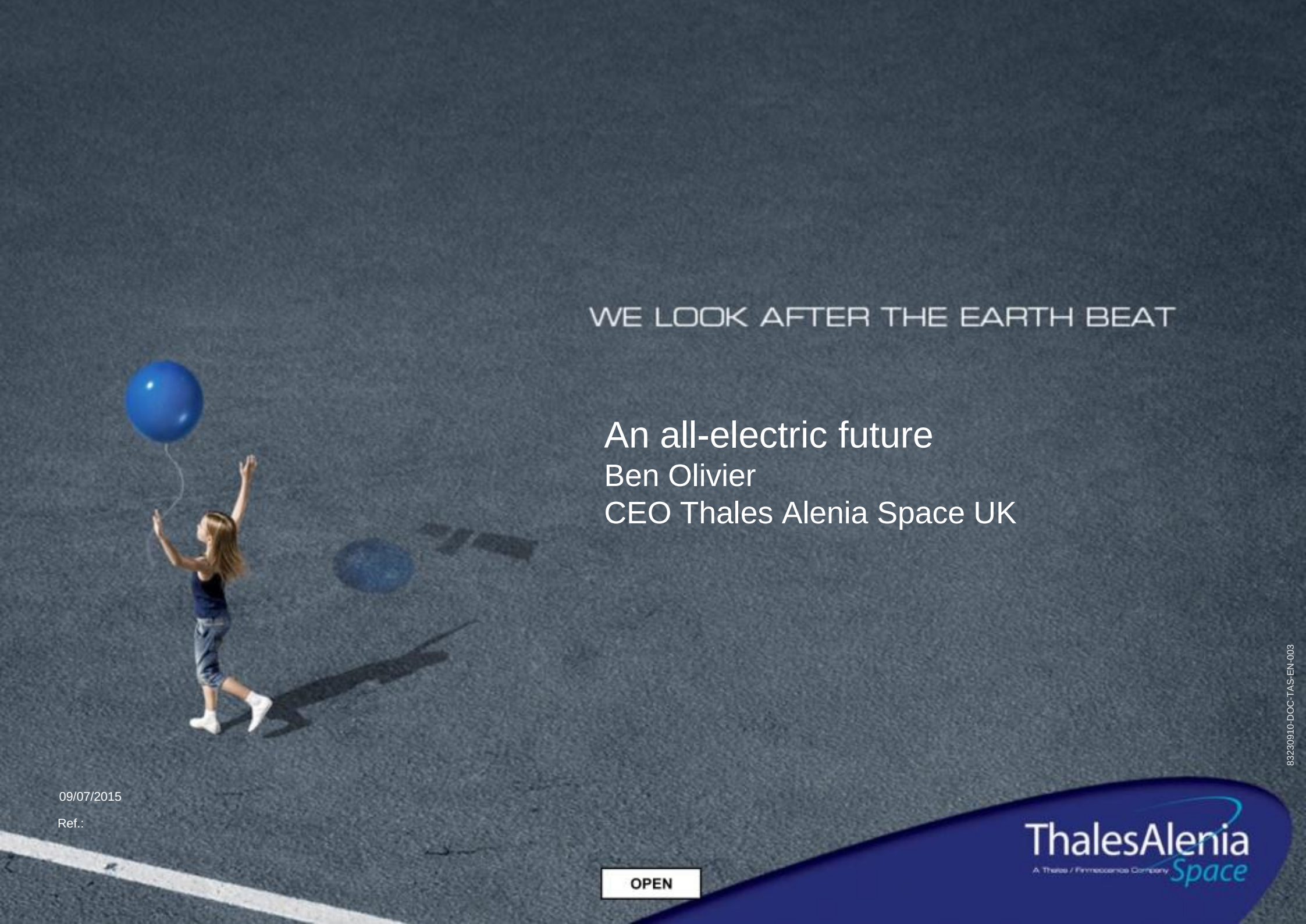

An all-electric future

Ben Olivier
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09/07/2015

Ref.:

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industrial strategy

- key questions for strategy development
  - what could the future look like ?
  - how to achieve an advantageous position for Europe ?
- challenges for Earth satellites
  - data relevance.. resolution, latency, revisit intervals, comms…
  - launch opportunities and costs
  - debris and end of life disposal
- barriers to innovation
  - risk is the customers' business plan not the technology
  - opportunities to evolve the technology, for example, compared with UAVs

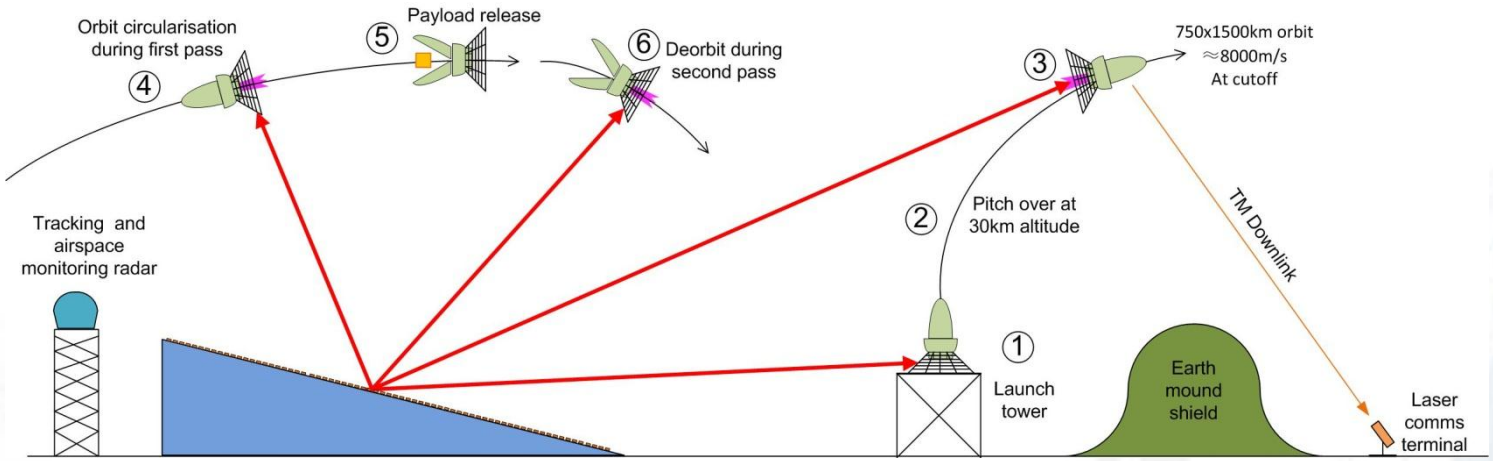
two future scenarios

- Skimsats
  - super low Earth Orbit satellites < 200Km perigee
  - atmosphere breathing electric propulsion
  - disposable technology, closer to missiles than spacecraft

- Electrically powered and propelled micro launchers
  - microwave beam power transfer
  - electrical propulsion
    - Magneto-plasma-dynamic thrusters (megawatt scale)
    - Aero-thermal thrusters (megawatt scale)

micro-launchers

- power transfer by microwave beam from ground mega-element arrays
- legacy technology from cold war era ‘Directed Energy Weapons’
- feasible payload into low Earth orbit < 200Kg



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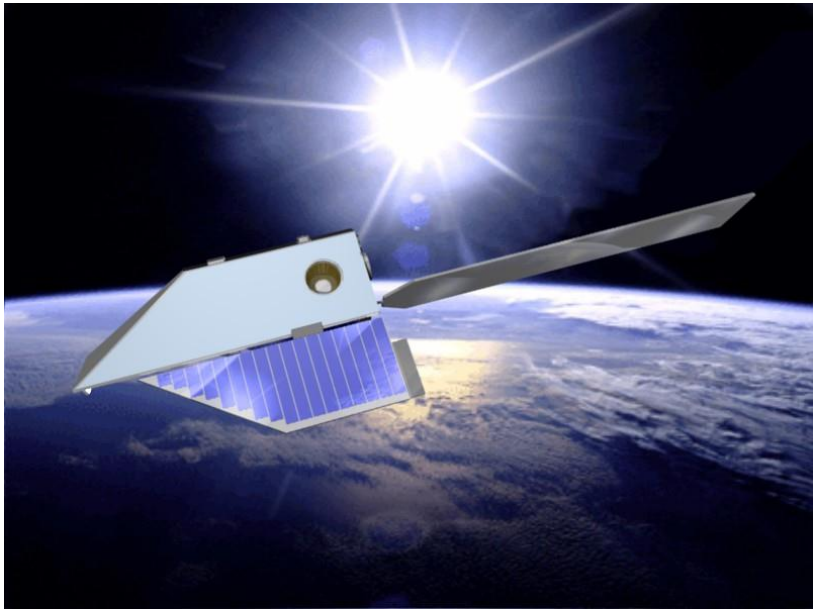
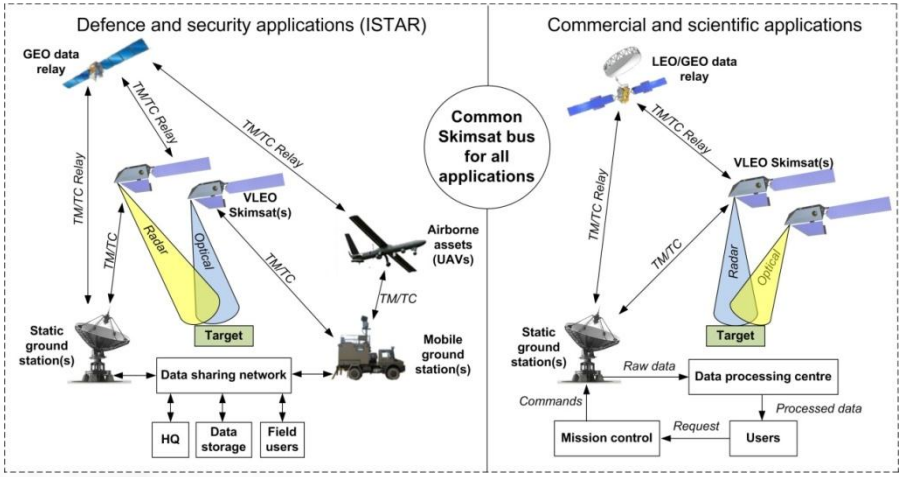
technology readiness of key elements

- MW Scale MPD thrusters
  - 15 years of research and development at NASA
  - test and development facilities in Europe are lacking
- Directed microwave energy
  - legacy from military projects... Russia etc
  - on-going developments of million element transceiver programmes at DARPA.
- Microwave Power Conversion
  - high power semiconductors (SiC and GaN)
  - novel microwave power conversion technologies

....pulled by non-space activities EG Rolls Royce E-thrust

skimsats





Very low Earth orbit <200Km

- Scales optics, antenna sizing for mass and power compared with 700Km.
- Smaller vehicles, lower altitude, assures rapid re-entry and burn-up.

But...

- Atmospheric Drag and ATOX erosion limits life without significant propulsion.
- Conventional and atmosphere fuelled (<160Km) Electrical Propulsion viable to provide a cost competitive life.

In summary...

- Cost scale down significantly and ‘space technology’ leverage is reduced

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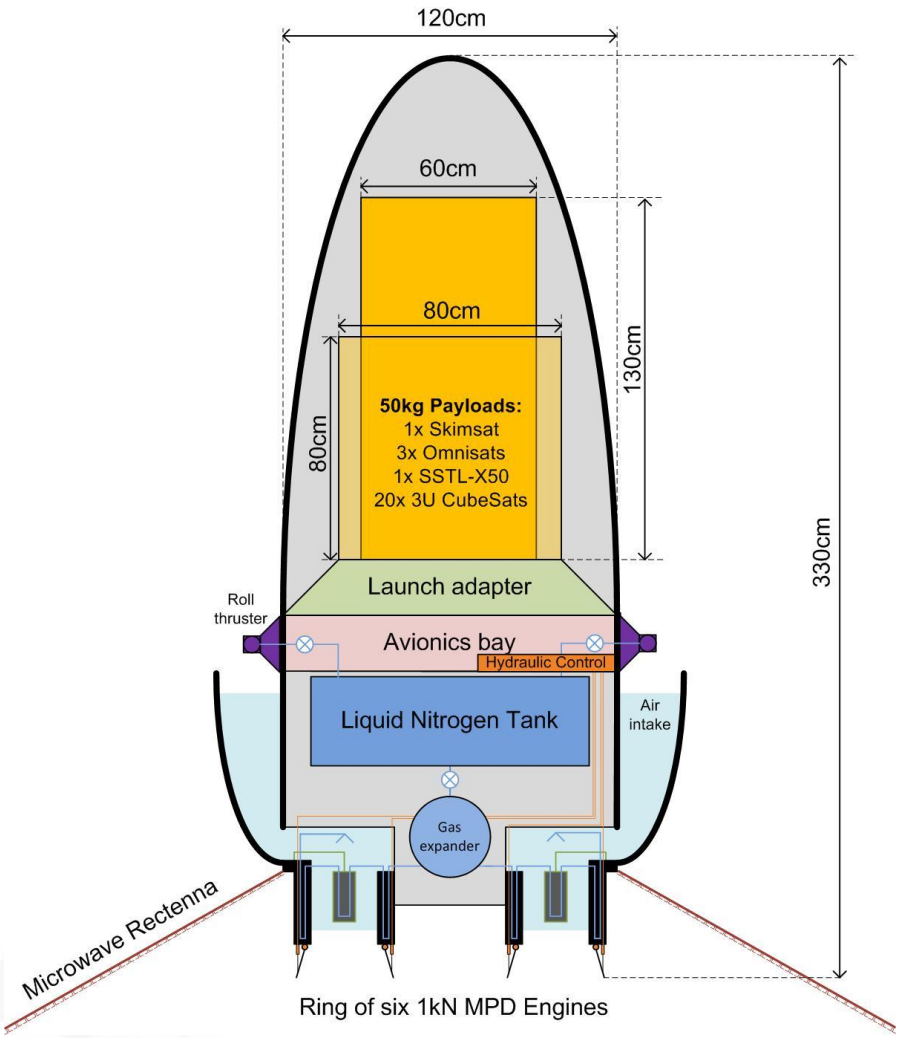
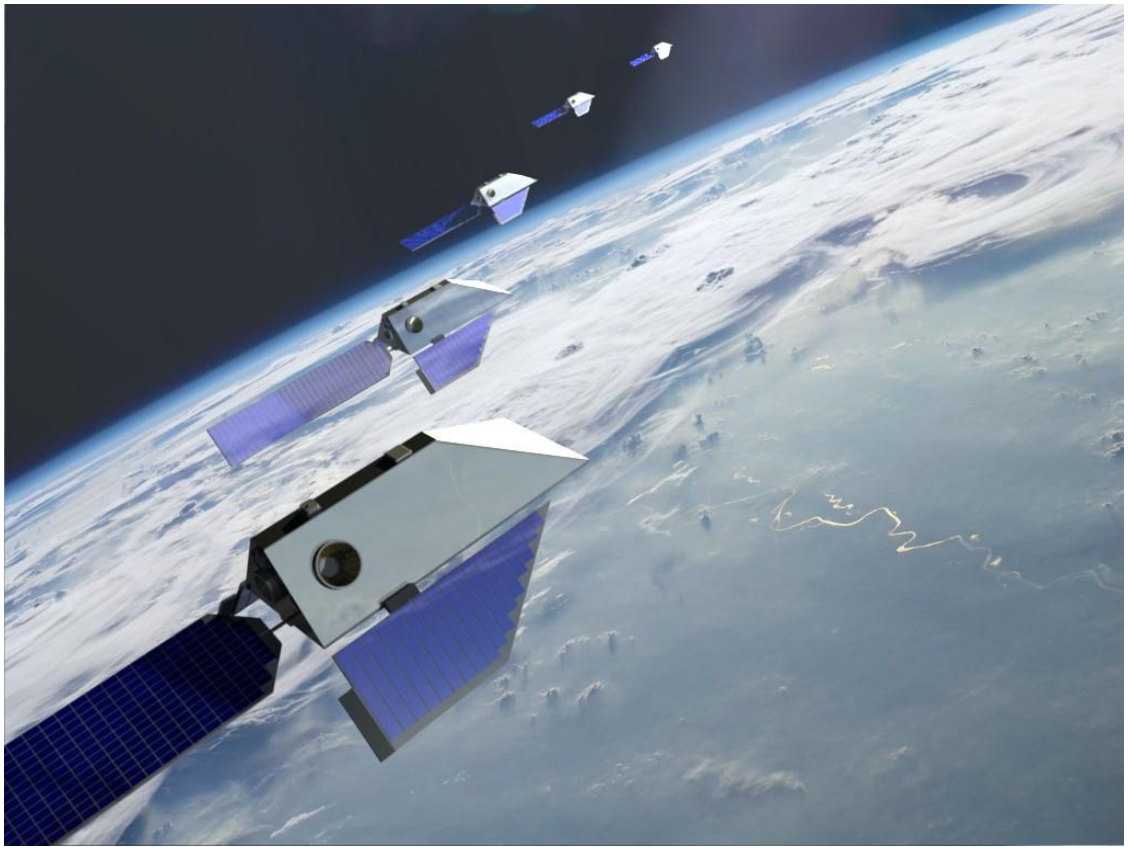
technology readiness of key elements

- VLEO orbital concept
  - was the orbit of the original US Keyhole satellites in the 1960's
  - recent experience of ESA GOCE satellite
  - Japanese SLATS concept
  - FP7 QB50 cubesats

- Propulsion
  - atmosphere breathing concept patent in the US
  - some early phase activities in Europe
  - conventional electrical propulsion optimised for ~1 year life.
  - existing test and development facilities are insufficient

all electric





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in summary

- an ‘all electric’ future is possible but it is not, today, the path of least resistance
- new approaches and technologies can disrupt established interests and behaviour patterns
- If we started the space race today, all electric would be the high risk, high return option. These options should be actively pursued in Europe if we are to be competitive.
- TAS has been working to identify capabilities, resources and gaps, we are keen to engage with other entities where the key technologies can be advanced in Europe.