BOOSTING SCIENTIFIC KNOWLEDGE

ELECTRIC PROPULSION

25th OCTOBER 2017

EPIC
HIGHLY QUALIFIED PERSONNEL
(80% MSc, MEngs and PhDs)

TÜV CERTIFICATES
ISO 9001
EN 9100

+3000 m² FACILITIES
- Clean room
- Temperature controlled assembly rooms
- Work-shops
- 5-axis CNCs

"OUR SUCCESS OUR PEOPLE"
"FROM CONCEPT TO COMMISSIONING"
**MOST POWERFUL NEUTRAL BEAM INJECTOR (NBI) IN THE PLANET:**

\[ P_{beam} = 17 \text{ MW} \]
\[ I_{acc} = 40-50 \text{ A} \]
\[ V_{acc} = 1 \text{ MV} \]
\[ t_{pulse} = 3600 \text{ s} \]
\[ \text{Weight} = 50 \text{ T} \]
NEW PLAYER IN THE EP MARKET

TEST FACILITIES

THRUSTERS

DIAGNOSTICS

GIPUZKOAKO ENPRESA BERRIAREN SARIA 2016
GIPUZKOA’S BEST YOUNG COMPANY 2016.

added value solutions
NEW PLAYER IN THE EP MARKET

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NEW PLAYER IN THE **EP** MARKET

**TEST FACILITIES**

**THRUSTERS**

- TRL 5
- Q2 2018
- XMET
- MINI-MET
- ECR-GIE
- MINI-ECR
- AQUAJET

**DIAGNOSTICS**

- TRL 5
- Q2 2018
- BIFEP
- LASER IND.
- FLUORESCENCE
- ORBITA
NEW PLAYER IN THE EP MARKET

TEST FACILITIES

THRUSTERS

TRL 5
Q2 2018

XMET
MINI-MET
ECR-GIE
MINI-ECR
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DIAGNOSTICS

TRL 5
Q2 2018

BIFEP
LASER IND.
FLUORESCENCE
ORBITA

NEW PLAYER - 2020 -
Integrated Microwave Propulsion Architecture for Small Satellites.
- Electron Cyclotron Resonance

2 THRUSTERS:
- PRIMARY: 4 grid, Dual mode ECR Gridded Ion Engine (ECR-GIE)
- Low ISP resonant cavity microwave electrothermal thrusters (XMET) for RCS

μ10 ECR Gridded Ion Thruster [JAXA]
Low ISP resonant cavity xenon microwave electrothermal thrusters (XMET) for RCS

Microwave electrothermal thruster 120W, 500s Isp, 20mN with helium (Courtesy of Penn State University)
Low ISP resonant cavity xenon microwave electrothermal thrusters (XMET) for RCS

Freq(1)=2.45e9  Surface: Electric field norm (V/m)

Streamline: Electric field

Propellant optimisation

Top: Ar
Bottom: Xe

E_field optimisation

<table>
<thead>
<tr>
<th>E_max</th>
<th>(V/m)</th>
<th>Frequency [GHz]</th>
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<tbody>
<tr>
<td>10^5</td>
<td>2.40</td>
<td></td>
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<tr>
<td>10^6</td>
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<tr>
<td>10^6</td>
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<tr>
<td>10^6</td>
<td>2.46</td>
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Nozzle / Injectors

CFD optimisation

Add value solutions
Microwave electro-thermal thruster
For CubeSats

Credit: Ben Longmier - University of Michigan

Mini-MET

Propellant optimisation
Top: Ar
Bottom: Xe

Nozzle / Injectors
CFD optimisation

Credit: Ben Longmier - University of Michigan
A WATER CATHODELESS (NO-NEUTRALIZER) ECR THRUSTER FOR SMALL SATELLITES

AQUAJET

UK industry
Surrey Satellite Technology Ltd
Airbus Defence and Space

New technology incorporated into missions and products

2017
Phase I

2018 - 2020
Phase II

2020 - 2025
Phase III

Government R&D investment

Combined development and knowledge transfer

Added Value Solutions Ltd
STFC Rutherford Appleton Laboratory
University of Surrey
National Physical Laboratory

Experience Gained

Good Product Idea

New UK EP alternative

Vacuum

Dielectric window

Gas inlet

Antenna

Incident microwaves

SmCo Magnets

Ambipolar Acceleration
A WATER CATHODELESS (NO-NEUTRALIZER) ECR THRUSTER FOR SMALL SATELLITES

AQUAJET

Time-domain

Frequency-domain

Surface: Magnetic flux density norm (T) Streamline: Magnetic flux density

Eigenmode
AMBI-POLAR EXTRACTION:
PLASMA DYNAMICS
Optimisation -> Avoid Magnetic Nozzle

AQUAJET

ASTROPHYSICS    ACCELERATORS    FUSION    SYNCHROTRONS    NEUTRONS    LASERS    SPACE
AQUAJET

ANALYTICAL OPTIMISATION & RESULTS
Mini-ECR

ARGON & ALTERNATIVE PROPELLANTS

VSim
PLASMA ACCELERATION

2.45 GHz
Ø16 mm
L = 6 mm
INDUCED FLUORESCENCE DIAGNOSTIC DEVICE FOR EP THRUSTERS

KNOWLEDGE TRANSFER FROM FUSION & PARTICLE ACCELERATORS
- Non invasive technique
- Rapid profile acquisition
- High resolution
- Adaptability and quick installation

BIFEP

QUICK DIAGNOSIS:
- In-orbit plume measurement
- Seconds vs. 8+ hours

QCT Thruster at Surrey Space Centre
Top: Plume measurements
Right: 3D Render QCT
Main collision processes responsible for optical radiation in the plume of Xe-propelled thrusters

\[ e^- + \text{Xe}^{(a)} \rightarrow \text{Xe}^{*} + e^- \]
\[ e^- + \text{Xe}^{(a)} \rightarrow \text{Xe}^{a+} + (q+1)e^- \]
\[ e^- + \text{Xe}^+ \rightarrow \text{Xe}^{a+*} + qe^- \]
\[ \text{Xe}^- + \text{Xe} \rightarrow \text{Xe}^{a+*} + \text{Xe}^* \]
\[ \text{Xe}^{2+} + \text{Xe} \rightarrow \text{Xe}^{a+*} + \text{Xe}^* \]

Where the asterisk identifies excited species (either long-lifetime metastable states or excited state with short lifetime leading to optical emission), and \( q \) represents the charge state.

Schematic (right) of the identified NIR Xe(\( ^1D_2 \)) transitions together with the corresponding energy levels (R.A. Dressler et al.)
INDUCED FLUORESCENCE DIAGNOSTIC DEVICE FOR EP THRUSTERS

Main collision processes responsible for optical radiation in the plume of Xe-propelled thrusters

Quick Diagnosis
Non Intrusive

- Spatial Profile of Electrons \( (n_e) \) and Ion Densities \( (n_i) \)
- Electron Temperature \( (T_e) \)

Where the asterisk identifies excited species (either long-lifetime metastable states or excited state with short lifetime leading to optical emission), and \( q \) represents the charge state.

Schematic (right) of the identified NIR Xe() transitions together with the corresponding energy levels [R.A. Dressler et al.]

Example method to sweep plume width BIFEP system rotation

ISO 2001
IN-OBJECT DIAGNOSTICS

WHY?
- EPS EXTENSIVELY CHARACTERIZED ON THE GROUND
- CURRENTLY:
  - NO INFORMATION OF PERFORMANCE IN ORBIT
  - DERIVED INDIRECT MEASURES -> ORBITAL PARAMETERS OF SPACECRAFT
- PHYSICS NEEDS TO BE RESOLVED IN THEIR OPERATIONAL ENVIRONMENT; i.e. IN SPACE

Comparison of current density measurements on-board the Russian Express-A spacecraft vs. computed values.
IN-ORBIT DIAGNOSTICS

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OBJECTIVES

- FEEDBACK ON HIGH PERFORMANCE EP THRUSTERS FOR FINE TUNING
  i.e. gas flow, RF power, etc.

- VALIDATION
  i.e. Reduce characterisation on-ground -> Cost
  -> Standardisation