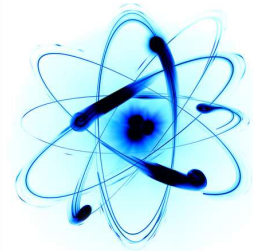


Imperial College London

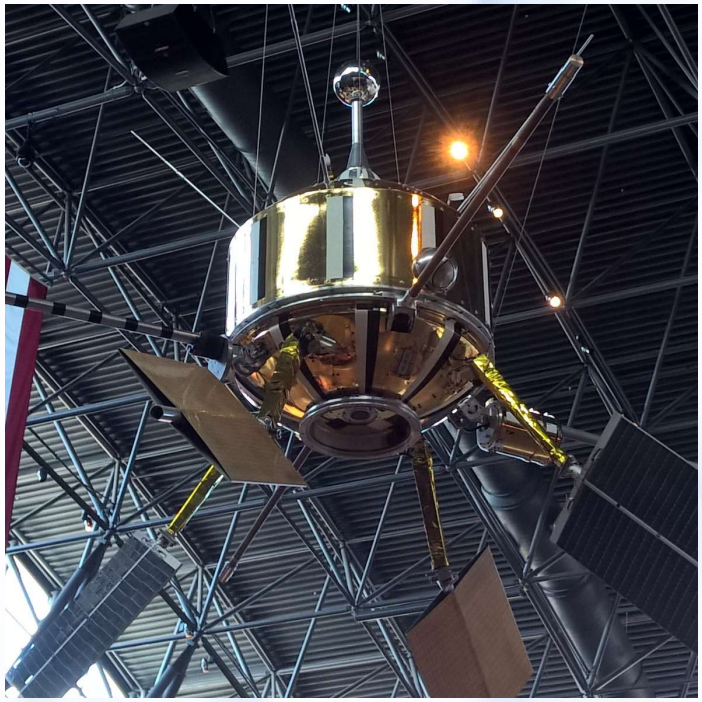
October 17th, 2018

Imperial Plasma Propulsion Lab

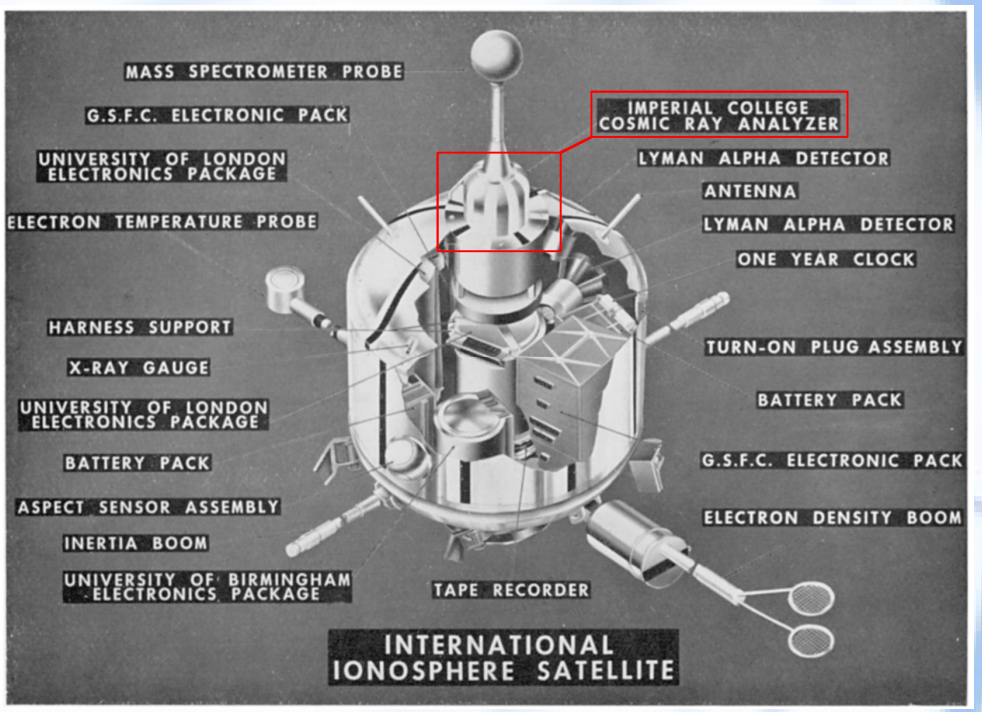
Research Overview

Aaron Knoll, on behalf of the plasma propulsion group

Imperial College – 55 years in space



Ariel 1, launch 26 April 1962

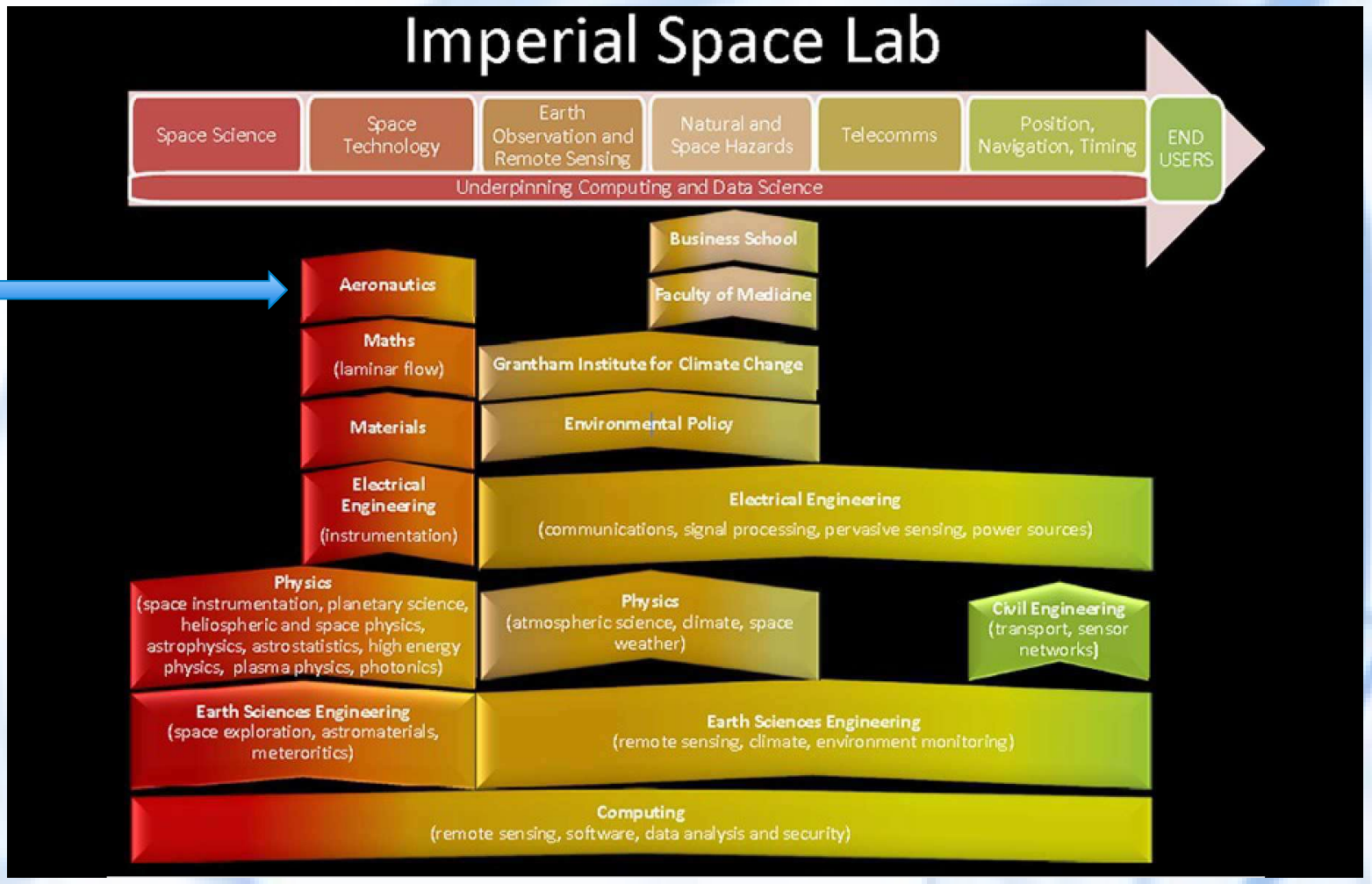


Baumann, Proc. Roy. Soc. A., 1964

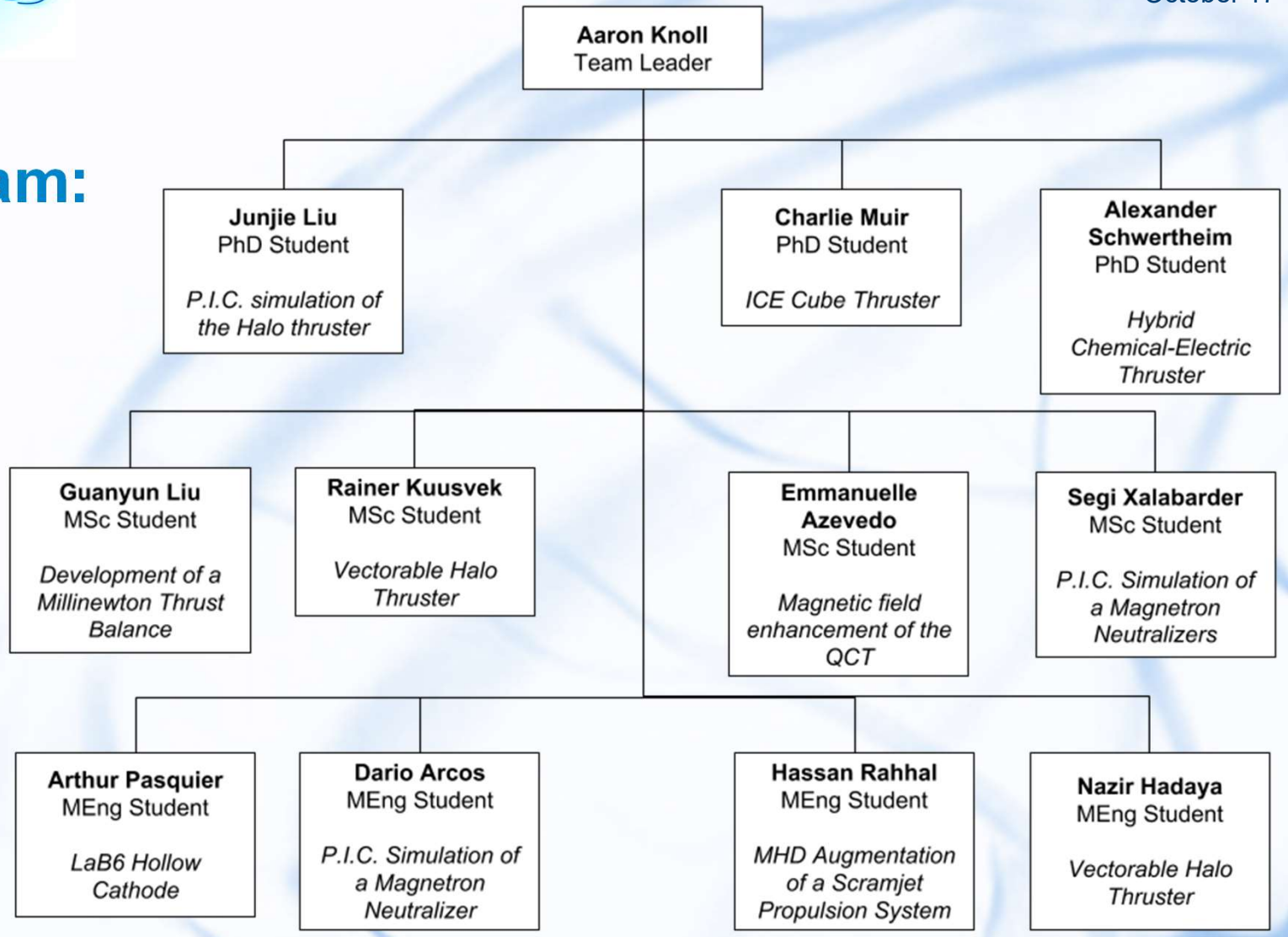
Space Lab - introduction

- Launched 2013 – director Prof. Steve Schwartz
- Imperial College Network of Excellence
- Brings together over 80 academics from across Imperial College with interests in:
  - Space-related technologies
  - Doing science from space
  - Using space-derived data products
  - Societal impacts and risks of space
  - Applications of space-developed expertise
- Internal collaborations, interactions with industry, public events, outreach
- Since January 2018, director is Prof. Tim Horbury

Plasma Propulsion Lab



Team:


Aaron Knoll
Team Leader
Junjie Liu
PhD Student
P.I.C. simulation of the Halo thruster
Charlie Muir
PhD Student
ICE Cube Thruster
Alexander Schwertheim
PhD Student
Hybrid Chemical-Electric Thruster
Guanyun Liu
MSc Student
Development of a Millinewton Thrust Balance
Rainer Kuusvek
MSc Student
Vectorable Halo Thruster
Emmanuelle Azevedo
MSc Student
Magnetic field enhancement of the QCT
Segi Xalabarder
MSc Student
P.I.C. Simulation of a Magnetron Neutralizers
Arthur Pasquier
MEng Student
LaB6 Hollow Cathode
Dario Arcos
MEng Student
P.I.C. Simulation of a Magnetron Neutralizer
Hassan Rahhal
MEng Student
MHD Augmentation of a Scramjet Propulsion System
Nazir Hadaya
MEng Student
Vectorable Halo Thruster

New Vacuum Test Facility

- **Provider:** Cutting Edge Coatings, Germany
- **Dimensions:**
  - 1.5m diameter x 2m main chamber
  - 0.75m diameter x 1.5m load lock
- **Pumps:**
  - Leybold cryopanel: 15,000 L/s Xe
  - 2 x Leybold turbopumps (2 x 2200 L/s)

- **Performance:** Operating pressure better that 2 x 10^{-5} Torr with gas for up to 1.5 mg/s Xenon

Research Activities

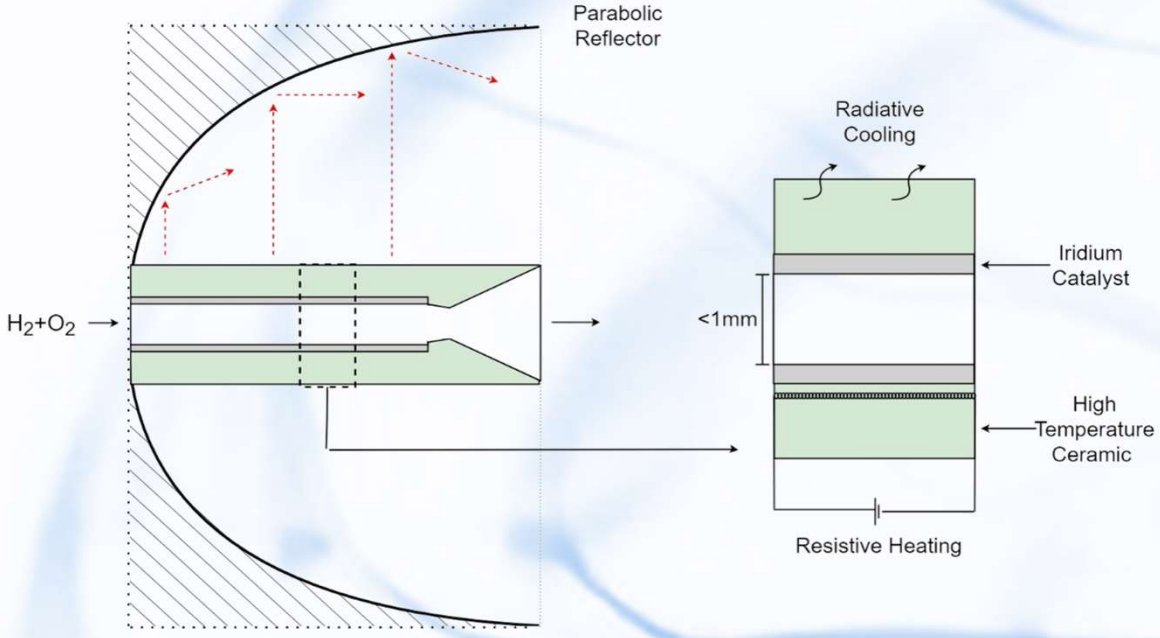
Technology	Target Performance	Commercial Need	Key Innovations
Vectorable Cross-Field (VeX) Thruster	• Input power: 300W total • Propellant: Xenon • Net specific impulse: 1800 s • Thrust: 17 mN • Net thrust efficiency: 50% • Power/thrust: 17.6 W/mN	Beam steerable EP alternative to Hall Effect Thrusters, aimed at the needs of next generation small geostationary platforms (< 5000 kg)	• Thrust vectoring capability • Centrally mounted hollow cathode
200W Quad Confinement Thruster (QCT-phoenix)	• Input power: 200W total • Propellant: Xenon • Net specific impulse: 1600s • Thrust: 7.6mN • Net thrust efficiency: 30% • Power/thrust: 26.3 W/mN	Next generation of the Airbus/SSTL QCT device currently flying on NovaSAR. Beam steerable EP alternative for the growing small satellite industry and 'mega-constellations' (50kg - 200kg platform)	• Improved thrust efficiency versus QCT-200 • Non-divergent beam profile

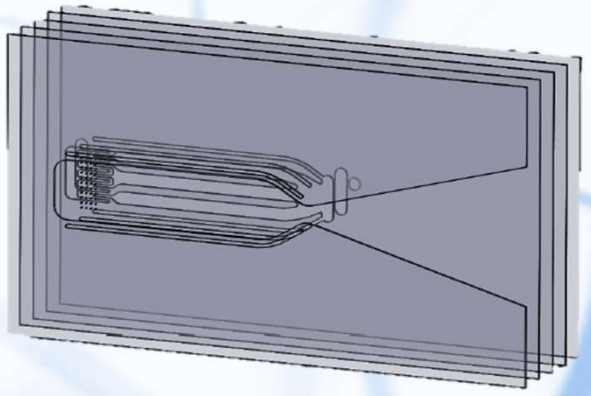
Research Activities

Technology	Target Performance	Commercial Need	Key Innovations
RF initiated hollow cathode + power electronics	• Input power: 20W running, 40W during start • Output current: 4A • Gas flow rate: 0.1 mg/s • mA/W: 200	Thermionic cathode that operates at low power and high efficiency, which uses a RF discharge during the start-up phase to rapidly warm the insert to its operating temerature (long-life and simple design/construction)	• Heaterless hollow cathode • Graceful low power start-up profile
Hybrid Chemical Electric Thruster	• EP Mode: 1800 s Isp, 85 mN thrust • CP Mode: 350 s Isp, 22 N thrust • Propellant: Water	A single propulsion subsystem (common propellant supply chain, PPU and thruster head) able to handle both CP and EP phases of a mission	• In-orbit fuel production via electrolysis • Combined function high thrust CP and high specific impulse EP
ICE Cube Thruster	• Input power: < 10W • New specific impulse: > 300s • Thrust: 1.6mN • Propellant: Water	Thermionic cathode that operates at low power and high efficiency, which uses a RF discharge during the start-up phase to rapidly warm the insert to its operating temerature (long-life	• Heaterless hollow cathode • Graceful low power start-up profile

ICE Cube Thruster: Thruster concept

An experimental concept realization of a high specific impulse, low thrust chemical bipropellant micro-thruster system featuring electrolysis propellant capture and catalytic combustion.

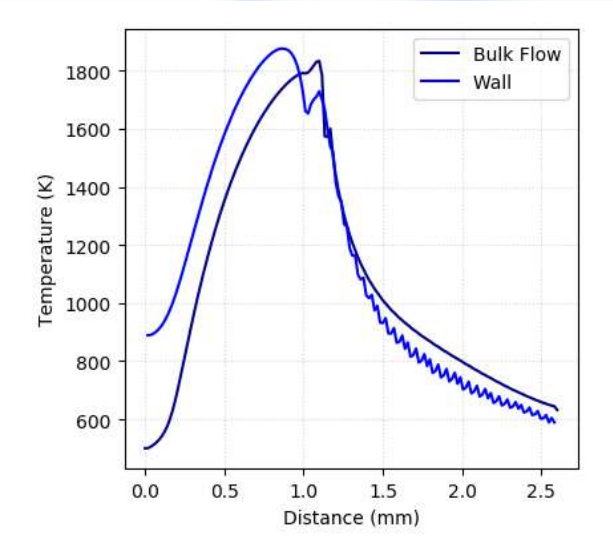


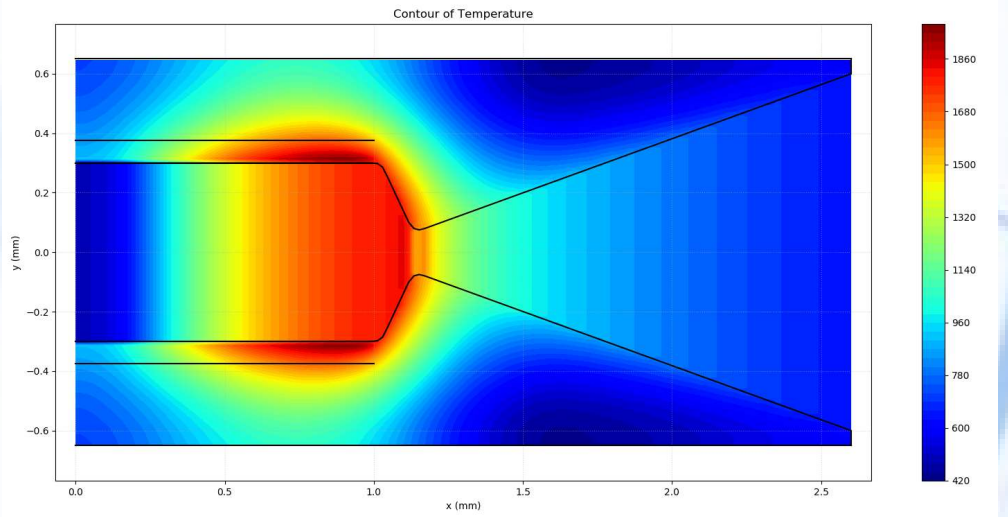


Our MEMS thruster design with half of the wafer stack shown

ICE Cube Thruster: System Definition & Modelling

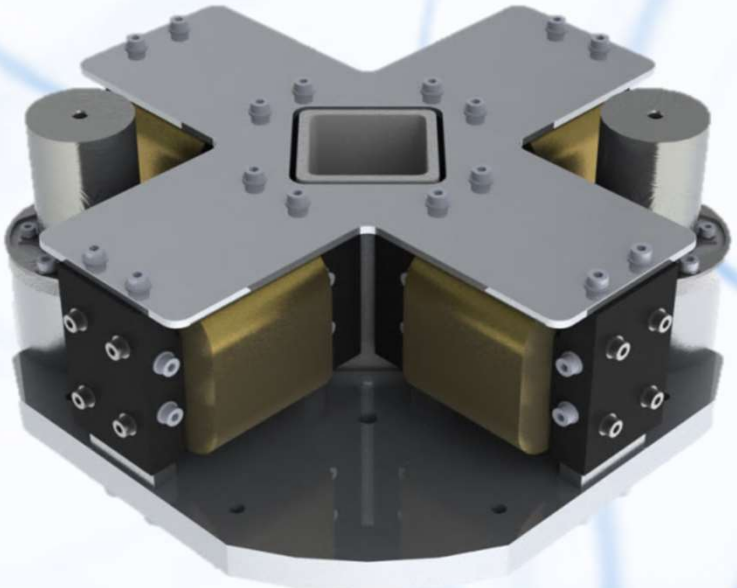
Initial results show that a desirable chemical decomposition can be achieved across the catalyst through purely surface reactions without exceeding the thermal constraints of iridium.





Quad Confinement Thruster

- Conceived in Autumn 2009
- DC powered cusped field thruster
- Magnetic topology based on plasma confinement proposed by Ioffe et al. (1981)
- Plasma confinement using four magnetic cusps
- Four independently controlled electromagnetics

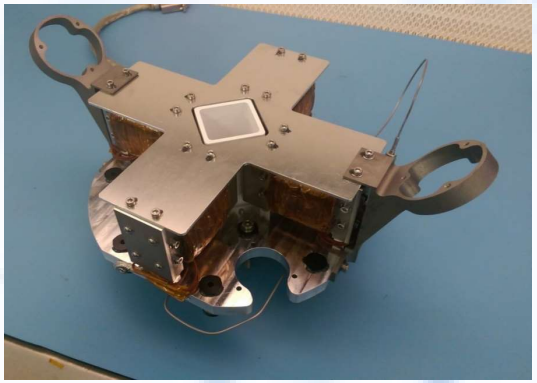


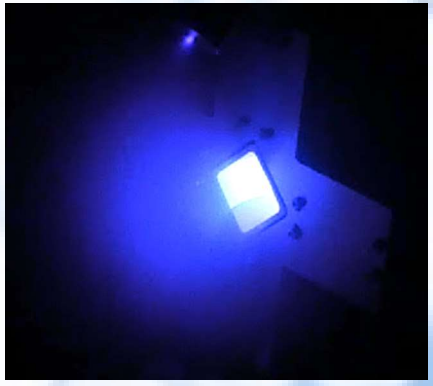
QCT in orbit demonstration on NovaSAR:

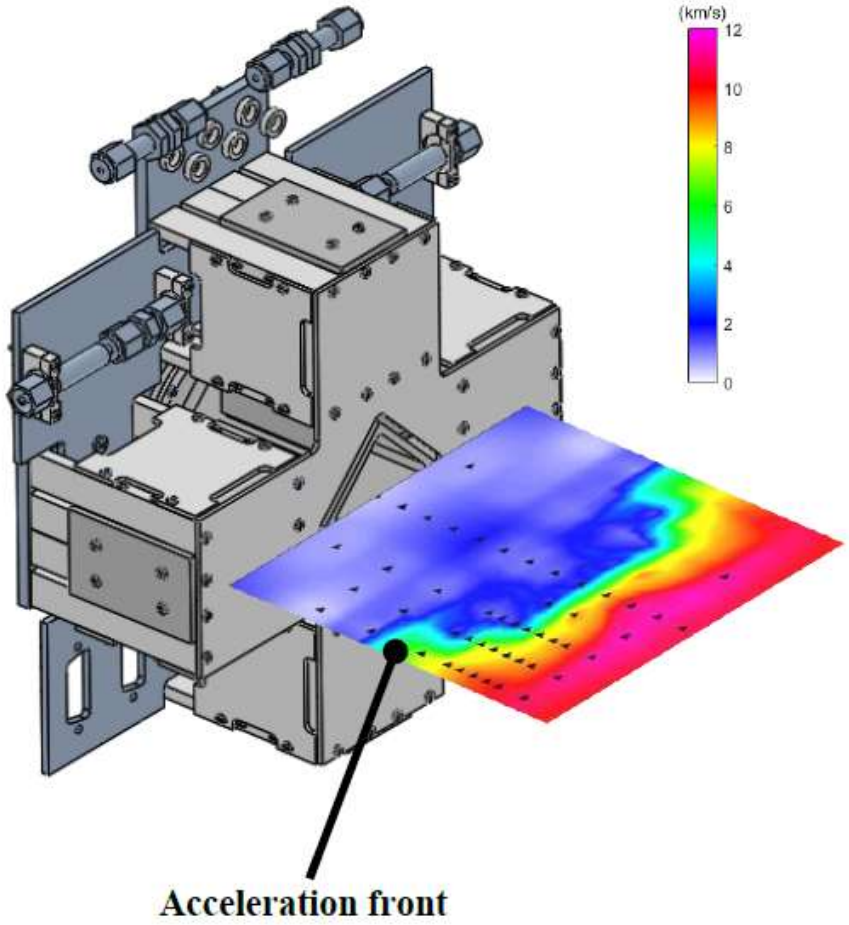
NovaSAR: UK radar satellite launches to track illegal shipping activity

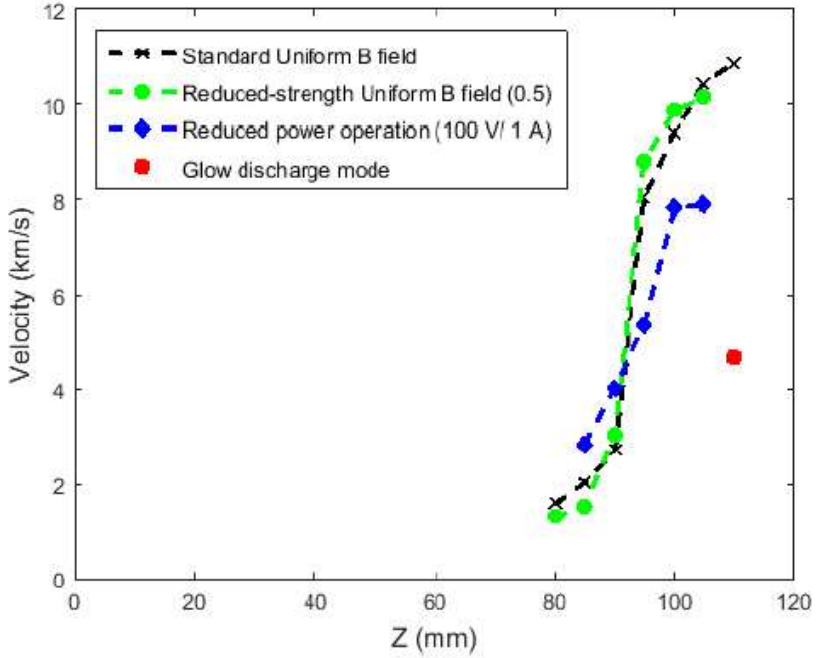
By Jonathan Amos
BBC Science Correspondent

16 September 2018 Share



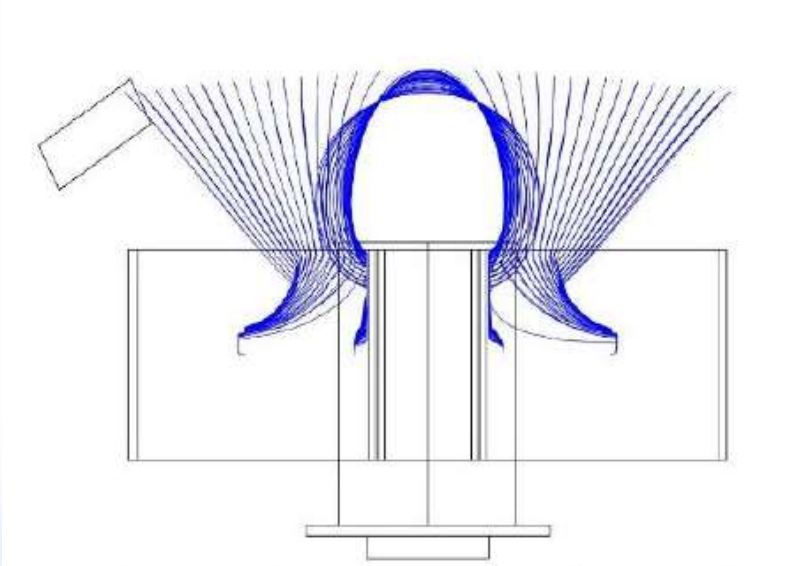



(km/s)
12
10
8
6
4
2
0
Acceleration front

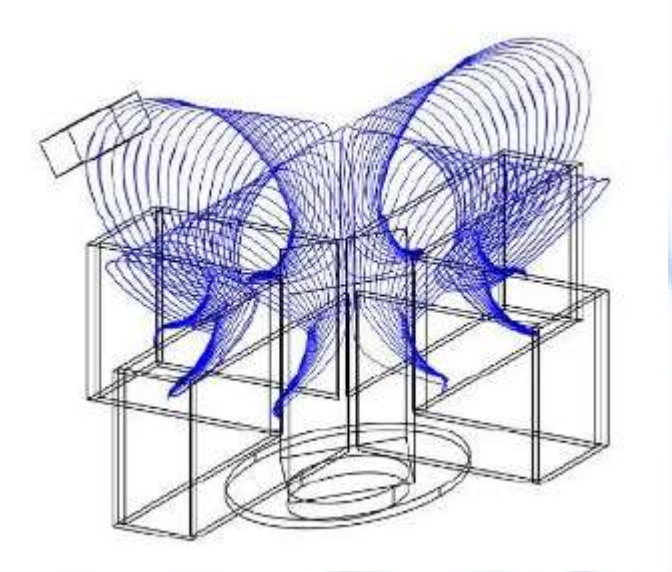

Standard Uniform B field
Reduced-strength Uniform B field (0.5)
Reduced power operation (100 V/ 1 A)
Glow discharge mode
Velocity (km/s)
Z (mm)
0
2
4
6
8
10
12
0
20
40
60
80
100
120

Original QCT Magnetic Topology

Side view

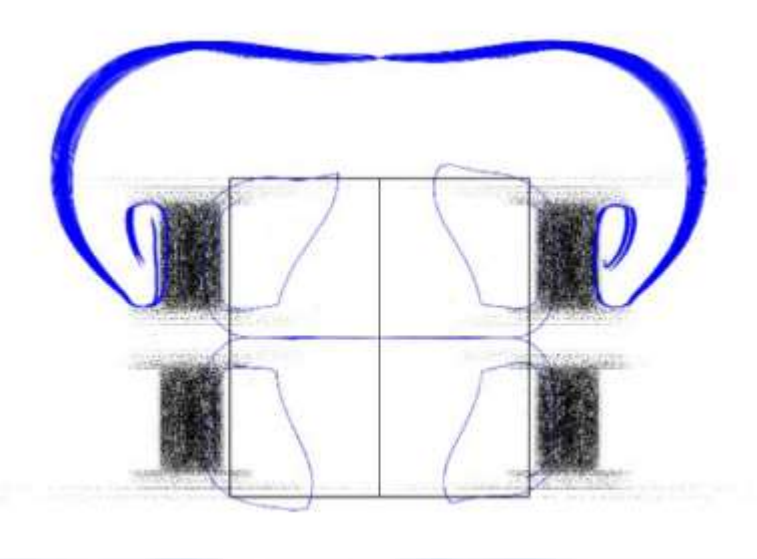


Isometric view

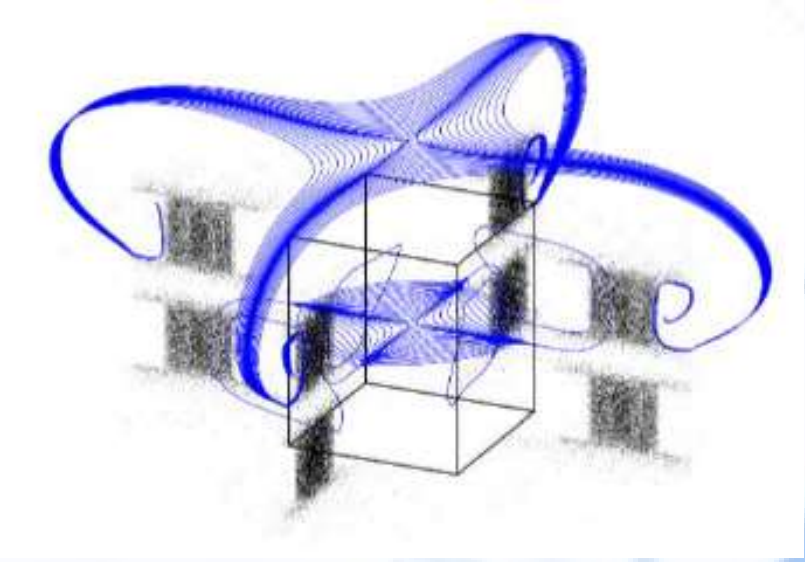


Optimized Magnetic Field (QCT-Phoenix)

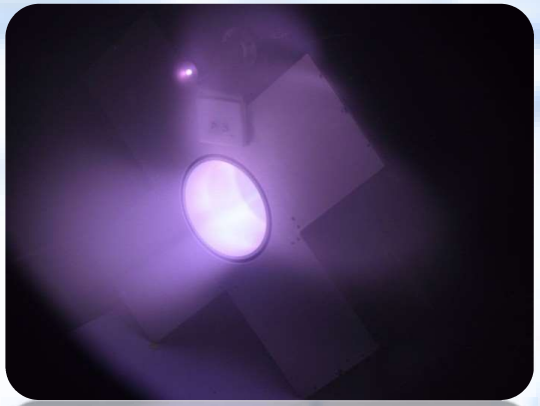
Side view



Isometric view



Imperial College London



Thank you for your attention