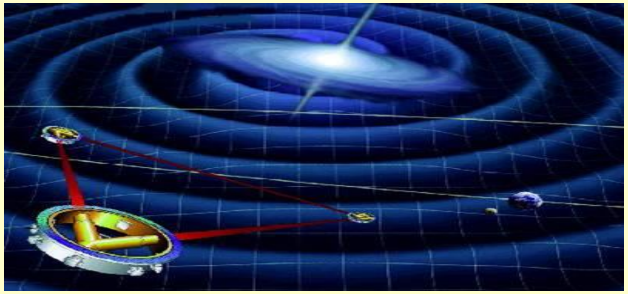



BepiColombo

Future Needs

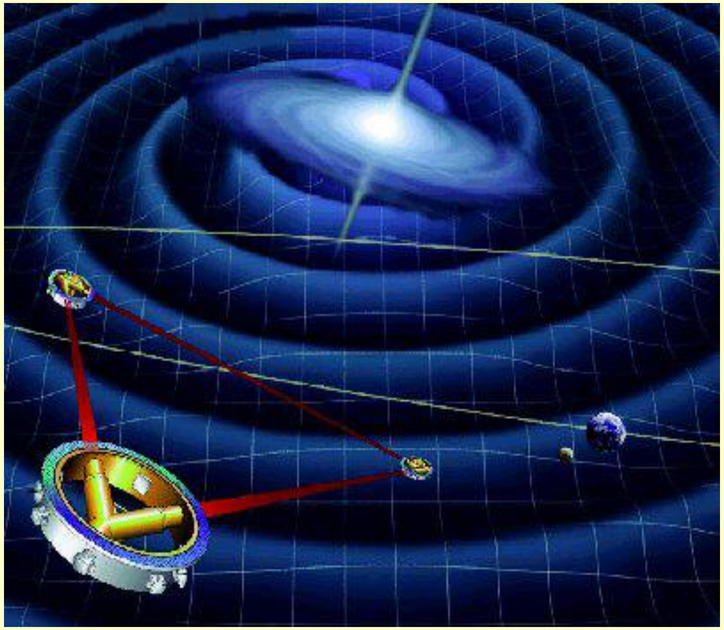






- Future Gravity Missions will require Mini-ion Engines or Field Emission microthrusters to provide drag compensation and formation control.
- LISA class missions will require micro thrusters for ultra-fine formation control. Mini-ion engines, cold gas and field emission engines are the main candidates.
- Future asteroid or planetary missions will require Ion Engines or Hall Effect Thrusters for cruise to the target object. MARCO POLO.
- Remote sensing and science missions using formation flying will need electric propulsion for formation control. Field Emission microthrusters and mini ion engines are required.

- The primary objective of the LISA mission is to detect and observe gravitational waves.
- The success of the mission is based on the performance of a sophisticated accelerometer, which must work under drag-free conditions on each LISA spacecraft.
- The drag-free control of the spacecraft will be provided by micro thrusters.
- 3 clusters of four micro thrusters each are mounted on each LISA spacecraft. The major force to be compensated is the solar radiation pressure force of approximately 50 µN.
- LISA Pathfinder is the technology demonstrator of LISA.

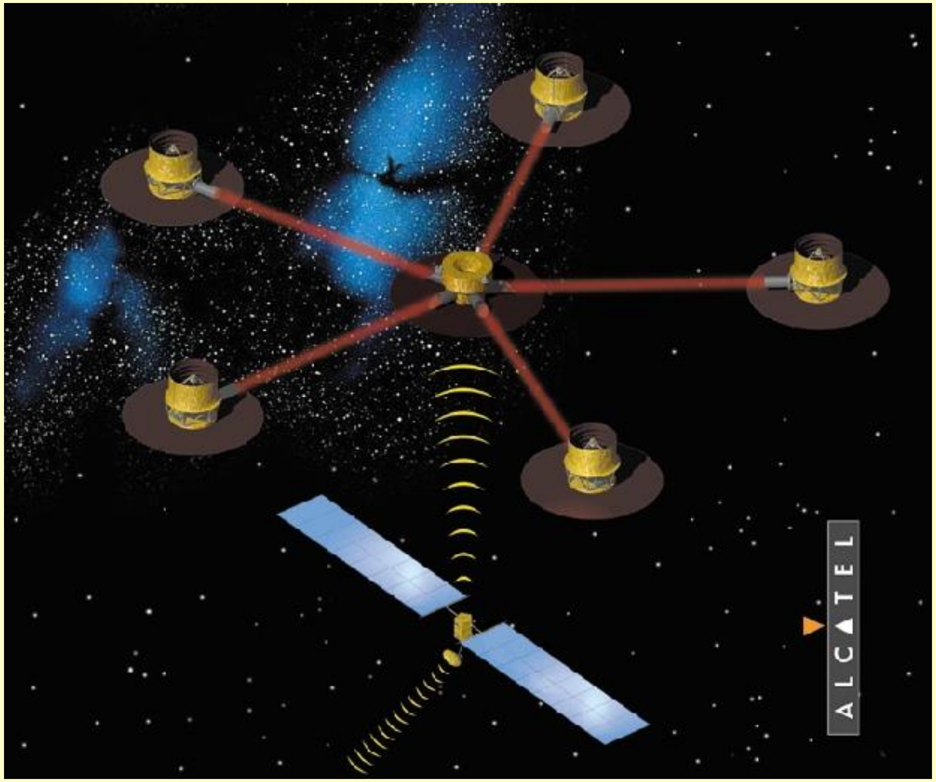


The goals for this mission is to detect terrestrial planets in orbit around other stars than our Sun and to allow high spatial resolution imaging.

A constellation of spacecraft will form the interferometer and will rely on electric propulsion to perform orbit and attitude control and reconfiguration of the cluster of satellites.

The propulsion system required will have to provide thrust ranging from several microNewtons for orbit maintenance to several milliNewtons for moving the constellation to observe different bodies. Mini-ion engines and FEEPs are candidates.

This missionn is not part of the current ESA Science programme today due to the technical difficulties in propulsion and metrology.



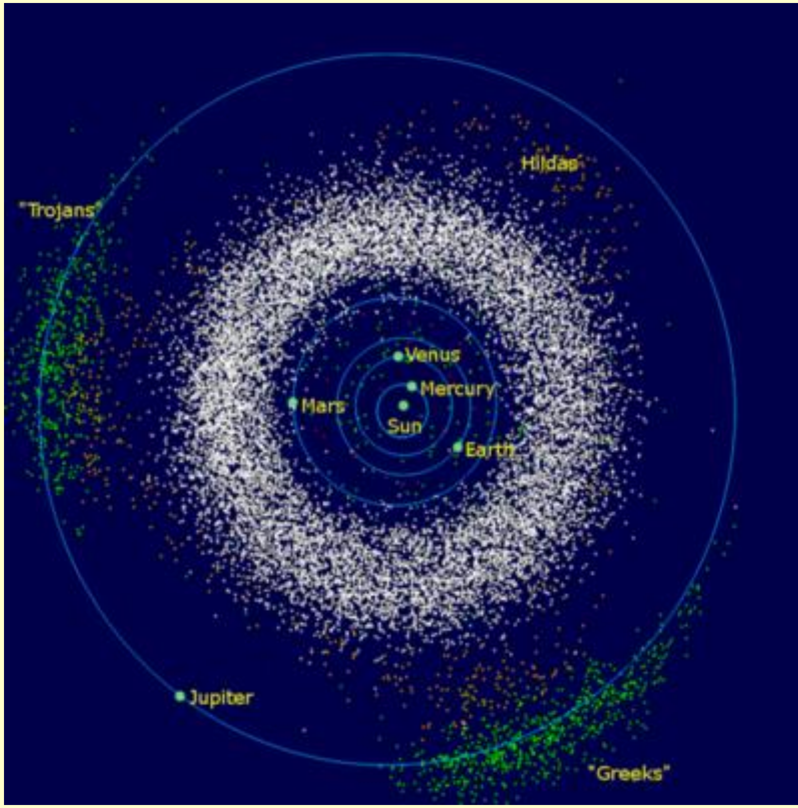
DARWIN Mission (concept)

Missions to Asteroids

- The Delta V required to reach many Asteroids is very high. Electric Propulsion systems providing high specific impulse are the best candidates to bring spacecraft to the vicinity of a celestial body of this kind.

- Asteroid proximity operations: in order to land it is needed to know the surface characteristics (orbiting phase). The low thrust of the electric propulsion implies that the spacecraft velocity when the spacecraft reaches the Asteroid is low. Breaking manoeuvres are affordable.

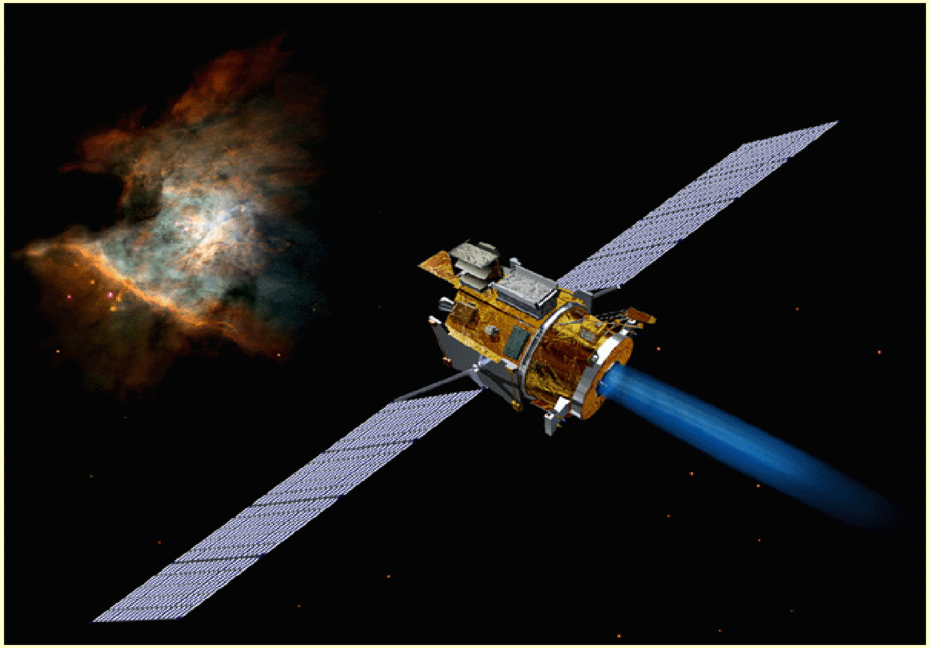
- The amount of swing-by manoeuvres is low when EP is used in this kind of missions.



This mission will bring a spacecraft to the Asteroid 1996FG3 which is between 0.7 and 1.4 AU in 8 years from GTO.

The current mission configuration is based on a “cruiser” which will touch down the Asteroid, catch a sample and come back to Earth.

Electric Propulsion will allow to launch the spacecraft in Soyuz



The main propulsion system for the cruise is composed of 2 Qinetiq T6 ion engines. One operating and the other one in cold redundancy.

Where are we today?

- Electric propulsion has taken us to the Moon (SMART-1) and is allowing us to measure the Earth's gravitational field with unprecedented accuracy (GOCE).
- Electric propulsion is planned to take us to the planet Mercury (BepiColombo) and will allow us to investigate the existence of gravitational waves (LISA).

Required future developments

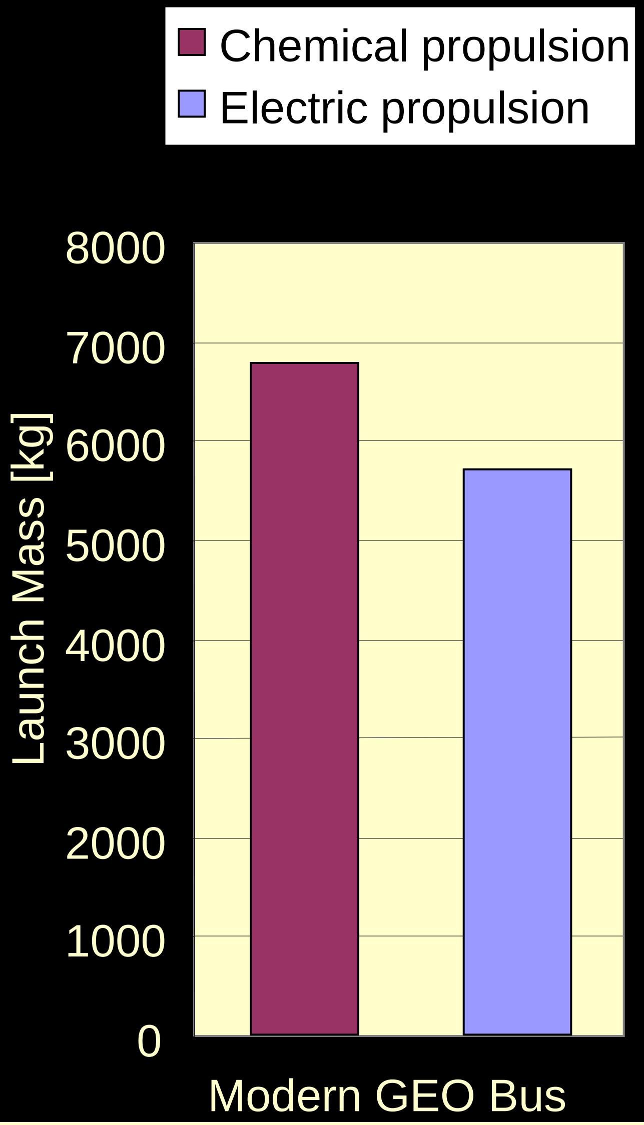
- Mini-ion engines and Mini-hall thrusters must be developed to satisfy the needs of future gravity missions and other science and remote sensing missions using formation flying.
- Large Ion Engines and Hall Effect Thrusters must be developed to meet the needs of future asteroid or planetary exploration missions. Cargo missions to Mars will also make a good use of these systems.

Geostationary Spacecraft

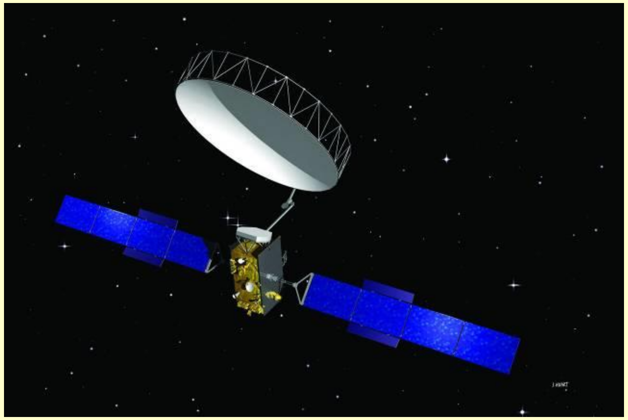
- Station Keeping
- Orbit Transfer to GEO
- De-orbiting at EOL

LEO/MEO Constellations

- Orbit transfer
- Relative positioning
- De-orbiting at EOL



Commercial Spacecraft,



- ESA **Artemis** satellite using 4 ion engines (2 RIT and 2 UK-10) has paved the way for the use of electric propulsion in telecommunication spacecraft.

- Astrium with 6 spacecraft launched (4 **Inmarsat,** 1 **Intelsat and 1 Yasat** satellites) and 3 more satellites in construction has the most important experience in Europe in integration of Electric Propulsion Systems (SPT-100 for NSSK operations).

- Astrium and Thales have demonstrated their capability to integrate this technology in GEO satellites. The ESA **Alphasat** spacecraft uses PPS1350 for NSSK operations. Alphabus evolution will also consider Electric propulsion for future missions. New spacecraft will use SPT-140 and PPs 5000 for orbit raising and NSSK..

- **Small GEO** satellites will have 4 Hall Effect thrusters, SPT-100, (HEMPTs were developed) for NSSK and EWSK (fixed configuration).

- **NEOSAT and ELECTRA** have been approved at the ministerial conference in 2012 as the new ESA projects in the telecommunication directorate. EP for station keeping and ORBIT RAISING manoeuvres. FULL EP SPACECRAFT

Electric Propulsion for Commercial Applications: 2016 and later

- The EP application lead achieved by Europe (ARTEMIS/STENTOR) has been all but lost with worldwide competitors offering orbit topping on its large platforms and developing small platforms with 'all-electric' orbit raising and station keeping functions.
- All of the existing European platforms use the Fakel (RU) SPT-100 Hall Effect Thruster or the Snecma PPS-1350G Hall Effect Thruster. Since the total impulse capacity of the both of these thrusters is limited, existing configurations can not offer significant orbit topping in addition to the baseline station keeping functions. PPS5000, SPT-140 , Aerojet-ESP thruster will allow orbit raising manoeuvres.
- The European reaction to the changing launcher market and commercial platform developments in the United States is now underway. Both **NeoSat (ARTES-14)** and **Electra (ARTES-33)** are intended to cover the small to medium class platform applications. Significant topping of between 4-8 months, or complete electric orbit raising configurations are expected from these developments.
- It is clear that the trend to increased use of electric propulsion will continue in the telecommunications market and that higher power thrusters will be needed to meet both the orbit raising and station keeping needs of future small and large platforms.

The aim of ESA is to ensure the technology building blocks are made available in a suitable timeframe to support this evolution in commercial satellites

Electric Propulsion for Telecommunications

- The use of Electric Propulsion in the telecommunication space market is essential to improve the position of the European space sector. The announcement of Boeing in 2012 on the procurement of 4 telecommunication spacecraft (platform 702SP) for Satellites Mexicanos (Satmex) and Asian Broadband Satellites (ABS), offered for only 125 million dollars each including launch, thanks to the use of electric propulsion for both NSSK and orbit raising from GTO to GEO, has been noted by European operators and primes.

- ESA is now fully involved in the preparation of several telecommunication programmes (Neosat, Electra, Hercules) that will make use of electric propulsion for all the key manoeuvres, paving the way for the commercial use of all-electric platforms by the primes Astrium, Thales and OHB Systems.

- Boeing has selected the Falcon 9 launcher for the launch of these spacecraft. Current and future European launchers will need to be capable to optimise their performances, interfaces and operations to offer the best launch options to new all-electric platforms.

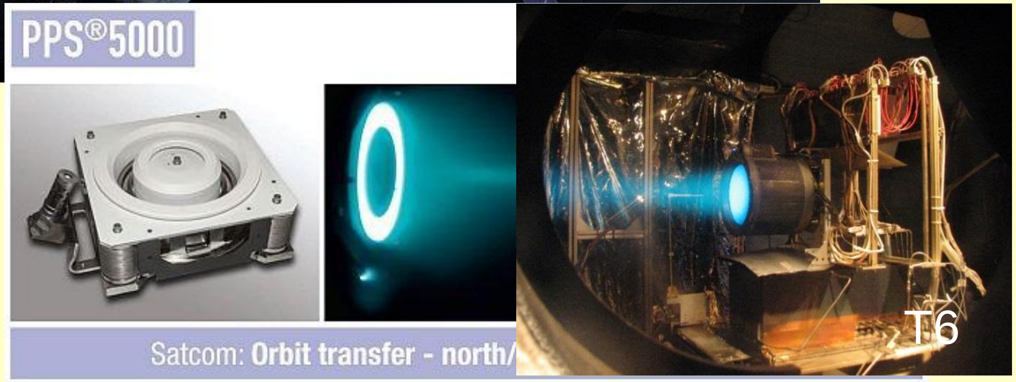
- In the short term, the adoption of electric propulsion might offer new opportunities for the heavy lift Ariane 5, that typically offers to launch two spacecraft, one large and one medium. Adding the option of a low mass 702 SP class comsat, Arianespace could accommodate larger primary payloads co-manifested with a single all-electric spacecraft, without exceeding the rocket's total capacity.

- Airbus Defense and Space, LORAL, Lookeed are building spacecraf using EP for orbit raising and station keeping manoeuvres.

- In the longer term, Ariane 6 will have to be compatible with a new generation of full electric spacecraft

Commercial Spacecraft

- existing European platforms use the Fakel (RU) SPT-100 Hall Effect Thruster or the Snecma PPS-1350G Hall Effect Thruster.
- They can not offer significant orbit topping in addition to the baseline station keeping functions.
- **NeoSat (ARTES-14)** and **Electra (ARTES-33) ,**the small to medium class platform. Topping of between 4-8 months, or complete electric orbit raising configurations are expected from these developments.
- The trend to increased use of electric propulsion will continue
- The higher power thrusters will be needed to meet both the orbit raising and station keeping needs of future small and large platforms.



Commercial Spacecraft

- Space X: ~5000 spacecraft using mini-HET
- OneWeb: > 675 spacecraft may also use electric propulsion
- Others (Leosat, etc.)

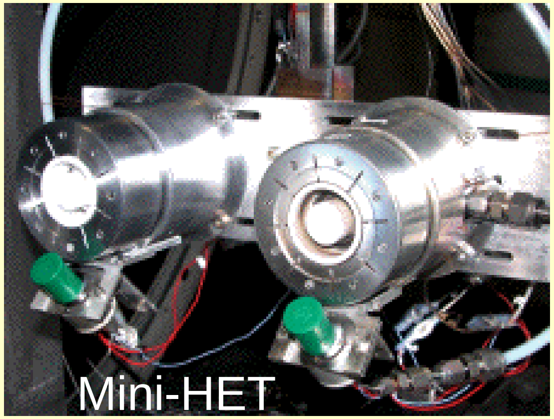
Constellations will use propulsion to perform;

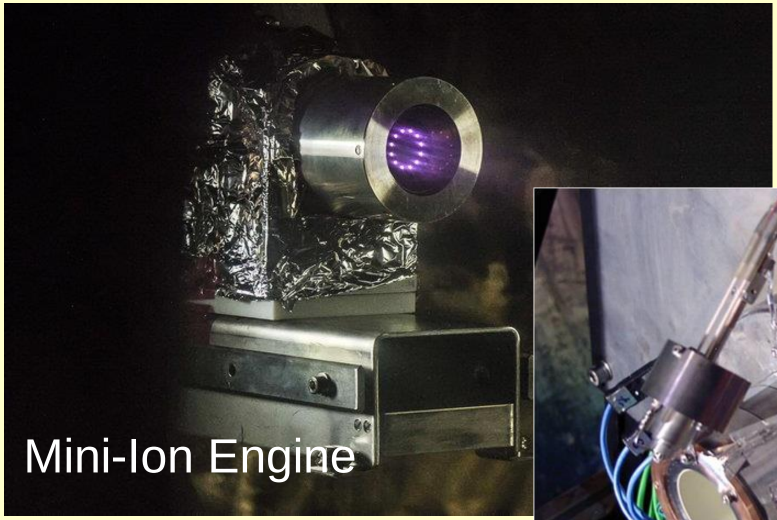
- orbit acquisition, maintenance and de-orbiting from low earth orbit (around 600 km)

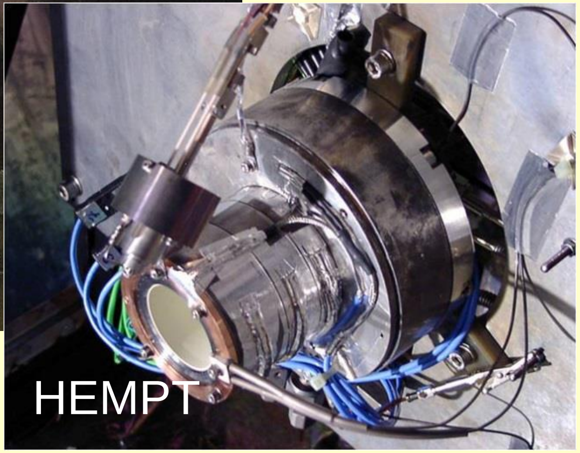
Satellites

- ~ 200 kg with
- powers for propulsion ~ 200 W.
- Mini-HET is one of the most interesting options.
- Spacecraft cost around 500 000 $
- the propulsion system (thruster ~15 000 $ and electronics

~25 000 $)







Electric Propulsion for Commercial Applications: 2000-2015

With the exception of ESA's ARTEMIS platform all European commercial platforms utilize Hall Effect Thruster Technology •

Platform	Prime Contractor	Status	EP Function	EP Thruster	EP Thruster Type
ARTEMIS	Thales Alenia Space- Italy	Flight Proven	NSSK (OR during recovery)	2 X UK-10 (T5) 2 X RIT-10	GIE
Eurostar E3000	Astrium	Flight Proven	NSSK	4 X SPT-100	HET
SpaceBus	Thales Alenia Space	Flight Ready	NSSK	4 X PPS-1350G	HET
AlphaBus	Astrium / Thales	Flight Proven	NSSK	4 X PPS-1350G	HET
AlphaBus Extension	Astrium / Thales	Under Development	NSSK, Orbit Topping	4 X PPS-1350G 4 X PPS-1350G OPTION T-6	HET/GIE
SGEO	OHB	PFM 2014	NSSK, EWSK, Momentum Management	8 X SPT-100 Or 8 X HEMPT	HET/HEMPT

Excepting SGEO these platforms have retained a full chemical propulsion capability; electric propulsion being offered as an option to the existing all chemical product range, rather than as a separate product line.

- Between the two technologies, a full range of

Characteristic	Hall Effect Thruster	Gridded Ion Thruster	Comment
Specific Power	18W/mN	25-35W/mN	Lower number represents improved Orbit Transfer durations for a given power ceiling
Thruster Efficiency	50%	70%	Higher number tends to reduce thermal interface demands for a given power ceiling
Specific Impulse	1500-2500s	2500-4500s	Higher number represents wet mass saving / higher payload fraction
Operating Voltage	300-400V	1000-2000V	
PPU Specific Mass	5kg/kW	10kg/kW	Higher number represents increased EP system dry mass penalty
Plume Divergence	45°	15°	Lower number reduces complications of thruster beam interaction with spacecraft appendages (Solar arrays, antennas)
Throttle Range	2:1	10:1	20:1 demonstrated on GOCE (QinetiQ T5)

Where are we today?

- Electric propulsion is providing operational NSSK on several Eurostar 3000 spacecraft and many Boeing and LORAL spacecraft.
- Electric propulsion has been selected for the Alphasat and Small GEO missions, performing station keeping operations.

Required future developments

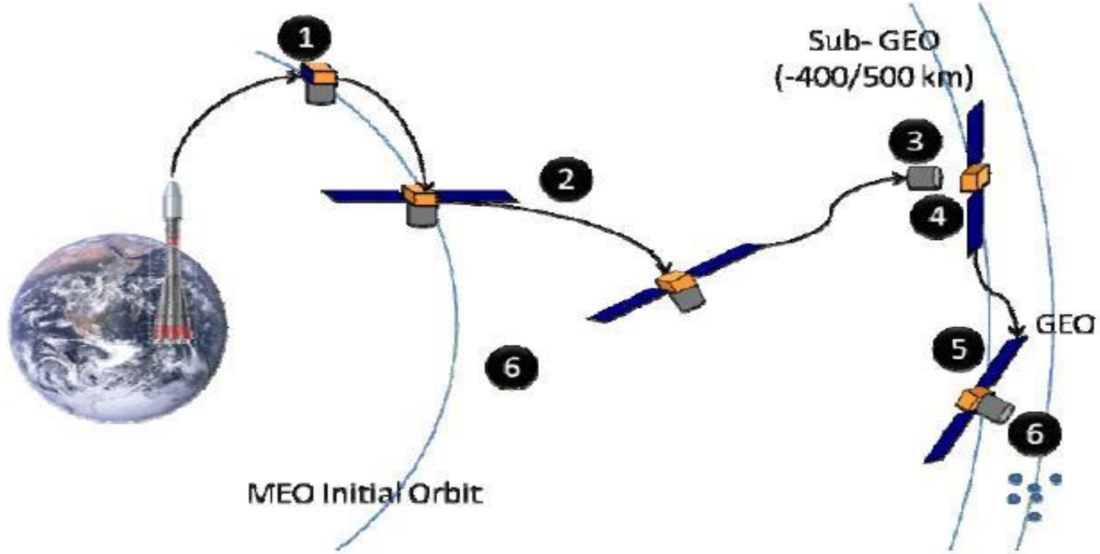
- Cost reductions must be achieved across the complete propulsion sub-system to improve competitiveness.
- Full qualification of European feed system components (regulators, latch valves and flow control valves) to remove ITAR dependencies.
- Life extension of existing thruster systems (SPT-100, PPS1350) to satisfy medium-term high power platform needs.
- Qualification of high power thruster variants (T6, PPS 5000, SPT-140) to satisfy the needs of future very high power platforms. **Orbit Topping and Orbit raising will be the new challenge.**
- **New ESA projects (NEOSAT and ELECTRA) will make use of EP for orbit raising and station keeping. FULL EP SPACECRAFT**

•ESA has initiated a reflection period on Exploration. A Working group has been set up and several technology missions have been studied.

• The main idea is to have technology missions that prepare the way to Exploration, taking into account the different needs of these missions on propulsion.R2D3 and Complex are technology missions with Electric Propulsion (10kW engines)

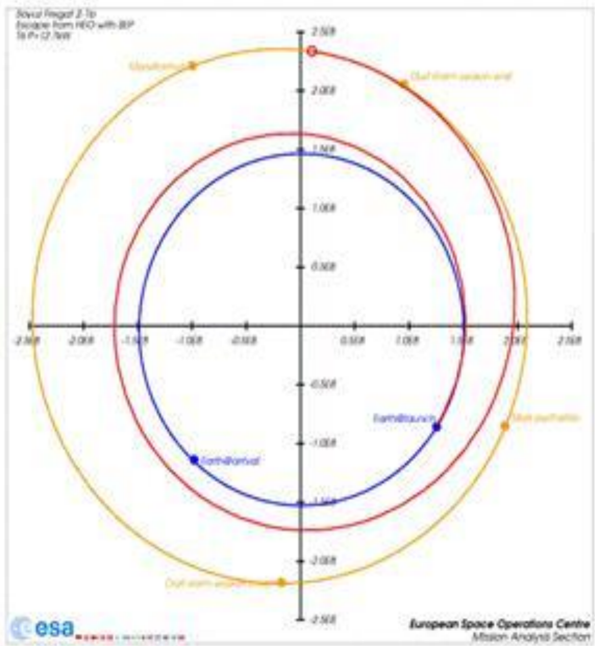
•The roadmaps for the technology needed for Exploration will be harmonised with industry.

Mission Phases

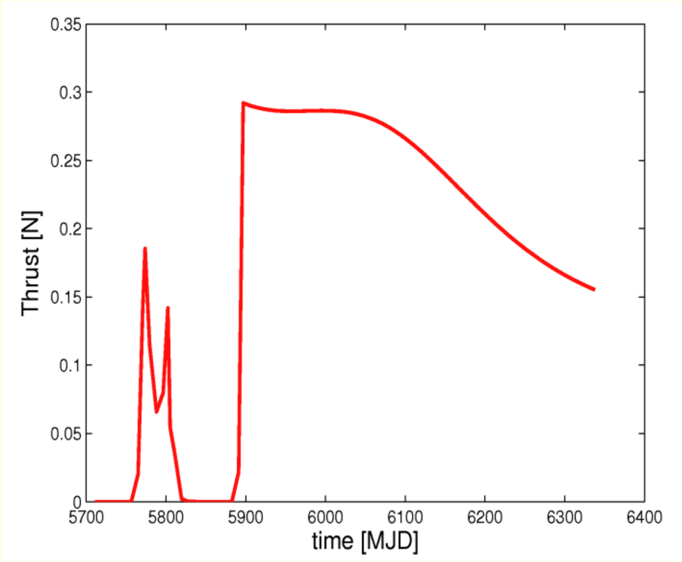


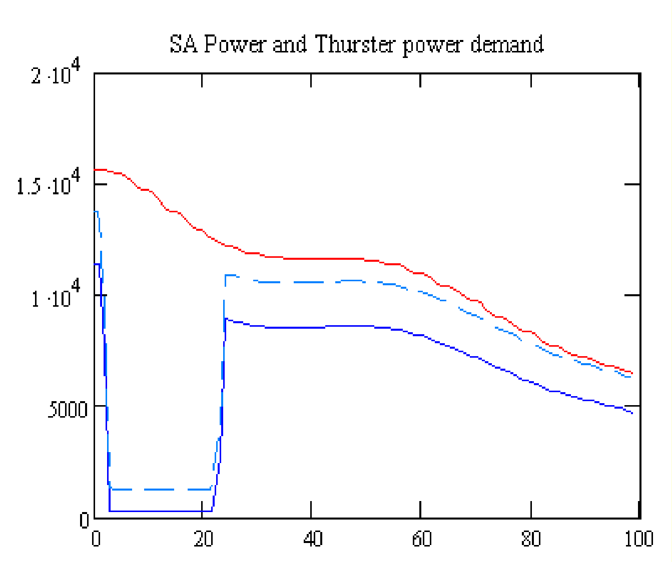
1. Soyuz 8000 km circular MEO launch of Chaser/Target composite
2. Spirals out with EP to a sub-GEO (-400 to -500 km) in around 150 days (TBC)
3. The composite separates
4. The Chaser performs RVD & docking experiment with the Target
5. Demonstration and validation of fuel transfer from/to the Target
6. Composite performs remaining optical missions (debris and Laser Communication Terminal validation)
7. EoL, composite remains in Sub-GEO

QINETIQ T6 case with escape from HEO



- Launch : Jun. 2015 into HEO (300x375000km)
- Mass at launch: 2300 (w/o adaptor)
- Escape by SEP: Sep. 2015
- Power @1AU: 12.7kW
- Mass into escape: 2235 kg
- Departure Velocity : 0.6 km/s
- Arrival SOI: 15 May 2017
- Arrival velocity: 350 m/s
- Arrival Mass SOI: 2017 kg
- Transfer time: 630 days
- DV: 4.5 km/s (w/o margin)





-Main requirement: at EOL power on the thruster to achieve a 150 mN thrust.

-Solar Array surface of 45m².

-Payload mass of 625 kg (CP 350 kg), similar mission time (2 years)

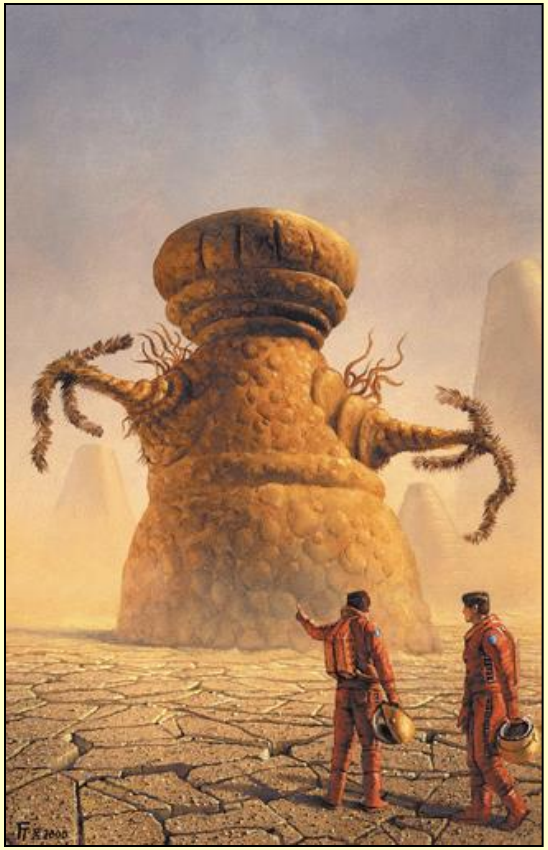
Interplanetary Human Missions, MARS

- *Land a crew of humans on Mars by 2030 and return them safely, ensuring planetary protection for both, Earth and Mars,*
- *Demonstrate human capabilities needed to support human presence on Mars,*
- *Perform exploration and expand scientific knowledge taking maximum advantage of human presence including sample selection,*

- *Assess suitability of planet for long term presence*
- *Use of Electric Propulsion Systems for cargo*

Required Knowledge

- *Existence of life forms on Mars*
- *Radiation Environment*
- *Effects of Radiation on Humans*
- *Medical and Physiological Aspects*
- *Psychological Reactions*
- *Martian Soil Properties*
- *Martian Atmosphere Properties*

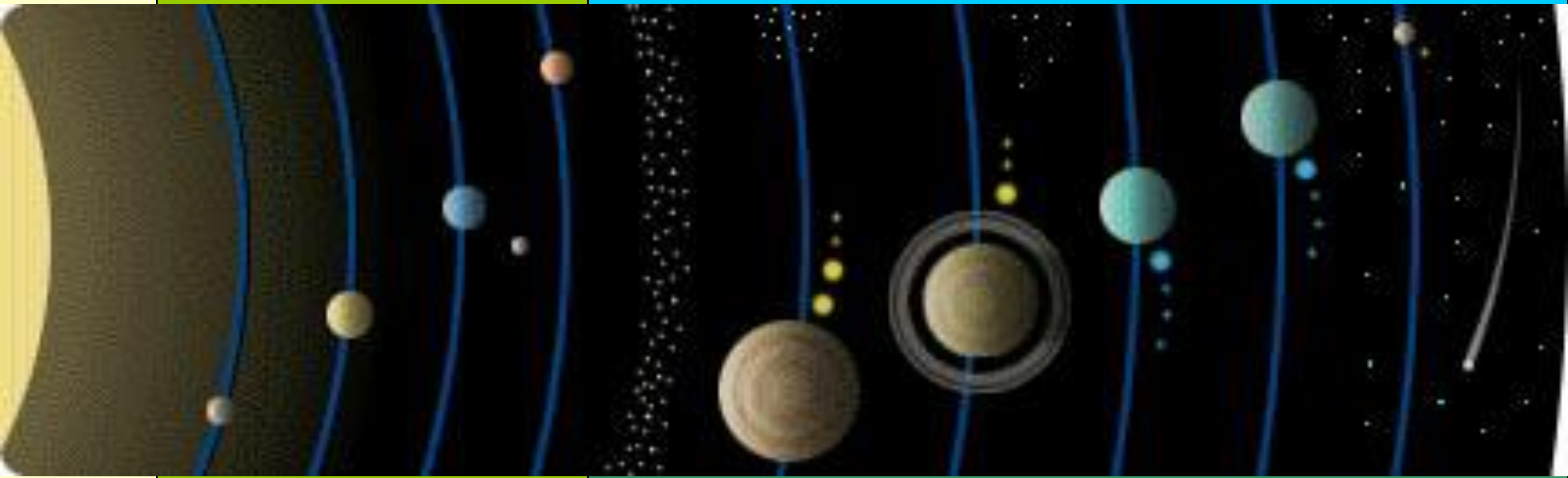


Required Capabilities

- *Assembly in Orbit*
- *Advanced Interplanetary Propulsion*
- *Light-weight Habitats*
- *Life Support Systems*
- *Aerocapture/Aerobraking*
- *Descent and Landing*
- *Space Infrastructure (Telecom, Navigation)*

The Last Frontier

	Main Asteroid Belt	Trojan Asteroids	Centaur Minor Planets	Trans-Neptunian Objects	Kuiper Belt Objects / Comets



Inner Planets	Jupiter and Moons	Saturn and Moons	Uranus and Moons	Neptune and Moons	Pluto/Charon

Solar Electric Propulsion for Inner Solar System

Radioisotope Electric for Outer Solar System Missions

- –Targets with low Mass
- – 500 W Class RTG
- – <50 kg payload
- –Delta II Launchers

Nuclear Electric for Large Flagship Missions to Outer Planets

- –Large Targets
- –100 kW Class Reactor
- –>500 kg Payloads
- –Delta IV Launch Vehicles

RTG for Surface Lander

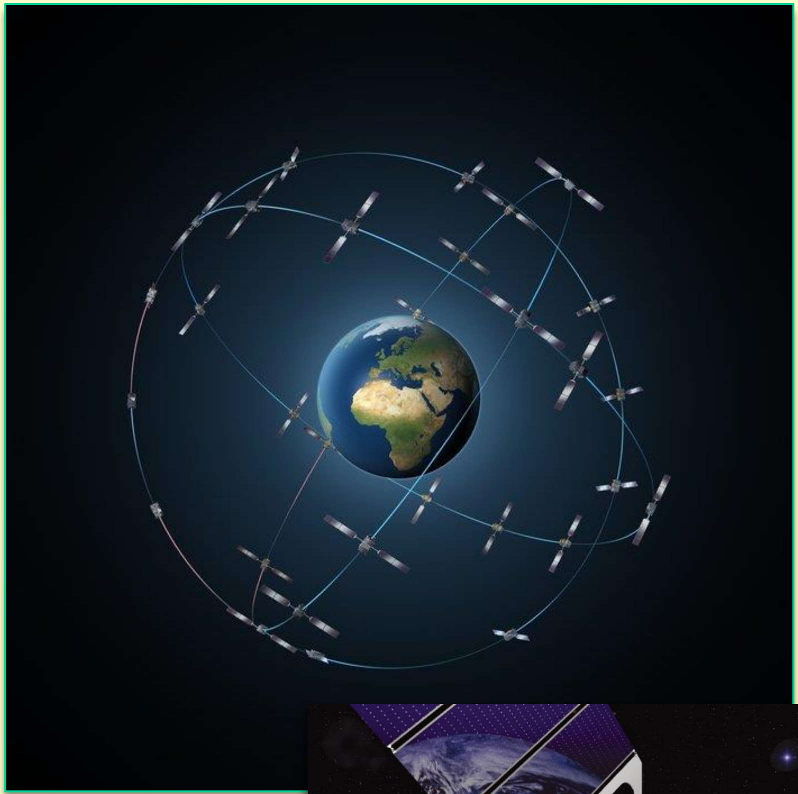
Navigation – Galileo 2nd Generation (G2G)

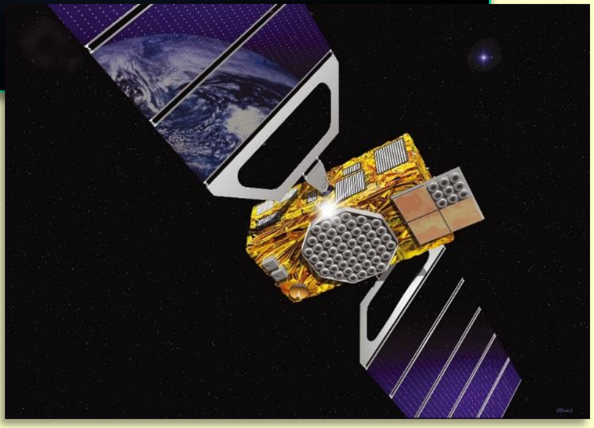
- ESA is preparing the future replacement of GALILEO constellation and is targeting the possibility to increase the Galileo Payload capability without impacting the launch costs (and possibly reducing them).

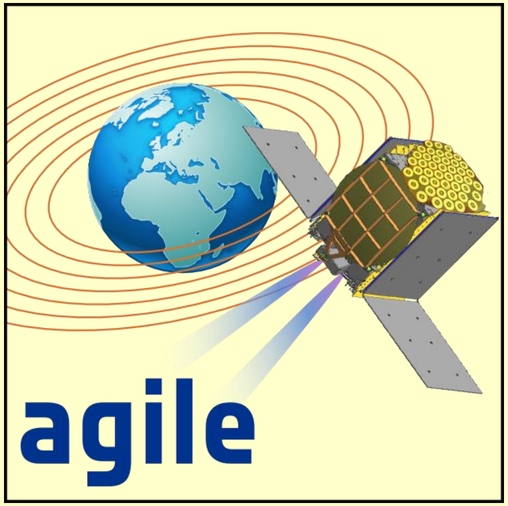
- The increase in payload capability could be achieved by changing the launch injection strategy and by using Electric Propulsion to transfer the satellite from the injection orbit to the target operational orbit.

- The use of the Electric Propulsion system 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.







- ESA is preparing the future replacement of GALILEO. The use of the Electric Propulsion system will allow to use small launchers such as VEGA or place more spacecraft in the current SOYUZ and Ariane 5 launchers.

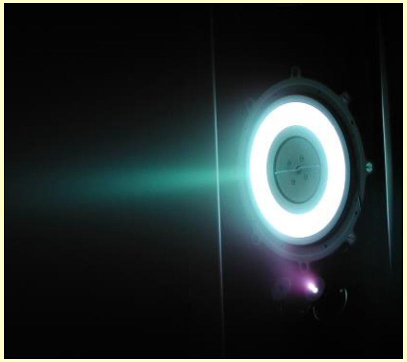
- T6 ion engine operating at 4000 seconds of specific impulse and at 150 mN requiring a power of 5kW is considered for the orbit raising operations. (1+1Redundant)

- Hall Effect thruster technology (PPS1350) could reduce the time of operation but at expenses of using more propellant. (3+1 redundant).

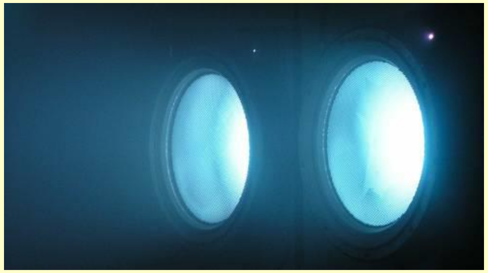
- The only way to use the VEGA launcher is by using a T6 ion engine as main engine of the orbit raising manoeuvre.

Important and last Technology Developments

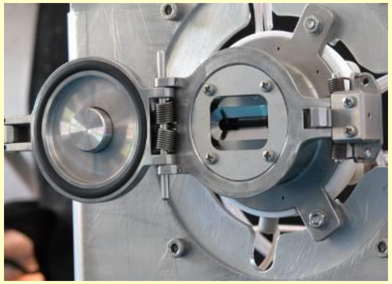
- **Thrusters**
  - **Higher and lower power versions of current engines (HETs, Ion Engines)**
  - **HEMPT engine**
  - **MEMS, Helicon Antenna Thrusters, In-Porous milliNewton thrusters, Micro-PPTs, etc.**
  - **Mini-ion engines, mini-Hall Effect thrusters**



- **Components (emphasis on cost reduction)**
  - **Xenon storage, regulation and flow control systems**
  - **Cathodes and neutraliser**



- **Electric Propulsion in-flight Diagnostic Packages**
- **Verification Tools and techniques**
  - **Advanced plume characterisation tools and models**
  - **Electric Propulsion EMI validation facilities**
  - **EP system design and performance verification models**



- **EP Implementation Support**
  - **Assessment of Flight data from missions in-orbit**
  - **Optimisation of systems configurations**

- The laboratory focuses 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.

EPIC: H2020 SRC for Electric Propulsion

- Electric propulsion has been identified by European actors as a Strategic Technology for improving the European competitiveness in different space areas.
- **The European Commission (EC)** has set up the "In-space Electrical Propulsion and Station-Keeping" Strategic Research Cluster (SRC) in Horizon 2020 with the goal of enabling major advances in Electric Propulsion for in-space operations and transportation, in order to contribute to guarantee the leadership of European capabilities in electric propulsion at world level within the 2020-2030 timeframe.
- The SRCs will be implemented through a system of grants connected among them and consisting of:
  - 1)"Programme Support Activity" (**PSA**): The main role of this PSA is to elaborate a roadmap and implementation plan for the whole SRC and provide advice to the EC on the calls for operational grants.
  - 2) Operational grants: In future work programmes (2016 and 2020), and on the basis of this **SRC** roadmap and the PSA advice for the calls, the Commission is expected to publish calls for "operational grants" as research and innovation grants (100%) and/or innovation grants (70%).

EPIC PSA

- The European Commission (EC) has funded, as part of the Horizon 2020 Space Work Programme 2014, a Programme Support Activity (PSA) for the implementation of the **Strategic Research Clusters (SRC) on "In-Space electrical propulsion and station keeping"**.
- The "**Electric Propulsion Innovation & Competitiveness**" **(EPIC)** project is the PSA for the Electric Propulsion SRC funded as response to the H2020 Space COMPET-3-2014 topic.
- It has been initiated in October 2014 and has a duration of **5 years**, during which it is meant to support the European Commission on the definition and successful implementation of the SRC in Horizon 2020, in order to achieve the objectives set for it and subsequently for Europe on this increasingly relevant technology area at worldwide level.
- **The EPIC PSA aims at providing advice to the EC preparing Roadmaps, drafting call texts and assessing results of the SRC operational grants.**
- The R&D work will come in the SRC as a part of future Calls made by the EC, open to all EU Member States and H2020 participants, and will be selected and supported through the normal Horizon 2020 grant procedures
- **EPIC PSA Partners: EPIC – ESA (coordinator), ASI, BELSPO, CDTI, CNES, DLR, UKSA, Eurospace, S4S**

EPIC FACT SHEET	
Project Title:	**Electric Propulsion Innovation & Competitiveness**
Grant Number:	640199
Subprogramme:	COMPET-03-2014 - In-Space electrical propulsion and station keeping
Call for Proposal:	H2020-COMPET-2014 - Competitiveness of the European Space Sector: Technology and Science
Total cost:	EUR 3498080,87
EU Contribution:	EUR 3496351
Funding Scheme:	Coordination and Support Action (CSA)
Duration:	5 years
Start Date:	1 October 2014
Coordinated by:	European Space Agency (ESA)
Project Partners:	• Agenzia Spaziale Italiana (ASI) • Centro para el Desarrollo Tecnológico Industrial (CDTI) • Centre National d'Etudes Spatiales (CNES) • Deutches zentrum fuer Luft – und Raumfahrt EV (DLR) • Eurospace • SME4Space VZW • Service Public Federal de Programmation Politique Scientifique (BELSPO) • UK Space Agency (UKSA)

Conclusions

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1. High power EP short term applications: telecommunication (orbit maintenance of 16 kW platforms) and science (interplanetary missions such as Bepi Colombo) will be able to make an immediate use of these technologies.
High power EP long term applications: high power telecommunication spacecraft (orbit-raising and orbit maintenance of 20 kW platforms), science (interplanetary missions) and exploration (the Moon, Asteroids and Mars) will require such systems.

3. Small platforms such as Small GEO and Electra are going to play an important role thanks to the use of launchers such as Falcon 9 that will allow to launch high power payloads in small platforms thanks to the use of electric propulsion for orbit transfer.

4. In order to improve European competitiveness some strategies could be envisaged in this domain: re-usability of systems such as T6 baselined in BepiColombo or PPS-5000 or RIT 22 in new missions and new developments such as high power HEMPT to enable new missions.

5. Europe can and shall benefit from the current advanced status of these technologies to enable non-dependence in this field and even to propose the provision of electric propulsion systems as part of possible collaboration on future international collaborative programmes in Science and Exploration.

6. ESA is also developing microthrusters such as mini-ion engines, FEEPs, mini-Halls, etc. with capability to fulfil stringent Science and Earth Observation requirements (LISA, NGGM, Euclide, etc.). Astrium, ALTA, FOTEC, etc. are busy with these developments.

7. The next Galileo programme is planning the use of electric propulsion to perform orbit raising from LEO or GTO to High Elliptical

8. Interplanetary missions may require Nuclear Electric propulsion Systems when the DeltaV is high and the Sun is far.

9. The Moon and Mars will be the next targets of the Exploration activities and Electric Propulsion will play an important role in Cargo missions to these planets.