Qualification of a Commercial Dual Frequency GPS Receiver for the e-POP Platform onboard the Canadian CASSIOPE Spacecraft

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CASSIOPE

- CASSIOPE = CAScade-demonstrator Smallsat and Ionospheric Polar Explorer

  (also low tufted evergreen shrubs of colder parts of north temperate regions having mosslike foliage and nodding white or pink flowers; a.k.a. heather)

- Canada's first multipurpose satellite
- Merger of CASCADE (very wide bandwidth store-and-forward data delivery platform) with e-POP (enhanced - Polar Outflow Probe)
- Planned 2007 launch

Players

- Funded by the Canadian Space Agency and the Natural Sciences and Engineering Research Council of Canada
- e-POP team includes researchers at 10 Canadian universities plus government agencies in Canada, the U.S.A., and Japan
- Chief e-POP scientist: Andrew Yau, U.ofC.
- CASSIOPE spacecraft prime: MDA
- Spacecraft bus: Bristol Aerospace

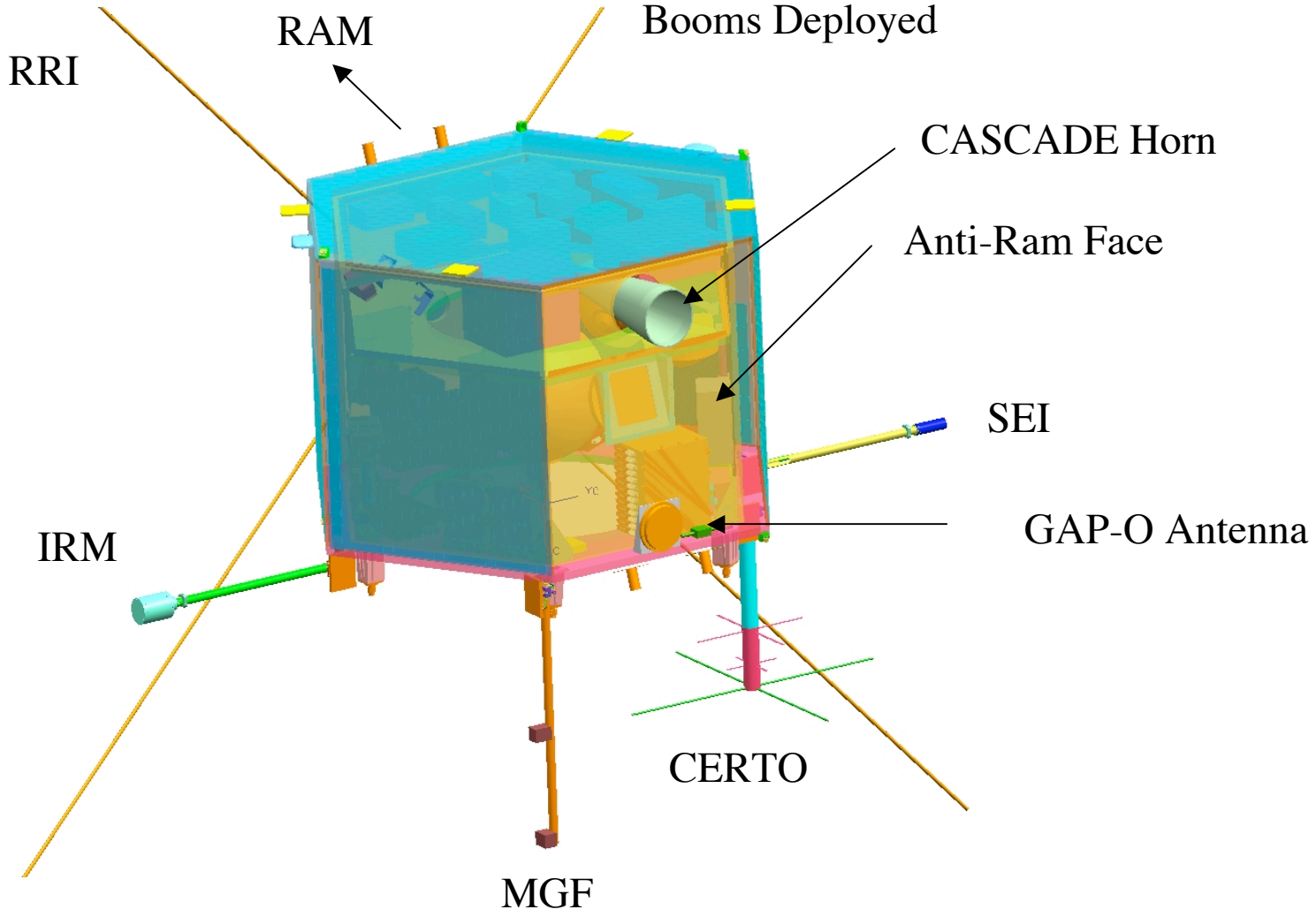
CASSIOPE Orbit

Semi-major axis	7280 km
Eccentricity	0.08
Apogee	1500 km
Perigee	325 km
Inclination	80°

e-POP Instruments

- Imaging Rapid-scanning Ion Mass Spectrometer (IRM)
- Suprathermal Electron Imager (SEI)
- Magnetic Field Instrument (MGF)
- Fast Auroral Imager (FAI)
- Radio Receiver Instrument (RRI)
- Neutral Mass and Velocity Spectrometer (NMS)
- Coherent Electromagnetic Radiation (CER)
- GPS Attitude and Profiling Experiment (GAP)

CASSIOPE



Background image courtesy of Bristol. S/C is for illustrative purposed only.

GAP Objectives-1

The GPS Attitude and Profiling instrument is multipurposed. It will determine:

- spacecraft three-dimensional position, velocity, and attitude
- time referenced to UTC
- ionospheric electron density profiles

Functions divided into GAP-A and GAP-O

GAP Objectives-2

GAP-A

- Position, velocity, attitude, and time can be determined in real time and made available to other spacecraft systems:
  - position to 100 metres
  - velocity to 10 metres per second
  - attitude to 5 degrees
  - time to 1 microsecond

- More accurate results will be achievable from down-linked data including attitude to 0.5 degrees.

GAP Objectives-3

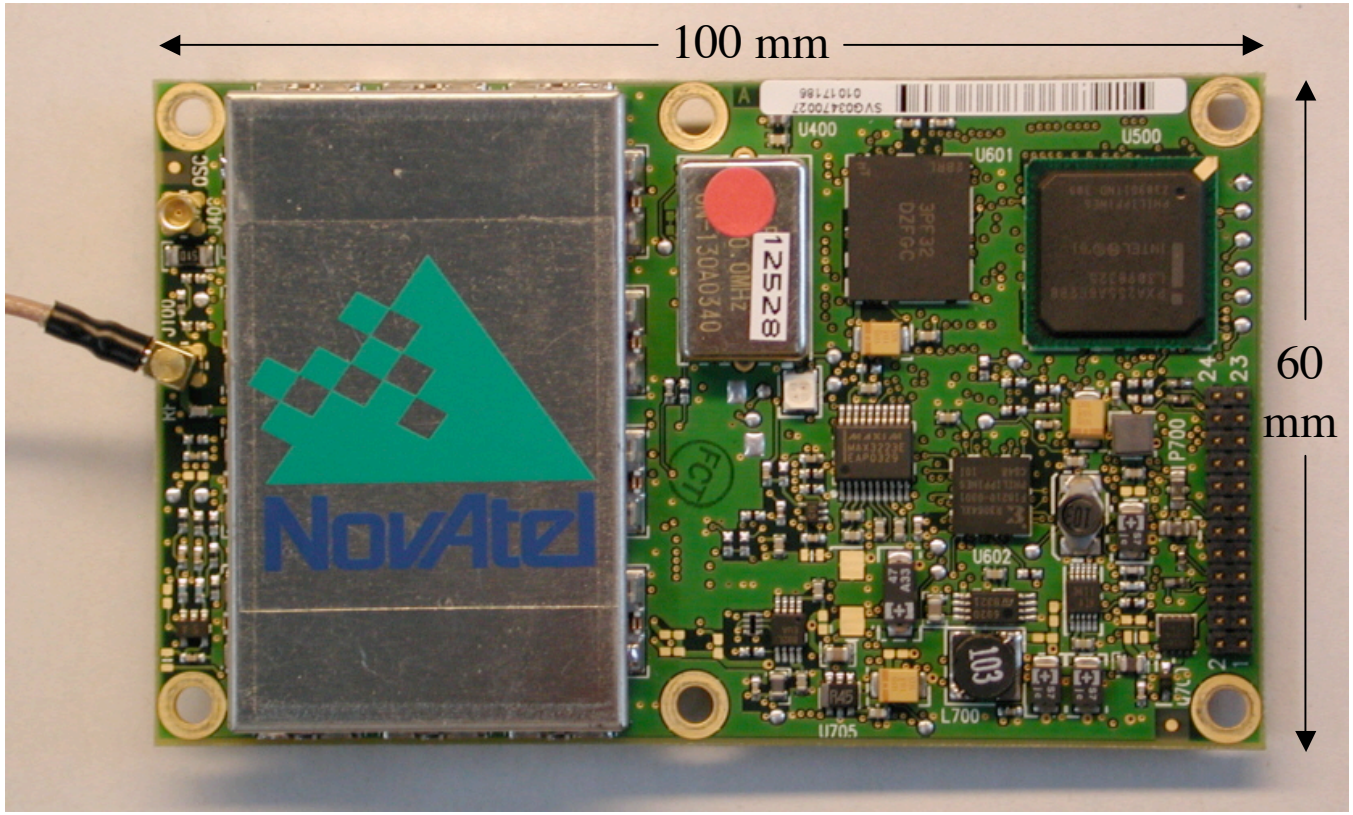
GAP-O

- Electron density profiling using antenna pointed in anti-ram direction
- High-rate measurements on setting (occulted) GPS satellites together with measurements from non-occulted satellites down linked to ground for analysis
- Analysis will provide high resolution profiles of electron density in the ionosphere and plasmasphere
- Not mandated to profile neutral atmosphere (likely insufficient antenna gain)

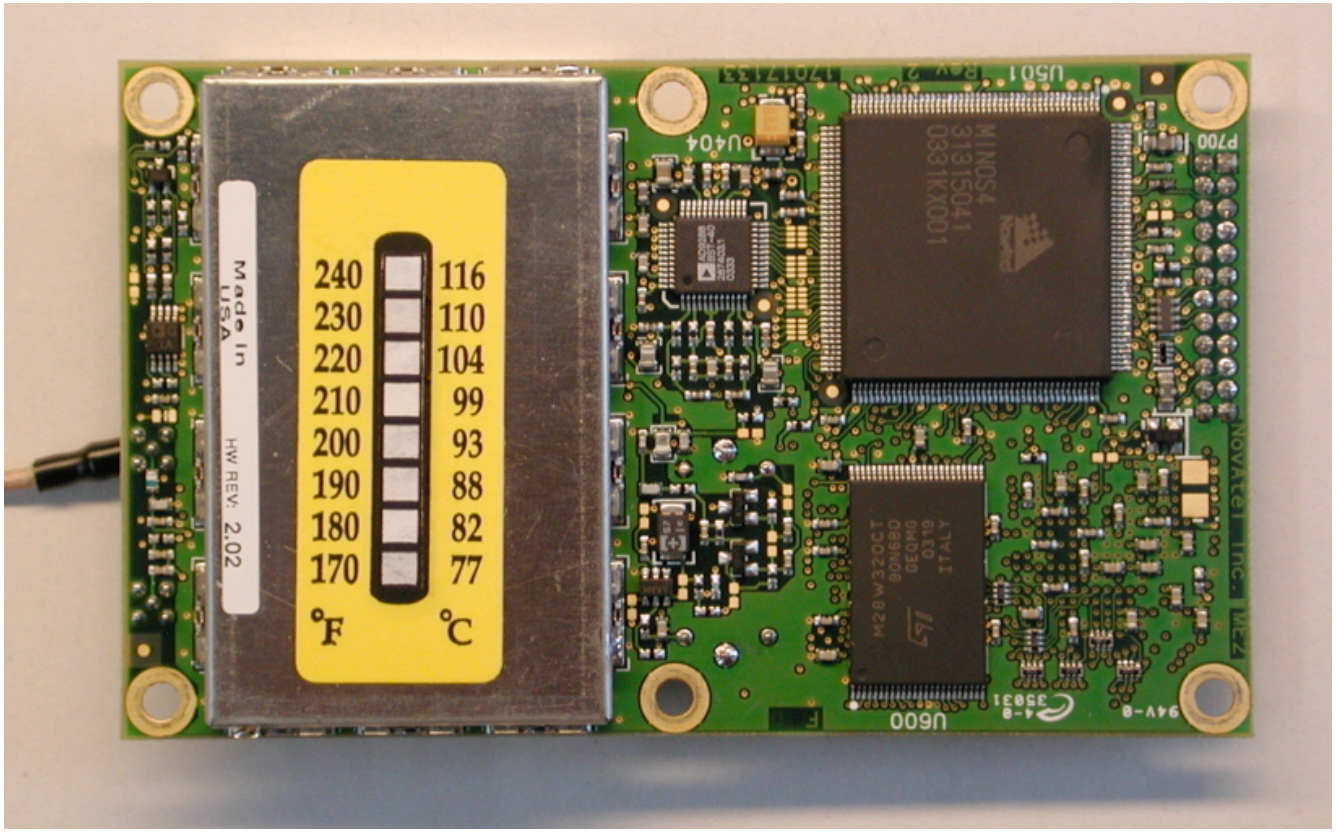
Receiver Selection

- Early in mission design, decision made to base GAP instrument on multiple COTS dual-frequency receivers
- Decision based on economics
- NovAtel OEM4-G2L selected

NovAtel OEM4-G2L



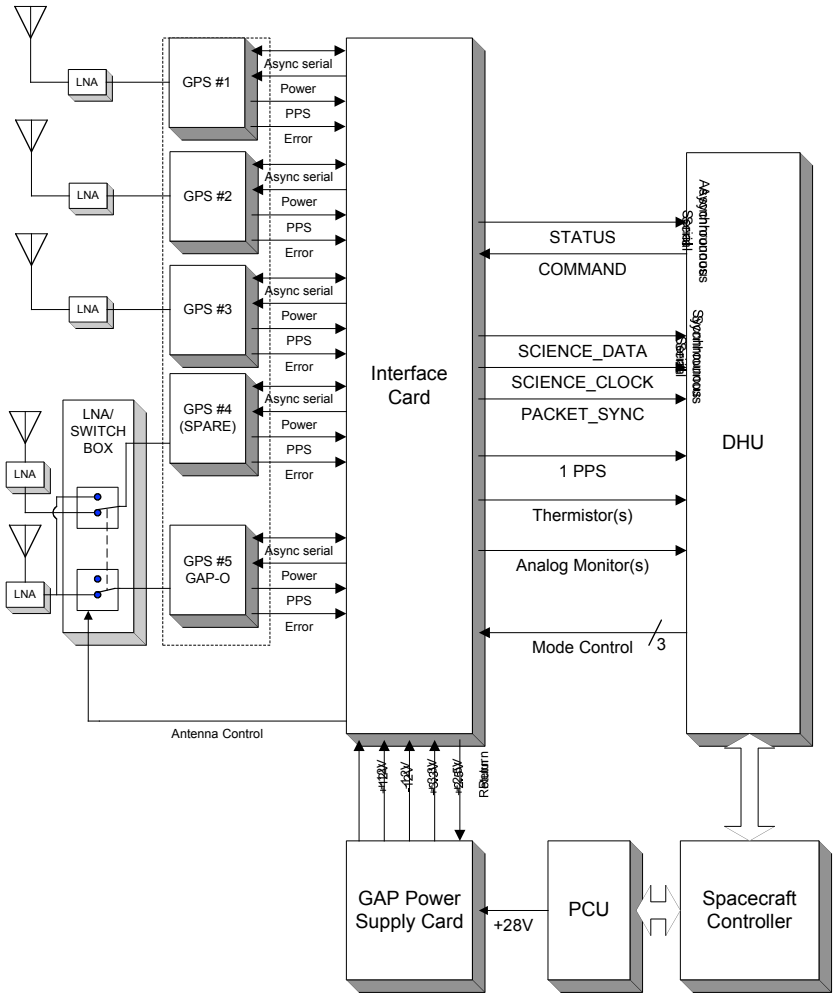
NovAtel OEM4-G2L



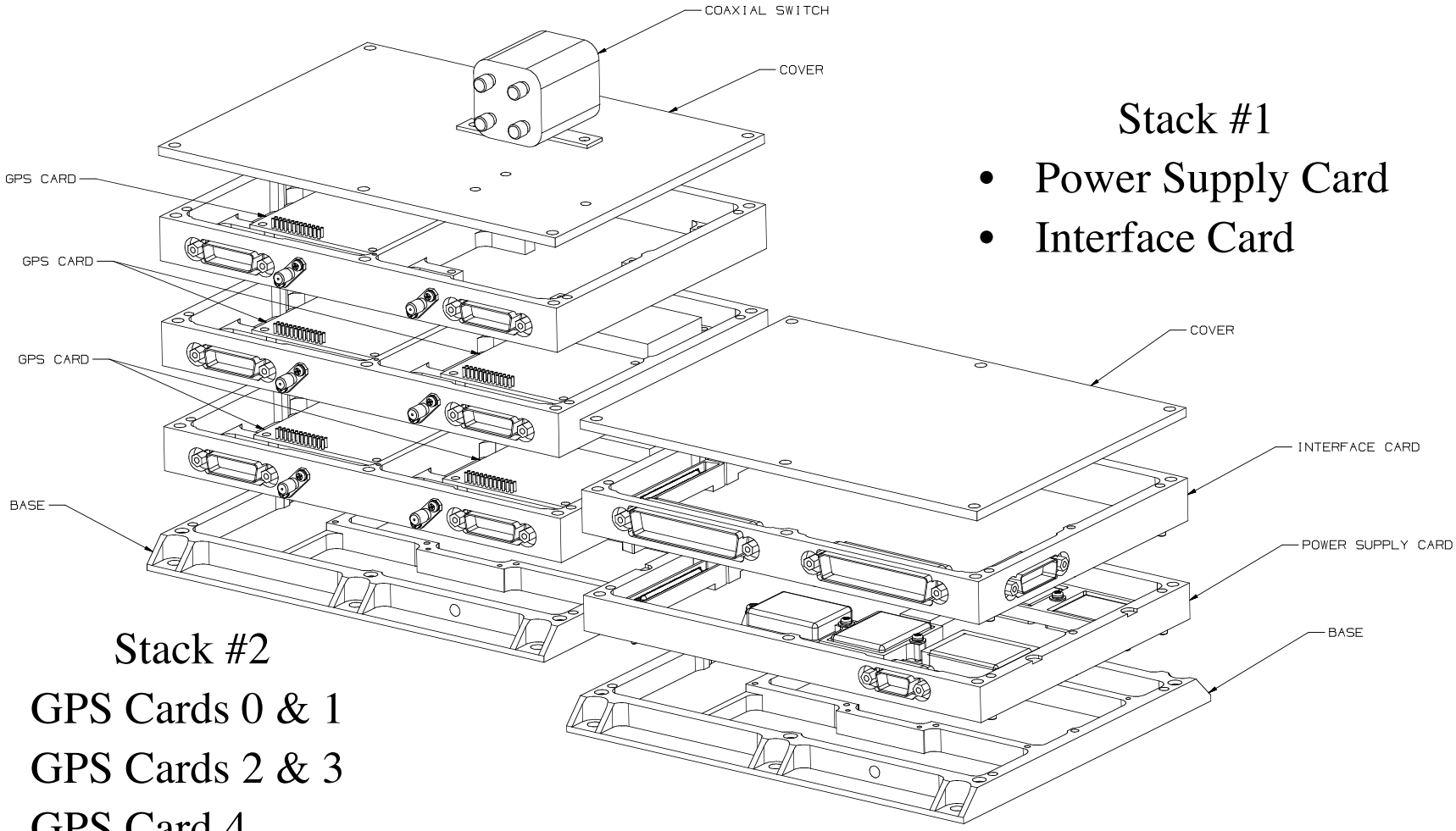
GAP Functional Description

- Instrument consists of:
  - An interface card
  - Power supply card
  - 5 GPS cards (includes one spare)
  - 5 GPS antennas and LNAs
  - Antenna/LNA switch

- GAP-A and GAP-O functions combined into a single instrument



Instrument Overview



Stack #1

- Power Supply Card
- Interface Card

Stack #2

- GPS Cards 0 & 1
- GPS Cards 2 & 3
- GPS Card 4
- Coaxial switch

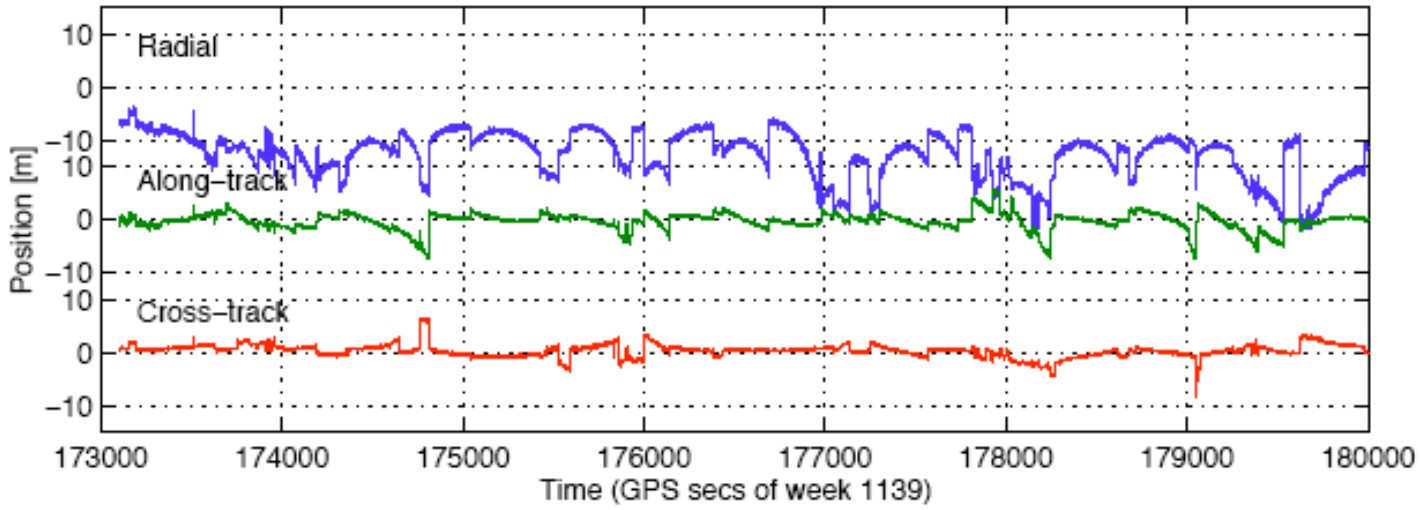
Testing

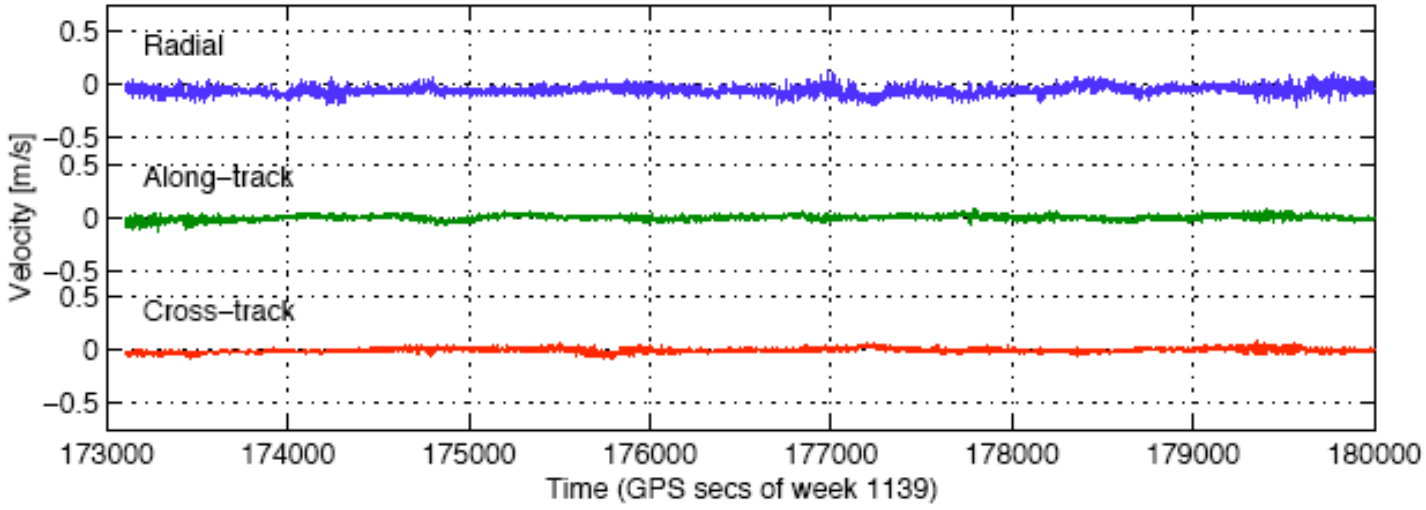
- A series of tests have been carried out to see if the OEM4-G2L could withstand the rigors of spaceflight:
  - Tracking
  - Radiation
  - Thermal vacuum

Tracking Tests

- Simulator tests carried out on an OEM4-G2 by DLR at the ESA/ESTEC RNL in Noordwijk
- Orbit used: CHAMP
- Real-time solutions and raw data quality assessed
- Test results demonstrated that the receiver could track GPS satellites with unmodified, standard firmware

Navigation Accuracy

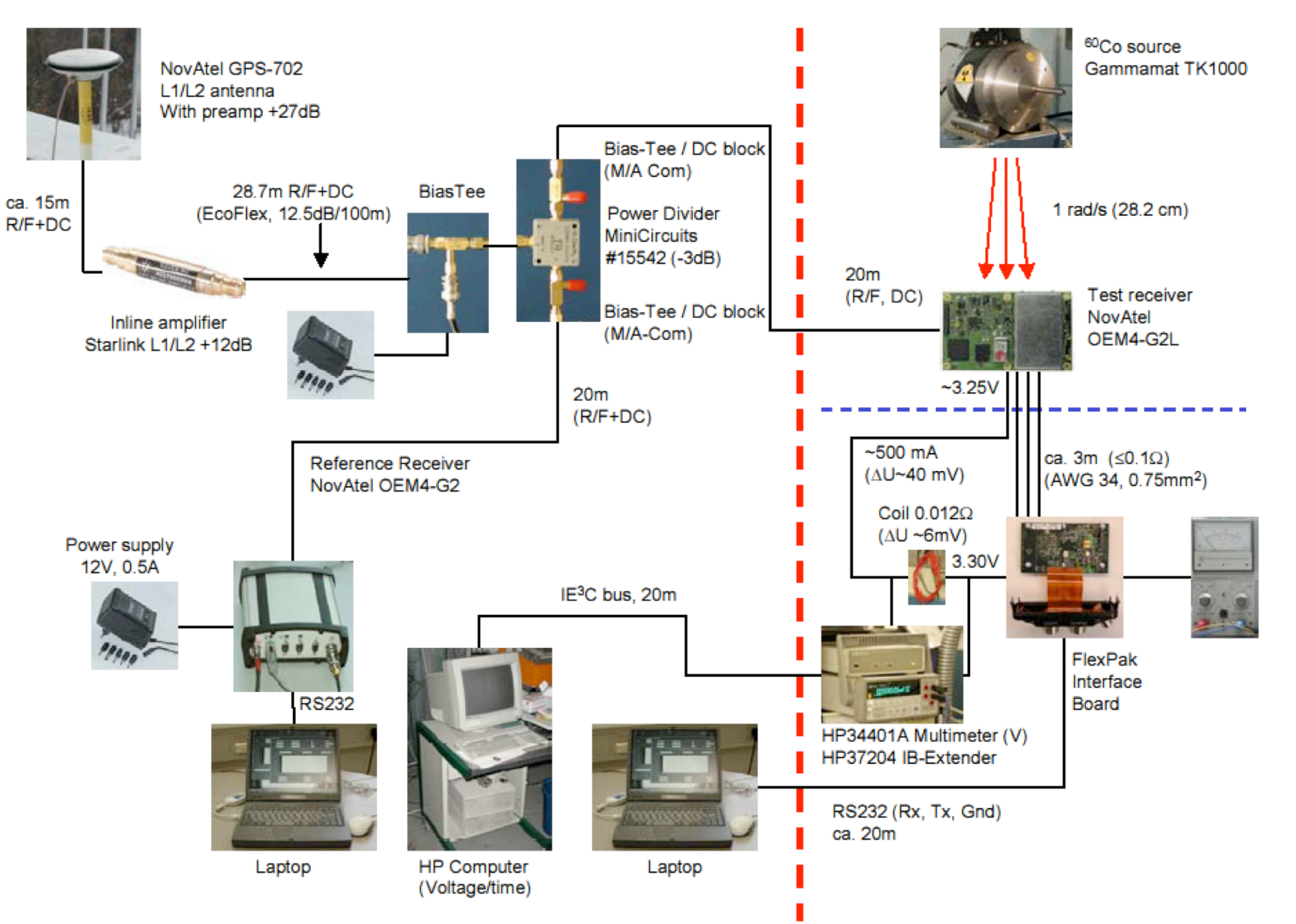




Radiation Tests

- Total ionizing dose (TID) tests by DLR at Fraunhofer Institute for Technological Trend Analysis using Co-60 gamma ray source

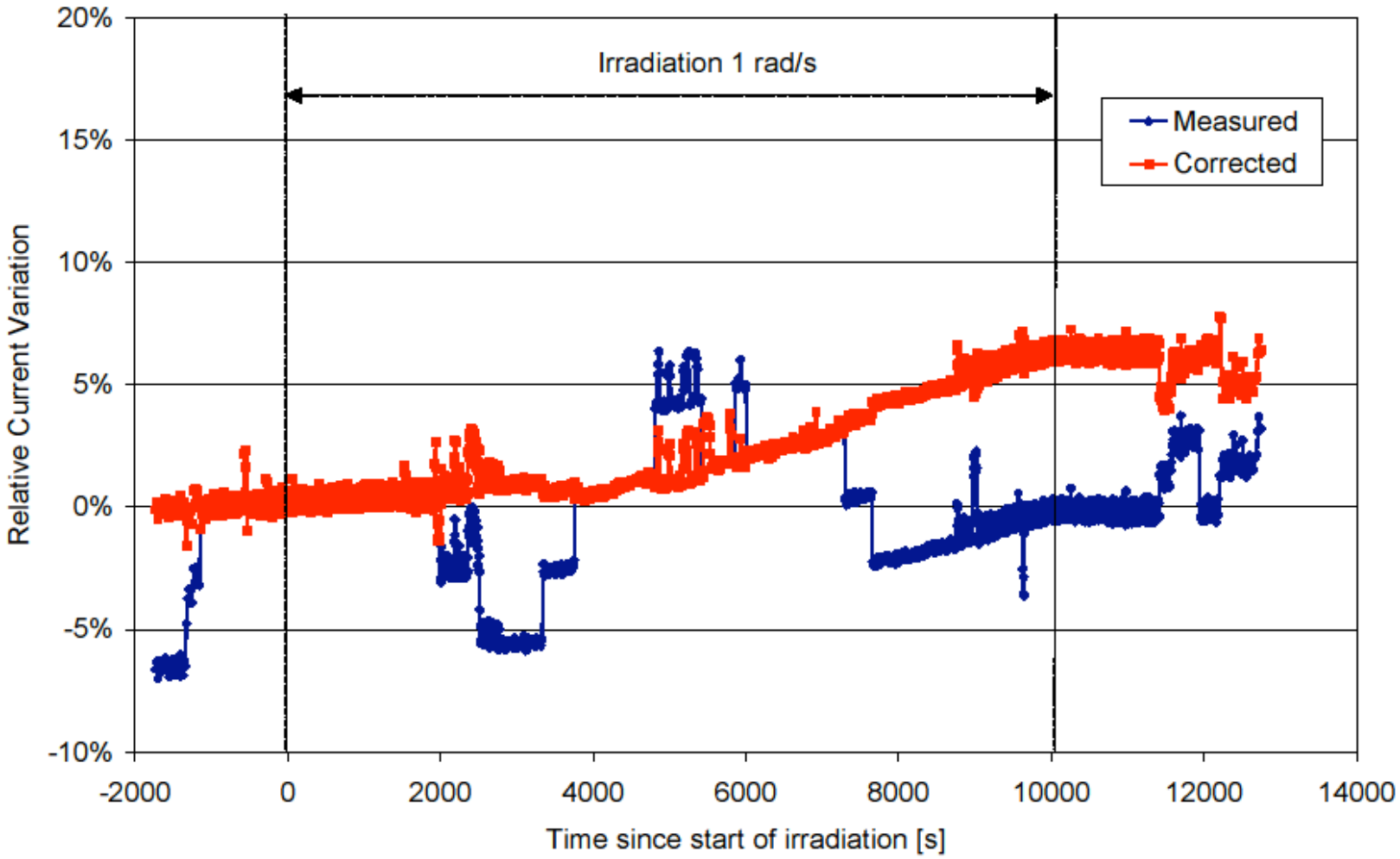
Total Ionizing Dose Test Setup



Radiation Test 1

- Applied total dose limited to 10 krad in an effort to avoid a destructive test
- Dose rate of 1 rad per second for about 3 hours
- Receiver continuously operated; no apparent malfunction noted during and immediately after the test
- Some increase in current consumption during the test

Current Consumption



Radiation Test 1 Outcome

- Several days after the test, the receiver failed to operate
- Post-mortem analysis by NovAtel indicated a failed microprocessor
- Radiation damage or some other cause such as electrostatic discharge?
- Second test planned

Radiation Test 2

- 2 new receivers tested
- Receiver power cycled off and back on several times during the test
- First receiver rebooted at 3.6 krad and 7.2 krad; failed to reboot at 7.2 krad
- Second receiver rebooted every 1 krad; failed at 6 krad reboot; came back to life after a few days
- Testing on first receiver indicated failed low-voltage monitor (TCM811)

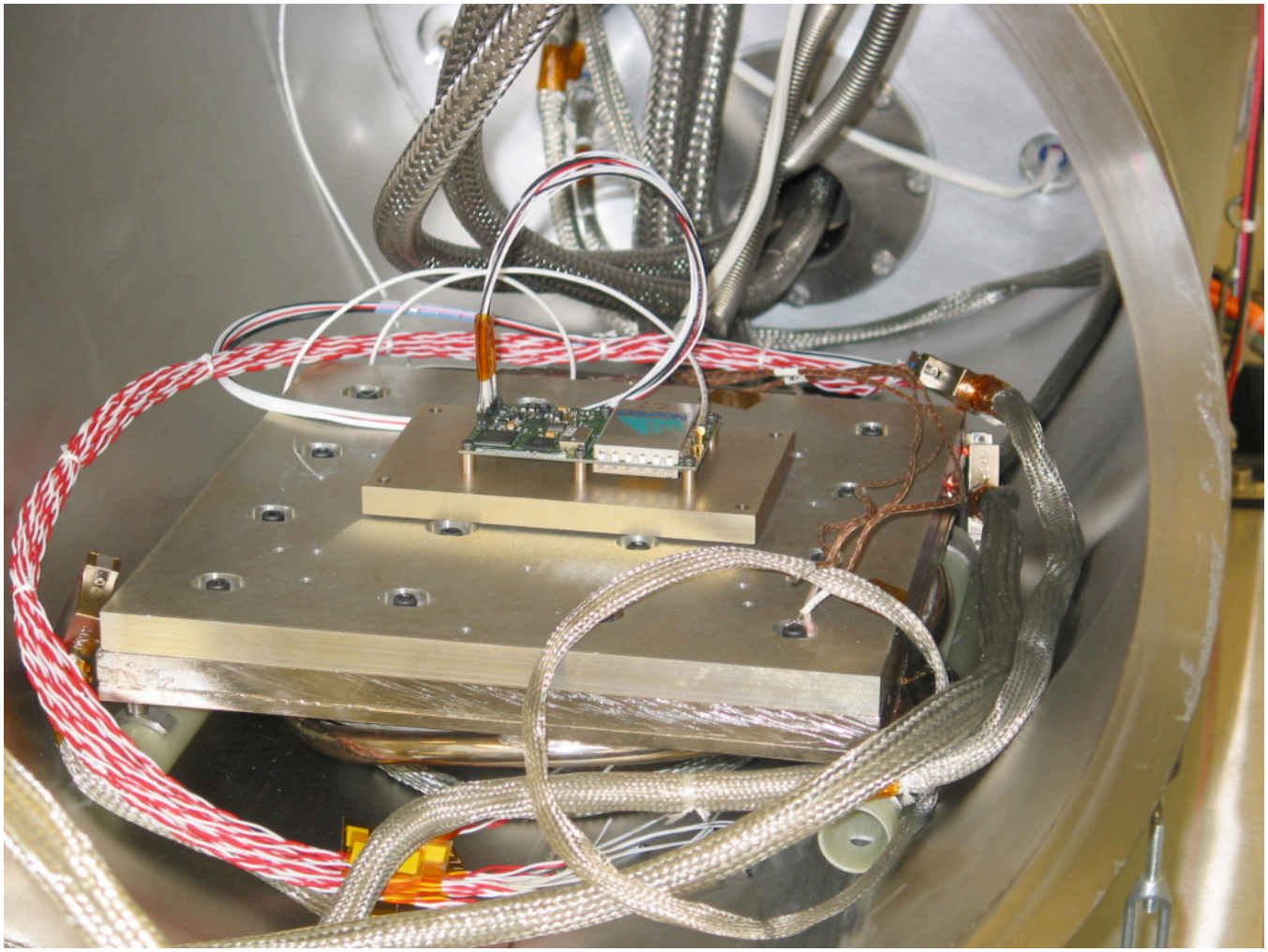
Radiation Test 2 - cont'd.

- Replacing the TCM811 with a manual reset circuit returned receiver to normal operation
- For flight, all TCM811s will be removed from boards and reset logic will be provided on the GAP interface card

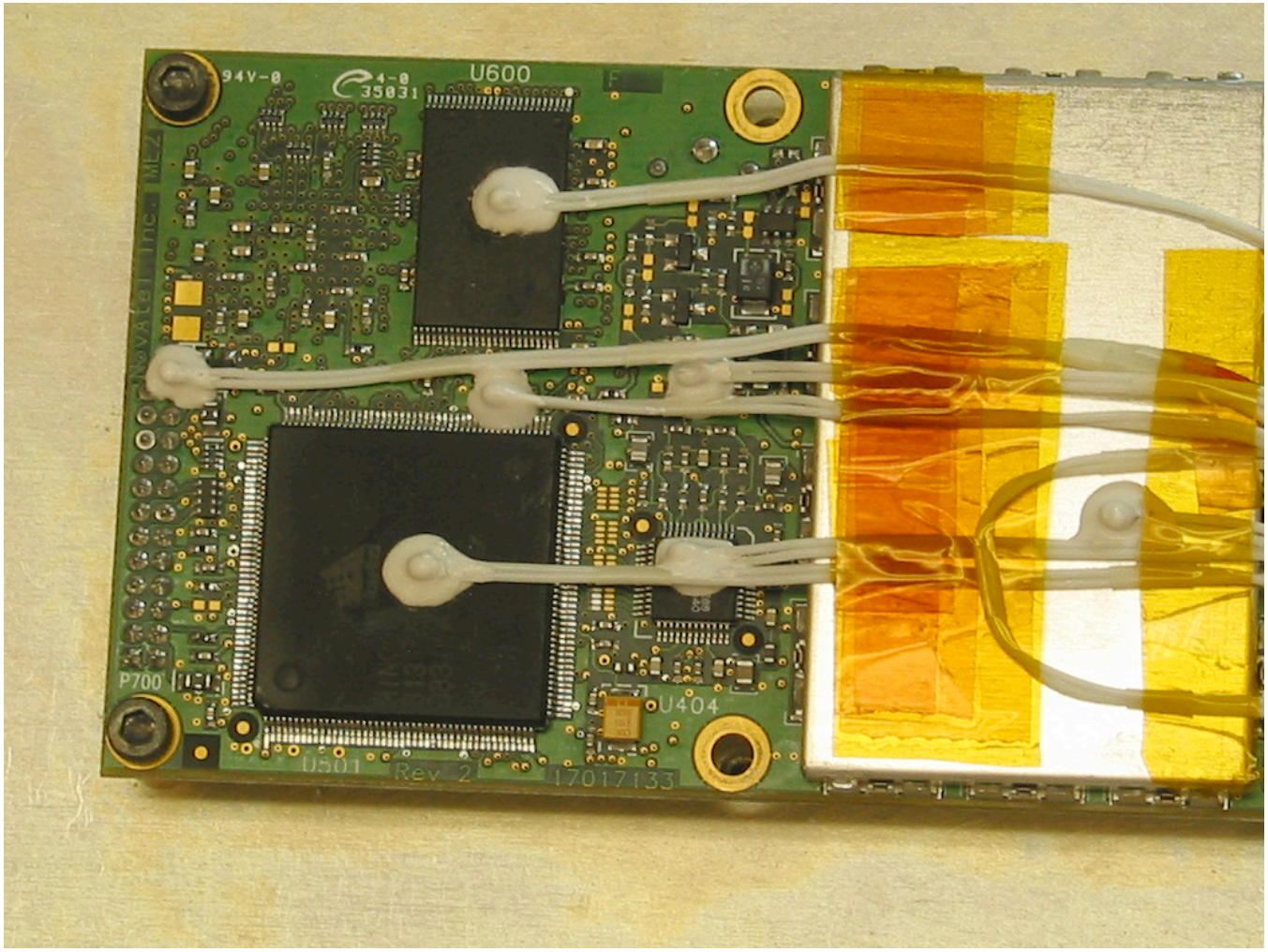
Thermal Vacuum Test

- OEM4-G2L board subjected to TVAC test at Bristol Aerospace
- Receiver tested (while operating) from -35°C (-40°C unpowered) to +50°C under a vacuum of 10^{-5} torr
- Minos-4 ASIC removed, thermal compound added and resoldered to board
- Board outfitted with about 13 thermistors

Preliminary Ambient Conditions Test



Thermistors



TVAC Test

TVAC Test Results

- Receiver performed normally throughout the test based on post-processing collected data
- Temperature of hotest component on the board was only about 22°C different from temperature of thermal control plate
- Power consumption near nominal; about 200 mW more at extreme high temperature

Conclusions

- Good evidence for proper functioning of the NovAtel OEM4-G2L receiver in low Earth orbit with only minor board changes required
- Opens up new prospects for future low-cost science missions

Acknowledgements

- Canadian Space Agency
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