QinetiQ Electric Propulsion Technology & Capability

EPIC Workshop
Brussels

25th – 28th Nov 2014

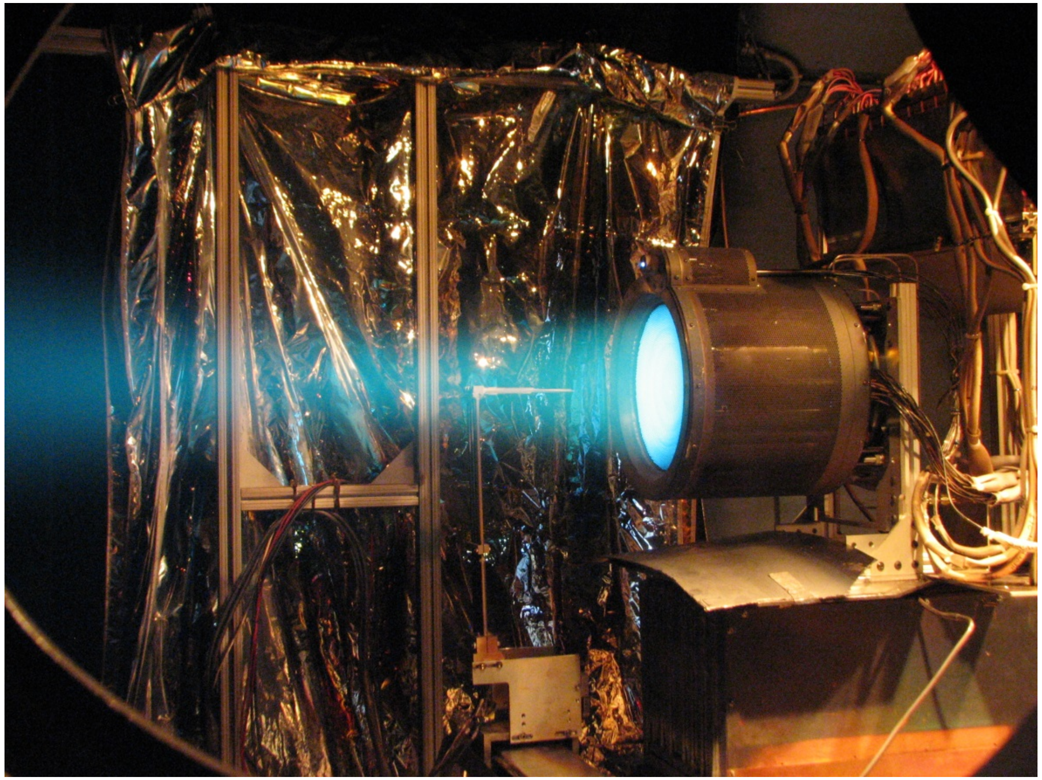


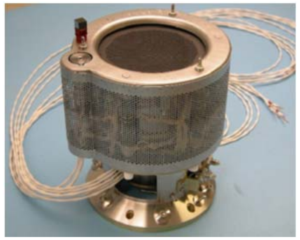
Image courtesy of Nasa JPL

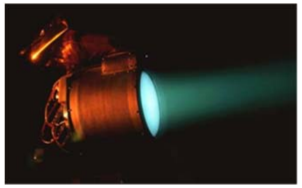
Mr Jon Huddleson

Space UK Engineering and Technical Lead
QinetiQ Ltd

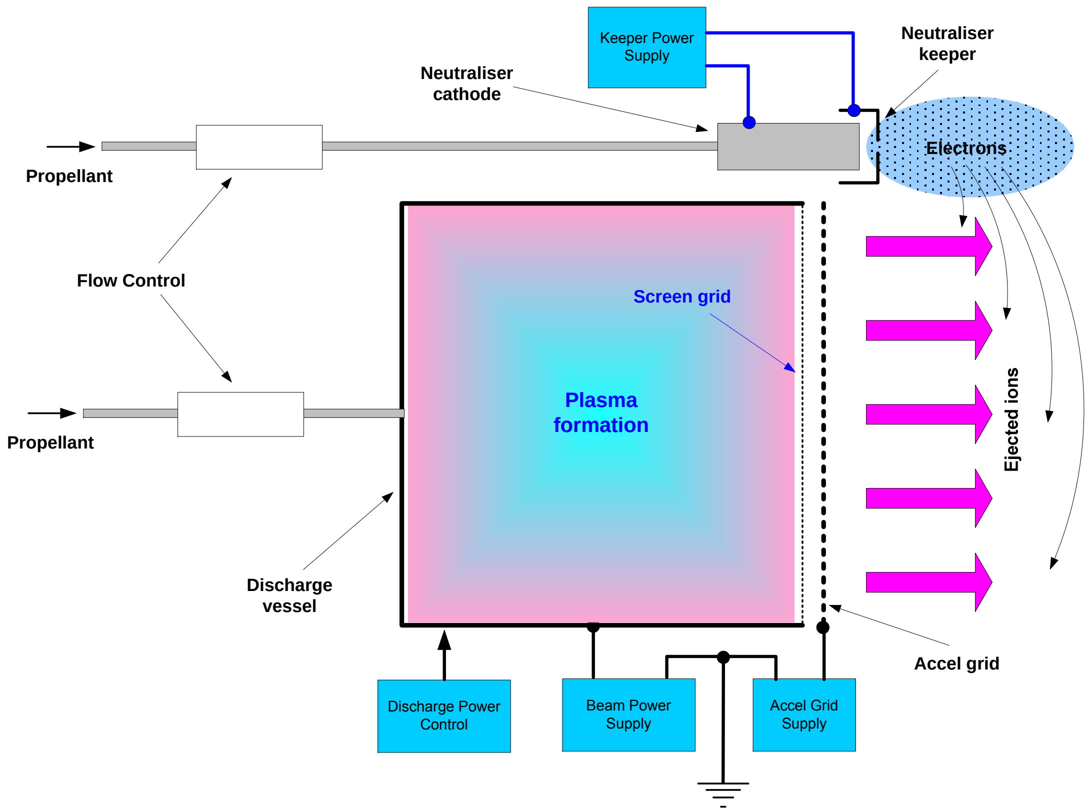
QinetiQ Electric Propulsion Technology

- EP development at QinetiQ Farnborough since the 1970s.
- Developments have concentrated on:
  - Early support to UK industry: UK-10 (Artemis) & UK-25 ion engines
  - Gridded Ion Engines (GIE)
    - Primarily: 10cm diameter T5 & 22cm diameter T6
  - Hollow Cathodes
    - For the GIEs and for HETs
  - Electric Propulsion System design
  - EP testing and verification
    - Own thrusters / 3rd party EP thrusters / customer end-to-end sys tests





QinetiQ Electric Propulsion Technology



3 types of GIE

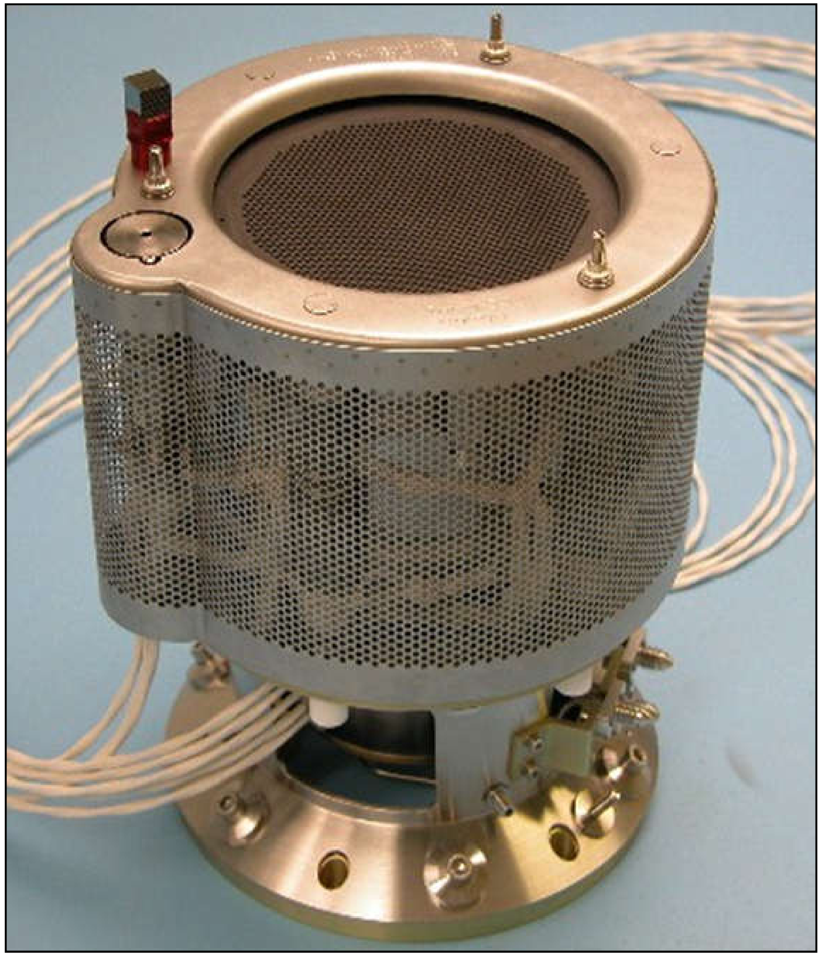
- UK/Russia - Kaufman
- USA/Japan – Ring Cusp
- Germany – Radio-frequency Ionisation Thruster (RIT)

3 'sinks' of energy

- Energy used to ionise propellant
  - Ionisation efficiency expressed as W/A
- Energy used to accelerate propellant
  - W/mN
- Energy used to neutraliser ion beam

Note that these process are independent of each other

QinetiQ Electric Propulsion Technology



QinetiQ T5 Ion Thruster

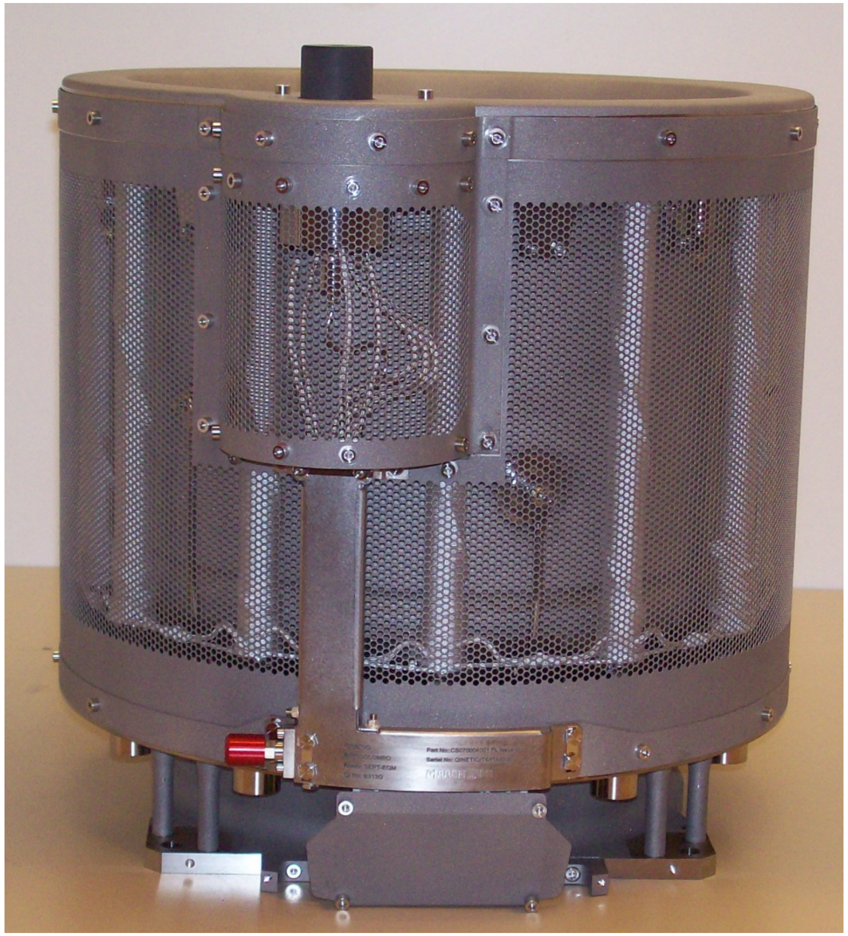
Current Performance

- Thrust range: 0.6 to 25 mN
- High Specific impulse: ~3500s
- Thrust energy ratio: 33 W/mN
- Total impulse capability > 3.5MNs

Physical Dimensions

- Ø 10cm ion beam
- Ø 180 x 250mm long
- Mass 2.5 kg (*excl. alignment bracket*)

QinetiQ Electric Propulsion Technology



QinetiQ T6 Ion Thruster

Current Performance

- 5kW class thruster
- Thrust range: 30 to 230 mN
- High Specific impulse: >4000s
- Thrust energy ratio: ~32 W/mN
- Total impulse capability > 13MNs

Physical Dimensions

- Ø 22 cm beam
- Ø 300 x 320 mm long
- Mass 8.3 kg

QinetiQ Electric Propulsion Technology

Key features of the technology

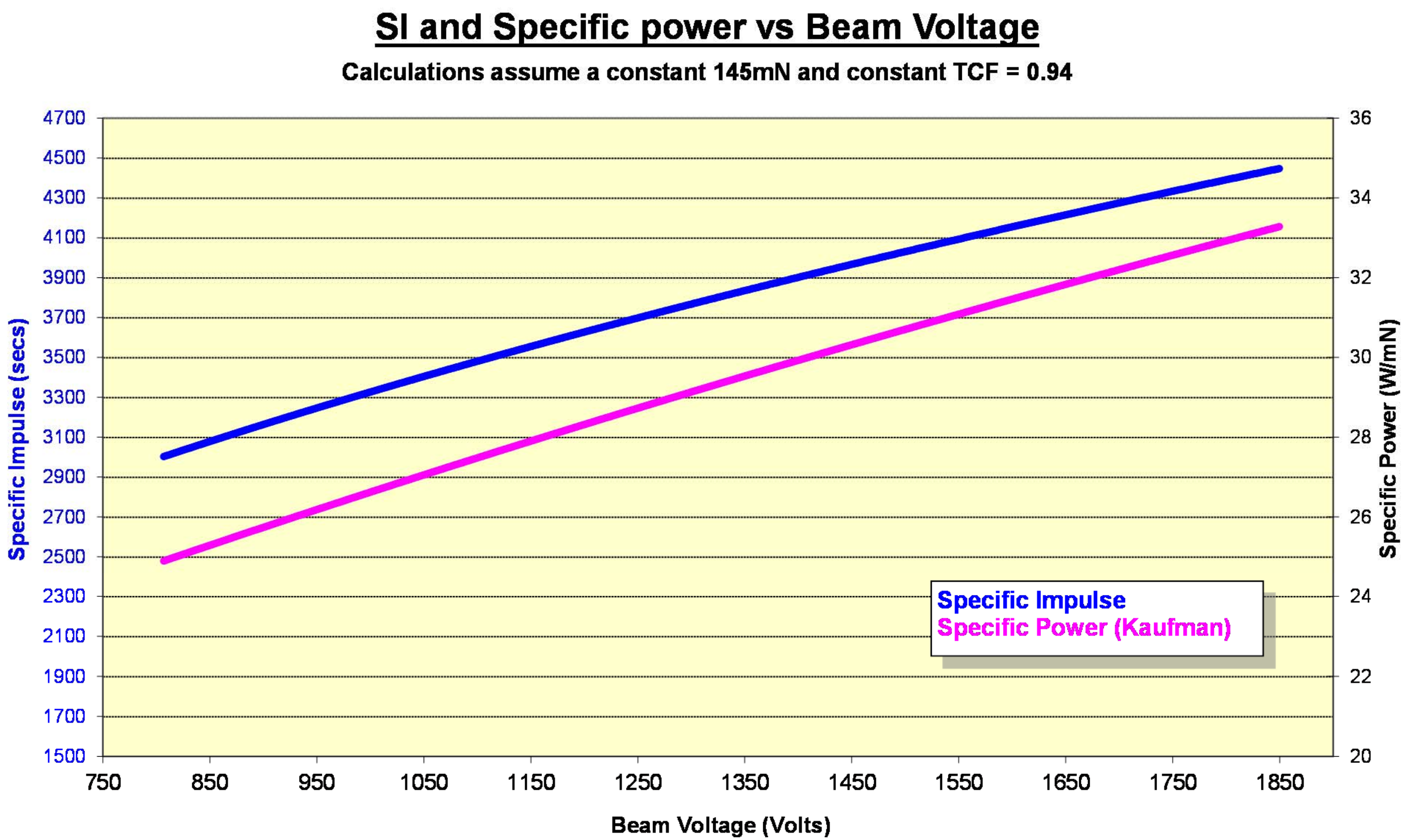
- High Isp capability
  - Nominally maintain over the thrust range
- Throttleability
- Narrow beam divergence
  - typically 95% beam energy within 15^{o} half cone angle
- EMI: Prime contributor is the Neutraliser Cathode, as the main discharge is inherently shielded by the structure and grids

The GIEs are capable of a wide range in performance

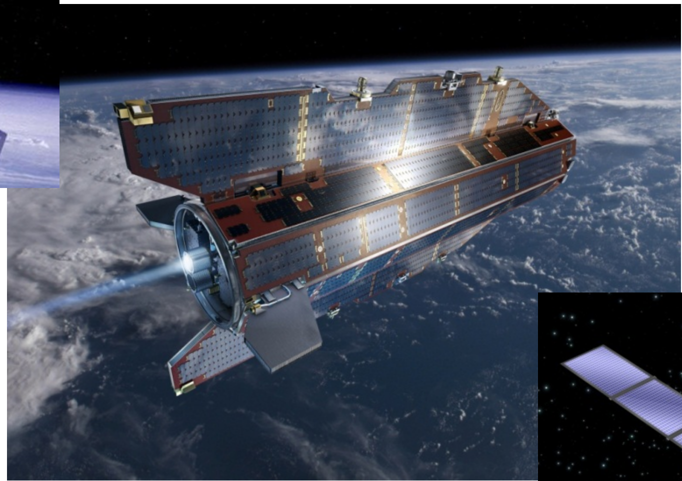
- System level parameters selected to suit application

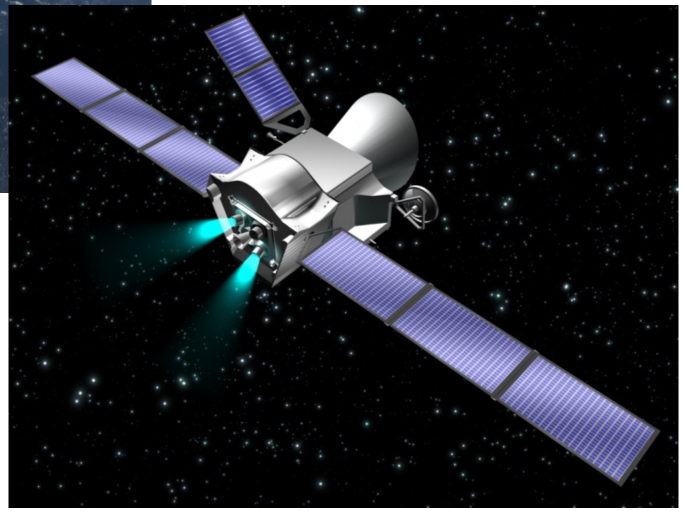
Typically trading: Isp – Thrust – Power

QinetiQ's Electric Propulsion Technology

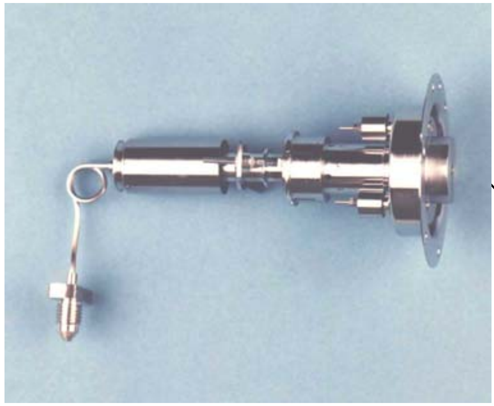


QinetiQ Electric Propulsion – Flight Mission Heritage



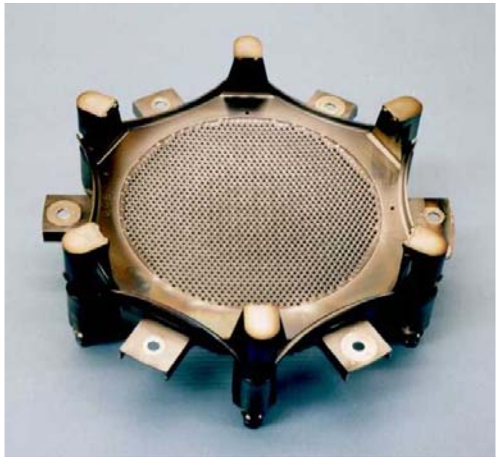


Flight Components – UK10 for Artemis



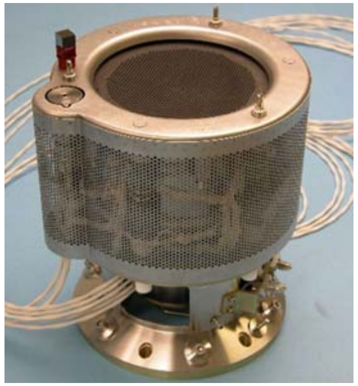
T5 Cathodes
QinetiQ (then DERA), UK

UK10 EITA (based on the T5)
Airbus D&S (then Matra Marconi)

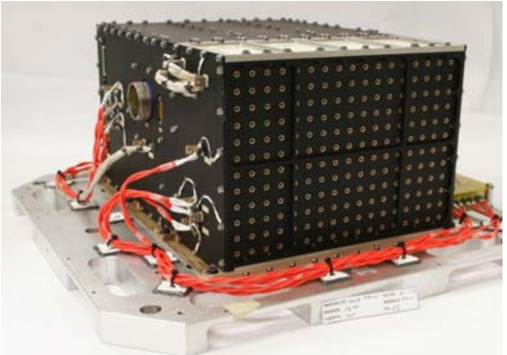


T5 Grid Assemblies
QinetiQ (then DERA), UK

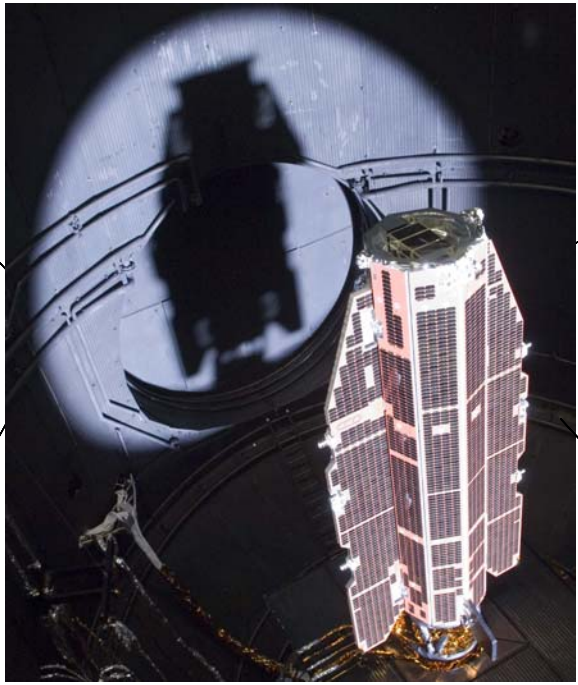
T5 System building blocks



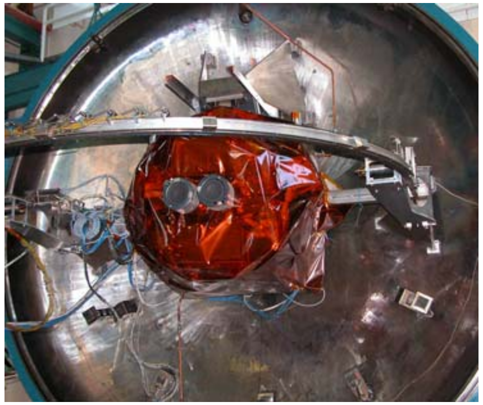
T5 Thruster
QinetiQ, UK



Power Supply
Aribus Crisa (Spain), with Airbus (Friedrichshafen)



Flow Controller
MOOG Bradford, NL



System integration and test
QinetiQ, UK

Use of T5 for GOCE

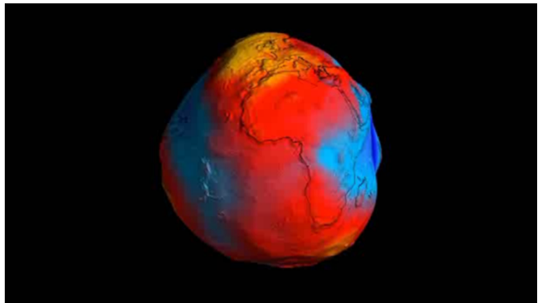
Part of the ESA's Living Planet programme of earth observation satellites.

- *A primary objective of which was to provide global mapping of the Earth's gravity field*

- GOCE application simultaneously exploited
  - the high Isp of the T5; and
  - the precise throttling control to compensate for variable atmospheric drag the S/C experienced
- Challenging and unique requirements:
  - Unprecedented thrust range: 1 - 20 mN
  - Ultra precise thrust control: +/- 12 µN
  - Rapid thrust response rate: > 2.5 mN/s
  - Continuous operation for drag compensation (18 months mission, extendable to 22 months)
  - Single thrust demand from spacecraft and autonomous EP system operations

GOCE – Mission

- Launched on 17 March 2009 on Rockot (Plesetsk, Russia)
  - Both prime and redundant engines commissioned.
- Original mission objectives achieved after 18 months
- Nov 2010: Mission granted extension.
- Nov 2012: Planned mission complete, lowered orbit to 235 km.
- Operation until October 2013, when the xenon tank was run empty.
  - Accumulated a total of ~36,000hrs operation on a single thruster.
  - Prior to deorbit the redundant thruster branch was operated and found to have same performance after 4 years hibernation.

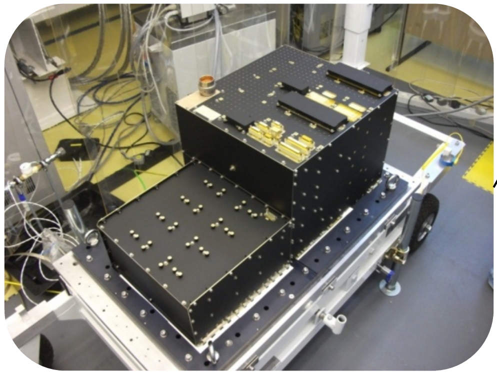


Mapping of the geoid: a unique surface of constant gravity potential that corresponds to the hypothetical ocean surface at rest

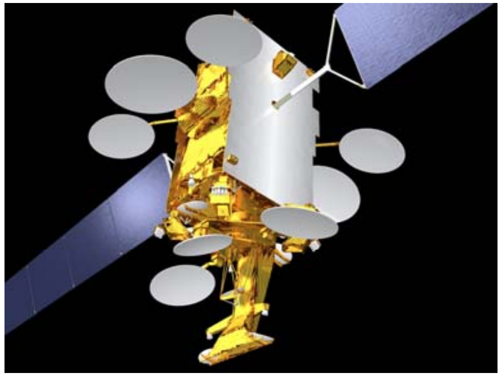
This photo of GOCE re-entering the atmosphere was taken from the Falklands by Bill Charter, on 11th Nov at 00:20 UTC:

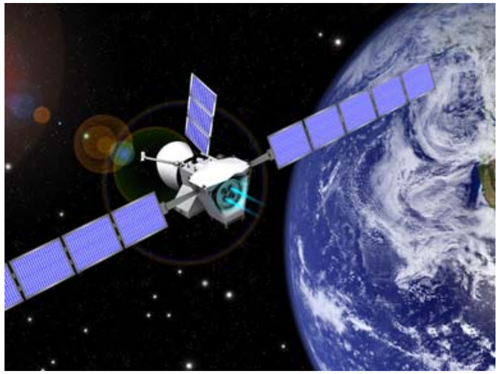
T6 System building blocks

T6 System & Thruster
QinetiQ, UK

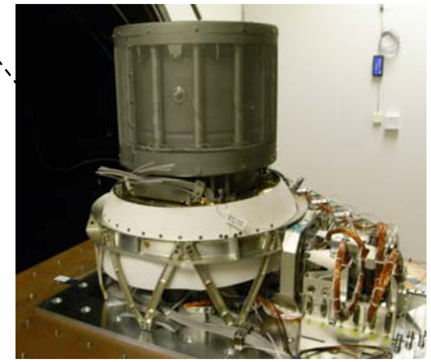


Power Supply
Airbus Crisa (Spain), with Airbus (Friedrichshafen)





Flow Controller
MOOG Bradford, NL



Pointing Mechanism
RUAG, Austria

T6 HPEPS

- T6 Thruster development started in late 90's

- T6 'High Power Electric Propulsion System' (HPEPS) development started in the early 2000's under ESA funding.
- Target application: Future Large European Geostationary Com-Sats
  - NSSK
  - Orbit topping (or, back-up in case of LAE failure).
- Primary development drivers:
  - Low cost / High Isp >4000s / Low mass

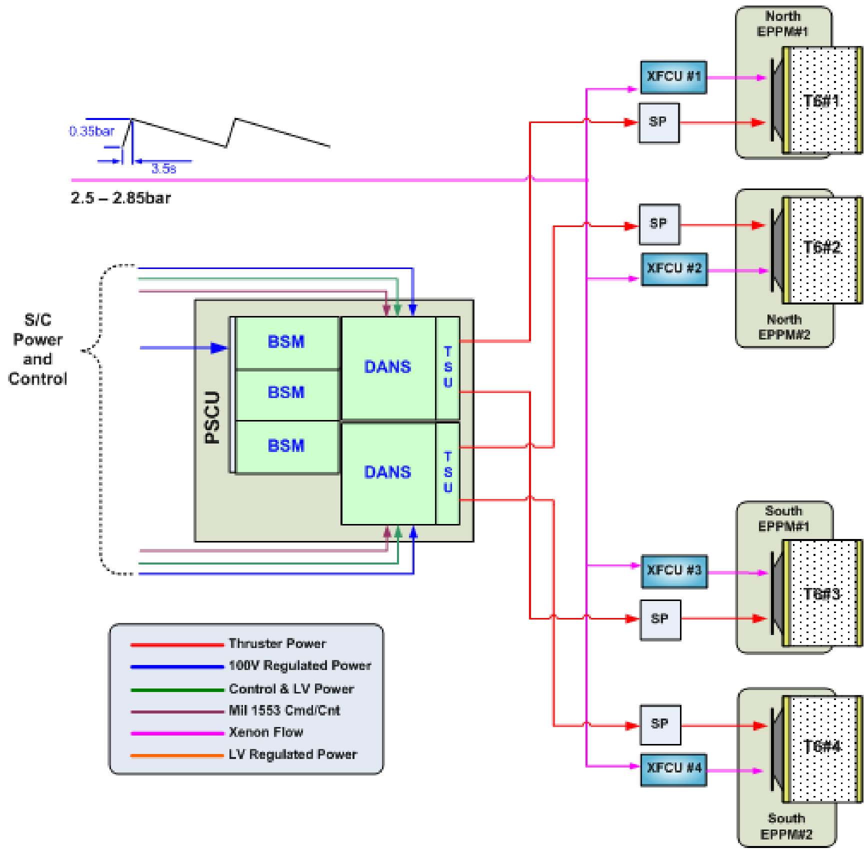
- From the onset QinetiQ adopted a modular system architecture

- From here, BepiColombo took on the same building blocks and drove the development and qualification

Electric Propulsion - T6 High Power Electric Propulsion System (HPEPS)

Single internally redundant PPU.

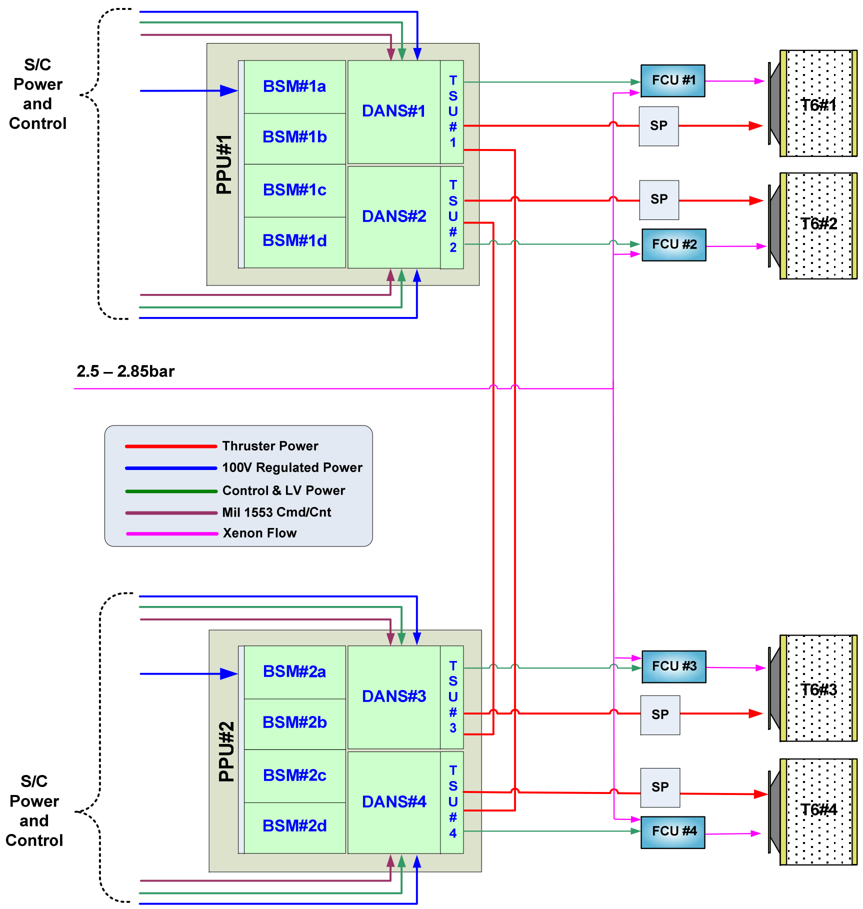
- Nominal 3.3KW operation producing 100mN (NSSK)
- Max capability of 5kW, producing 145mN (orbit raising)



Electric Propulsion - T6 Solar Electric Propulsion System (SEPS)

BepiColombo SEPS Architecture

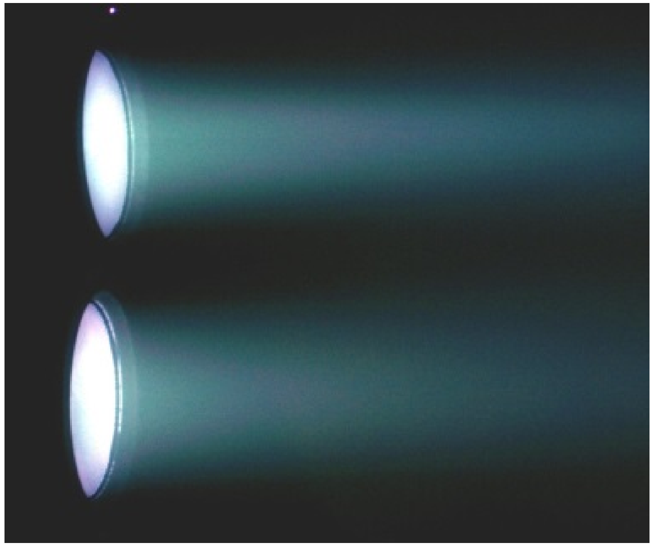
- SEPS architecture capability of twin thruster firing to deliver a guaranteed 290mN or up to 145mN from a single PPU/thruster
- SEPS includes cross strapping between PPUs allowing mission Total Impulse to be shared between thrusters



T6 System for BepiColombo

BepiColombo ESA Cornerstone Mission to Mercury:

- Providing the primary propulsion for the **Mercury Transfer Module**, transporting a 2 satellite stack to the planet mercury.
- Key requirements include:
    - High Isp (> 4200s)
    - Total impulse (> 11.5MNs)
    - Thrust range (75 - 145mN)
    - 10kW, simultaneous thruster operation



Twin engine testing: both engines operating at 5kW

T6 System for BepiColombo

T6 Programme Status

- Pre-development activities: extensive thermal and endurance testing
  - Incl. 5700 hours @ 175mN
- T6 thruster is environmentally **qualified**
  - *Qual. endurance test to be completed*
- T6 EMC test successfully completed at Farnborough

The four T6 FM engines

- All 4 flight T6 Thruster built
  - FM1 & FM2 Acceptance Testing complete
  - FM3 Vib'n complete, TVT nearing completion
  - FM4 Vib'n complete, TVT to be performed.

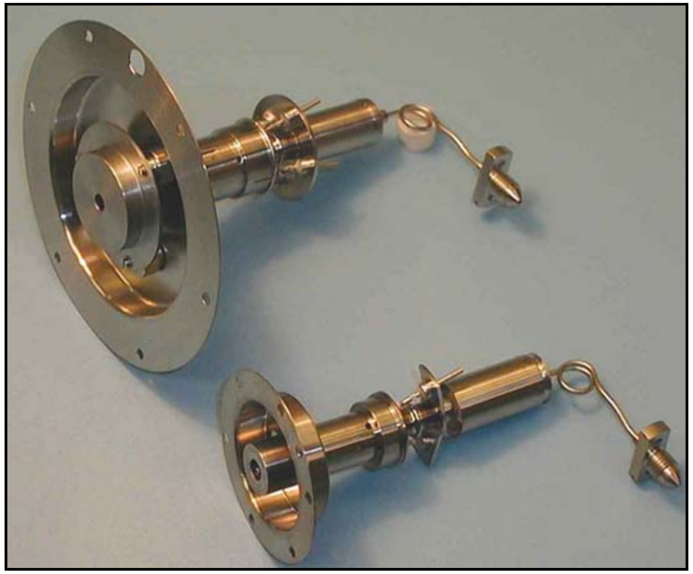
- T6 System successfully qualification tested
  - *Remaining final test: accommodate all equip in test chamber.*

Hollow Cathode Technology

- Discharge Cathode & Neutraliser Cathode are nominally the same in both the case of T5 and T6
  - Internal working parts and construction are the same, only packaging and mounting varies.

- Extensive testing performed over the years
  - Including. contamination testing
  - Heater cycling (>18,000 cycles on one unit)
  - Representative thruster conditions

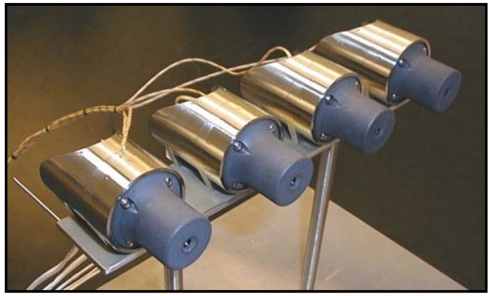
- Reliable and robust product that can be stored under standard cleanroom conditions.



T5 and T6 discharge cathodes

Hollow Cathode Technology

- HET Cathode variants have been derived from both these sizes of cathode
  - Again, same internal components – repackaged for HET application
    - *Low Power (LP) HET cathode ~5A= repackaged T5 cathode*
    - *High Power (HP) HET cathode ~20A= repackaged T6 cathode*



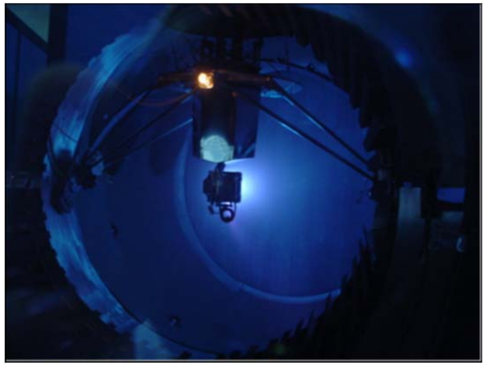
20A HET Cathodes

Further to that…

- High Current Cathodes up to 50A
- Together with Mars Space Ltd have done further work on high current cathodes & hollow cathode thrusters

EM and EQM ROS2000 thrusters

(image courtesy of Airbus D&S)



PPSX000 under test in QinetiQ's LEEP2 chamber

(image courtesy of Snecma)

QinetiQ Electric Propulsion Technology

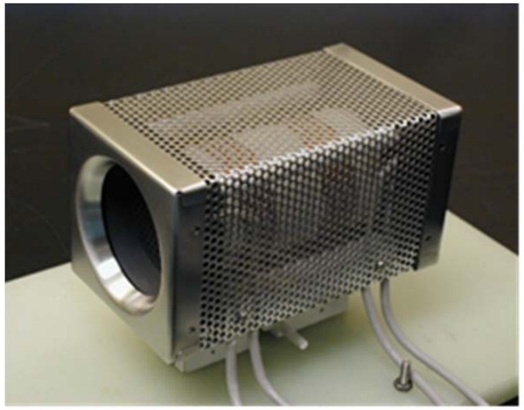
In parallel to those core activities QinetiQ has, and continues to develop and explore new developments

As examples;

- Application of new materials
    - E.g. carbon components
- Thermo-throttles and flow sensors
- Thrust vectoring T5 thruster
- Micro propulsion thruster - MiDGITS
    - Tested at 1mN, potential for <1mN

Work to date potentially relevant to EPIC for the future

Thrust vectoring T5 Engine



MiDGITS

QinetiQ Electric Propulsion Capability

Over the last 20 years we have grown a strong and experienced European capability together with our key partners;

- *Mars Space Ltd, Southampton University, Airbus CRISA and Moog Bradford…..*

Capability in terms of;-

- The **know-how** behind the EP design, analysis, integration, verification and test; and
- The **facilities and tools** developed.

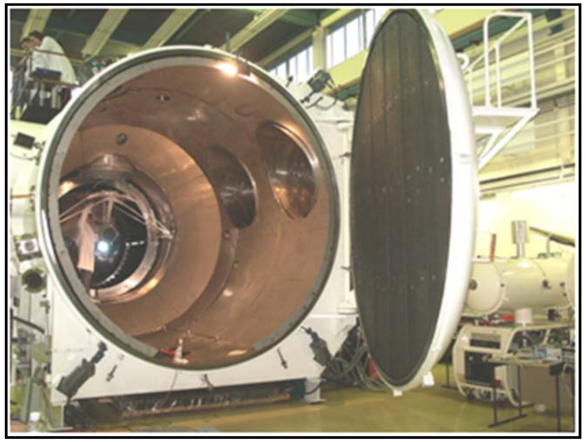
- QinetiQ has today >30 FTEs directly engaged in EP activities.
  - As well as supply chain experts to drive down costs and ensure robustness of delivery
  - Draw on the wider Space Business team, as well as extensive capabilities within QinetiQ.
    - E.g. *such as materials & process, EMC engineering,*

World Class Test Facilities at Farnborough

LEEP1

Recently modified to perform EMC testing on T6

Ø 1.6m x 3.0m long

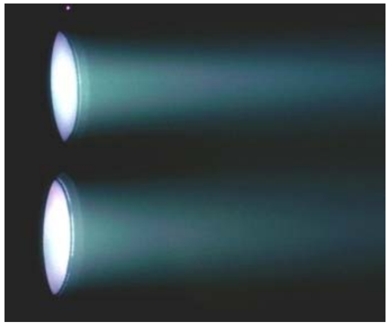


LEEP2

3.8m diameter, 10m length

LEEP3

Ø 3.3m x 8.5m long



Twin engine capability

QinetiQ Electric Propulsion Developments

Today, the T6 & T5 System products have been driven by challenging science mission req's.

1. Opportunities identified to achieve significant cost savings (both thruster and PPU)
    - T6: Through internal effort, and activities such as the EGEP Programme
        - QinetiQ to implement T6 cost reductions; and
        - CRISA to introduce simplifications to the T6 PPU
    - T5: Studies by QinetiQ and CRISA have scoped the simplifications and savings that could be achieved for more standard applications.

2. Development of a Ring-Cusp variant of the T6 thruster has started
    - Inherent improvement in W/mN
    - Simpler thruster construction, and reduces functionality within the PPU .
    - Targeting the recurring markets, such as GEO ComSats

QinetiQ Electric Propulsion Developments

T6 Ring Cusp (T6-RC) Thruster Design

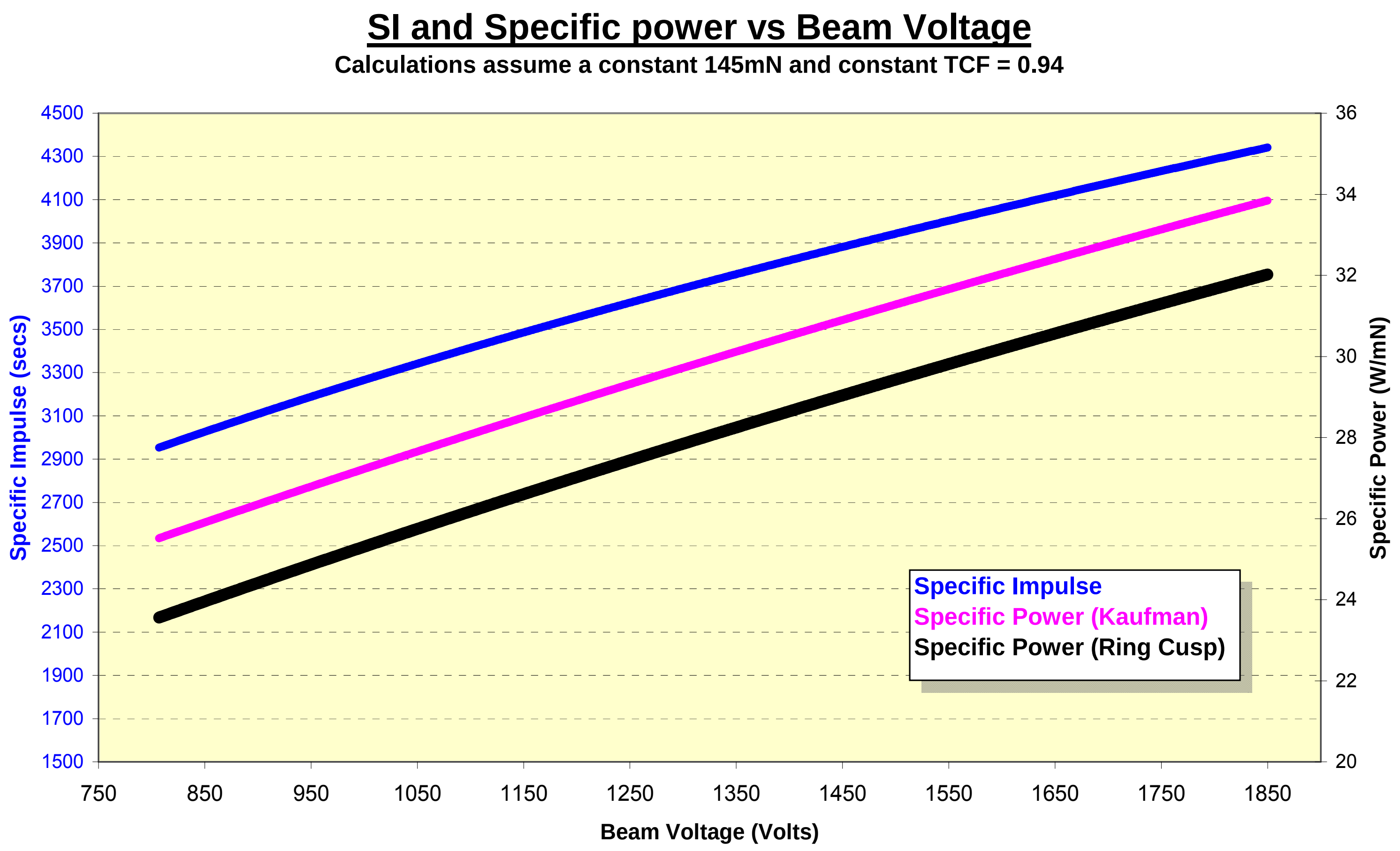
- A prototype T6-RC has been built and tested by QinetiQ.
- Mars Space Ltd conducting further performance assessment with a view to optimising certain design parameters.

Prototypes T6 Ring Cusp Ion Engine

T6-RC System Design

- Together with the primes establish the optimum solution
  - System operational set point or points(s)
  - System configuration

Electric Propulsion - T6 Future Development



QinetiQ Electric Propulsion - Conclusion

Exploitation

- Exploit the mature T6, T5 and Cathodes and EP test services we have today
- Implement the cost reductions identified for the benefit of our customers

Innovation

- Develop the Ring Cusp thruster – targeting the commercial recurring market.
- Committed to working closely with the primes, to identify the optimum system solutions
  - Novel system architectures, in particular in the power subsystem
  - Dual Isp Modes
- Continue to evaluate and develop new concepts and ideas
  - Materials / alternative propellants / novel thruster concepts

QinetiQ's aim is to deliver solutions that give its customers the edge in mission possibilities (enabling), and in competitiveness on the global stage (winning).

QinetiQ Space

Thank you