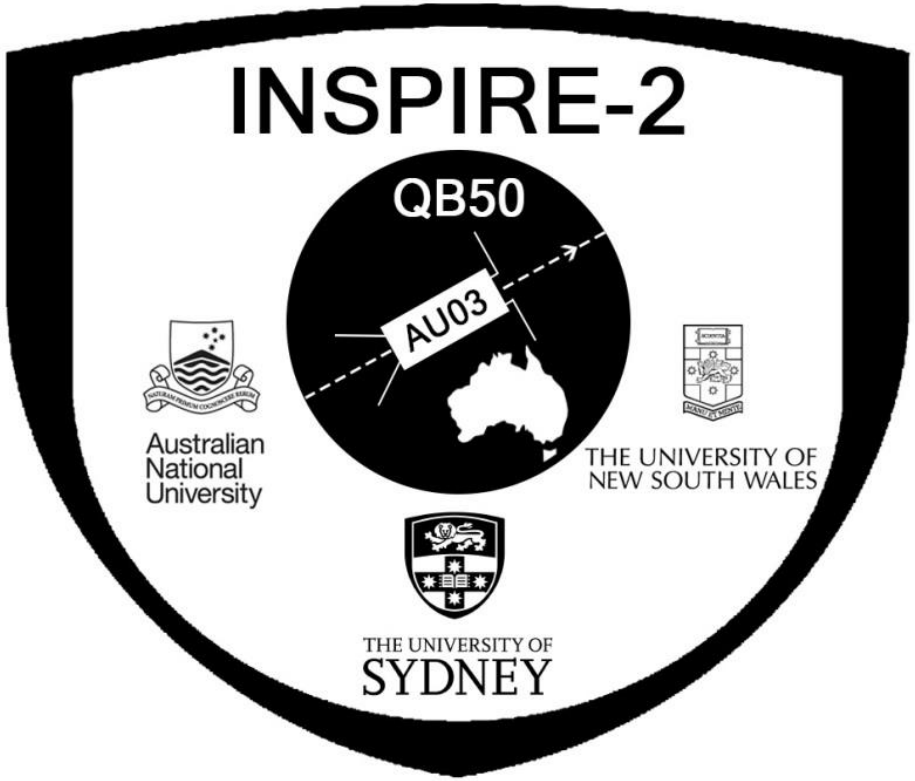
# The INSPIRE-2 / AU03 Cubesat for the QB50 Project

Iver H. Cairns [1], C. Charles [2], A. Dempster [3], J. Funamoto [1], J. Cheong [3], W. Peacock [1], J. Lam [3], B. Osborne [3], W. Andrew [3], T. Croston,[1,3], B. Southwell [3], R. Boswell [2], A. Monger, [1] C. Betters [1], S. Leon-Saval [1], J. Bland-Hawthorn [1], J. Khachan [1], X. Wu [1], S. Manidis [1], H. Brown [1], D. Dall [1], and D. Tsifalkis [2]

1. U. Sydney
2. ANU
3. UNSW




THE UNIVERSITY OF SYDNEY

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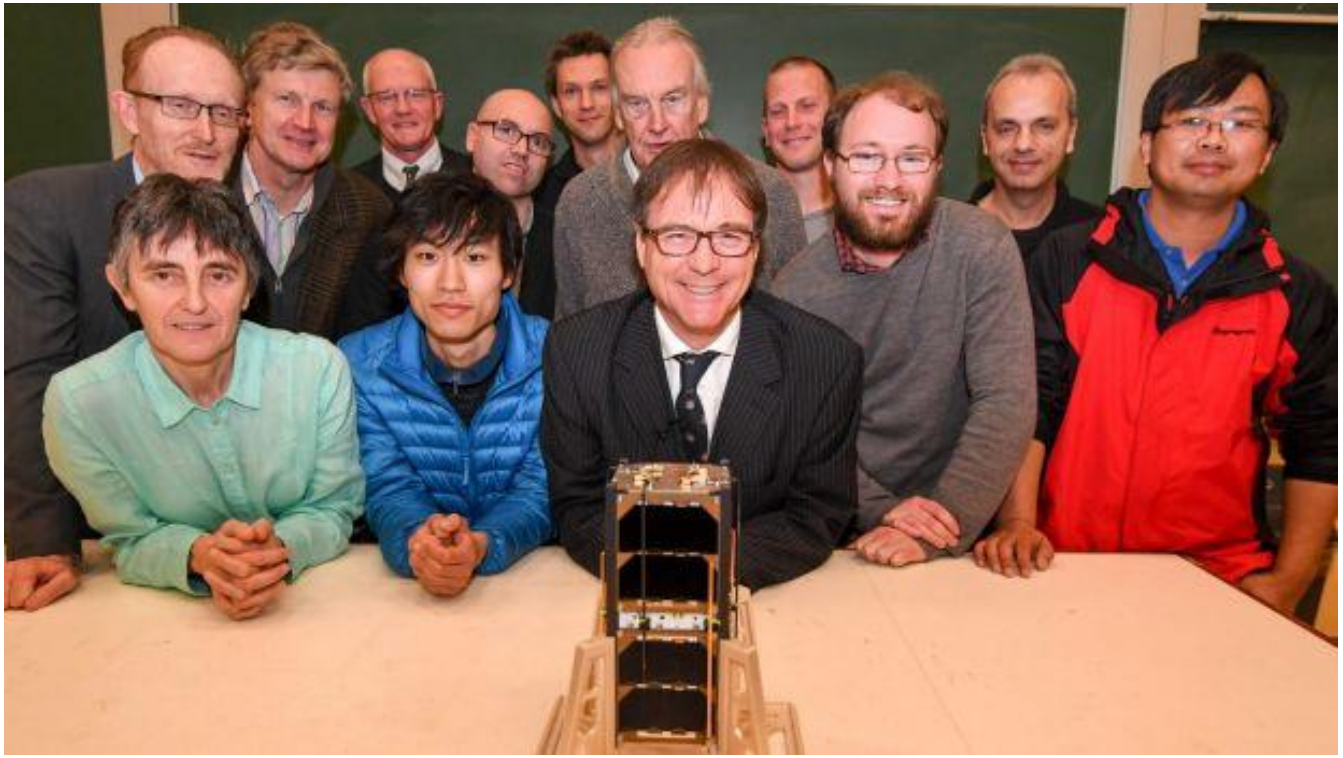
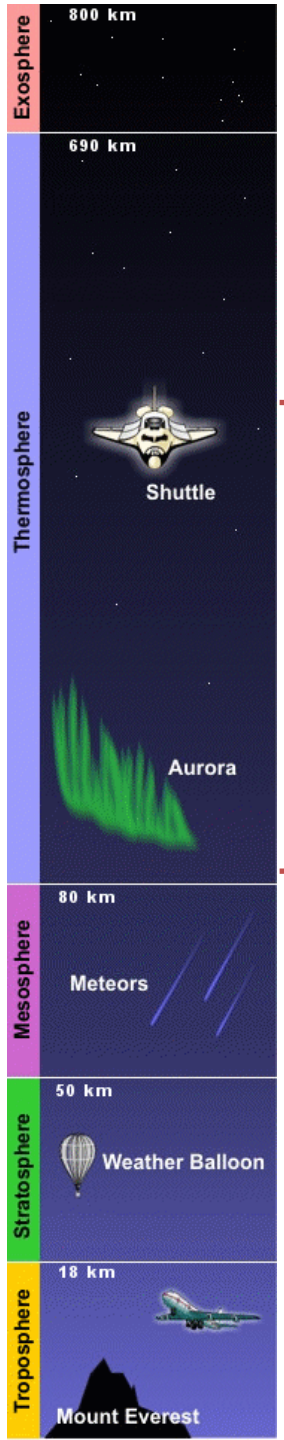


# 2. The QB50 Project & Australian CubeSats

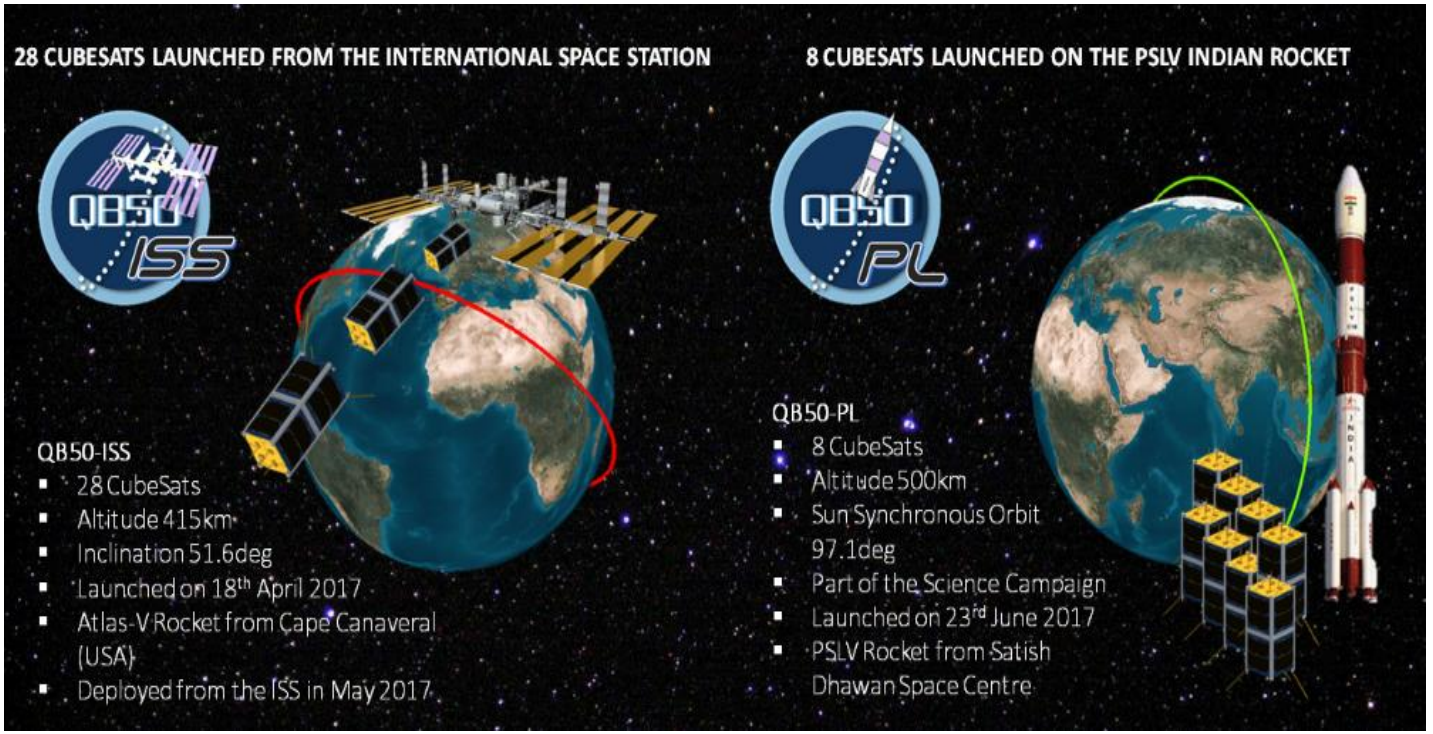
QB50, an FP7 Project




410 km

80 km

ozone




Explore the strength, composition, & variability of the lower thermosphere and ionosphere in position and time ("ignorosphere").

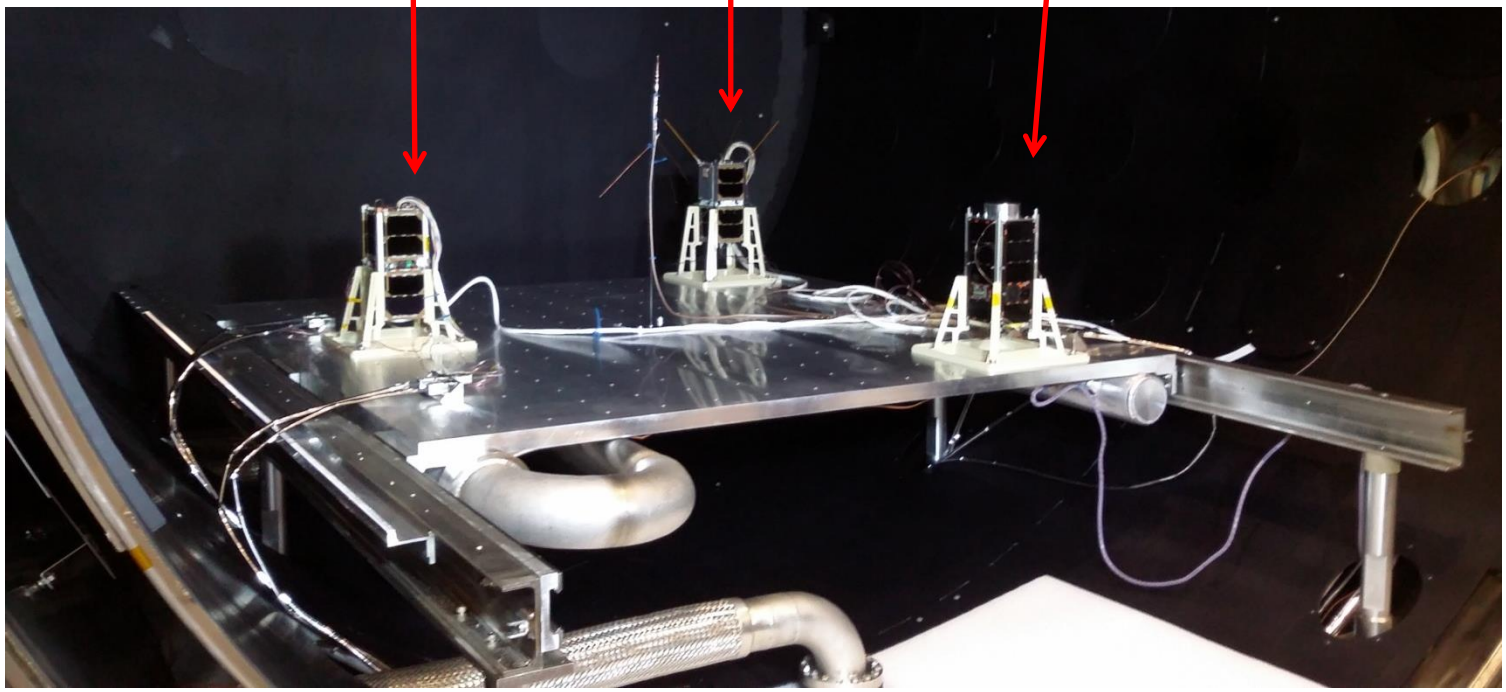
Australia's • 1st CubeSats, • 1st sats from ISS,
• 4th, 5th, 6th sats only, • 1st in 15 years

QB50, an FP7 Project

www.qb50.eu

- The 3 Australian QB50 CubeSats after thermal vacuum testing in Wombat-XL at ANU's AITC:

UNSW-Eco INSPIRE-2 SUSat



# The INSPIRE-2 / AU03 CubeSat

- Started 30/9/2015 & delivered 19 August 2016 .... < 10 months

USydney: 3+ payloads, components, assembly, integration, testing, launch, overall project, legal, leadership, ....

- QB50 multi-Needle Langmuir probe (mNLP)
- Nanophotonic spectrograph (Nanospec)
- Radiation counter
- Microdosimeter

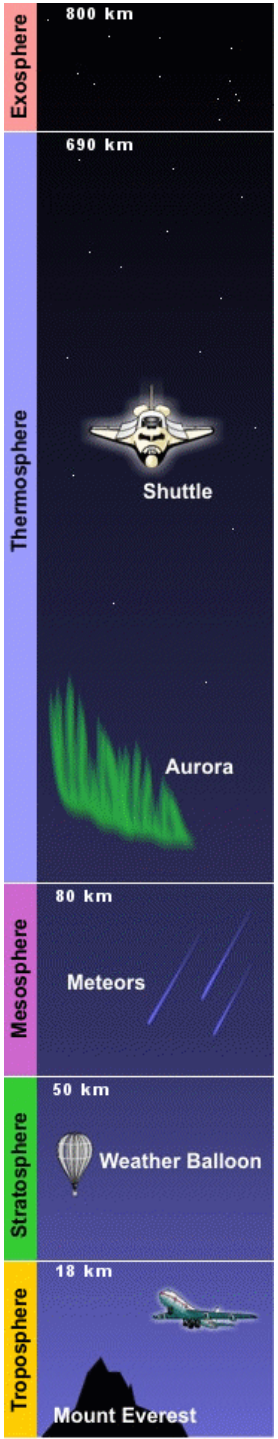
UNSW - Sydney: Spacecraft design, integration, testing, software

- Kea GPS instrument

ANU: Spacecraft COTS parts, groundstation, advice, AITC ...

Groundstations: ANU and UNSW

# 3. A Taste of the Science




410 km

80 km

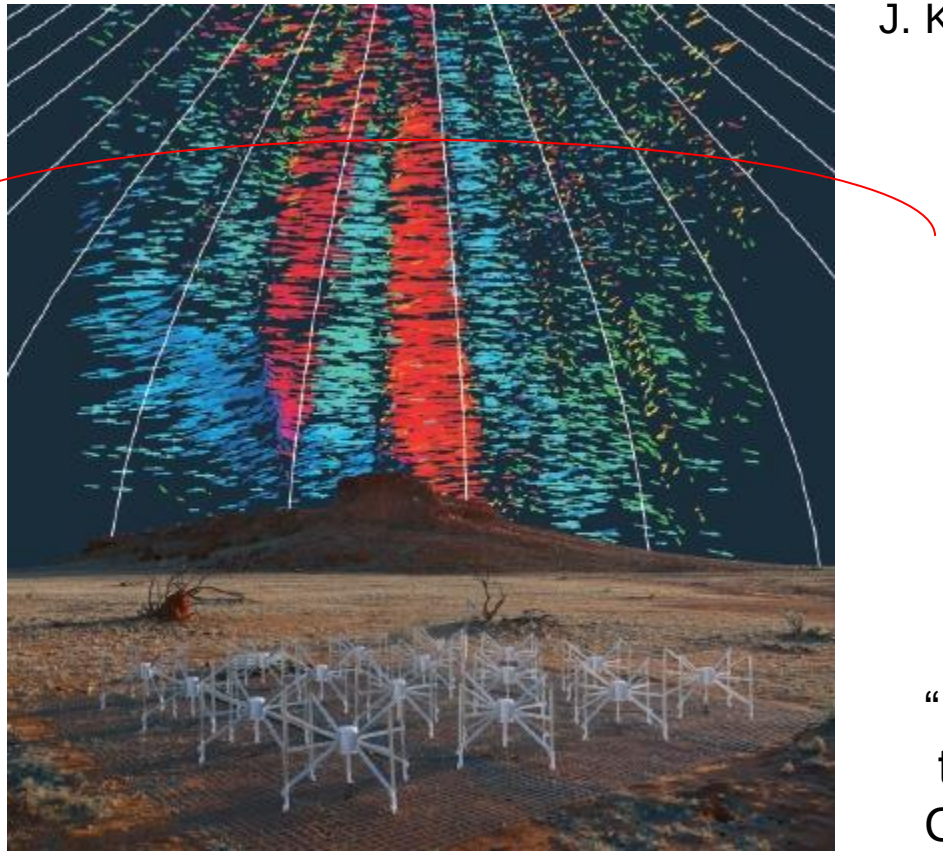
ozone

- QB50 focusing on the science of the Earth's upper atmosphere ≈ 80 – 410 km altitude:
  - Ionosphere (focus is on plasma)
  - Thermosphere (neutrals)
- Earth's environment & space weather ... changes with (t, **r**):
  - Daily (sunrise / sunset)
  - Season
  - Space weather (Solar X-ray flares ➔ ionisation, heating, currents, energetic particles due to solar wind – ionosphere – magnetosphere coupling, ...).

# 3.1 mNLP: Ionosphere & thermosphere plasma density

U.Oslo instrument –

AU03:R. Boswell, IHC,
C. Charles, &
J. Khachan

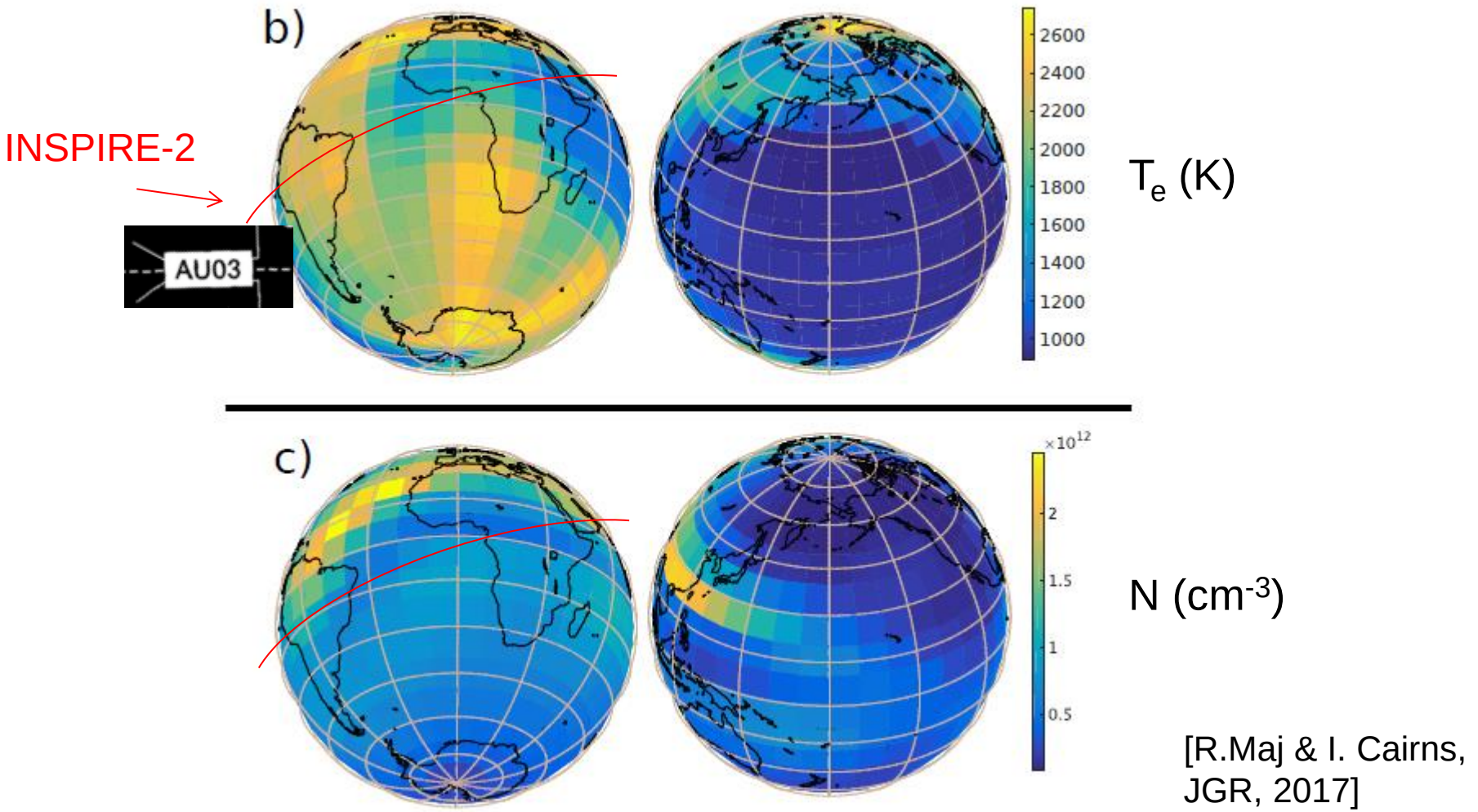
INSPIRE-2

Will explore growth & properties of plasma tubes & new space weather in situ.

"Plasma tubes in the sky",
C. Loi et al.,
GRL, 2015

# mNLP: major issues with IRI model for ionosphere & thermosphere plasma

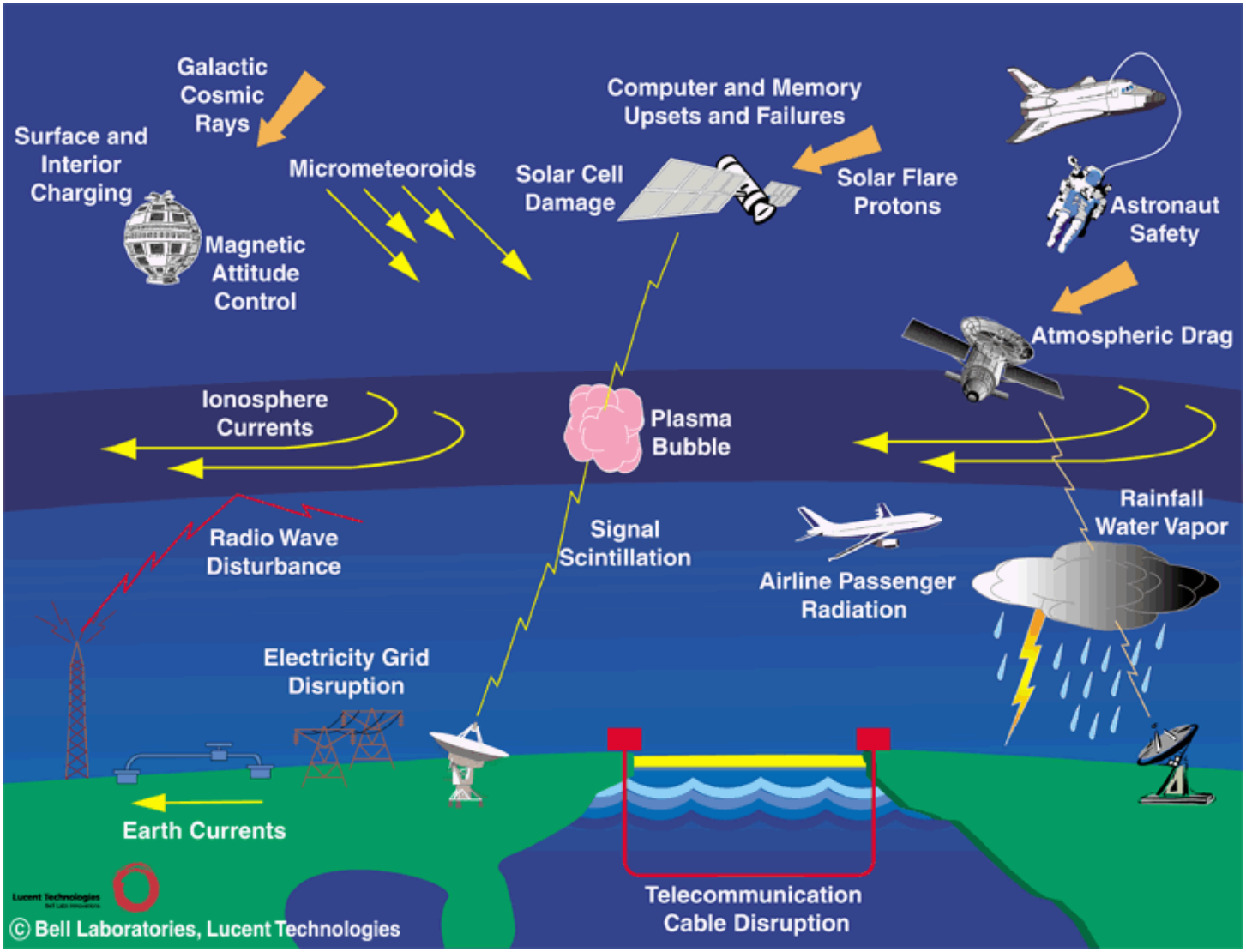
➔ INSPIRE-2 will test IRI & help develop better models



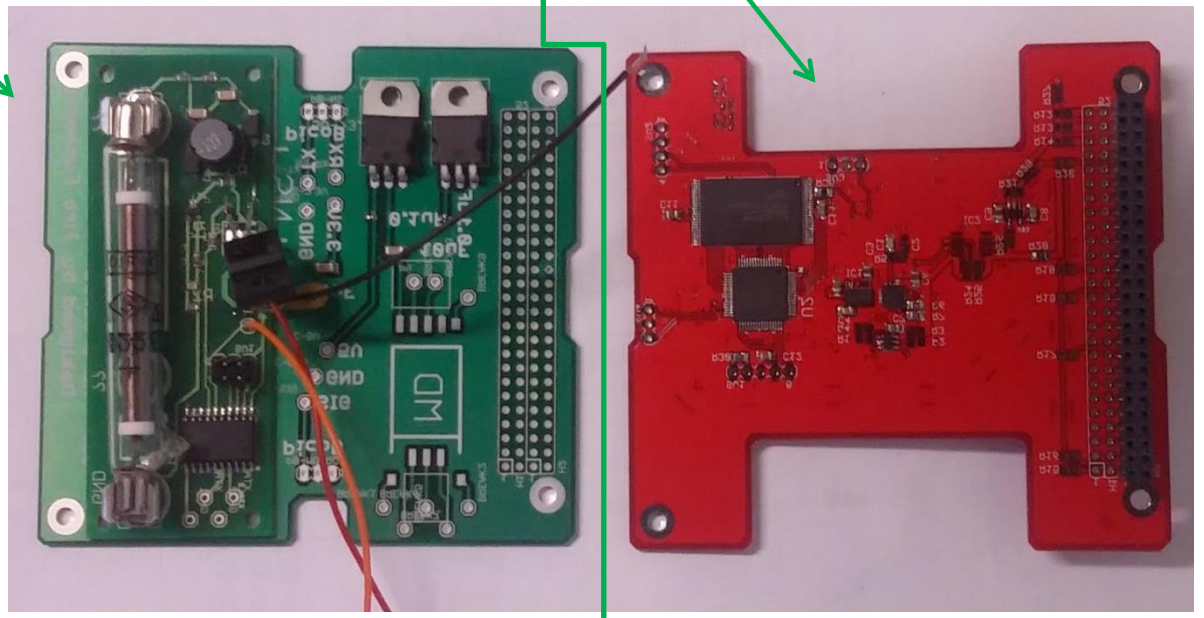

[R.Maj & I. Cairns, JGR, 2017]

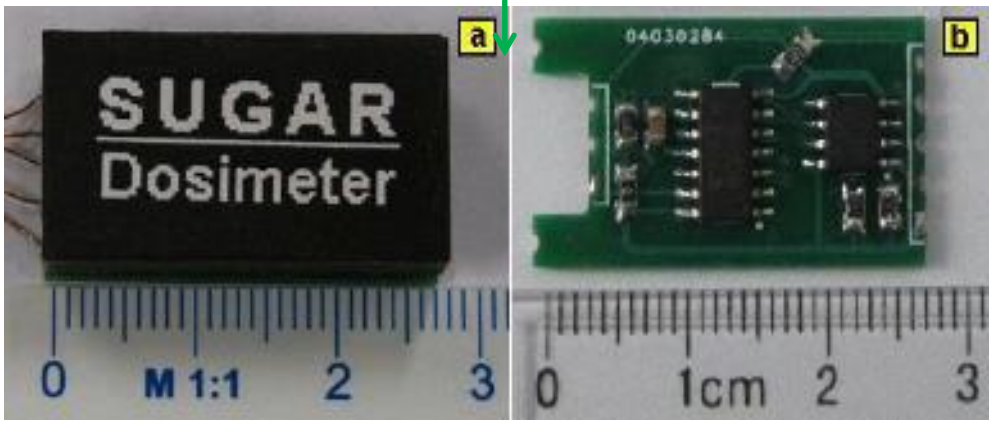
# 3.2 Radiation Counter & Microdosimeter: Space Weather at Earth

Sydney PIs:
J. Khachan,
X. Wu



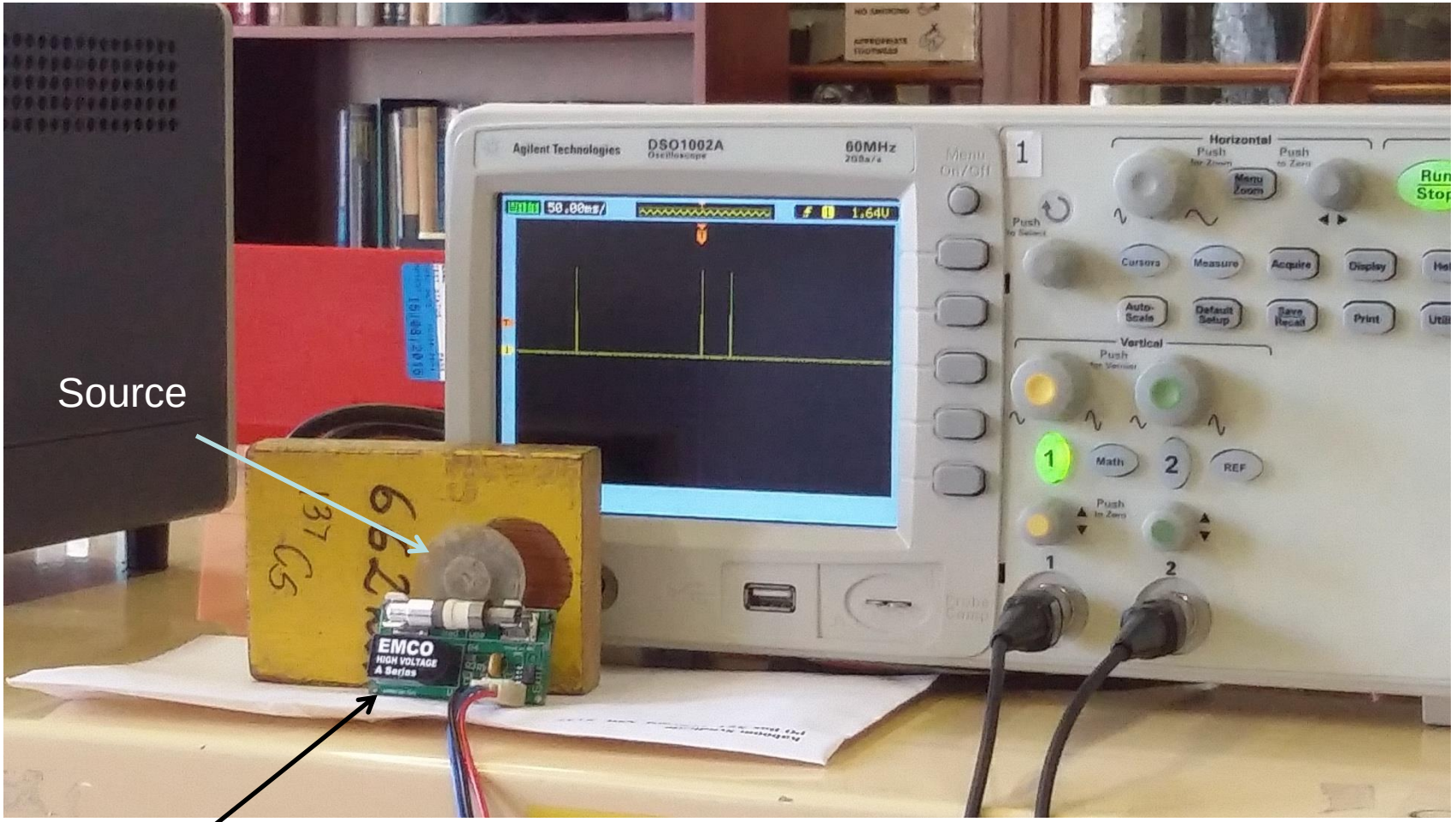
# Radiation Counter (J.Khachan), the EAUX PCB, and the Microdosimeter (X.Wu)






J. Funamoto, J.Lam (not pictured), W. Peacock

# Pulses from the Radiation Counter



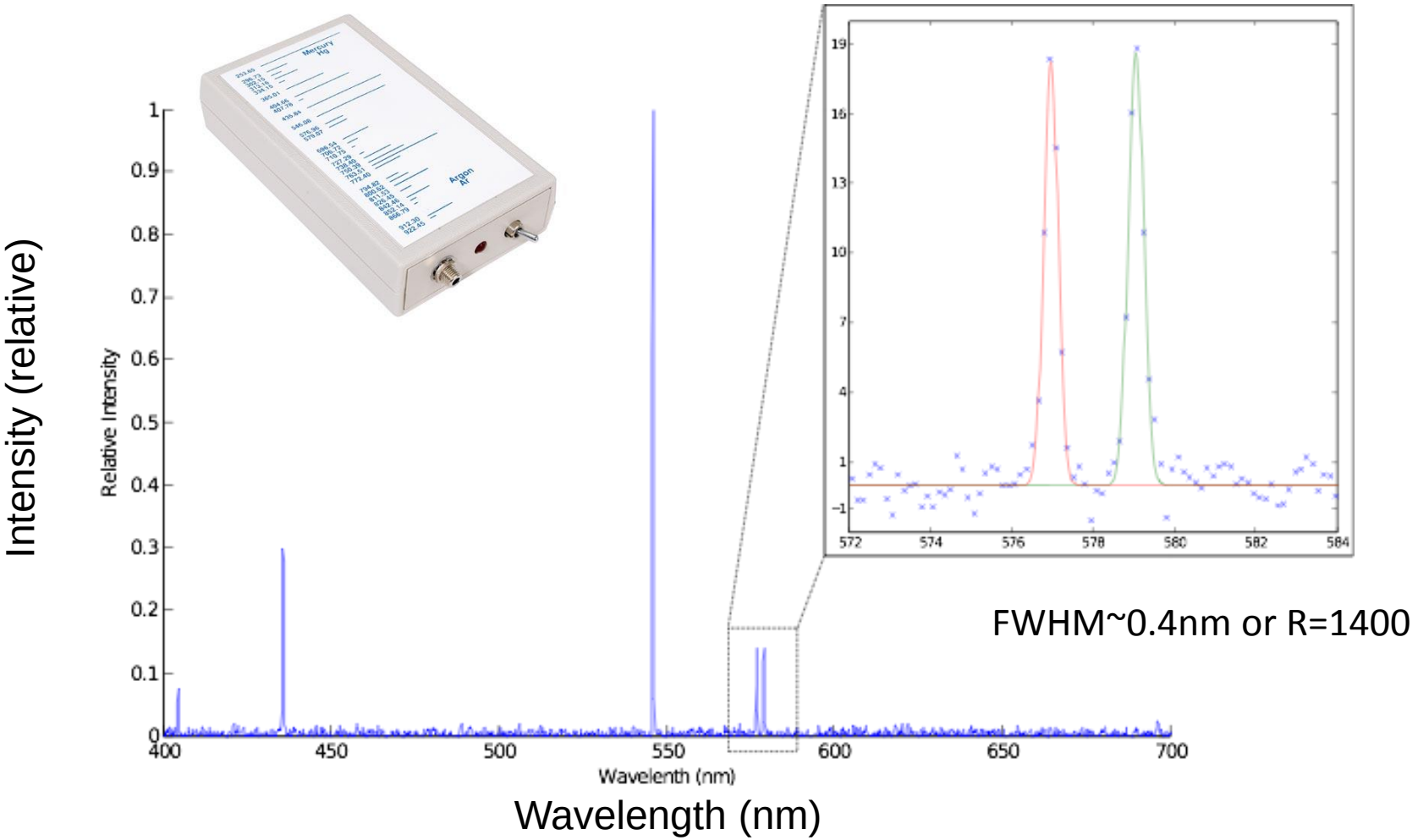

Radiation Counter [J.Khachan]

# 3.4 Nanospec: Photonic Spectrograph

U. Sydney PIs:
S. Leon-Saval,
C. Betters,
J.Bland-Hawthorn

- Light → optical fibres → diffraction grating → spectrum dispersed on a CCD
- Fully photonic with no moving parts and excellent spectral resolution
- First photonic lantern & nanophotonic spectrograph in space

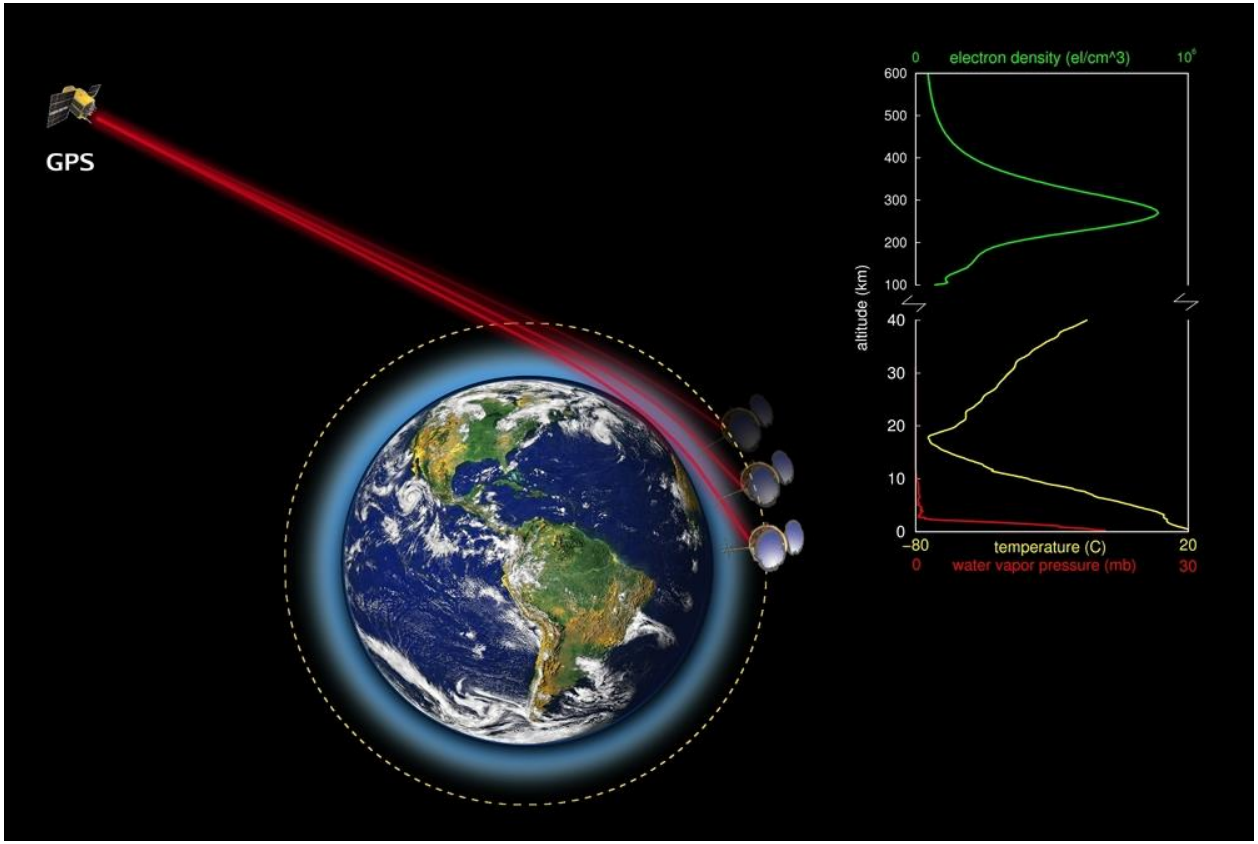
# Nanospec: Predicted resolution R = λ/Δλ = 1400 ➔ separate the 2 primary photosynthetic pathways for Australian native plants






Note: Data for earlier version of Nanospec

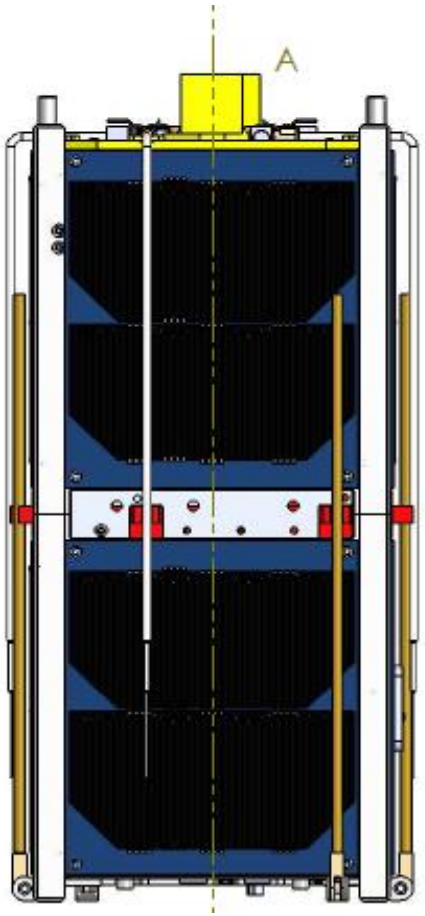
# 3.4 Kea GPS receiver: radio occultation, reflectometry, & position / attitude

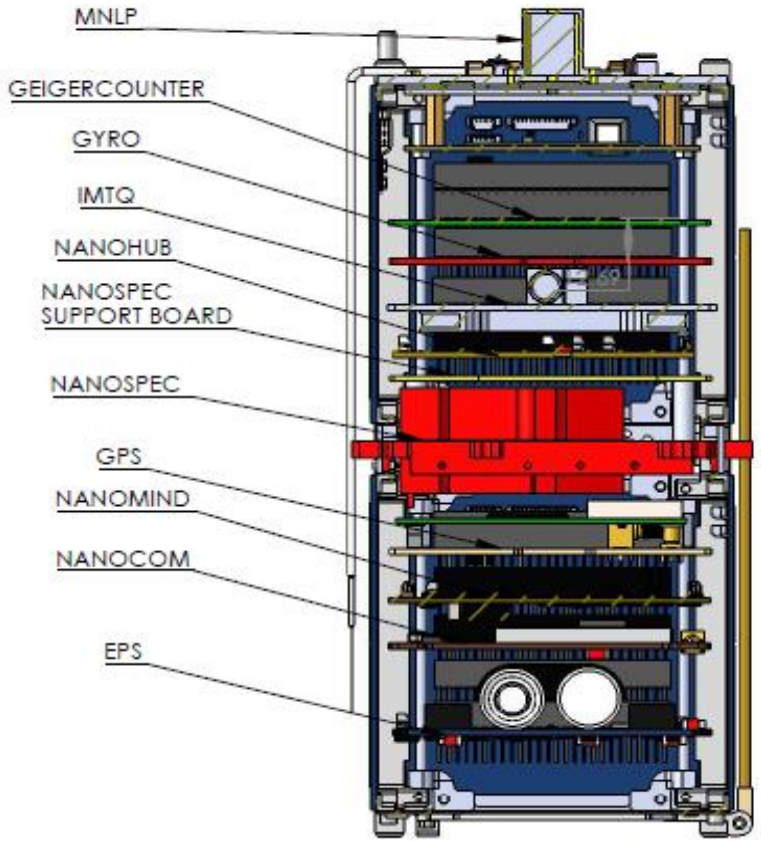



UNSW PIs:
A. Dempster,
J.W. Cheong, ...

# 4. Design, Building, & Testing

- De-risk ➔ modified version of UNSW design & mostly COTS
- Power, mechanical, layout design: B. Osborne, J.Funamoto, T. Croston
- Electronics & software design: J.Lam, B. Southwell, W. Andrew, J.Funamoto & W. Peacock



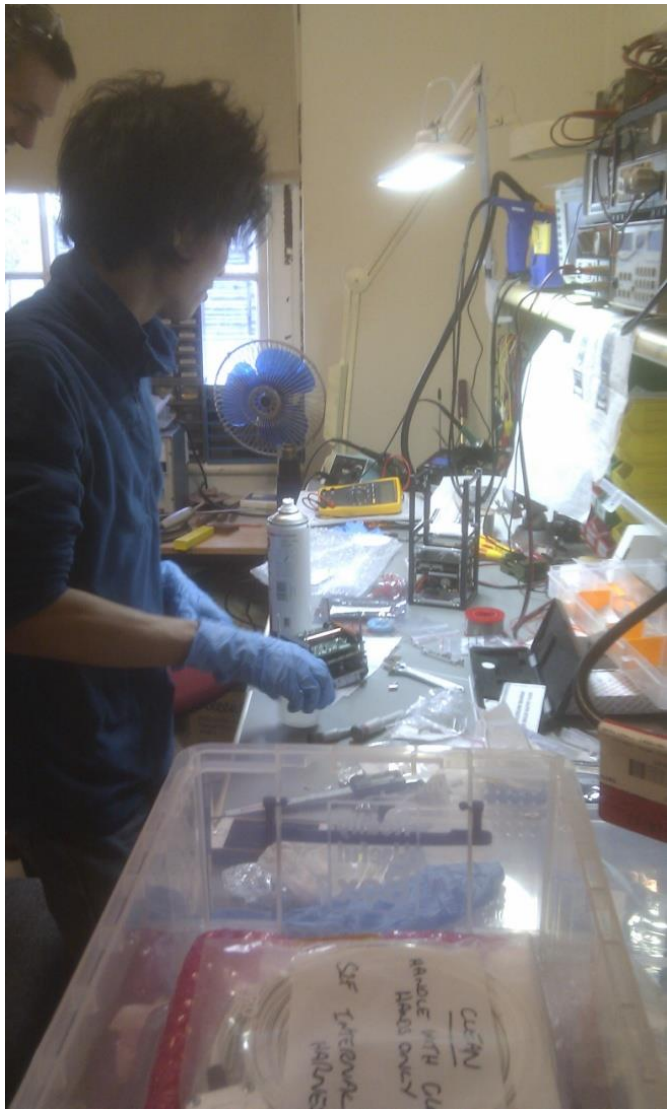
# Commercial Off-The-Shelf (COTS) parts ~$80K

- mostly from GOMspace, some Innovative Solutions in Space



ADCS board

# Building: Hardware & Software



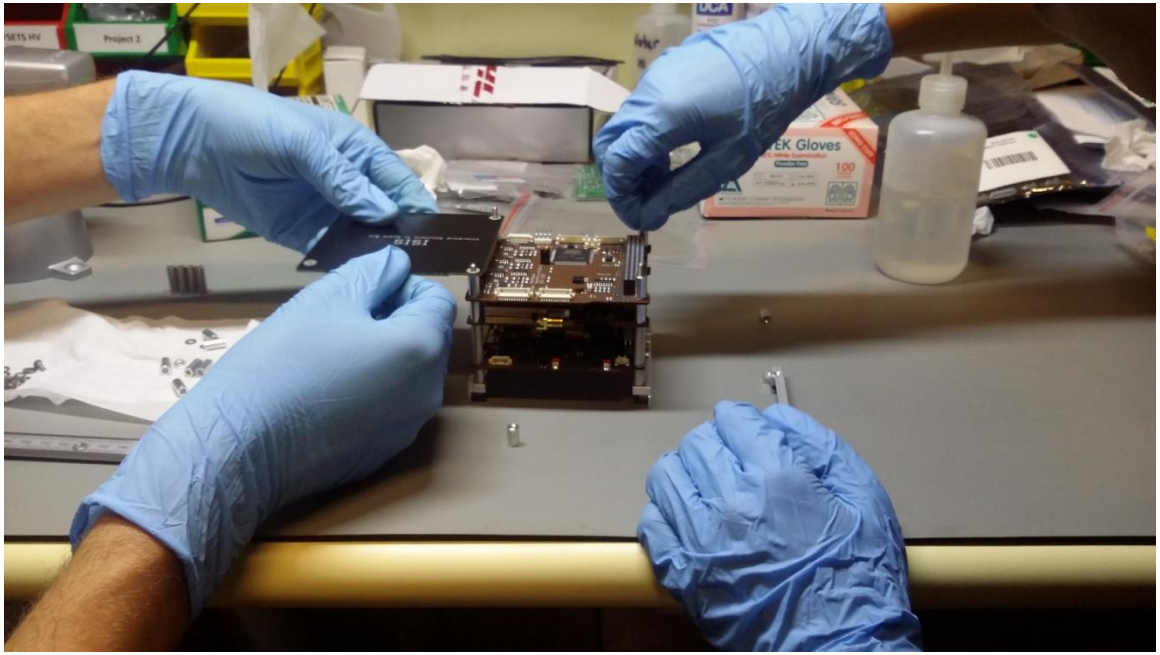
J. Funamoto & W. Peacock at USyd

- U. Sydney
- UNSW
- (Some at AITC too).

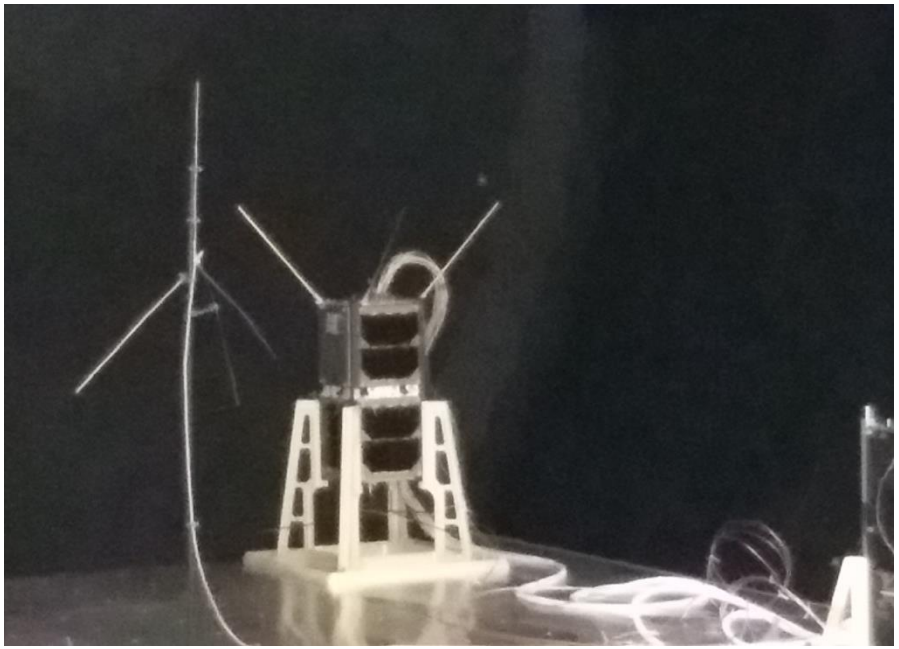
- Extremely demanding schedule with little margin for major problems ... (April start with initial delivery within 2 months)

# INSPIRE-2: First stack (22 April 2016)

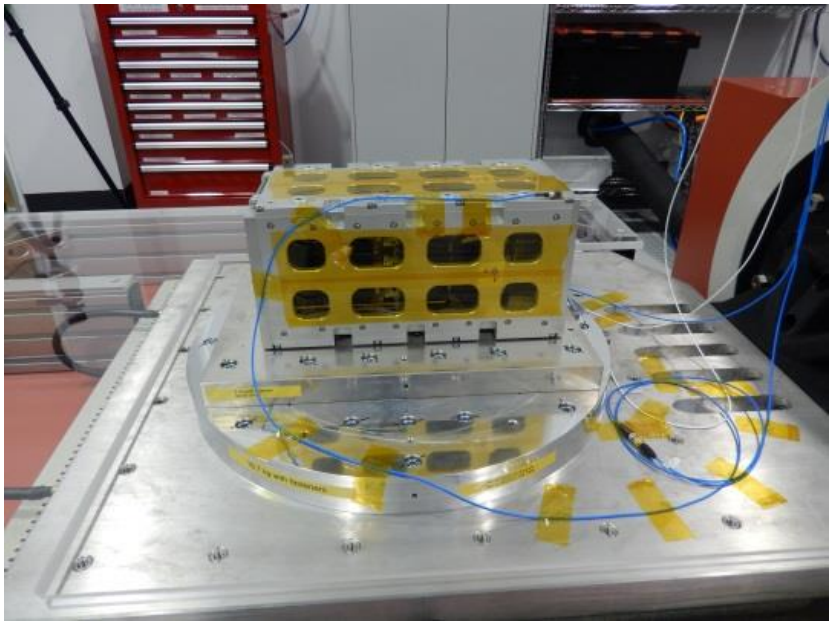




# Testing at AITC: TVAC & Vibe (13 – 26 June 2016)

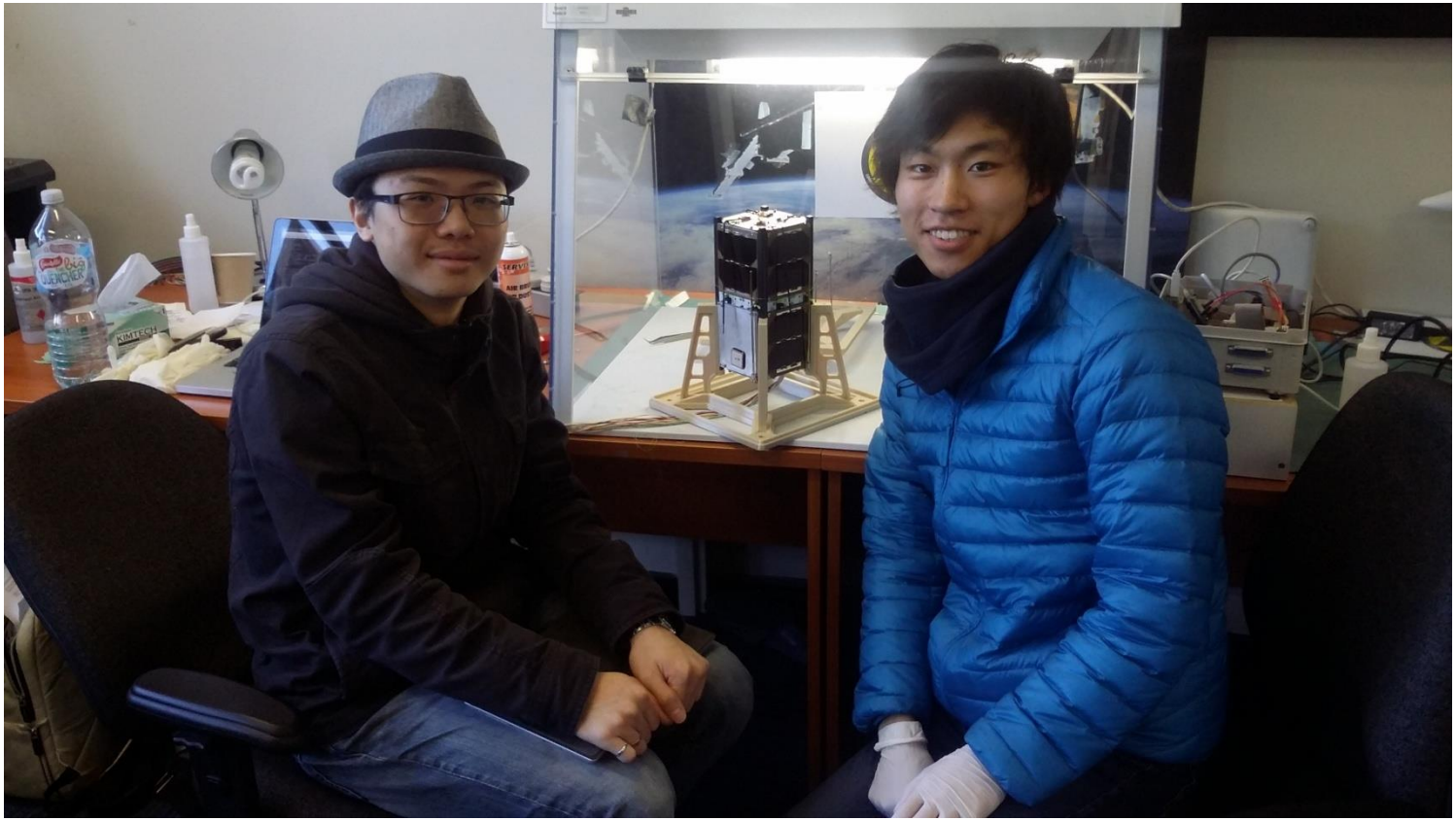


After TVAC in Wombat XL – fully deployed on command and nominal performance throughout.



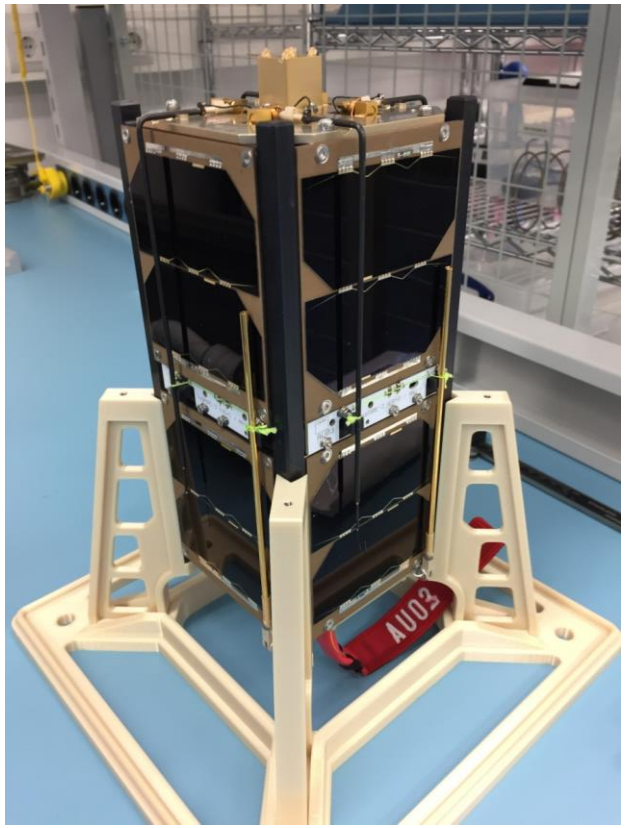
Vibration Test (Quasi-static, z-axis) ... nominal.

# Building, testing, & software finished (8 August)



# Delivery to QB50 and then Nanoracks:

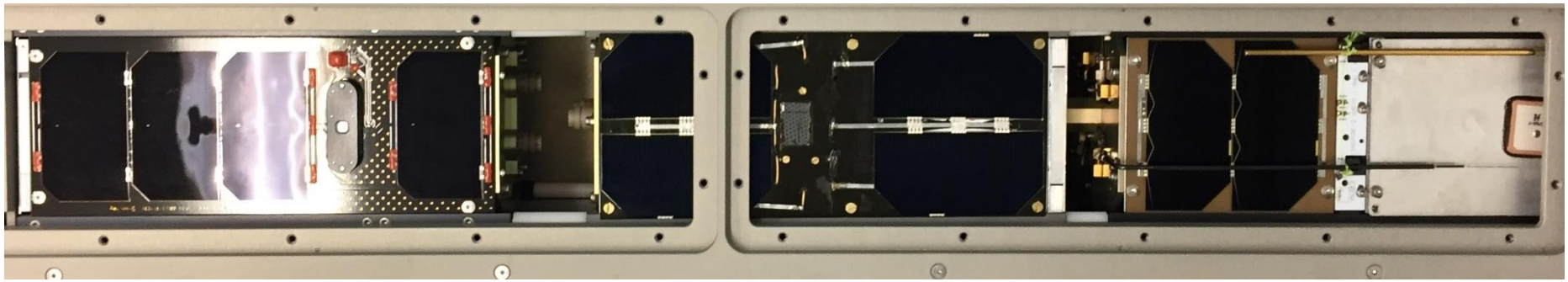
## AU03 first QB50 spacecraft ready for the fit test (16/8/2016).



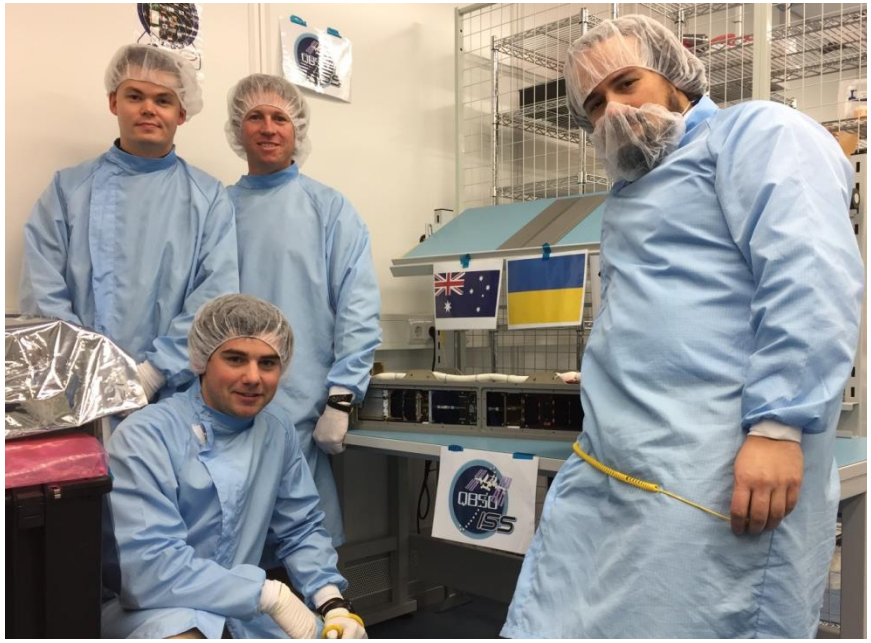

Davide Masutti:
QB50 Deputy
Principal Investigator

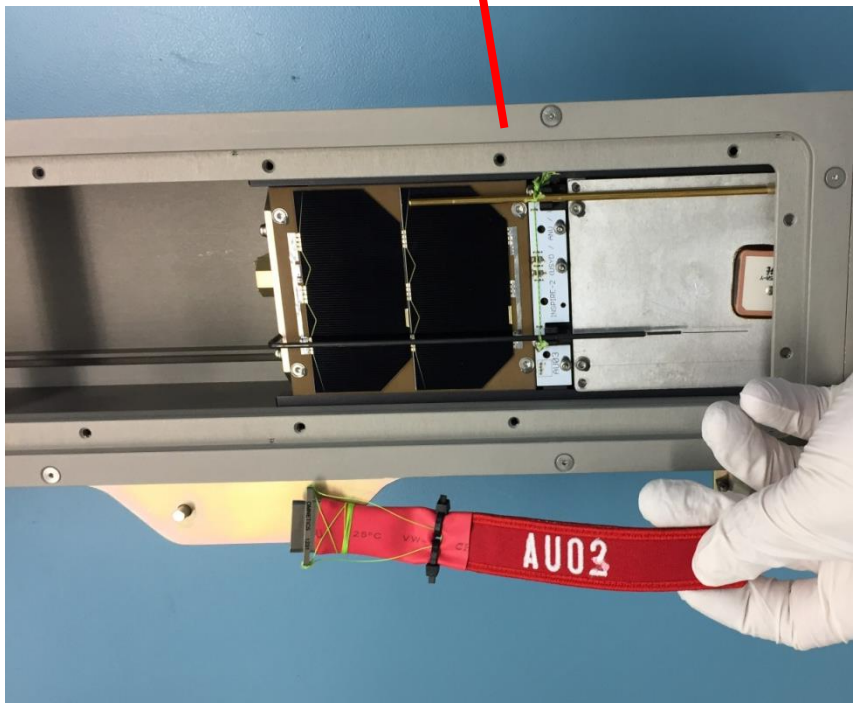
INSPIRE-2 / AU03

# 5. INSPIRE-2 in Nanoracks Pod



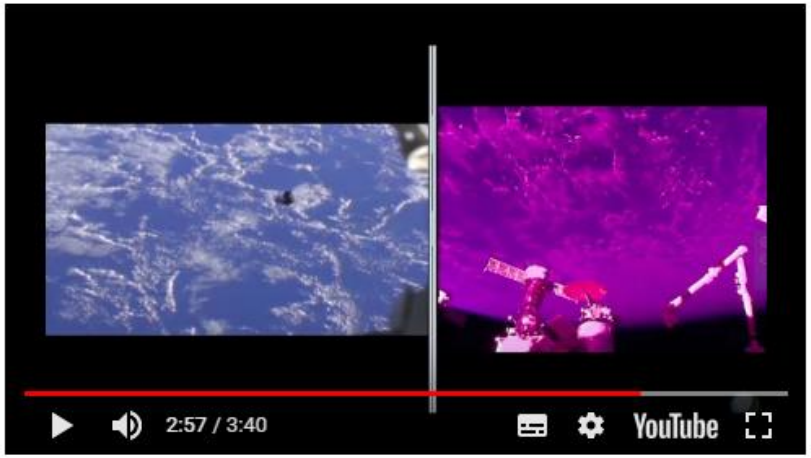
**First in ... First out !!**






With Ukraine and South Korea CubeSats

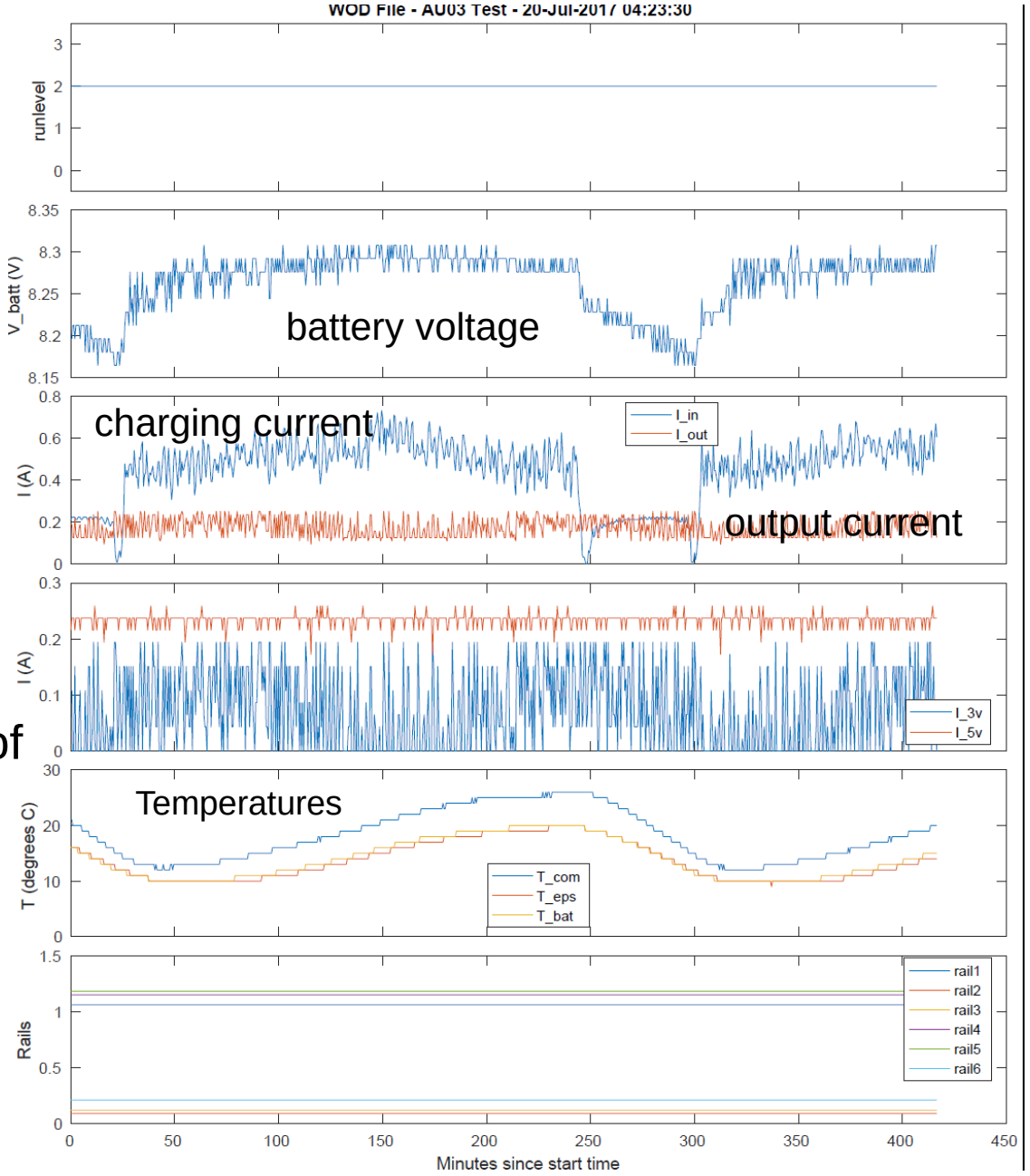
# 6. Atlas V launch & deployment from ISS




INSPIRE-2 headed for outer space

# 7. First spacecraft health data for INSPIRE-2

- Spacecraft battery, solar cells, and temperatures all fine.
- Can see expected effects of day – night transitions
- Lots of media attention due to original contact issues.
- Do have downlink issues



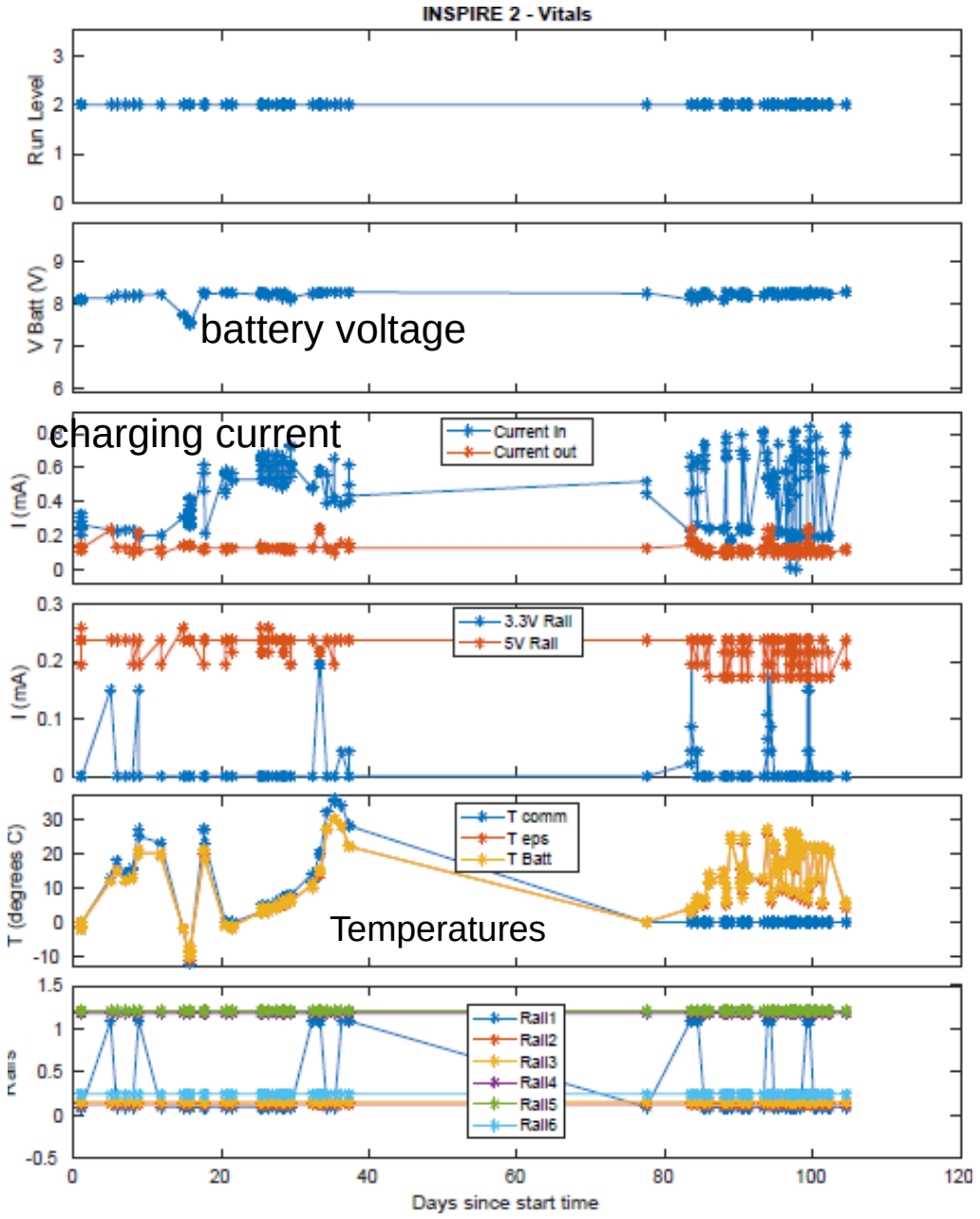
# All Beacon Data to 3 October

- Stable battery voltage
- See day-night variations
- Large changes in temperature with time. Why?

- Spacecraft went quiet for about 1.5 months. Why?

- Recovered spacecraft & reset beacon.

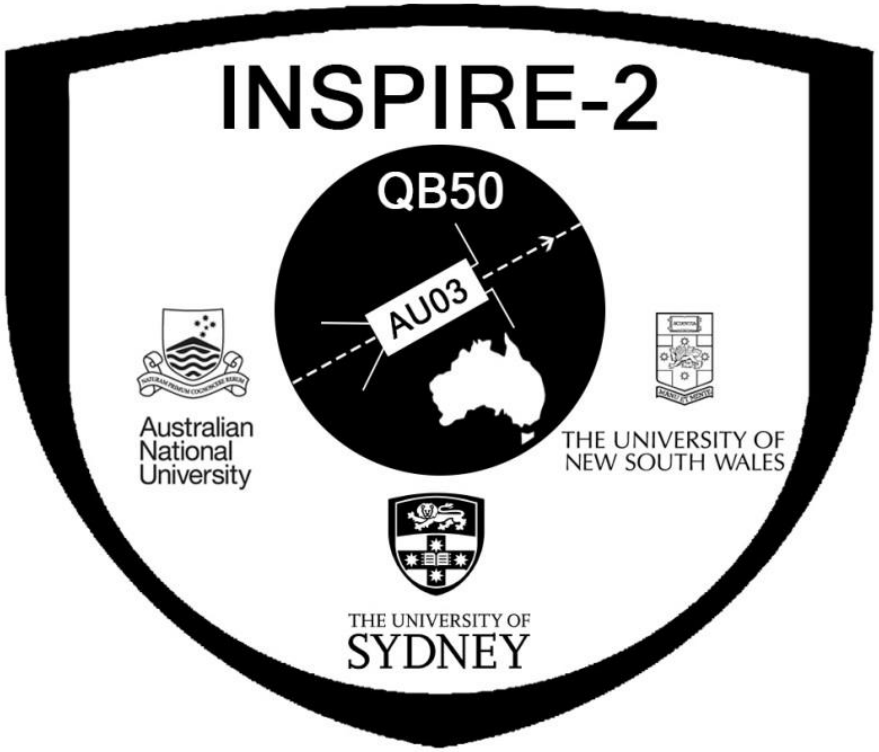
- Filesystem corrupted. Why?
- $T_{com}$ = 0 now ➔ Comms board damaged. Why?



# 8. Conclusions

- QB50 has 36 CubeSats: strength, composition, & variability of the lower thermosphere and ionosphere in position and time ("ignorosphere").
- INSPIRE-2 and 2 other Australian-built QB50 CubeSats are in space now, representing multiple firsts & a new beginning:
  - They demonstrate existence of Australian space capability and breaking the economic barrier to Australia entering space community
- INSPIRE-2 has 5 instruments (mNLP, Nanospec, Kea GPS, and 2 radiation detectors), 4 Australian, and a mostly COTS bus.
- INSPIRE-2: start to delivery in 10 months (first partial stack to delivery in 4 months). Cash cost < $150 K. Multiple students.
- INSPIRE-2 is alive in space.
- High hopes for significant science but downlink issues.
- A new funded ARC Training Centre for CubeSats, UAVs, and Their Applications → 1 CubeSat flight a year for 5 years ➔ Continuity and open for collaboration on space science, technology, and commercialisation.

# Conclusions: INSPIRE-2 / AU03 Ready for Nanoracks & Launch





- 10 months from start to delivery / acceptance
- Novel science & technology (5 payloads,4 Oz)
- De-risk with COTS and small-change design
- Strong collaborations AU03, AU02,AU01 → future

# INSPIRE-2 / AU03

QB50, an FP7 Project

- Revised into a 3-university project from 30/9/2015:
  - University of Sydney
  - Australian National University
  - University of New South Wales (Sydney)
- Third Australian cubesat for QB50 (➔ AU03)