Technology Market Case Study No. 13 (Draft 1)

BABEL – A Novel Microwave Geolocation System for Earth Observation Applications

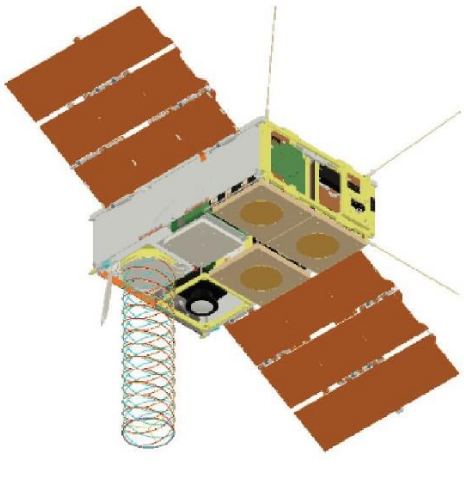
The Opportunity

In-Space Missions Ltd (In-Space) developed the Faraday Spacecraft to provide hosted payload opportunities for early service & technology demonstration in Low Earth Orbit. It is the backbone of In-Space's Faraday Missions programme which provides regular launch services for companies, universities and other organisations.

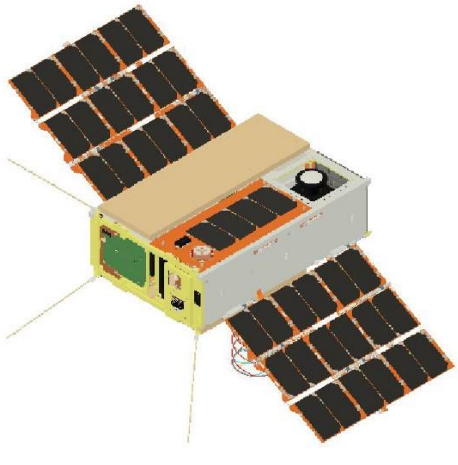
The Faraday Spacecraft uses a 6U-CubeSat platform with 3-axis stabilisation which can host a 4.5 kg of payload. A Software Defined Radio (SDR) configured as an S-band transceiver is used to provide communications from the multiple payloads embarked on the satellite.

During development, In-Space realised that, if suitably re-configured, the SDR subsystem could also be used to sense microwave emissions from the earth's surface, providing novel geospatial data for new EO capabilities. Potential applications include surface feature information, monitoring patterns of life and infrastructure capability in under-developed countries via cell tower usage, or experimenting with alternative methods of monitoring the locations of ships that have disabled their AIS transmitters.

While these are not traditional Earth Observation applications, In-Space discussed the concept with CEOI. Following detailed evaluation, CEOI agreed to fund development of this enabling capability for potential novel new earth observation techniques.



Nadir view of Faraday-1 showing main payload antennas and optical camera



Zenith view of Faraday-1 showing Babel S-band antenna, optical camera and body mounted solar cells.

Figure 1: Faraday 1Spacecraft Configuration
Source: In-Space

The Solution

CEOI's Babel PD4 Pathfinder project funded development of the SDR functional software and an operations campaign post-launch to acquire / download 4G mobile signals and aircraft / ship radar signals to demonstrate novel geolocation techniques.

In-Space procured an additional C-band antenna and attached it to a spare RF front-end on the SDR to enable it to perform the spectrum measurement tasks. The wide spectral bandwidth (2.6 – 3.1 GHz) and non-isotropic beam pattern of the S-band antenna enables:

- Limb monitoring of ship radar (2.9 – 3.1 GHz)
- Monitoring and mapping of 4G signals (2.6 – 2.7 GHz)
- Demonstrations of novel techniques to geolocate signals on the ground by combination of attitude manoeuvres and signal processing from a small antenna (applicable to other bands) – correlated with ground aerodrome surveillance radar in the 2.7 – 2.9 GHz band.

In-Orbit Demonstrations

Following the technical development, In-Space ran an experimental in-orbit campaign performing the following demonstrations:

A) *Limb monitoring of ship radar (2.9 – 3.1 GHz):*

- Boot Mission SDR into S-band spectrum capture mode
- Pitch spacecraft by 112 degrees such that antenna beam centre is pointed at Earth horizon.
- Acquire 2 minutes of spectrum in a pre-selected sub-band (in the 2.9 – 3.1 GHz band) at a spectral resolution ranging from 200kHz to 1MHz
- Pitch spacecraft back to nominal pointing
- Boot Mission SDR back in S-band transceiver communications mode & download spectrum
- Process Data

B) *Measurement of 4G signals (2.6 – 2.7 GHz):*

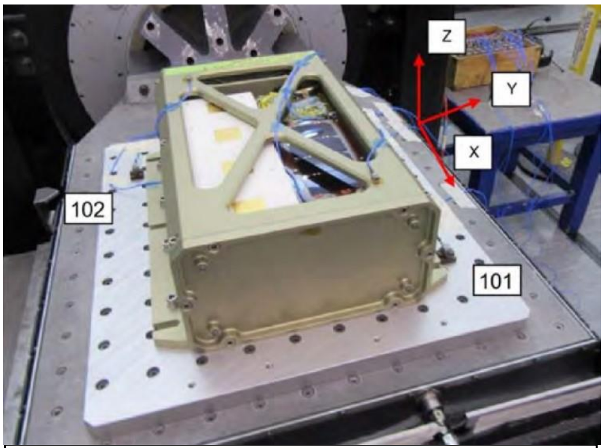


Figure 2: Spacecraft on Vibration Slip Table for X-axis Testing

- Boot Mission SDR into S-band spectrum capture mode
- Pitch spacecraft by 180 degrees to point antenna beam centre at satellite nadir.
- Acquire 2 minutes of spectrum in a pre-selected sub-band (in the 2.6 – 2.7 GHz band) at a spectral resolution of 360 kHz
- Pitch spacecraft back to nominal pointing
- Boot Mission SDR back in S-band transceiver communications mode & download spectrum
- Repeat for a range of pitch angles from 112 degrees (limb pointing) to 180 degrees (nadir)
- Process Data

C) *Demonstration of novel geolocation techniques:*

- Boot Mission SDR into S-band spectrum capture mode
- Pitch spacecraft by 180 degrees to point antenna beam centre at satellite nadir.
- Introduce satellite yaw rate of rate 6 °/s
- Acquire 2 minutes of spectrum in a pre-selected sub-band (initially in the 2.7 – 2.9 GHz band where there are known fixed emitters) at a spectral resolution of up to 1MHz
- Remove yaw rate and pitch spacecraft back to nominal pointing
- Boot Mission SDR back in S-band transceiver communications mode & download spectrum
- Repeat the above using a roll rate of 6 °/s to sweep the antenna pattern over the Earth on each roll revolution
- Repeated the two cases using a latitude tracking guidance rather than nadir pointing while performing the yaw or roll rotations.

- Process data using the signal strength and doppler shift of known emitters to attempt to achieve improvement in geolocation of target location. The yaw rate introduced combined with the anisotropic antenna beam is where improvements in spatial resolution of the system may be possible.

Next Steps of Wider Deployment

The satellite lifetime is 3 years and as satellite operator, In-Space is able to provide operational access to the satellite following its 6 month Babel demonstration phase. Consequently, positive results from the demonstration phase can be built upon and improved over subsequent years.

Additionally, with the launch of the Faraday-2 satellite planned for Qu 4 2023, the possibility of a follow on Babel payload with a tailored antenna and SDR is possible – particularly as Faraday-2 is proposed to be a larger vehicle.

Exploitation of the datasets acquired and potential passive monitoring services demonstrated will be performed in collaboration with domain appropriate partners. In-Space are not experts in these technical fields, nor in the diverse domains where this data can be exploited. Indeed, the In-Space business model relies on teaming with World class companies rather than trying to acquire such skills inhouse. Discussions are underway with potential partners in the Defence, Commercial, and Civil Institution sectors.

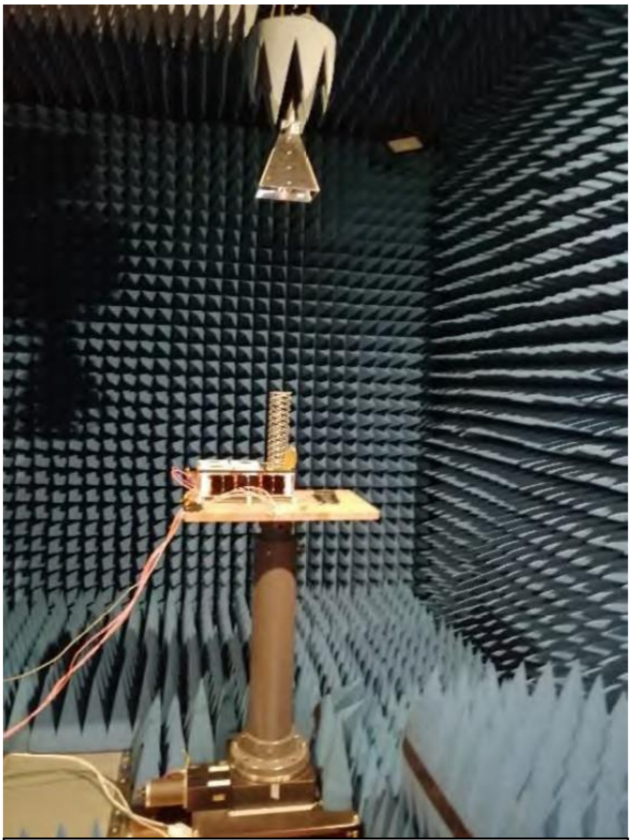


Figure 3: Spacecraft In EMC Chamber

Support from CEOI

The project was undertaken by In-Space Missions Ltd and funded by a Pathfinder grant under the CEOI 12th Call for EO Technology within the thematic programme of new and innovative ideas.

CEOI

The Centre for Earth Observation Instrumentation (CEOI) works with UK academia and industry. Its objective is to develop a world leading, internationally competitive, UK Earth Observation (EO) instrument and technology research and development capability, enhanced through teaming of scientists and industrialists. The CEOI is funded by the UK Space Agency with parallel technology investment sourced from the commercial sector.

Further information regarding this project and other technology developments funded by CEOI can be found at www.ceoi.ac.uk. Alternatively, please contact:

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