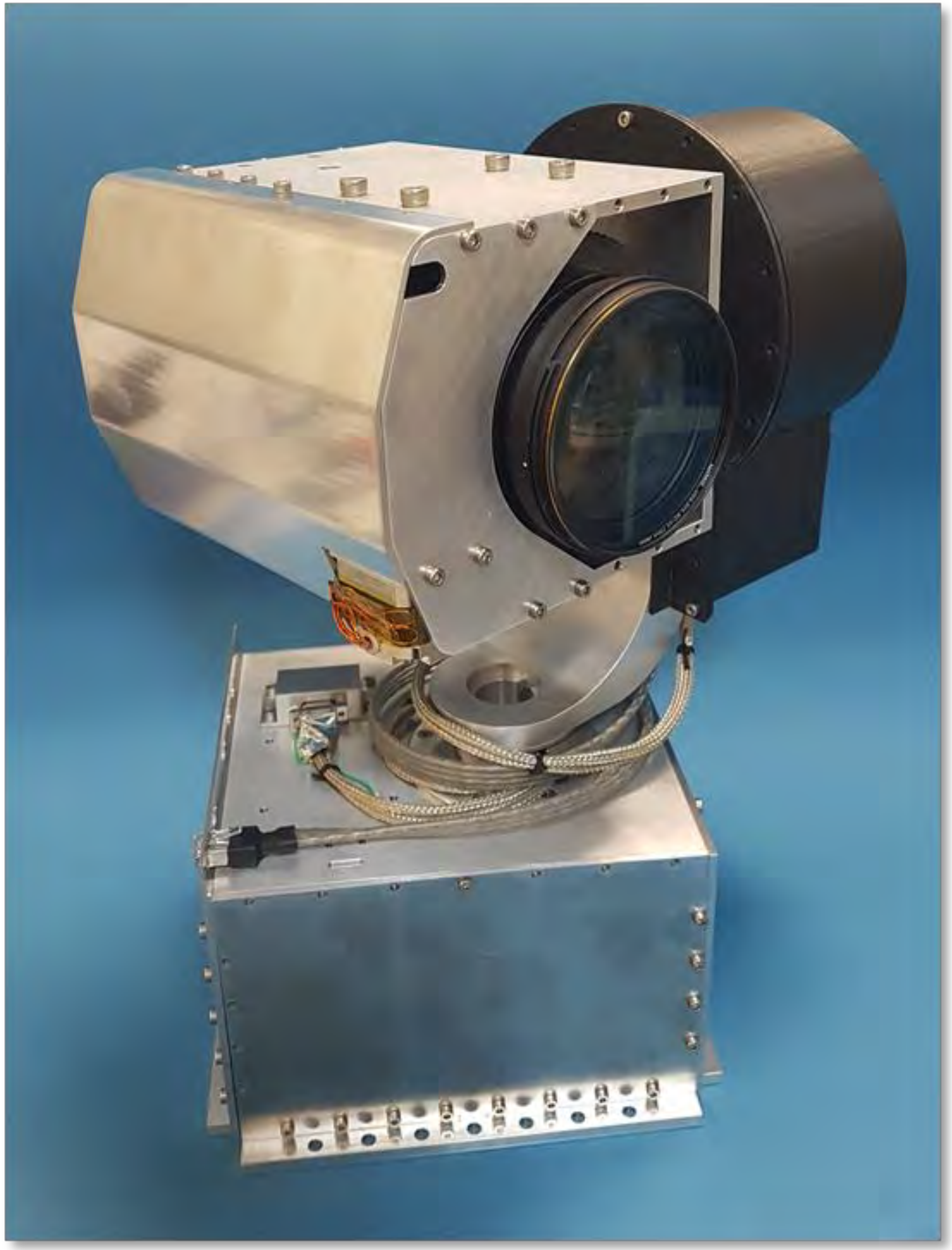

UNIVERSITY OF SURREY

NIMBLE: Fast Slew Gimbaled Optics for Real-time EO

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C0ntents

Project Overview

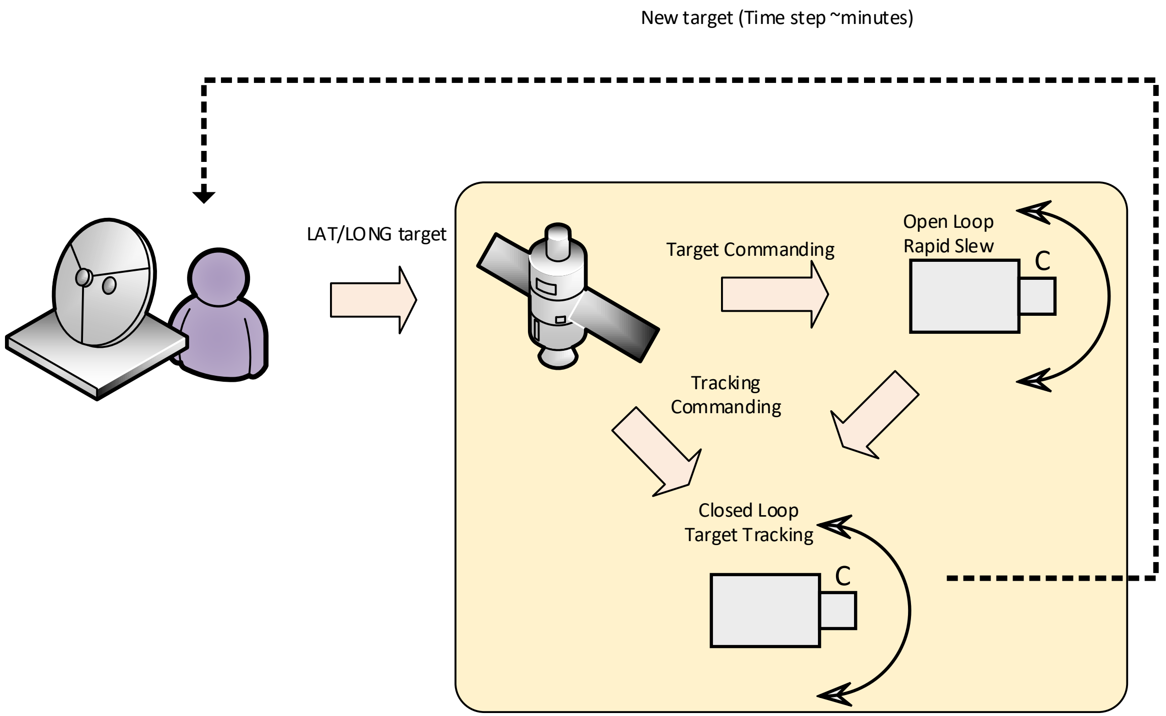
MISSION TARGET(S):

Agile imaging system for low cost commercial imaging missions

OBJECTIVE:

This project will develop the mechanisms, optics and interfaces to deliver a qualified protoflight model of a zoomable, fast slew, gimbaled video and still camera system.

The development will exploit terrestrial COTS hardware and processes to provide cost effective, agile, imaging payloads for small platforms.



MODES OF OPERATION:

- Fast Slew: >5deg/s fast slew to target.
- Tracking: <1deg/s precise pointing to track target in centre of Field of View (FoV).

System Overview

System consists of four top level modules:

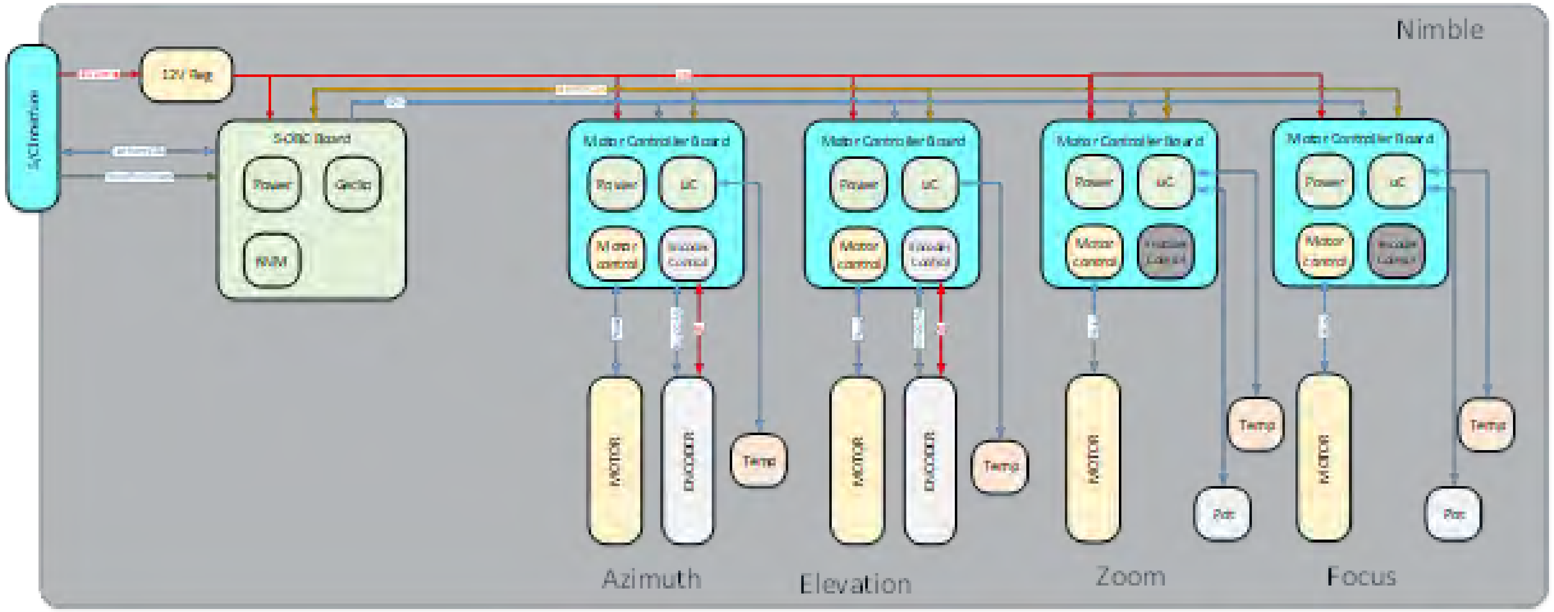
OBC – System controller in charge of Spacecraft TT&C interface, system supervision and trajectory control

Motor Controller Board – dedicated board per degree of freedom. In charge of achieving and maintaining set position as instructed by OBC

Pointing Mechanism – Azimuth/Elevation mechanism with integral motors, gears, bearings and encoders

Optics Module – consists of camera, lens and focus and zoom control elements

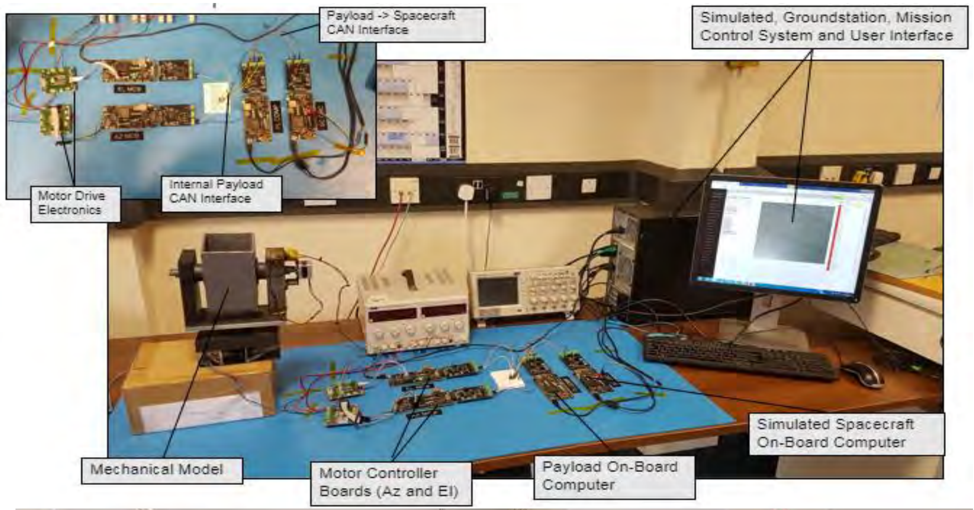
System Overview



Nimble electrical system consists of:

- a supervisor commanding On-Board Computer (OBC)
- separate Motor Controller boards (MCB), each responsible for a degree of freedom of the system including motor control and position feedback

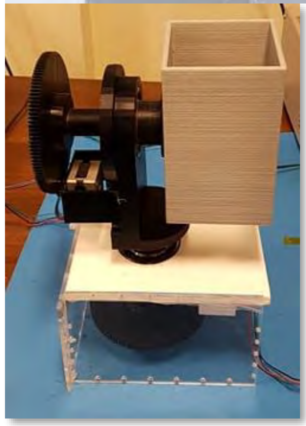
Protype Design – Electrical System

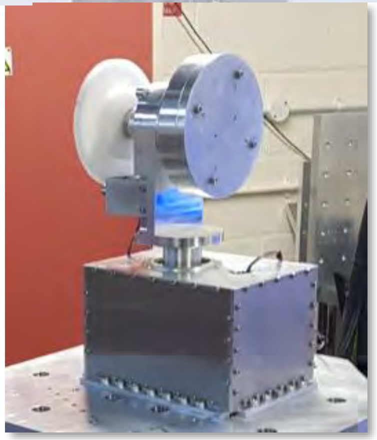


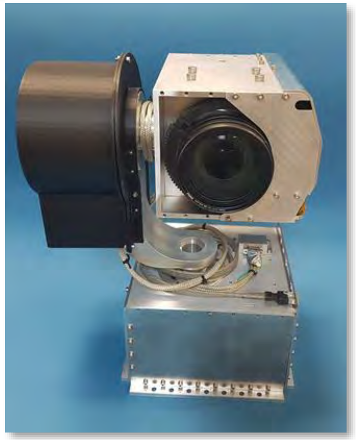
- System development approach used a development model testbed to integrate breadboard elements for each subsystem which could be swapped out as elements are iterated

- Provided environment for development of software, as well as testing of mechanical solutions

Prototype Design – Mechanical System



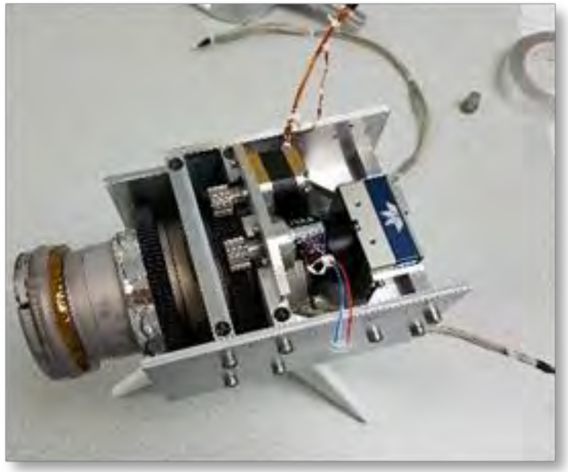


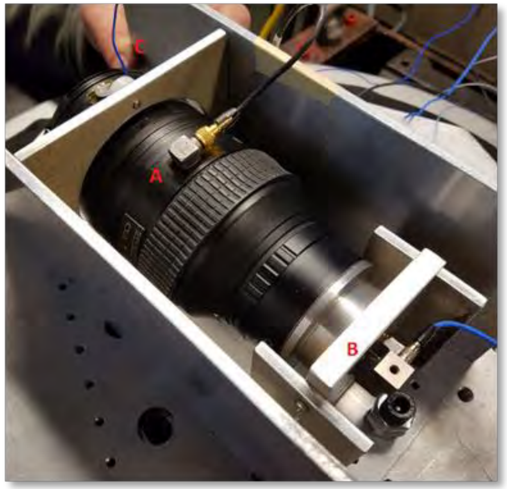


- Evolution of the digital design and physical representations

- The delivery strategy was to make best use of rapid prototyping to aid early system build and test – particularly of the core features and functionality
- Use of development model testbed to trial electronics components and software modules
- Commercial lens selected to meet functional and performance requirements within timeframe of project
- Relatively massive system for moving imaging head
- Mechanical design underwent significant evolution to final version, utilising 3D printed and metalwork mock-ups incorporating mechanism drive elements

Prototype Design – Optical System

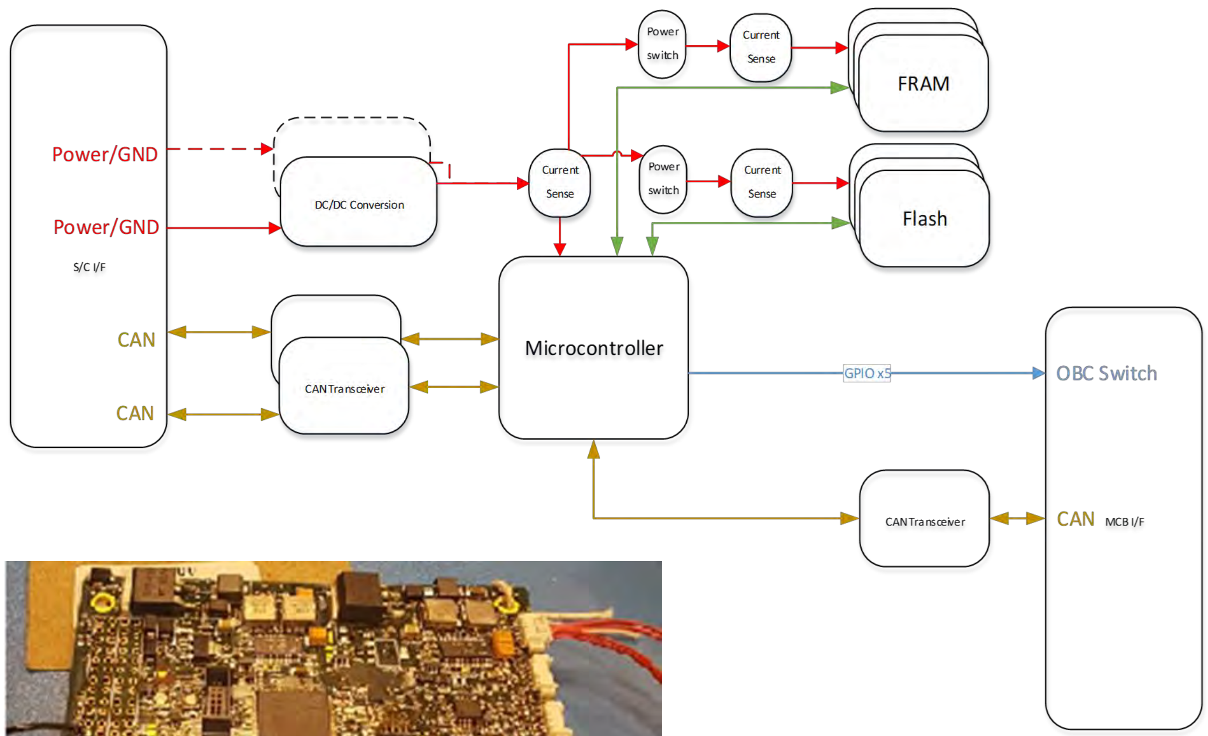


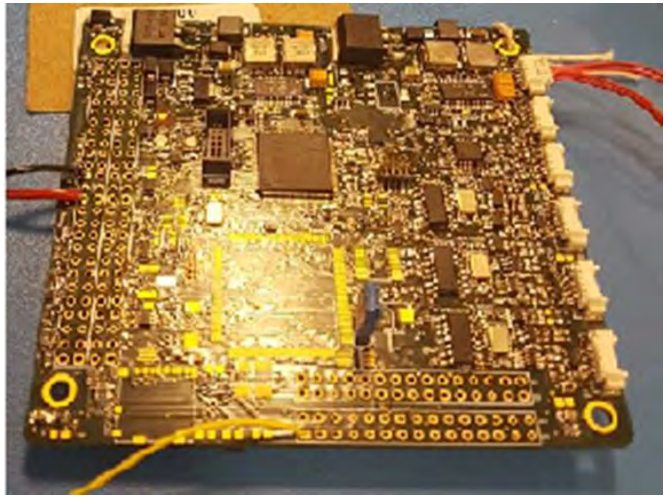


- Lens, Nikon AF-S 28-300
- Grease replaced with vacuum rated
- Zoom + Focus control, uses the same motor as all moving parts
- Mounting, Clamps around Body of Lens.

- Zoom/Focus actuator driven with same MCB design with:
- End-stops (two state operation)
- Smaller motor
- No encoder (potentiometer only)

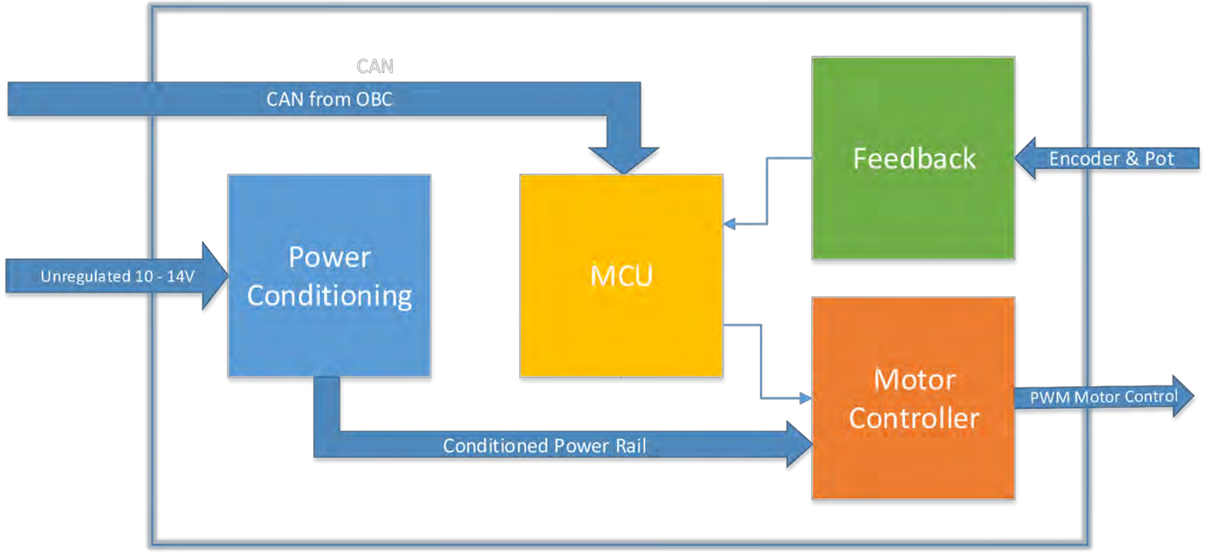
Prototype Design – On Board Computer





- » Nimble OBC handles:
  - » Platform TM/TC
  - » Persistent data storage
  - » Trajectory files
  - » Logging
  - » System status, flags, reset conditions
  - » Power management
  - » System configuration
  - » MCB speed, ramp rates, step modes
  - » Error handling
  - » Controlling slews and tracking

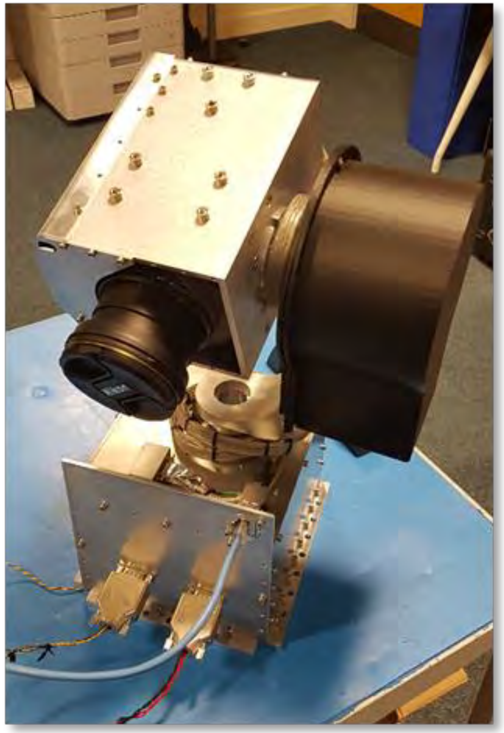
Prototype Design – Motor Control Board

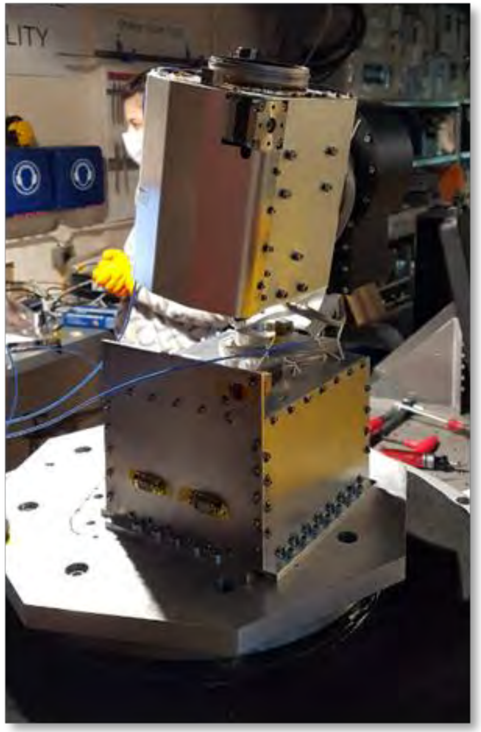


» Receives commands from Nimble OBC
» Controls the driving of a stepper motor
» Monitors position of axis via encoder
» Reports back to Nimble OBC
» Forms part of control loop with Nimble OBC

» Voltage - 12V & 3V3
» Current (per board)
» 12V - 50mA (holding at 7.8% max) to ~450mA (active, but peak is greater)
» 3V3 - ~30mA
» 12V: 600mW to 5.4W
» 3V3: ~100mW

Prototype Manufacture & Assembly





- **Life Test Model (LTM)**

  To support the Life Test Model prime use of life-testing of the mechanism, the LTM consists of a fully flight representative mechanism and optics with electronics configured from the EM system

- **Proto-Flight Model (PFM)**

  The ProtoFlight Model (PFM) is the unit being built for flight. As such, the system will be in full flight configuration for the test flow, aside from some testing during the integration process.

Testing - Phases

Functional Test Phase

- Demonstrate the core functionality of the system
- Eg: Slew the actuator to target

Operational Performance Test Phase

- Demonstrate the performance of the system in an operational context
- Eg: Slew the actuator to point at target to required accuracy

Environmental Test Phase

- Demonstrate the system survives and operates in an appropriate environment
- Eg: Slew the actuator to point at target to required accuracy under vacuum at thermal extremes

Testing – Procedures

Functional Test Phase

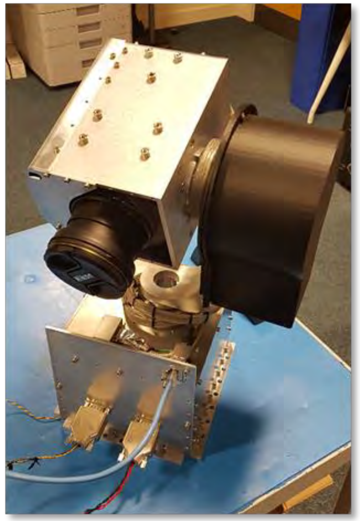
- Integration Test (NG-INT-01)
- Short Optical Test (NG-OPT-01)
- Full Functional Test (NG-FUN-01)

Operational Test Phase

- Full Optical Test (NG-OPT-02)
- Pointing Test (NG-POI-01)
- Ambient Thermal Test (NG-ATH-01)
- Full Functional Test (NG-FUN-02)

Environmental Test Phase

- Vibe Test (NG-VIB-01)
- Full Functional Test (NG-FUN-03)
- Pointing Test (NG-POI-02)
- Life Test (NG-LIF-01)
- Short Functional Test (NG-FUN-04)
- Pointing Test (NG-POI-03)



Functional Test Phase

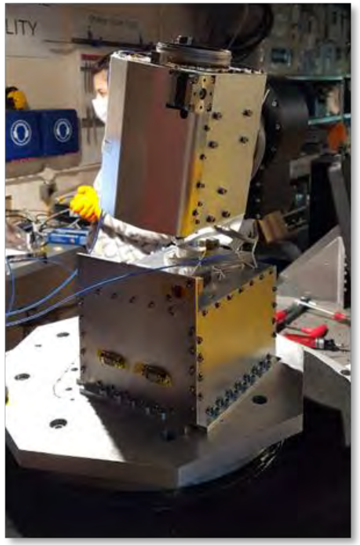
- Integration Test (NG-INT-01)
- Short Optical Test (NG-OPT-01)
- Full Functional Test (NG-FUN-01)

Operational Test Phase

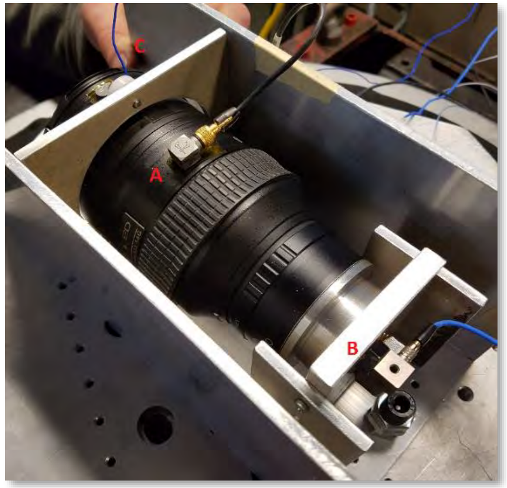
- Full Optical Test (NG-OPT-02)
- Pointing Test (NG-POI-01)
- Ambient Thermal Test (NG-ATH-01)
- Full Functional Test (NG-FUN-02)

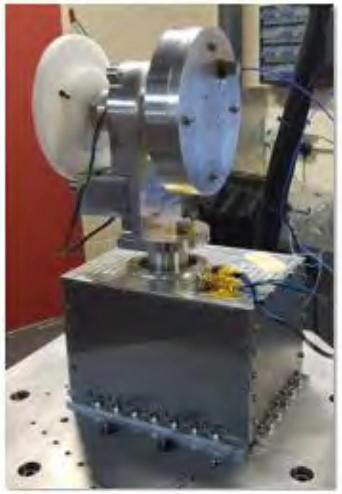
Environmental Test Phase

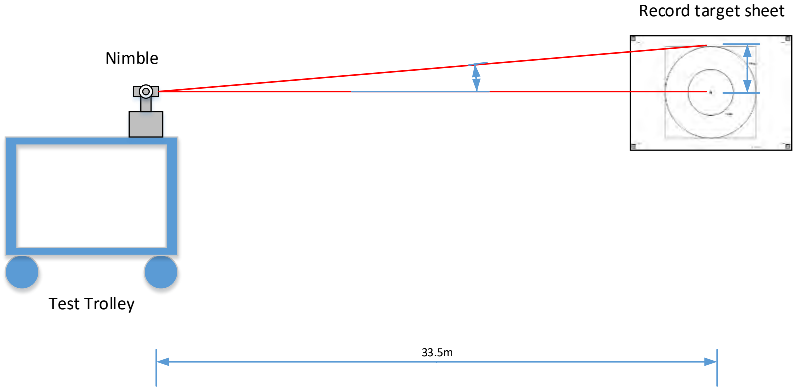
- Vibe Test (NG-VIB-01)
- Full Functional Test (NG-FUN-03)
- Pointing Test (NG-POI-02)
- Thermal Vacuum Test (NG-THV-01)
- Short Functional Test (NG-FUN-04)
- EMC Test (NG-EMC-01)
- Short Functional Test (NG-FUN-05)
- Reset & Resume Test (NG-RES-01)
- ISS/Lunar Tracking Test (NG-TRA-01)
- Short Functional Test (NG-FUN-06)

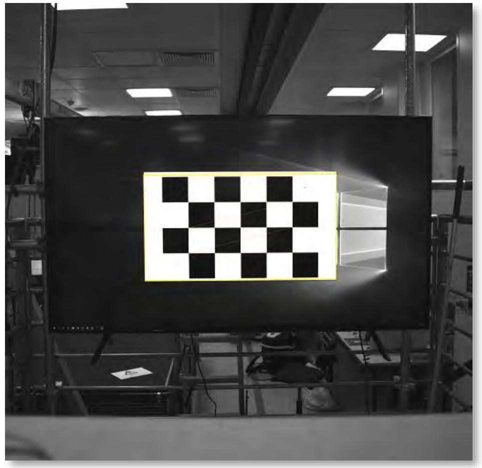


Testing – Setup









Testing – Results

Vibration

- Workmanship and low level failures, fundamental design validated

Pointing

- 0.09deg in scope of test, 0.45deg requirement

Optical

- 15m resolution, 10m requirement

Lifetime

- 2 years without failure, 5 year requirement

Thermal

- consistent operation over temperature range

Enhancements & Commercialisation

Performance Enhancement

» Potential to improve smoothness of motion with change of the drive mechanism to a more compact and lower current brushless DC motor with appropriate gearbox à trade off against potential lifetime.

» Focus control scheme improvement

Creating a user focused product

» Bring electronics ‘in-board’ as separate module with scalable capability to manage multiple camera heads. Look to re-use schematics and EEE devices as much as possible and re-spin boards.

» Multiple solutions for mechanical lightening

- Single arm / yoke trade-off
- Some previous success on topology optimization for mechanical parts. Large number of local suppliers.
- Trade-off on lens selection - e.g. use of COTS lenses and strip down (Fixation) and bespoke lens design (e.g. Beck Optronic). Preference is use of COTS lenses

» Software UI and interface enhancement – can be delivered internally

Summary

» The Nimble design has gone from early concept stage through to largely flight ready hardware and has produced a camera design that has been characterised and gone through a qualification campaign.

» The system development approach was successful in finding and solving design issues through fast iteration

» Testing has shown good indicative performance for future flight for In-Space mission applications.

» This design can now be readily industrialised into a commercial product by In-Space – both for its own use and also as a subsystem to market and sell.

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