Te Pūnaha Ātea -1 (TPA-1), a capability development and validation mission from New Zealand

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Mission

Mission goal:

"Stepwise capability building leading to delivery of high quality, science or application driven missions with repeatable success"

Operation goals:
- Capturing identifiable imagery of NZ landmass.
- Upload and use of student and researcher image processing tools.
- Inspecting exposed surfaces and elements of the CubeSat.
- Demonstrating and monitoring the deployable structures.
- Monitoring the thermal profile inside the CubeSat.
- Demonstrating timely de-orbit at end of life.

Mission objectives:
- Commissioning and demonstration of TPA-SI facilities.
- Establishment and validation of mission delivery processes.
- Outreach, education and training in mission delivery and operations.
- Generation of core mission documentation set.
- Flight heritage for in-house spacecraft platform avionics and structures.

Project partners

nano avionics A KONGSBERG COMPANY · ROLATUBE TECHNOLOGY · CIRRUS MATERIALS SCIENCE

Spacecraft

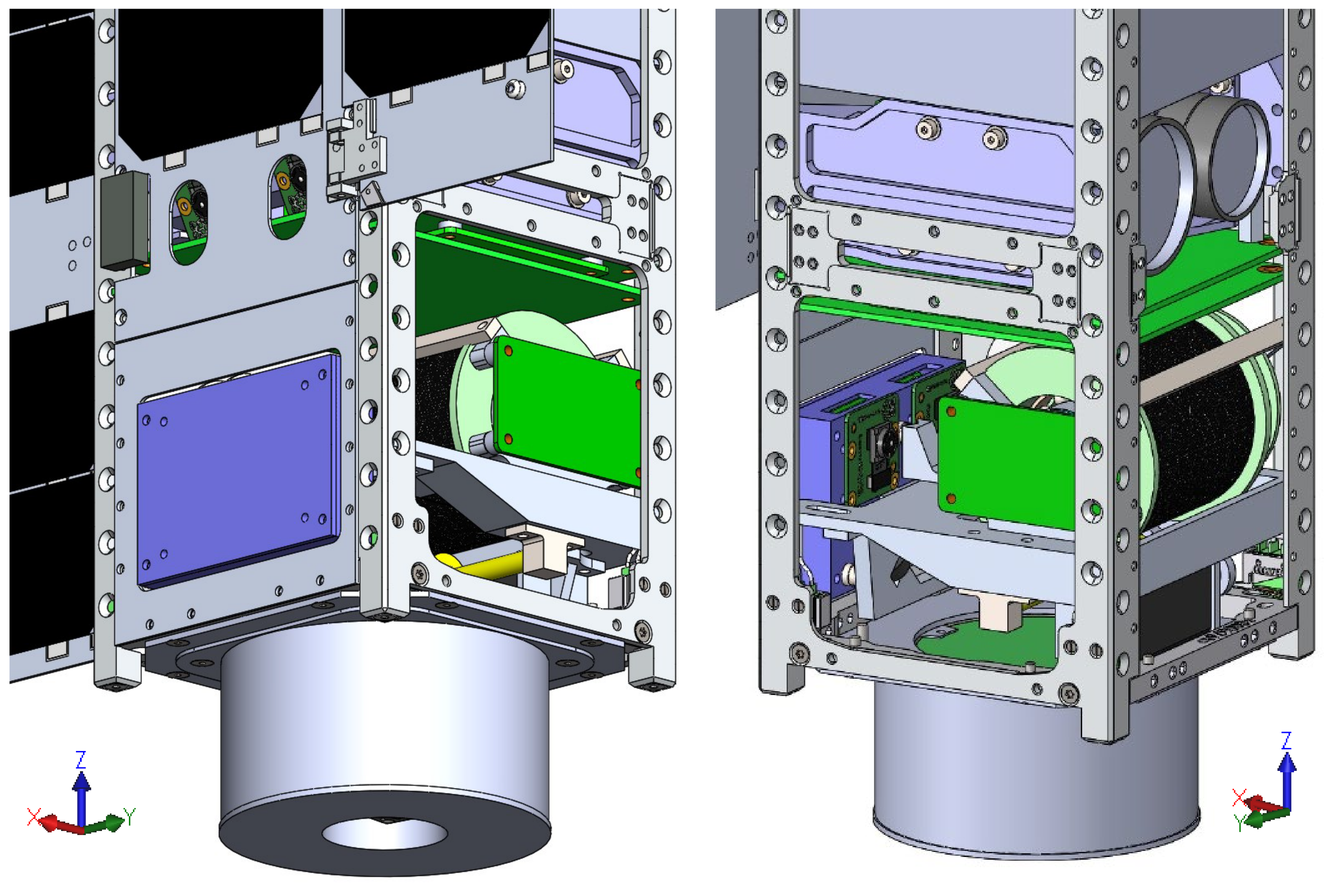

Figure 1: Payload positions viewing the +X and +Y faces, left, and –X and +Y faces, right.

- 3U (M3P) CubeSat platform from Nanoavionics with external dimensions of 340 x 100 x 100 mm when in the stowed configuration.
- ~5kg spacecraft mass including payload compliment.
- Duplex communications via amateur UHF and S-band frequencies with data rates up to 130kb/s.
- Two deployable solar panels supply Electrical Power System (EPS) with 40WHr battery.
- Dedicated Payload Computer (v1.5) for control and scripted payload operations
- Full 3-axis pointing control with Sun, Nadir and Lat/Long pointing modes. ADCS comprises 4 reaction wheels and magnetoquers controlled by dedicated Flight Computer equipped with Fine Sun Sensors, magnetometers, GPS module and accelerometers

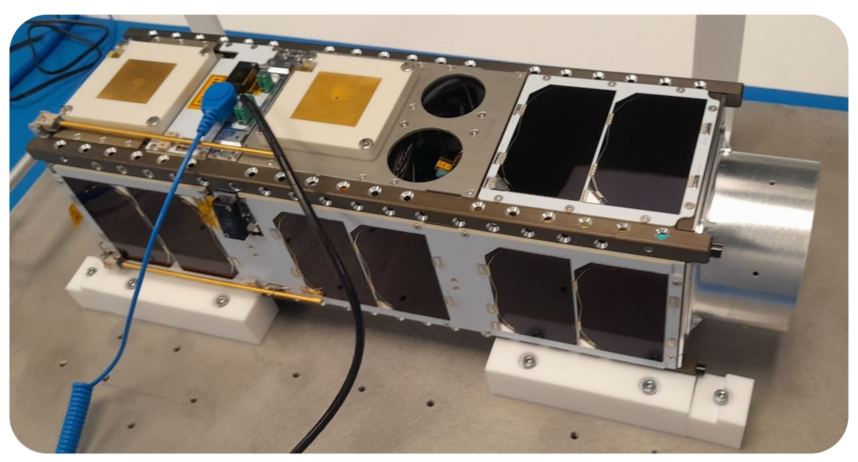

Figure 2: TPA-1 FM Spacecraft in AIT

Imagers payload

- The imagers payload consists of four RaspberryPi cameras supported by 2 Raspberry Pi Compute Module 4 (CM4) providing 1.5GHz quad core Cortex-A72 and 2GB RAM for onboard image processing
- Two cameras face the Earth (Nadir) with a narrow-field lens and wide-field lens, which provide approximately 50m/pixel and 200m/pixel ground sample distance (GSD), respectively on 12.3MP (Sony IMX477) RGB sensors.
- Two smaller 8MP (Sony IMX219) RGB camera face at an offset angle to Zenith with field of view and focus settings to image the deployment of the boom and dragsail in 3D.
- Payload stack mounted with simple Thermal monitoring unit with 8 additional temperature sensors to characterise the thermal environment of the spacecraft for model development.
- Ruggedising of commercial-off-the-shelf components enables student involvement for accessible Python application development to run on the CM4s in orbit as an educational and outreach programme.

Mass: 400g, **Power:** 200-500mA at 5V, **Volume:** 0.3U

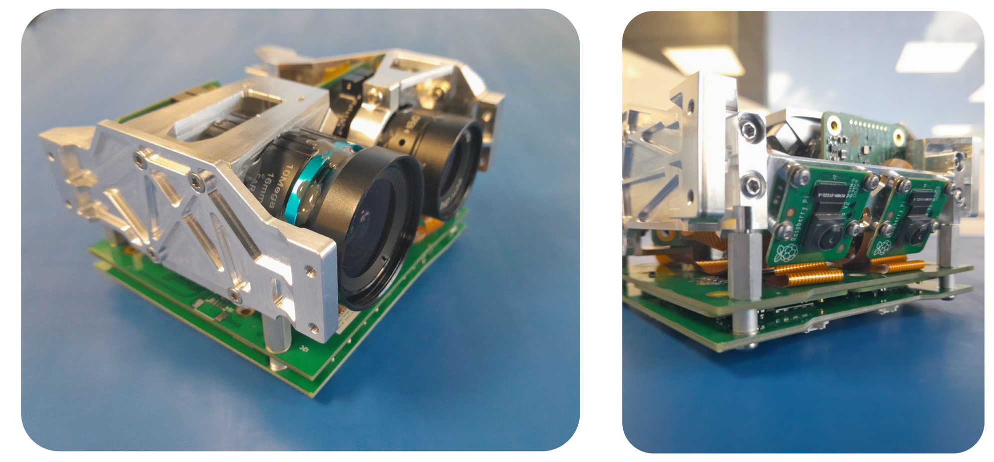

Figure 3: FM Imagers payload – EO cameras (left), and deployables cameras (right).

Deployable inspection boom payload

- The versatile deployable boom extends a tip payload up to 1.3m (nominally 0.7m) away from the satellite, here implemented as an inspection system with two RaspberryPi cameras and a CM4.
- The deployable boom from RolaTube Technology is manufactured from thin-ply carbon fibre reinforced epoxy and is bistable with embedded harnessing carrying power and data to the boom tip module.
- The two cameras allow stereoscopic (3D) images and video to be captured of the satellite, including inspection of token of paint-less colour coating developed by Cirrus Materials Science to assess impact of space exposure and perform colour calibration of the camera sensors.
- The boom is extended using a co-coiled drive ribbon, that is motor driven through a set of spur gears.
- Retracting the boom is driven by a constant torque spring where the motor acts as a brake. This allows for automatic stowing of the boom in the event of a spacecraft power failure or anomaly.
- Imagery and video captured by cameras will be used to build experience in teleoperation technologies for Active Debris Removal and servicing applications
- Boom system can be used for a variety of different applications including magnetometer payloads,

Mass: 400g, **Power:** 300mA at 12V, **Volume:** 0.5U

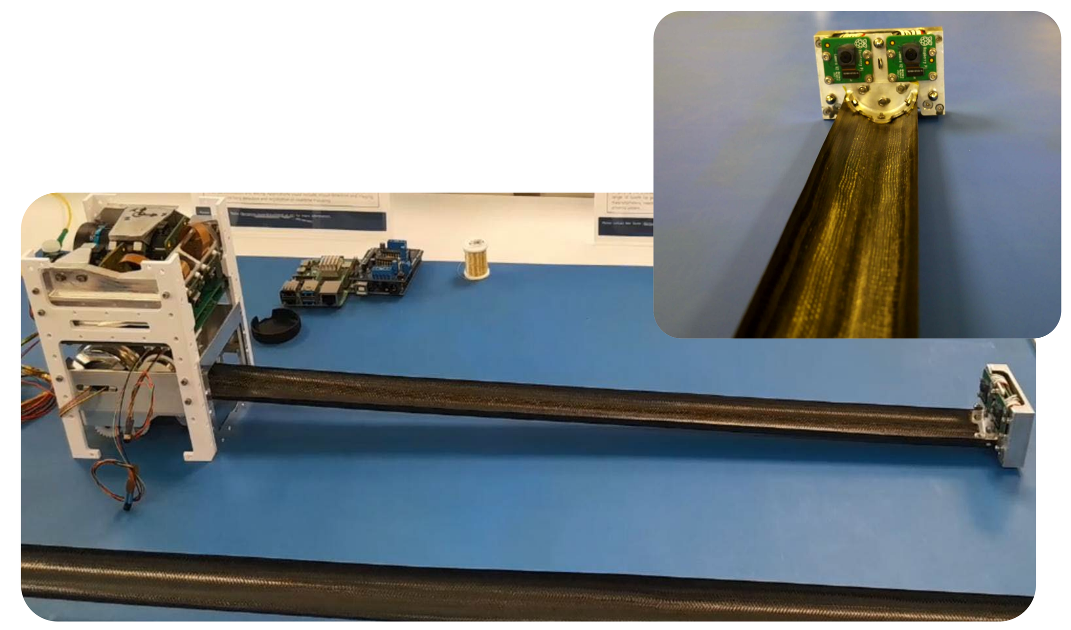

Figure 4: Deployable inspection boom EQM integrated in dummy structure, and as imaged by Imagers payload (inset)

Dragsail payload

- On command, a 1m^2 dragsail is deployed to accelerate the deorbiting of the spacecraft.
- Module integrated entirely into "Tuna can" volume of CubeSat and designed to be added late in AIT without platform disassembly
- The module will reduce the orbit's natural decay time from 2-3 years to <3 months.
- The system includes accommodation for self-powered power and data watchdog to detect the status of host spacecraft and automatically deploy in the event of a long-term failure, though not implemented on this demonstration.
- The dragsail is manufactured from 12.5μm thick PET with vapour-deposited aluminium providing resistance to atomic oxygen.
- The system is released by a burn-wire system and jack-in-the-box-style spring.
- Pass-through harnessing and recess provides accommodation for platform ADCS Fine Sun Sensor for operation before and after deployment.

Mass: 250g, **Power:** 1.8A at 3.3V (for <6s), **Volume:** Tunacan (45mm x 80mmø)

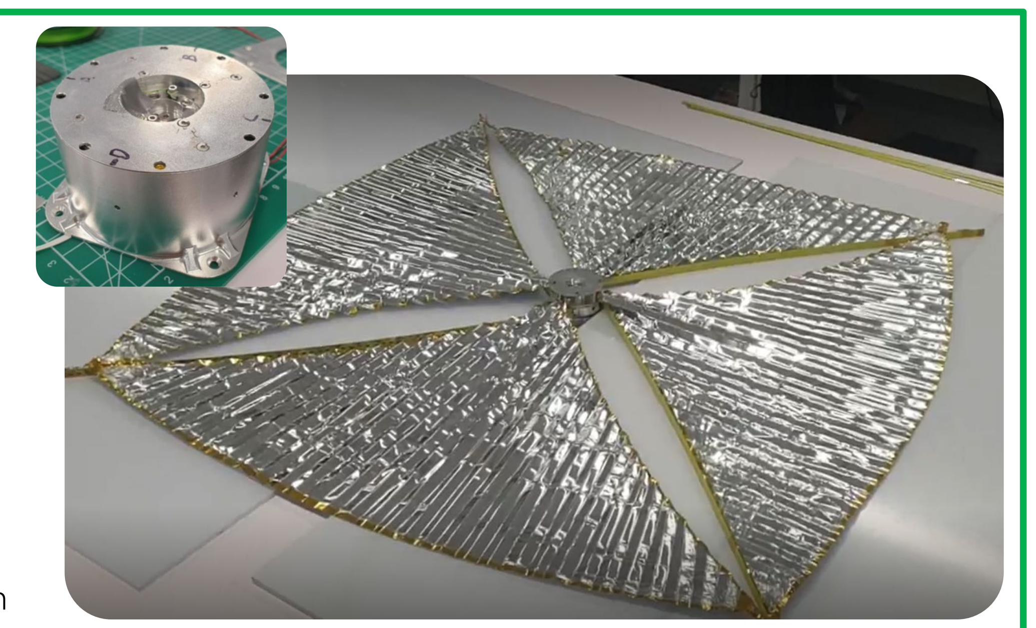

Figure 5: Deployed Dragsail EQM and stowed state (inset)

Ground Segment

- A Mission Operations and Control Centre (MOCC) established at TPA-SI to support missions from the University, as well as national missions – in particular the MethaneSat mission in collaboration with US organisations
- A groundstation is being established at Ardmore field station, 30km from Auckland with capability to support:
  - UHF (amateur 435MHz and commercial band 405MHz),
  - VHF (amateur 144MHz)
  - S-band (2.2-2.4GHz) on 3.7m dish
  - Optical communication node
- All RF channels utilize N210 USRP SDR supported by GNURadio with appropriate amplifier and filter chains.
- Ground station emulator established on site at TPA-SI cleanroom for representative over the air testing.

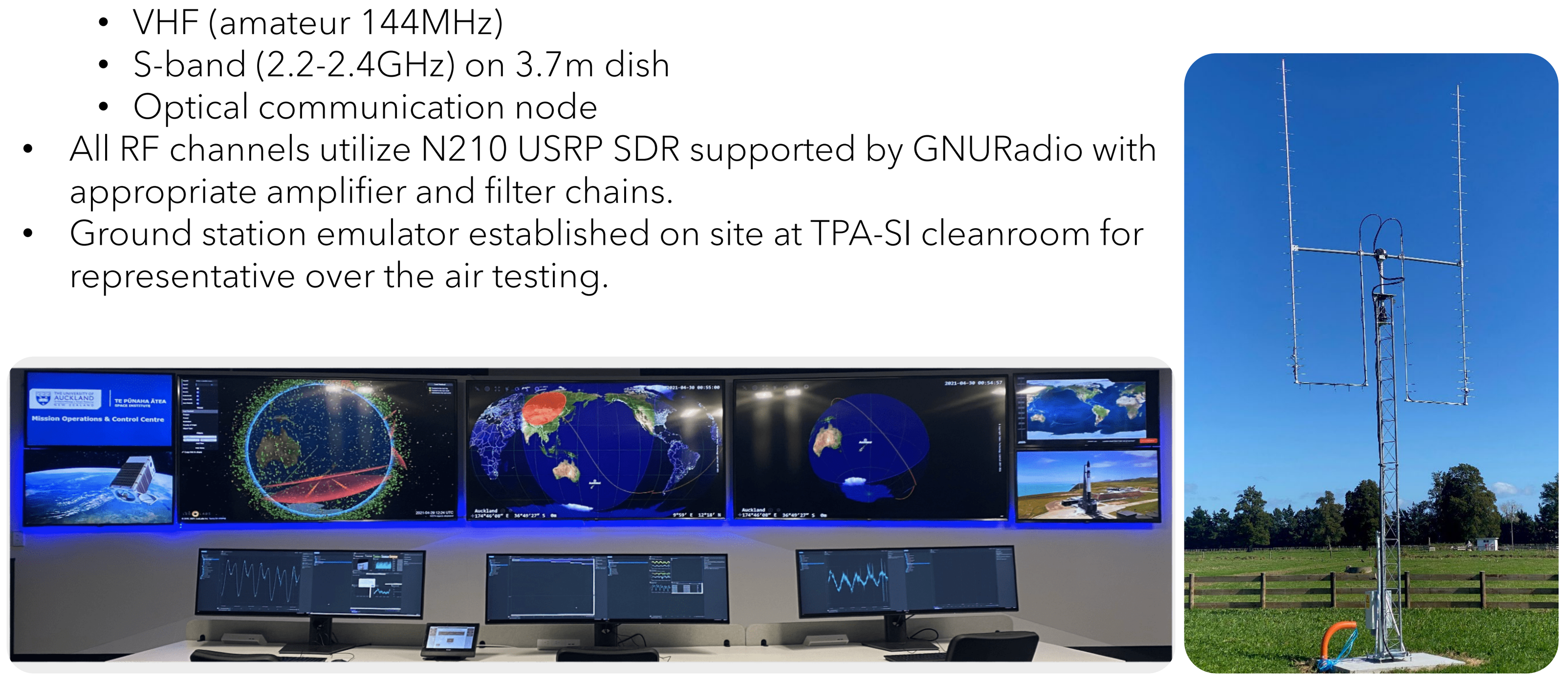

Figure 6:TPA-SI Mission Operations Control Centre (left) and UHF mast (right)

Testing

- The National Satellite Test Facility (NSTF) established at TPA-SI provides Thermal vacuum, vibration and shock test capability in house.
- "Hardware rich" development campaign making use of rapid prototyping, COTS components and metal development models tested to rapidly verify design and modelling.
- All payloads tested to Falcon 9/ Electron enveloped vibration loads with further qualification to GEVS on the imagers and dragsail payloads
- Payloads tested in thermal vacuum extremes between -30°C and +60°C
- Focus settings of imagers adjusted during vacuum tests for performance in orbit

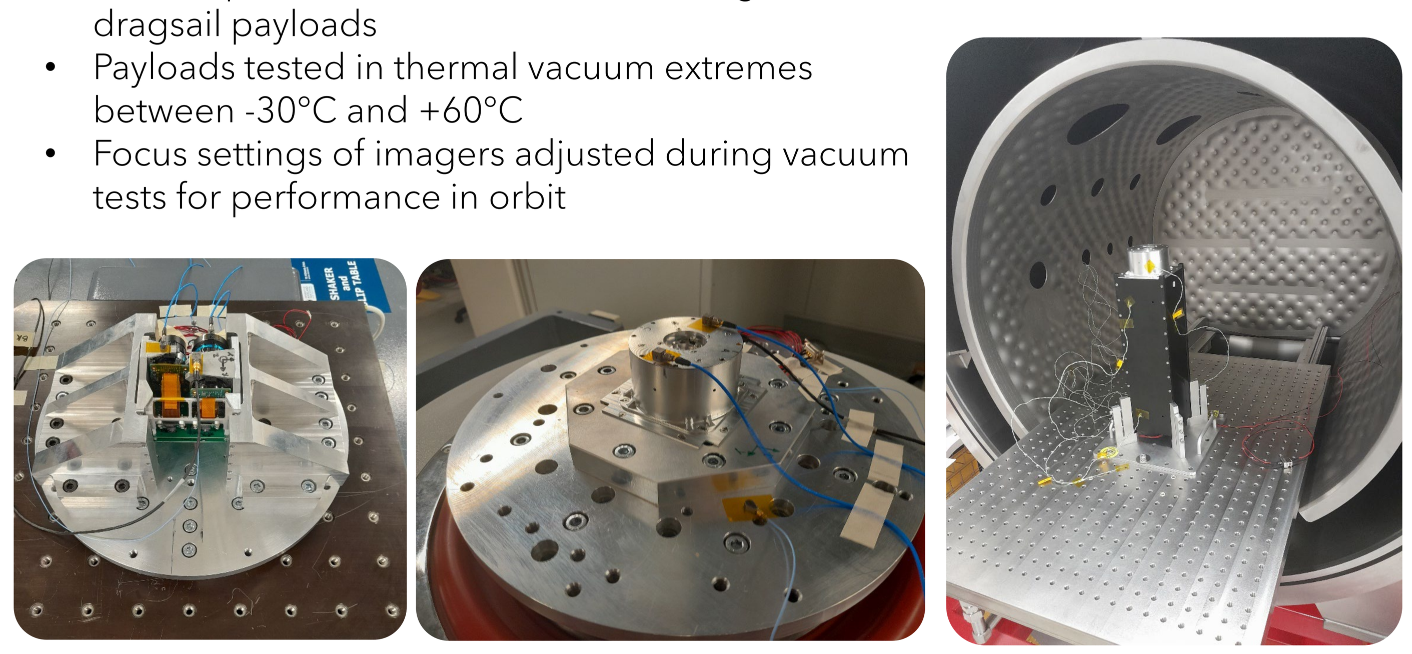

Figure 7: TPA-1 payloads in test in the NSTF, subjected to vibration (left, centre) and TVAC (right)

Operations

- Launch planned on Transporter-11 mission (Falcon 9) in mid 2024
- One year nominal mission lifetime up to sail deployment, may be extended
- First phase of mission operations are planned to perform early demonstration of the Imagers and Boom payloads, capturing imagery to build capacity in EO operations
- Second phase of mission will see software developed by students and researchers uploaded to spacecraft for on-board image processing
- End of life disposal via sail deployment. Imagery of deployed sail and control of spacecraft will be attempted, though shadowing and RF interference from sail present challenges.
- To be used as observation target for NZ Space Situational Awareness activities
- UHF amateur beacon packet format will be published prior to launch
- Anticipated student training activities to support mission operations

TPA-2

- Development of second mission underway with near identical platform
- Mission goal to demonstrate in-house avionics elements, flown here as payloads on primary Nanoavionics bus. Payloads include star tracker with deployable baffle, reaction wheels, thermal control unit and a highly integrated core avionics suite with communication, power and OBDH capacity
- Enhanced undergraduate and postgraduate student involvement
- Targeting launch in late 2024

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