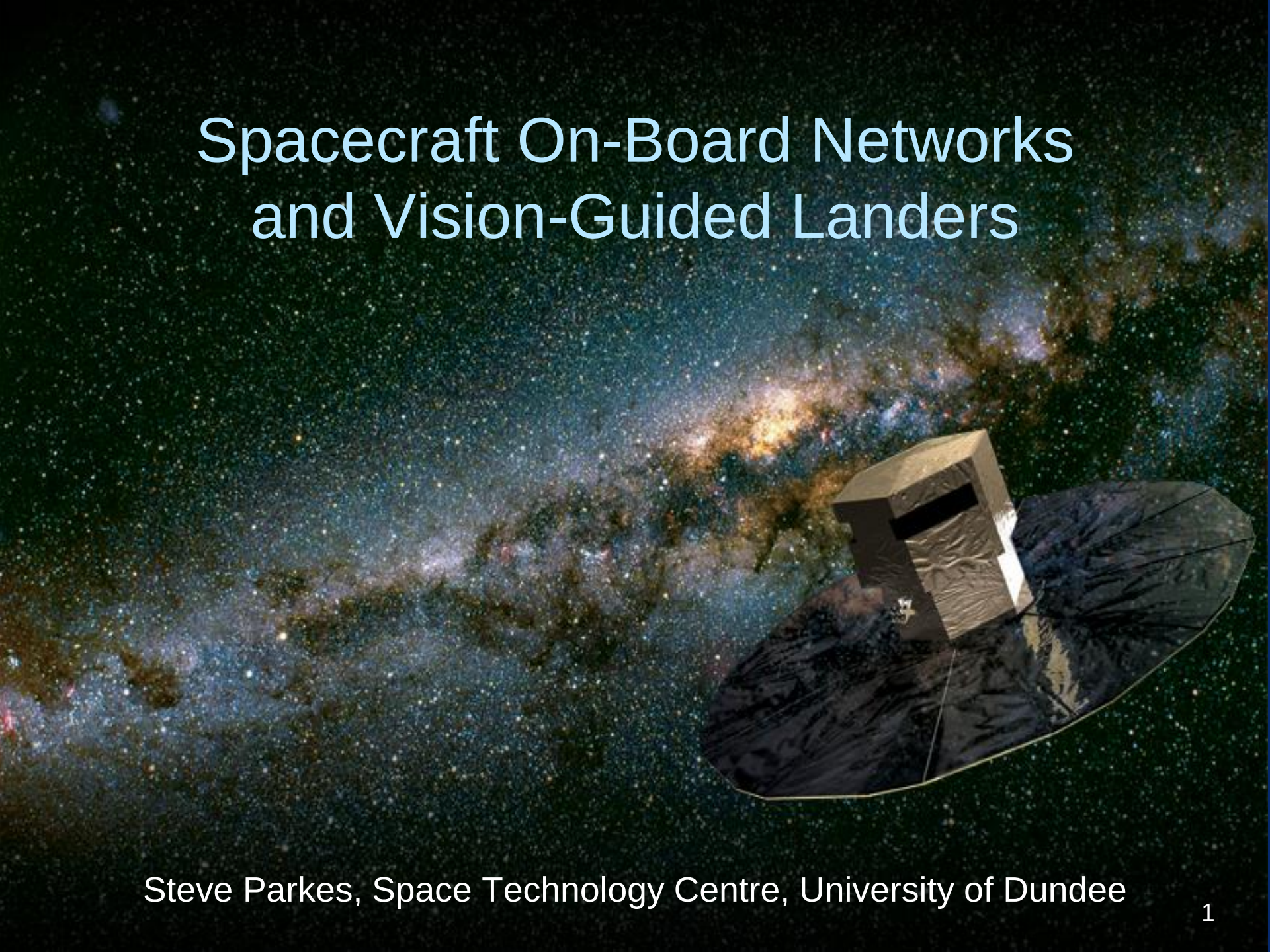
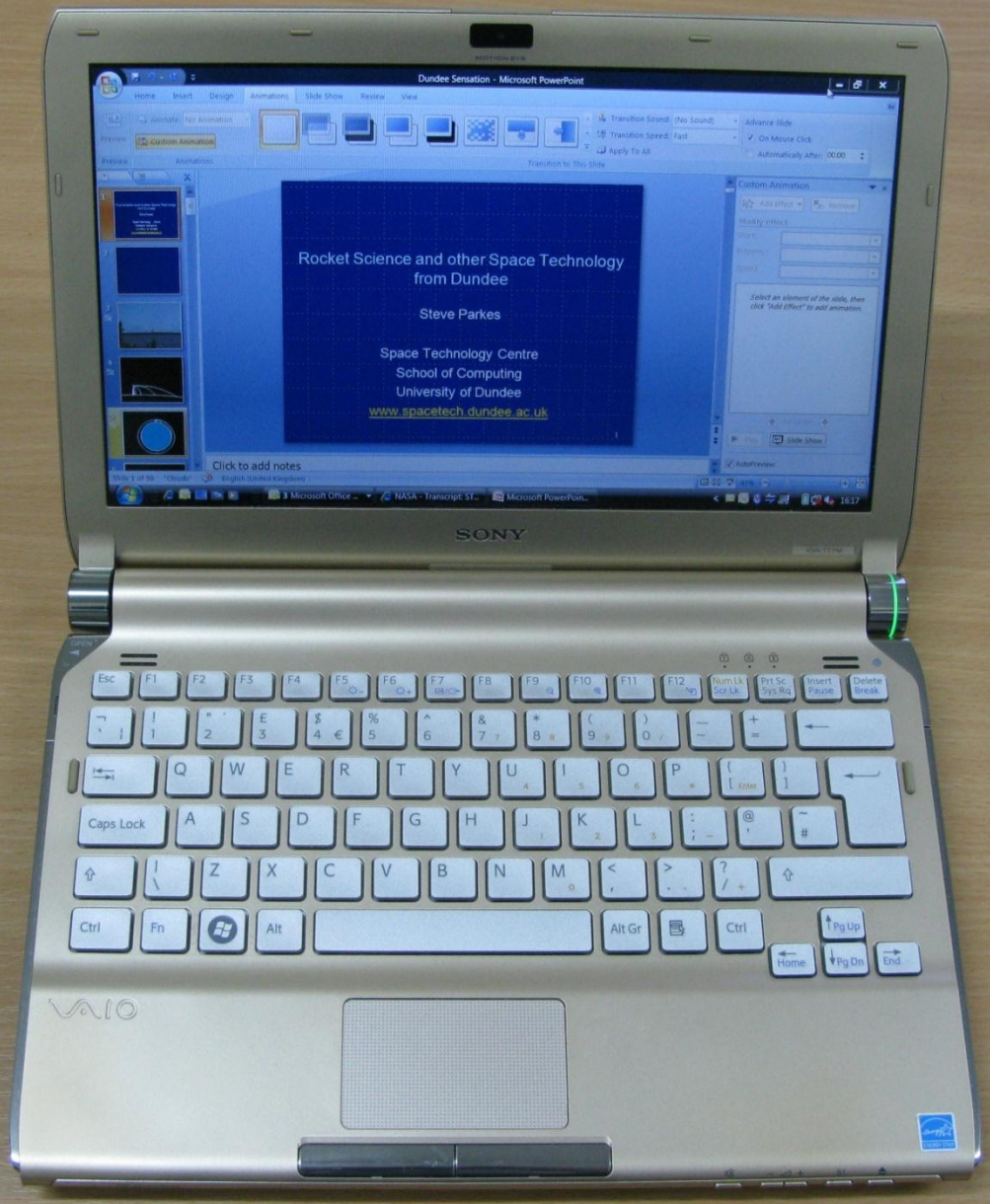
Spacecraft On-Board Networks and Vision-Guided Landers



Steve Parkes, Space Technology Centre, University of Dundee

Spacecraft onboard data-handling

- Computer network technology for spacecraft
  - SpaceWire
- Connects together data-handling elements onboard a spacecraft:
  - Instruments
  - Processors
  - Mass memory
  - Telemetry and Telecommand
- Standard interface
- Forms the nervous system of a spacecraft


Dundee Sensation - Microsoft PowerPoint
Rocket Science and other Space Technology from Dundee
Steve Parkes
Space Technology Centre
School of Computing
University of Dundee
www.spacetech.dundee.ac.uk
Click to add notes
SONY
VAIO

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Rocket Science and other Space Technology from Dundee
Steve Parkes
Space Technology Centre
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Installing device driver software
SONY
PHILIPS
VAIO

Dundee Sensation - Microsoft PowerPoint
Found New Hardware
Windows needs to install driver software for your Unknown Device
Locate and install driver software (recommended)
Windows will guide you through the process of installing driver software for your device.
Ask me again later
Windows will ask again the next time you plug in your device or log on.
Don't show this message again for this device
Your device will not function until you install driver software.
Cancel
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WD

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Don't show this message again for this device
Cancel
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WD
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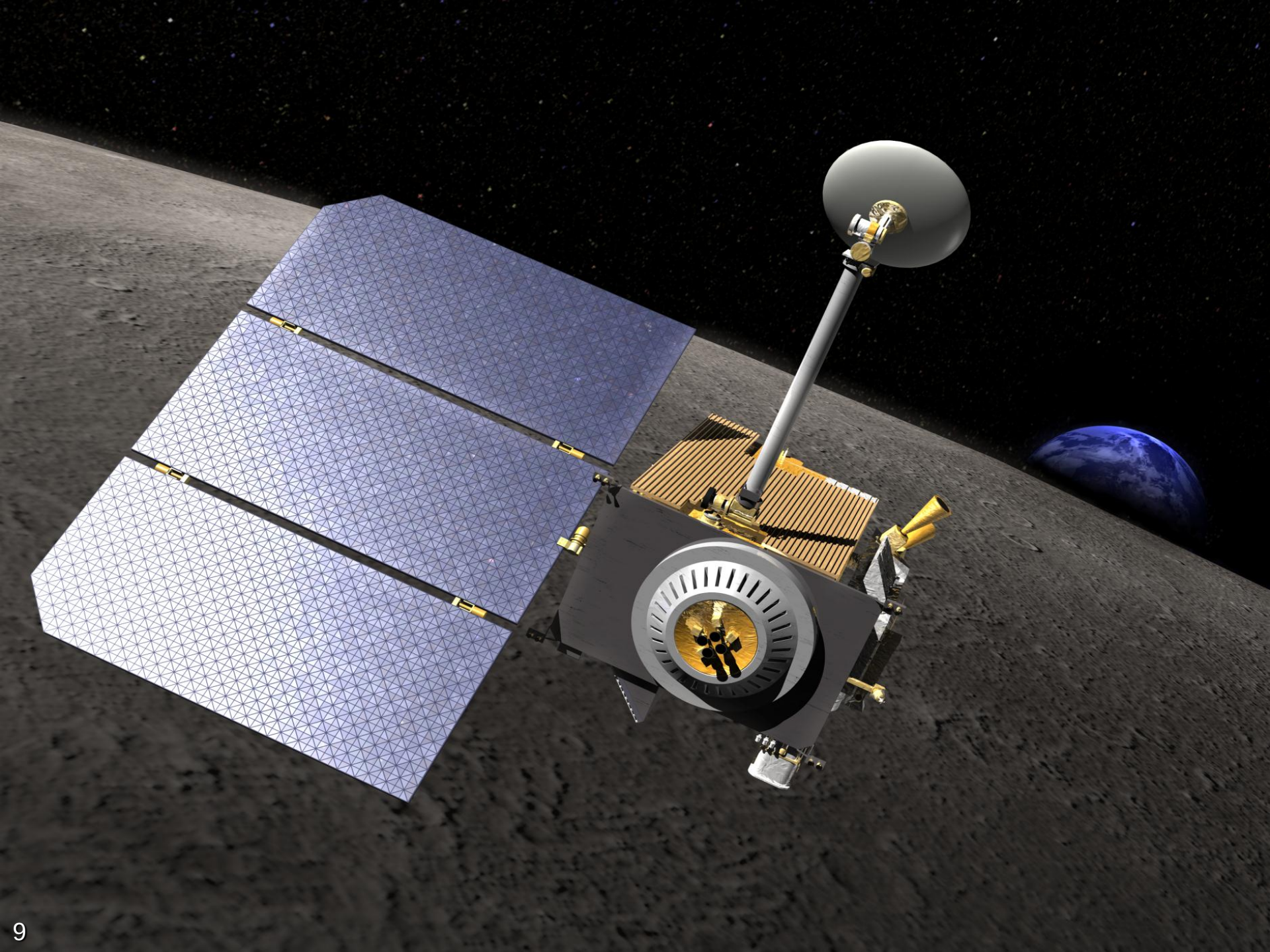
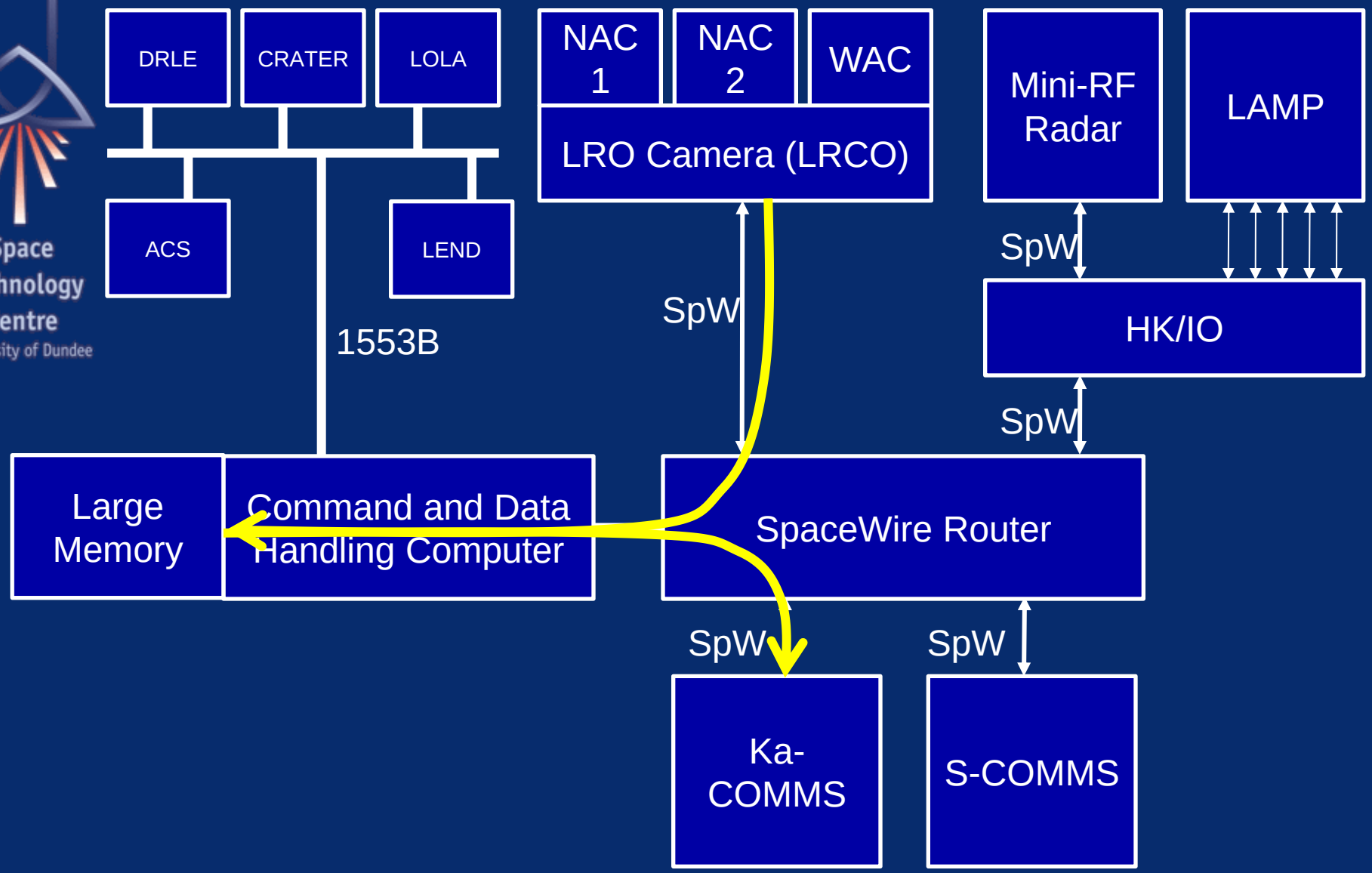
University of Dundee

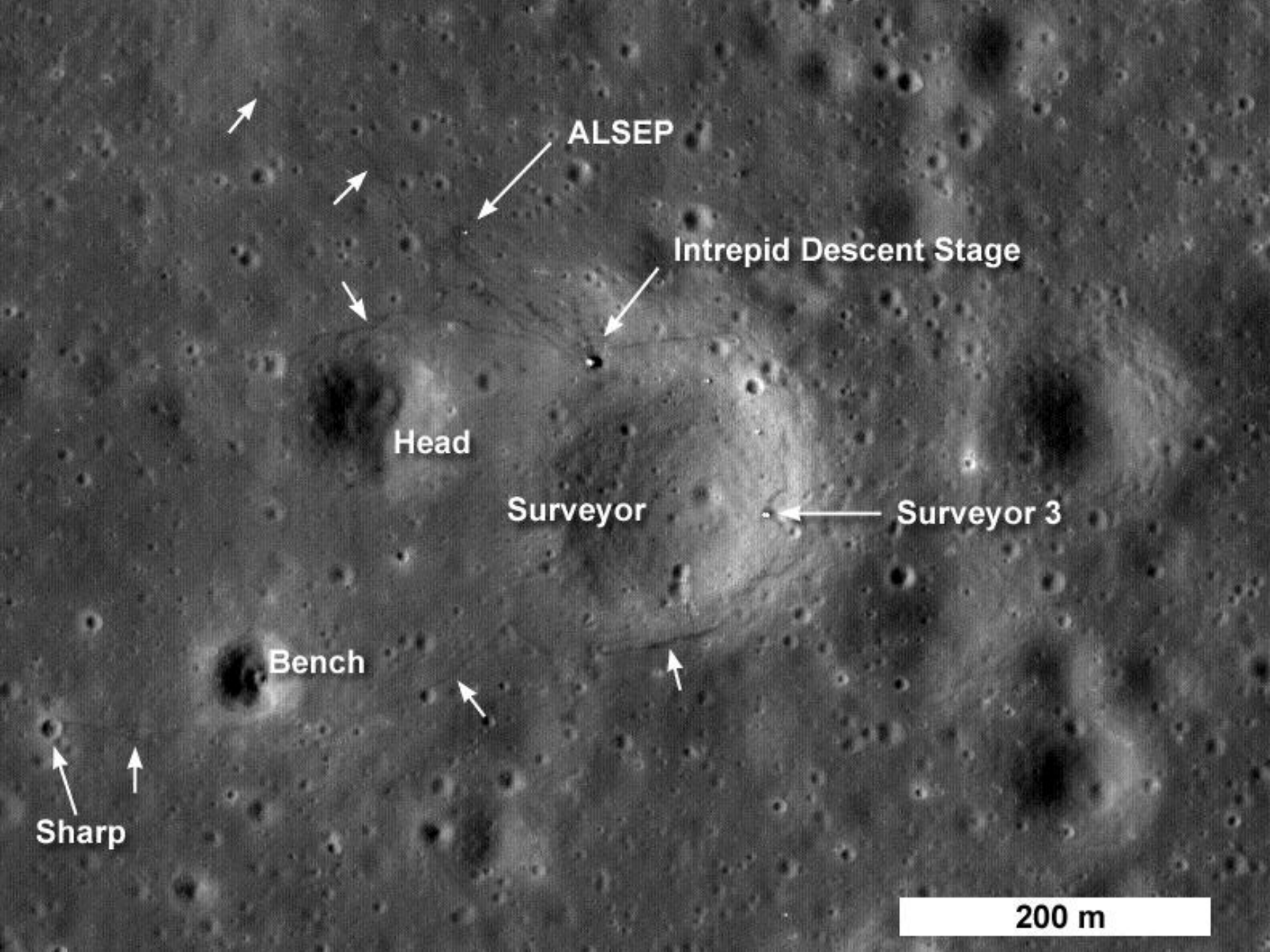
SpaceWire Key Features

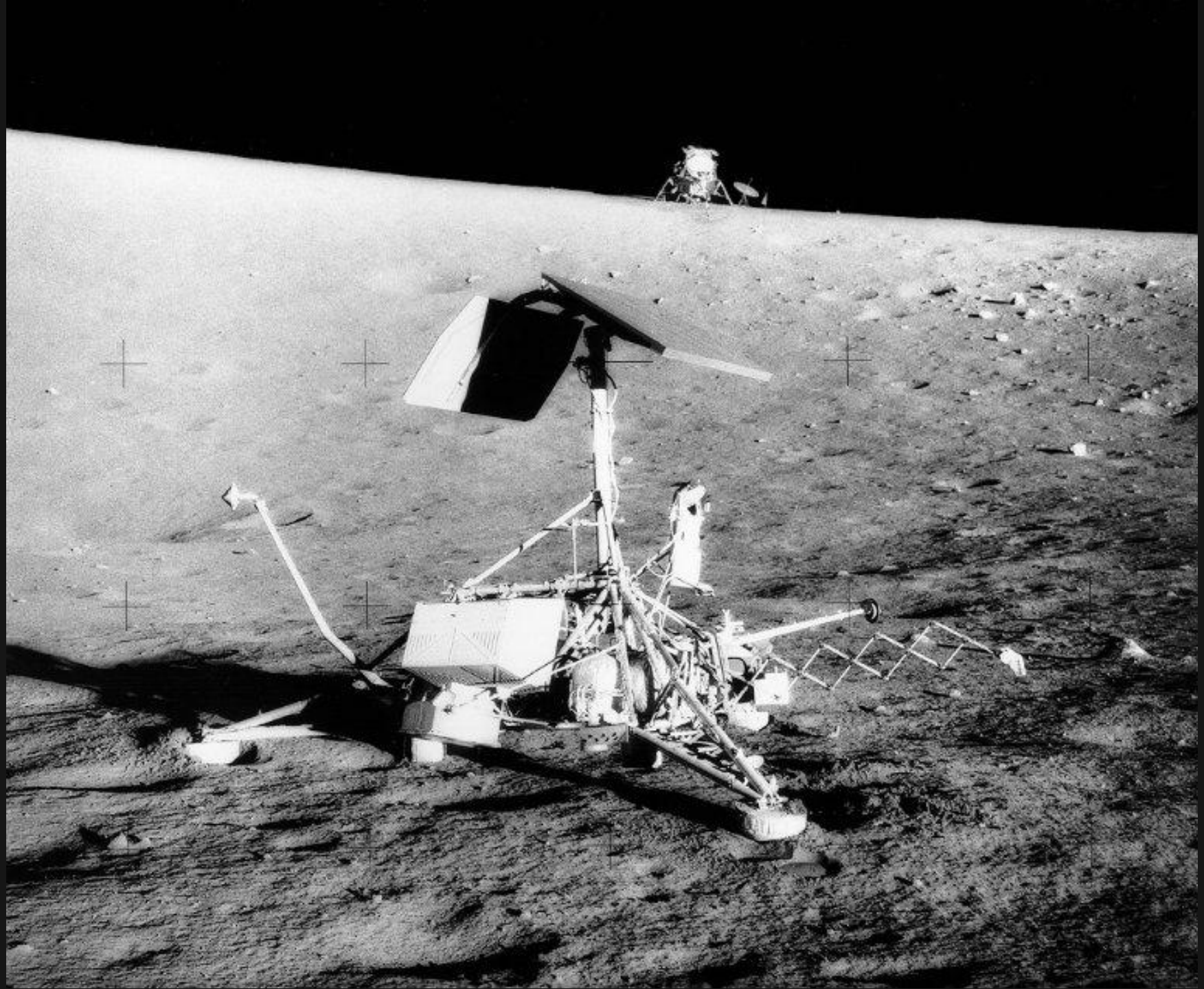
- Similar purpose to USB
  - Different technology
- Designed for space applications
- Simple
- Implementation requires few logic gates
- High performance
- Flexible architecture



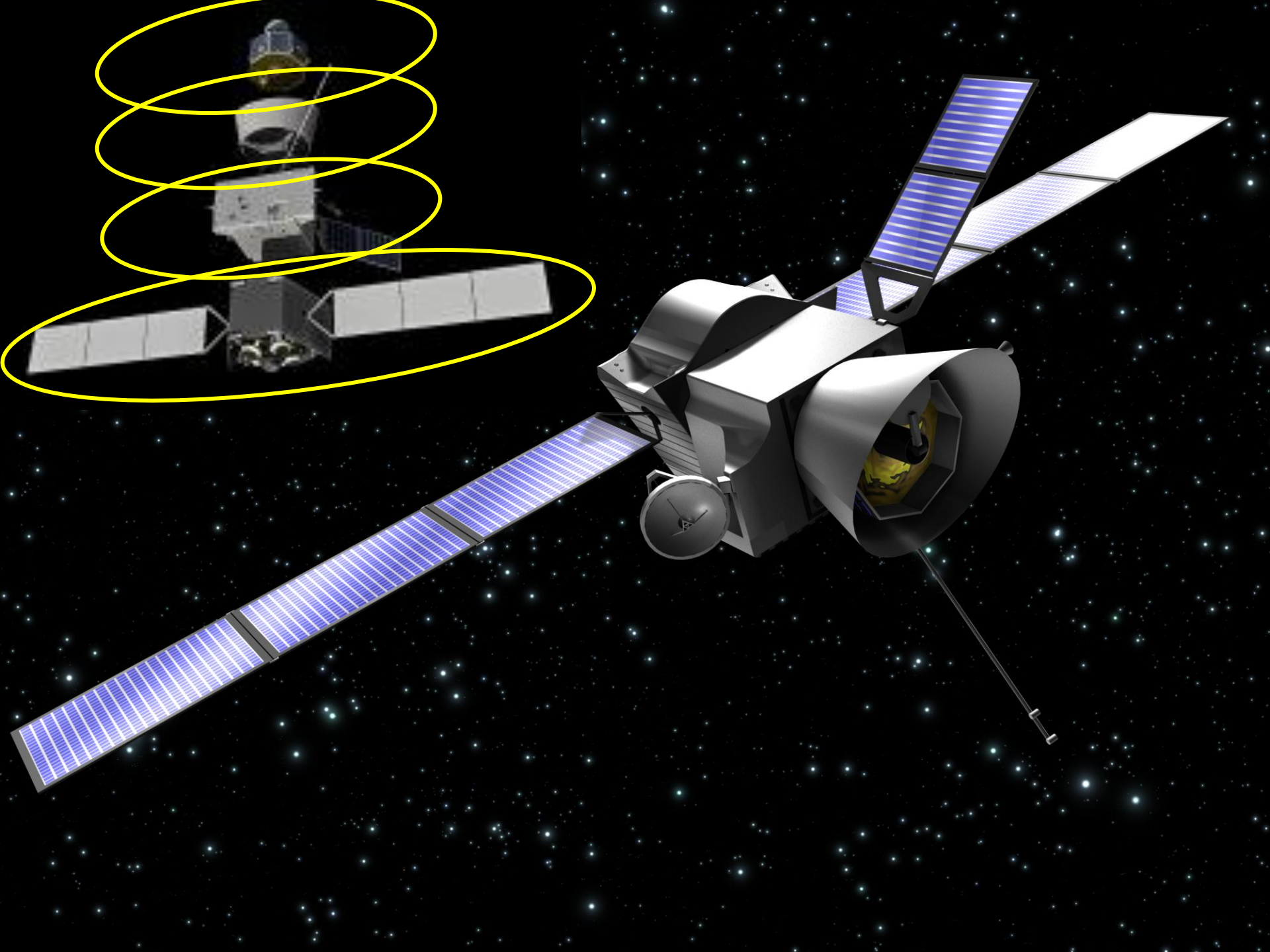
Lunar Reconnaissance Orbiter




ALSEP
Intrepid Descent Stage
Head
Surveyor
Surveyor 3
Bench
Sharp
200 m



Magnetospheric
MultiScale
NEXTAR
TacSat
Sentinel-5
Sprint-A
Gaia
JWST
Sentinel-3
GOES-R
BepiColombo
ExoMars
SpaceWire
LCROSS
Sentinel-2
Sentinel-1
Astro-H
Lunar
Reconnaissance
Orbiter
ASNARO
SWIFT
PnPSat
ESA
JAXA
NASA



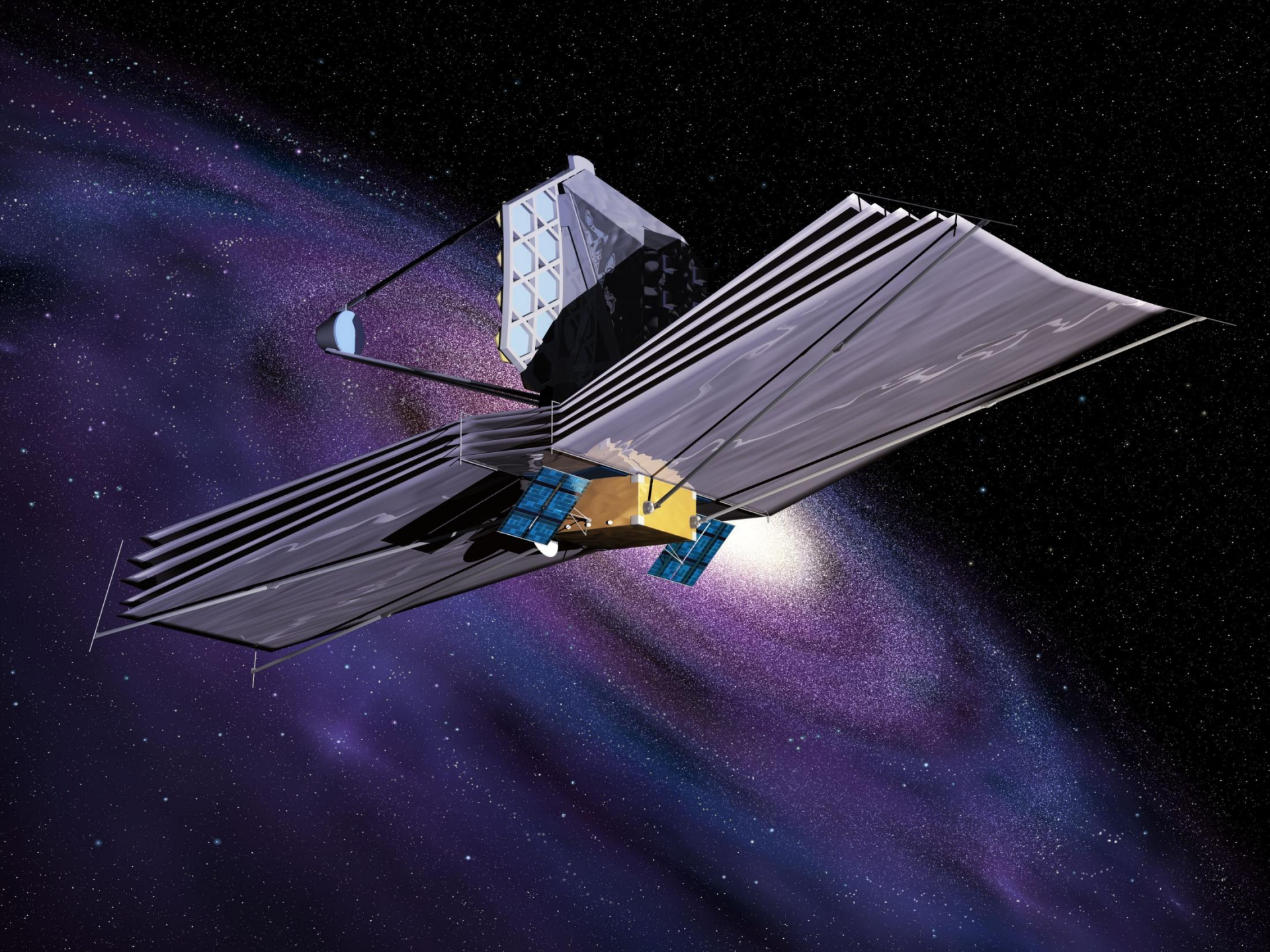


Illustration: Akihiro Ikeshita / JAXA.

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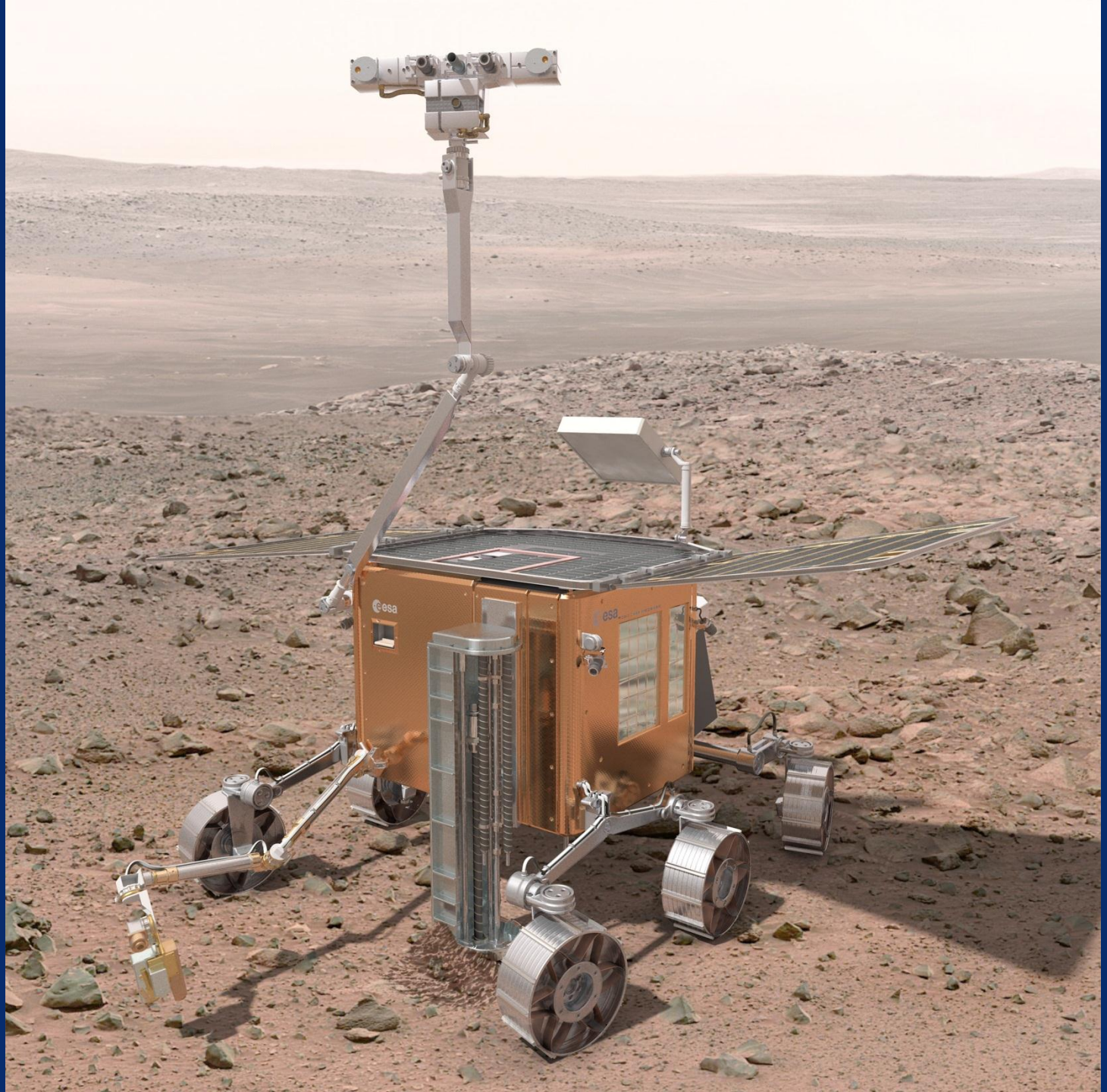

SpaceWire Routing Switch

- 8 SpaceWire Ports
- 2 Parallel Ports
- Fully integrated routing switch
- VHDL Design by University of Dundee
- Used on ExoMars, Sentinel 3, BepiColombo, and others

SpaceWire

- SpaceWire standard
  - Written by University of Dundee
  - With inputs from international spacecraft engineers
- SpaceWire technology
  - Being used or designed into over 100 spacecraft
  - Over $15 billion worth of spacecraft rely on it
    - Scientific, Exploration, Earth observation, Commercial
- Dundee SpaceWire chip technology designed into
  - European, Japanese, USA, Chinese spacecraft
- Successful spin-out company STAR-Dundee

STAR-Dundee Ltd

- Operational for 10 years
- Grown organically
- Winner of two SMART awards
- Customers in 50 countries
- Including ESA, NASA, JAXA

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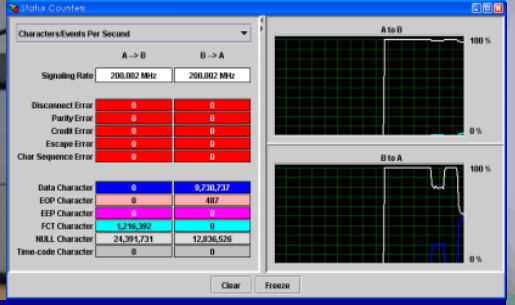
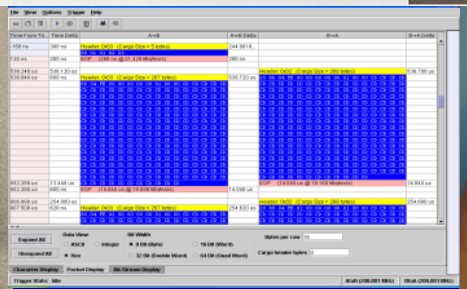


- Products
  - SpaceWire test equipment
  - SpaceWire chip designs
- High value, low volume
- Responsive to customer requirements
- Support important



The Team

- 17 people
- 14 FTEs
- 7 PhDs
- Other highly skilled people
- Mix of technical skills
  - Chip design
  - Circuit design
  - Board design
  - Box design
  - Software drivers
  - Application software

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Wideband Spectrometer

- Planetary and Earth Atmospheric Science
- Microwave/THz Spectrometer
- Instrument design
  - Rutherford Appleton Labs
    - Front end receiver
  - University of Dundee / STAR-Dundee
    - Back end spectrometer

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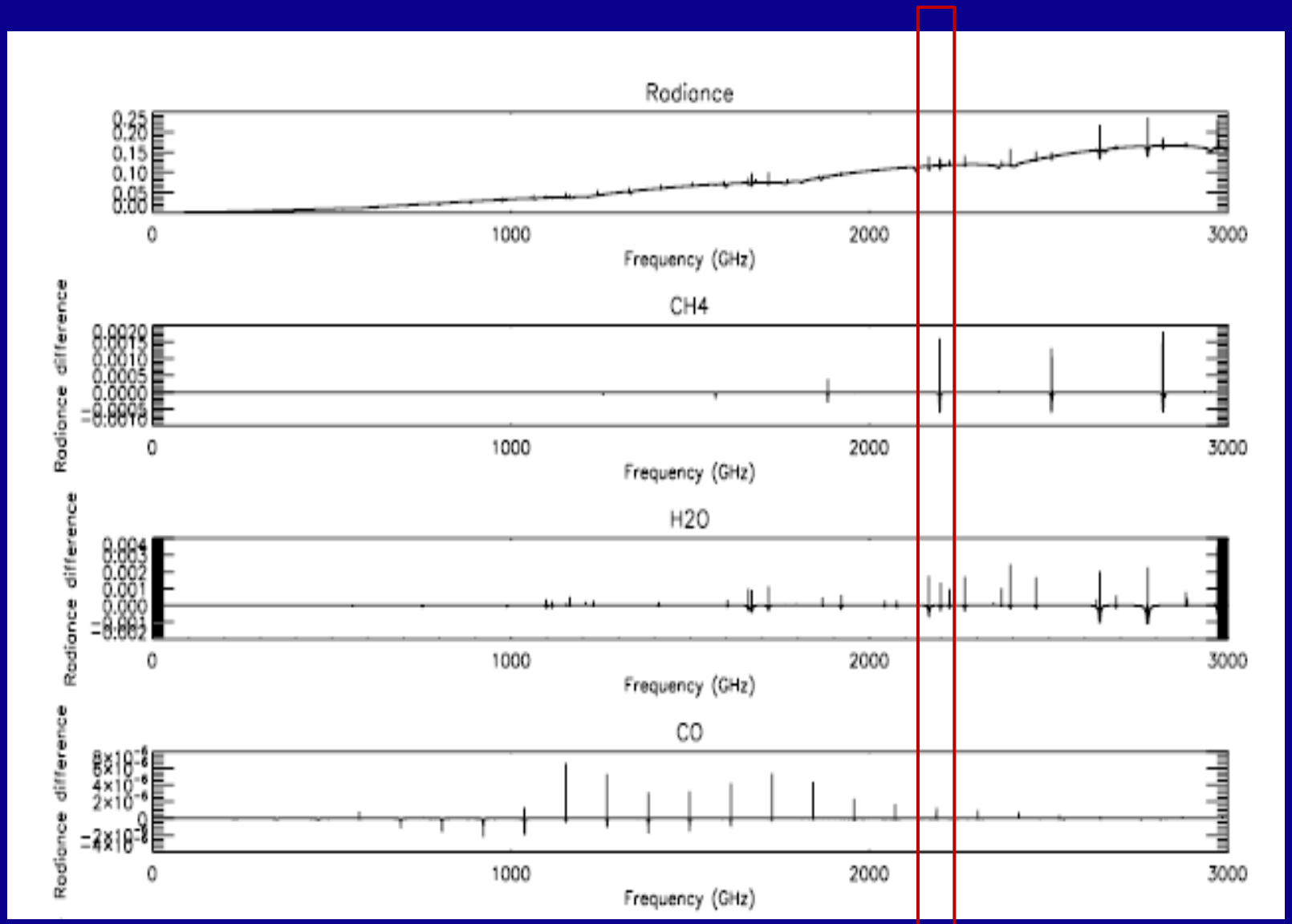
Wideband Spectrometer



- Pat Urwin, University of Oxford

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Wideband Spectrometer

- Measuring atmospheric constituents
  - Spacecraft points receiver at limb
  - Receives microwave radiation from atmosphere
  - Containing the spectral lines from various atmospheric species
  - Spectral lines are completely submerged in noise
  - Need to measure the spectrum and average
  - To extract the wanted signal from noise

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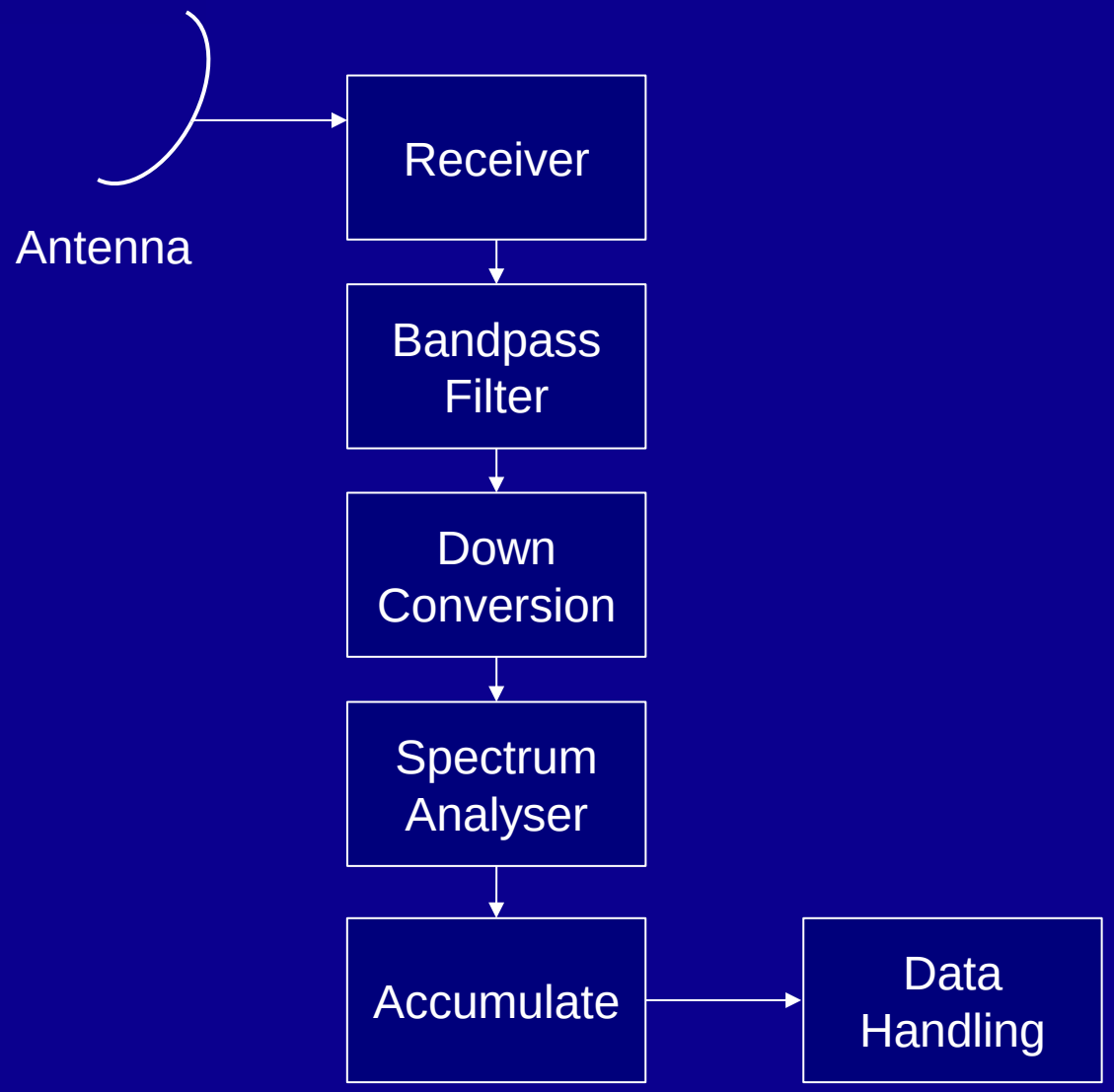
Wideband Spectrometer



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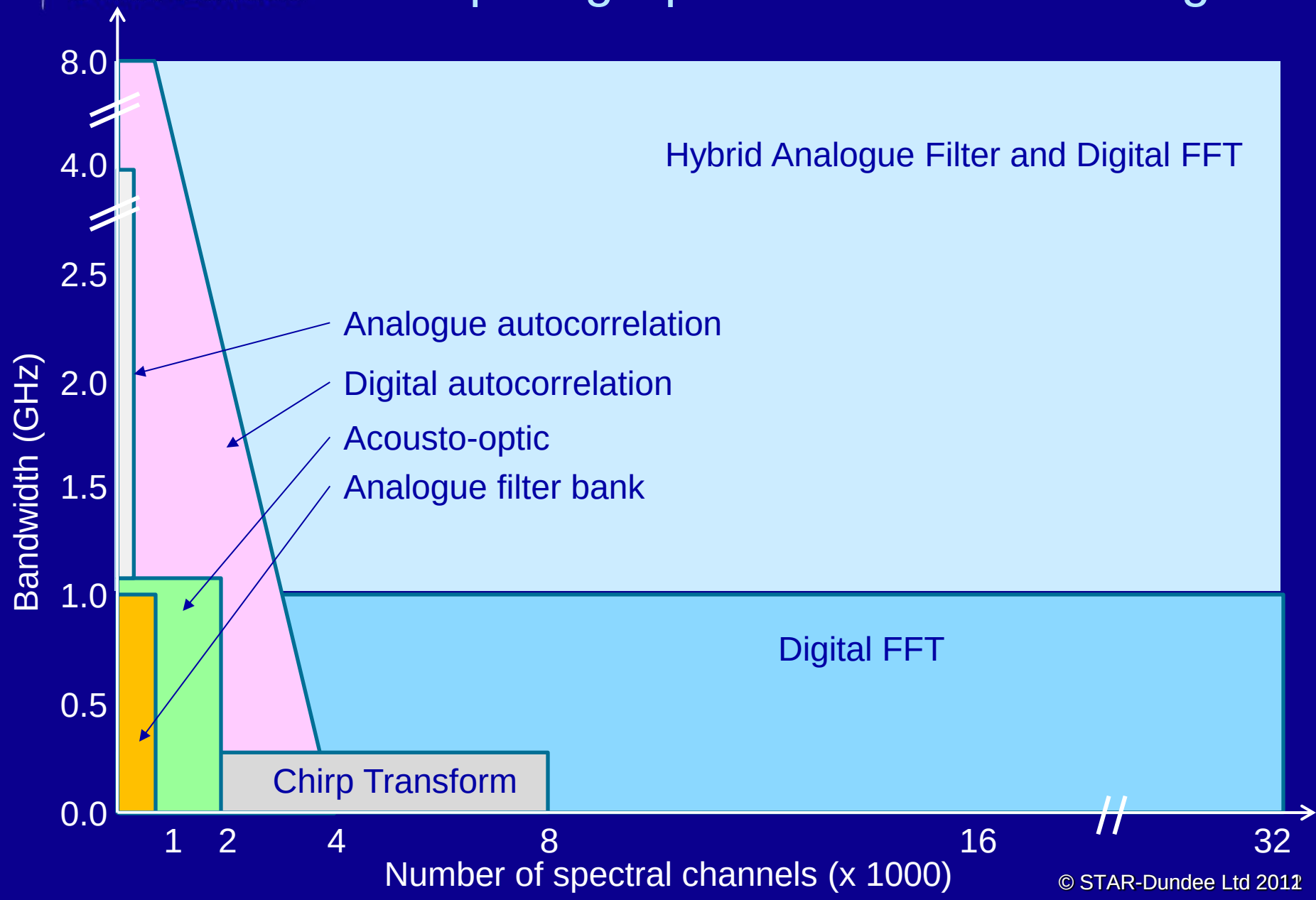
Competing Spectrometer Technologies



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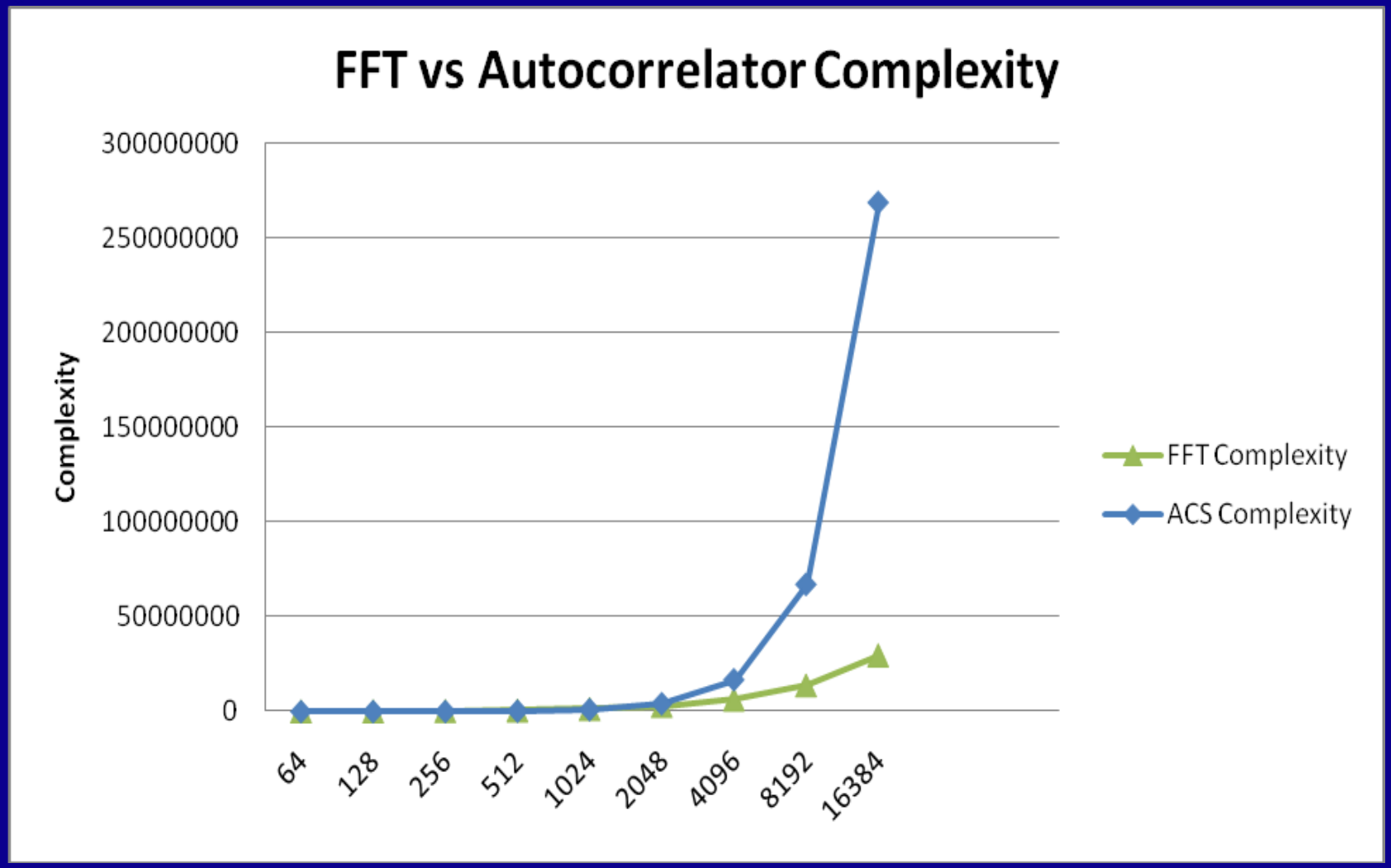
FFT Spectrometer vs Autocorrelator



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WBS II

- A Wideband Spectrometer (WBS) unit:
  - Two ADCs sampling at 3 Gsamples/s
    - I & Q sampling
    - Resulting signal bandwidth > 2 GHz
  - Custom Fast Fourier Transform (FFT) chip design
    - Windowing
    - 2048 point complex FFT at 3 G samples/s
      - ~ 1.5 MHz resolution
    - Power detection and accumulation
    - Zero time between data acquisitions
    - 300 G operations/s
  - Trigger interface
    - Start/stop individual acquisitions
    - Start/stop groups of acquisitions of predetermined duration

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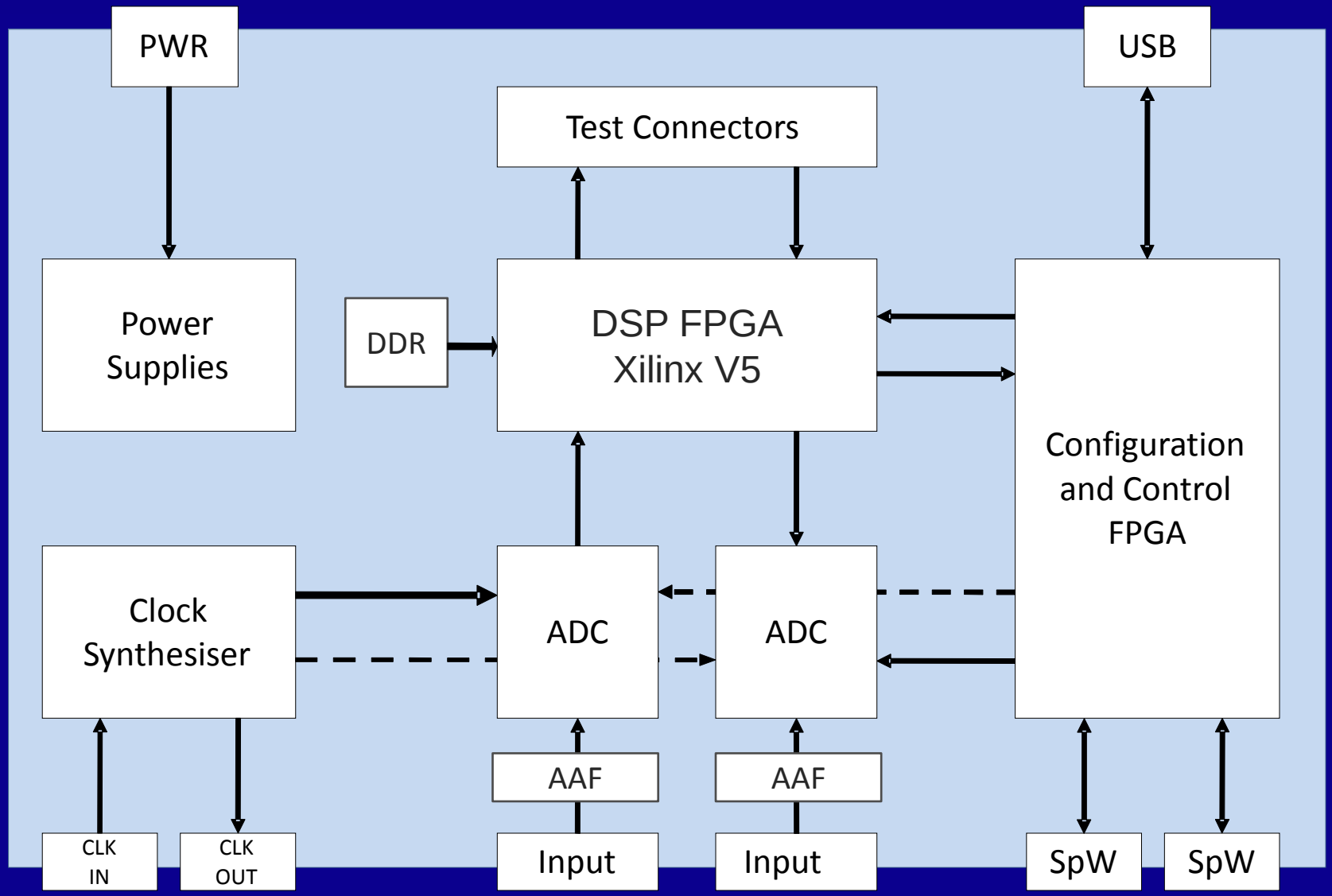
Wideband Spectrometer Prototype



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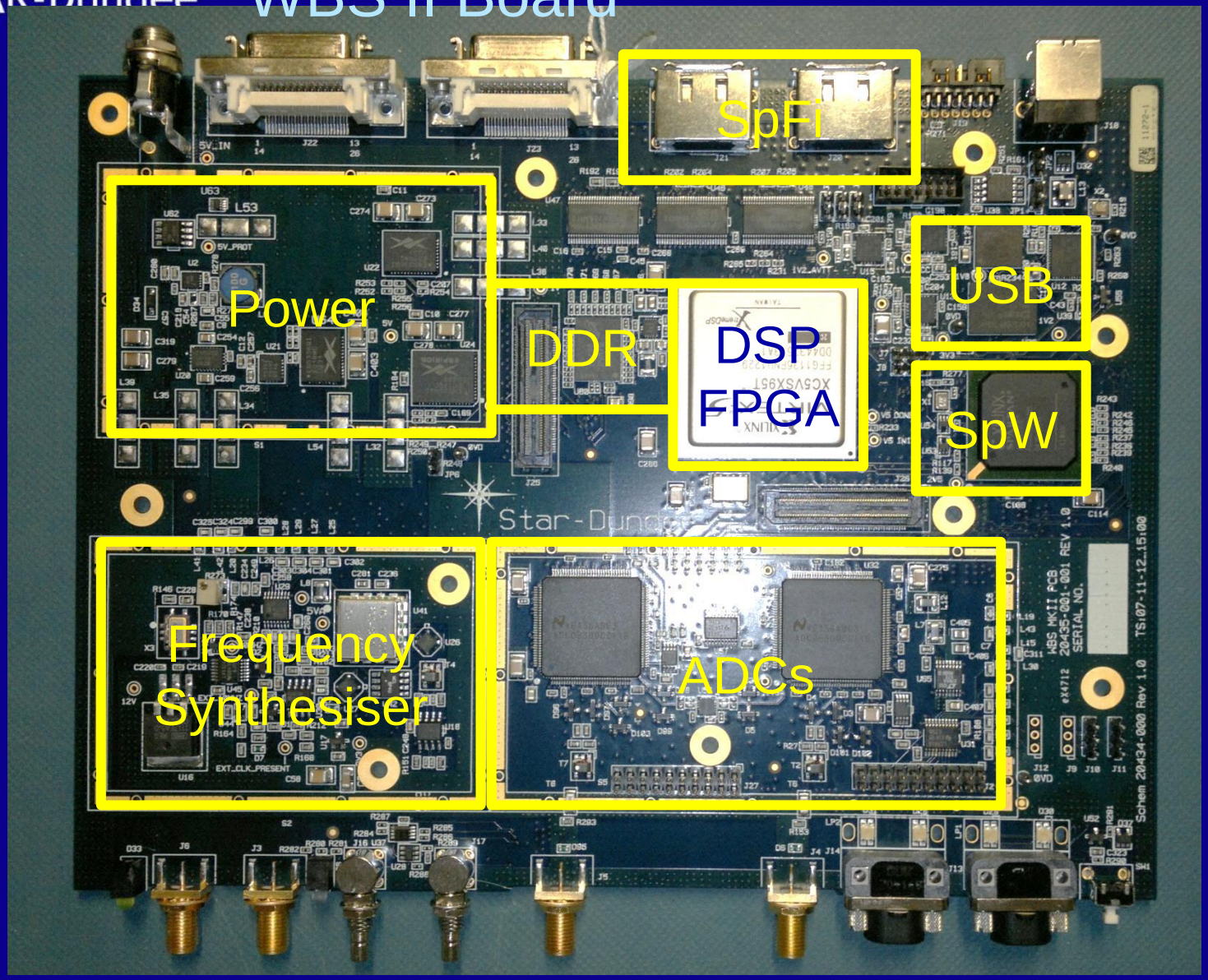
WBS II Board



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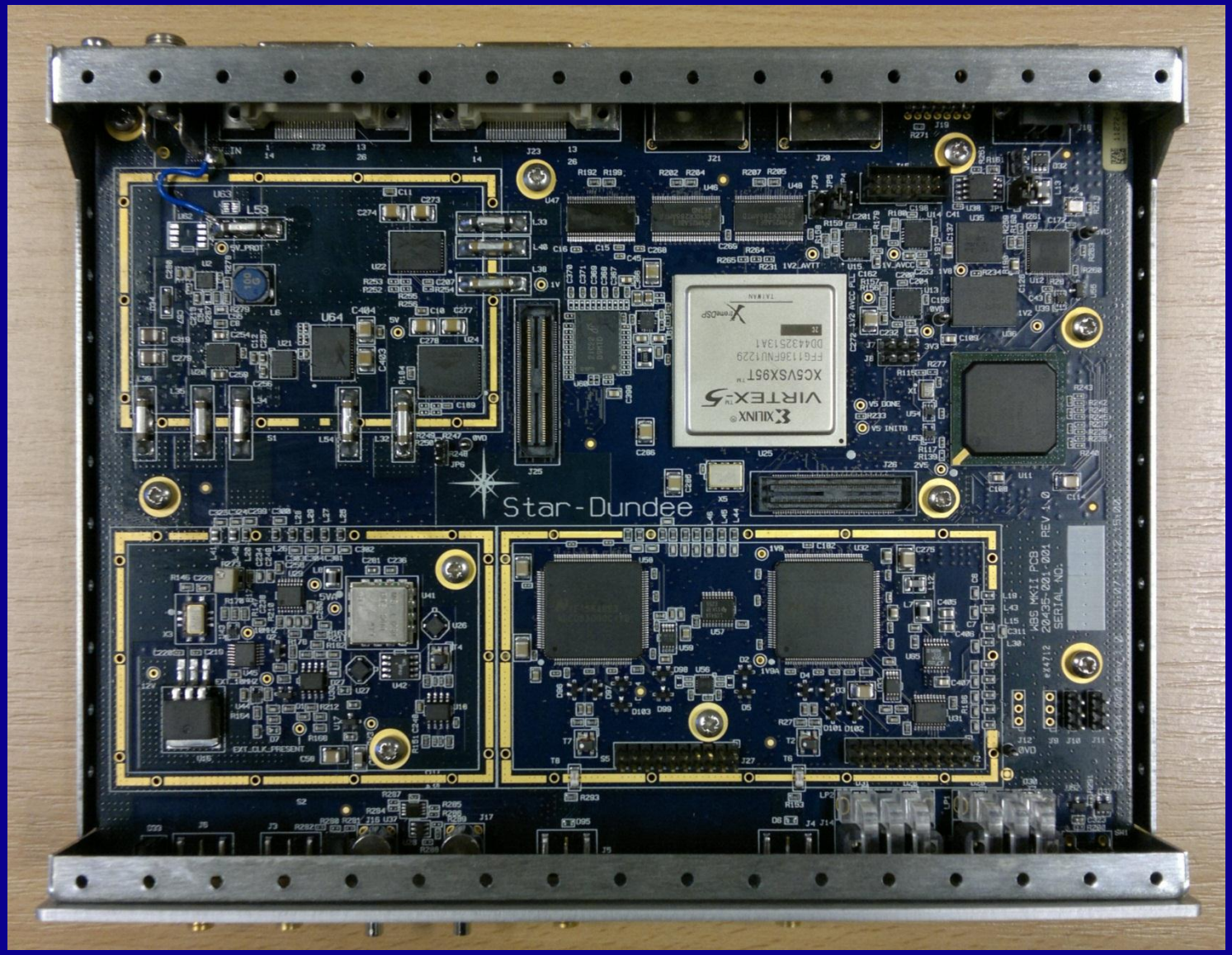
WBS II Board



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Wideband Spectrometer II

Dimensions
L= 165 mm
W= 220 mm
H= 30 mm

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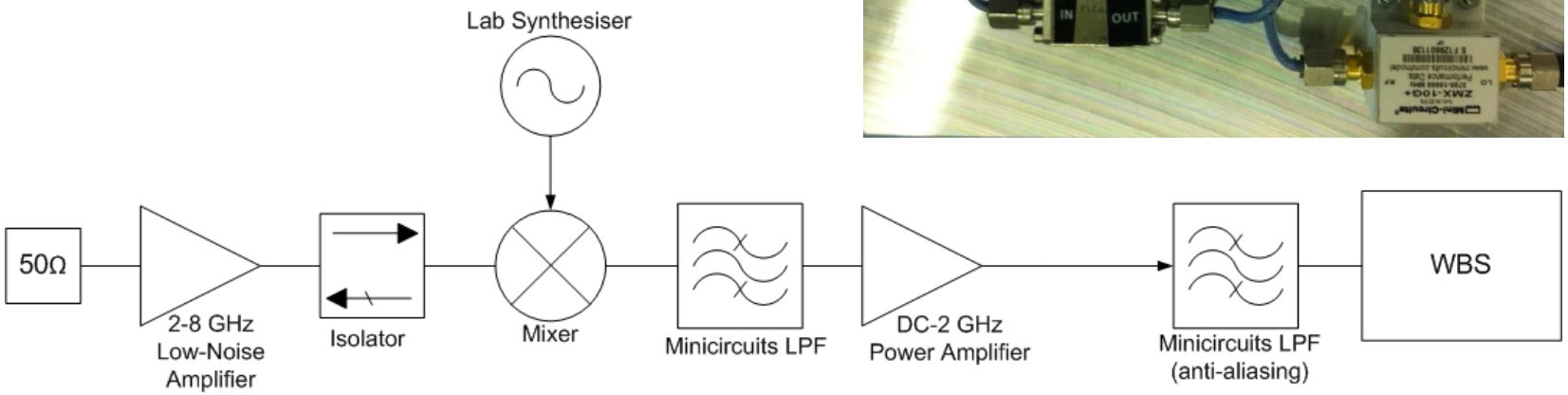
Initial Testing with Microwave Receiver

- Microwave receiver operating bandwidth: 2-8 GHz
- Receiver noise temperature = 80 K



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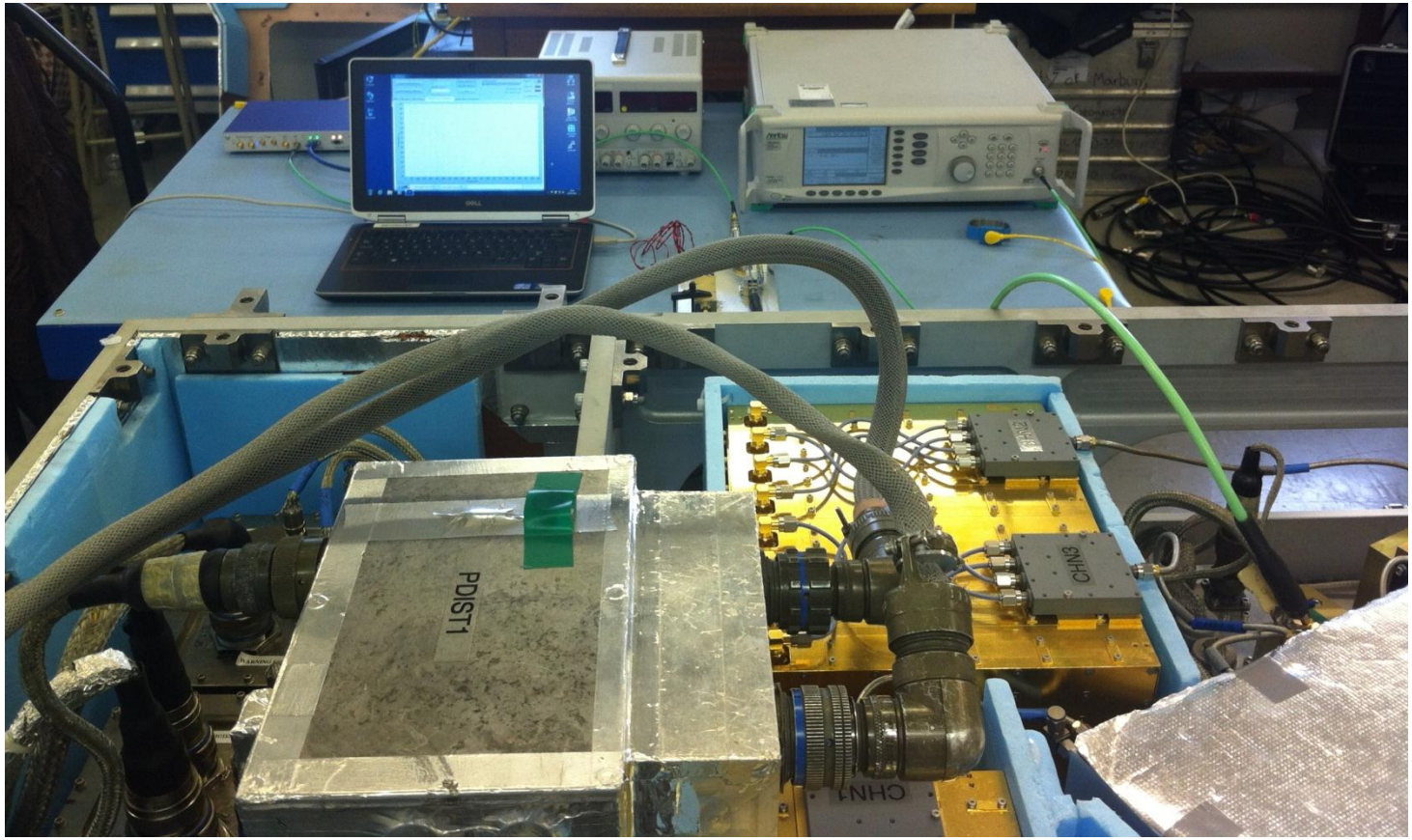
WBS Testing with MARSCHALS (WP2200)



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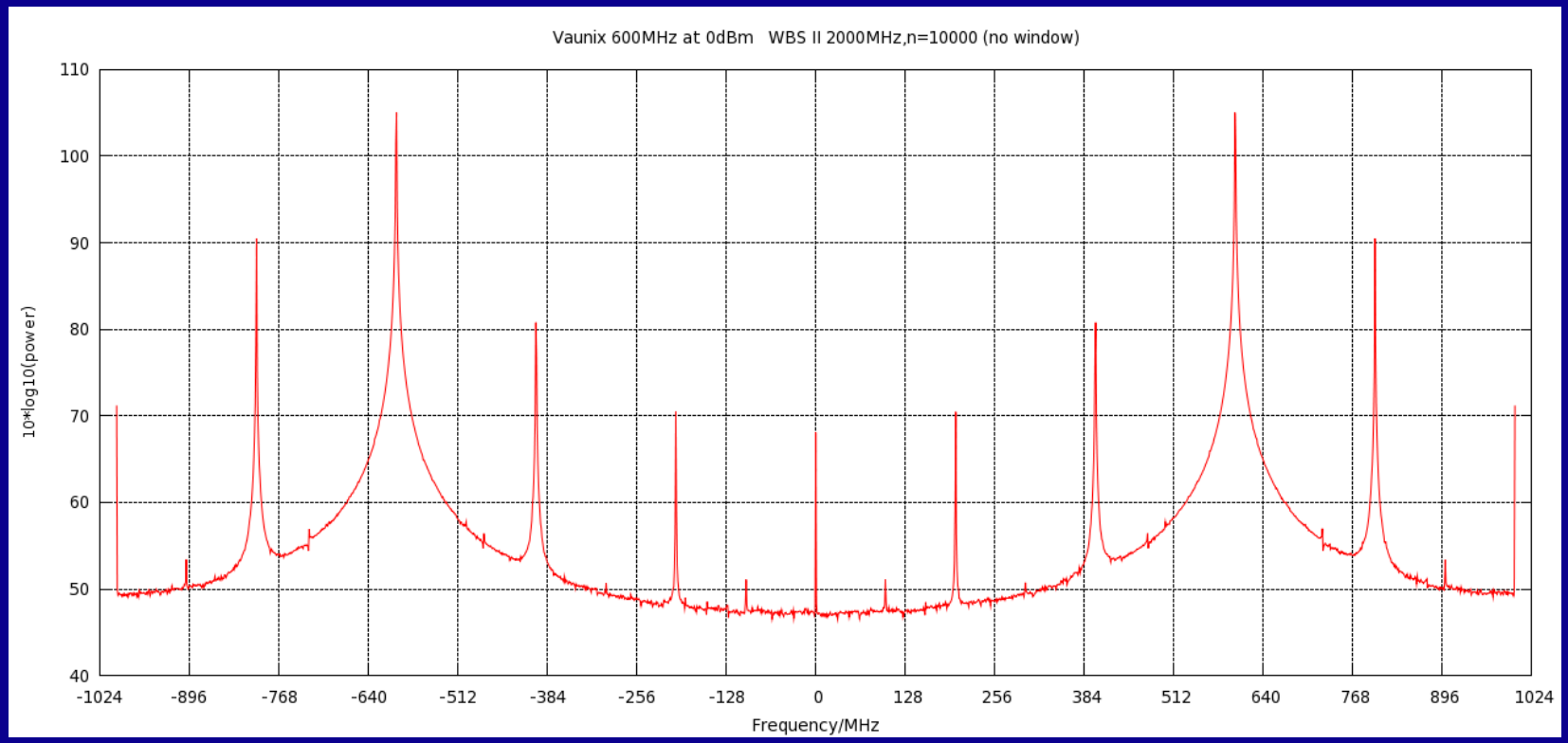
Wideband Spectrometer Initial Results

Preliminary Test Results: FFT running in hardware



Signal fed into I input, Q input = 0
Averaged for 10,000 spectra
Primary signal at 600 MHz (spurs at ~200, 400 & 800)
Clock breakthrough is low (@ 100 MHz)

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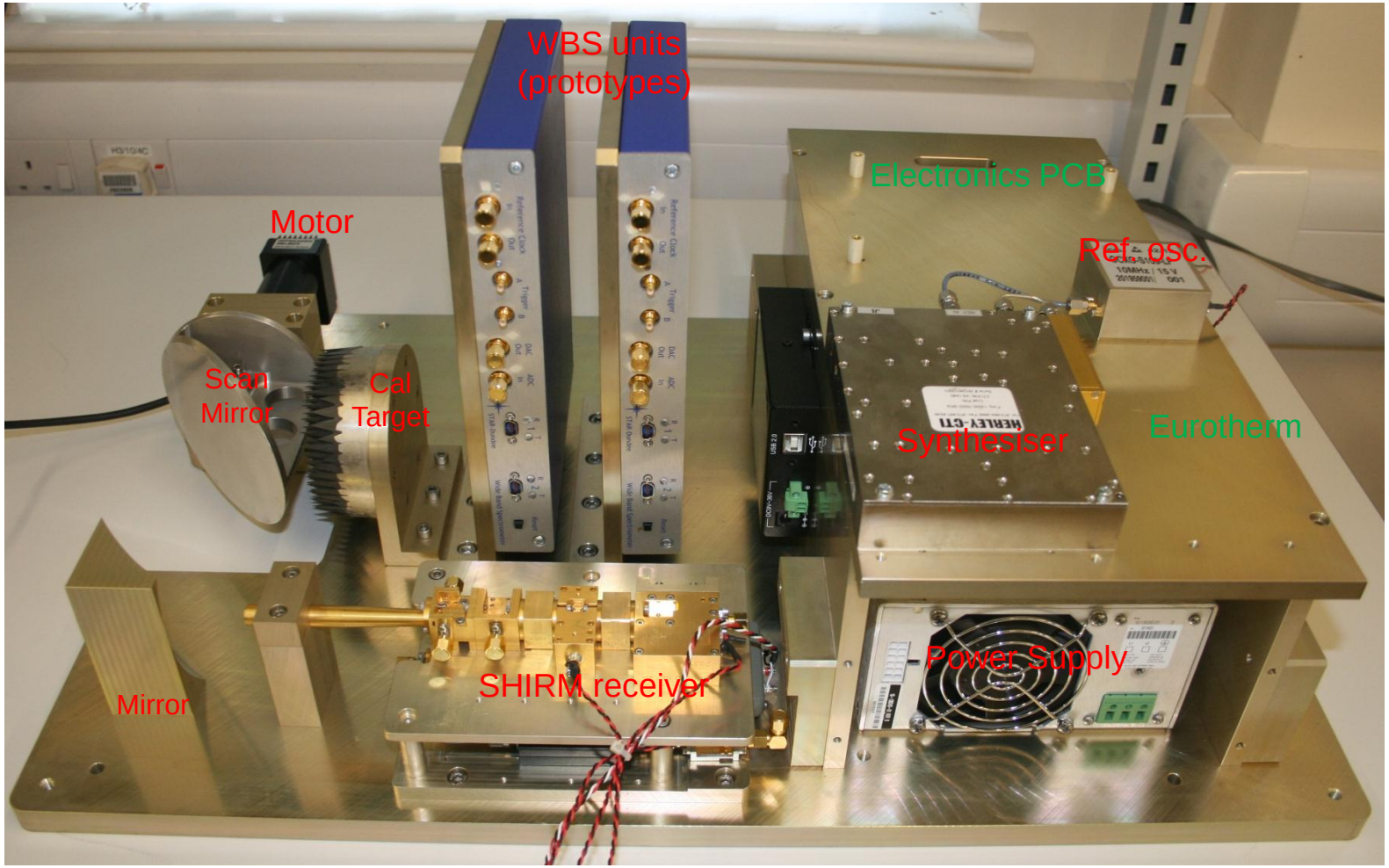
SHIRM-WBS II Breadboard



System Integration

- MARSCHALS
  - Millimetre-wave airborne limbsounding radiometer
  - 3 channels @ 300, 325, 345 GHz (H2O, O3, CO)
  - Currently supporting PREMIER Earth Explorer Mission

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Current Projects

- SpaceWire
  - SpaceWire EGSE
  - SpaceWire Physical Layer Tester
  - Flight SpaceWire chips and IP cores
  - SpaceWire Plug and Play
  - SpaceWire-RT
  - Multi-core processing chip
- SpaceFibre
  - SpaceFibre standard and IP core
  - VHiSSI Very High-Speed Serial Interface
  - High Processing Power Digital Signal Processor
  - Next generation mass memory
- Software Tools
  - Software development tools
  - Flight processor debug tools

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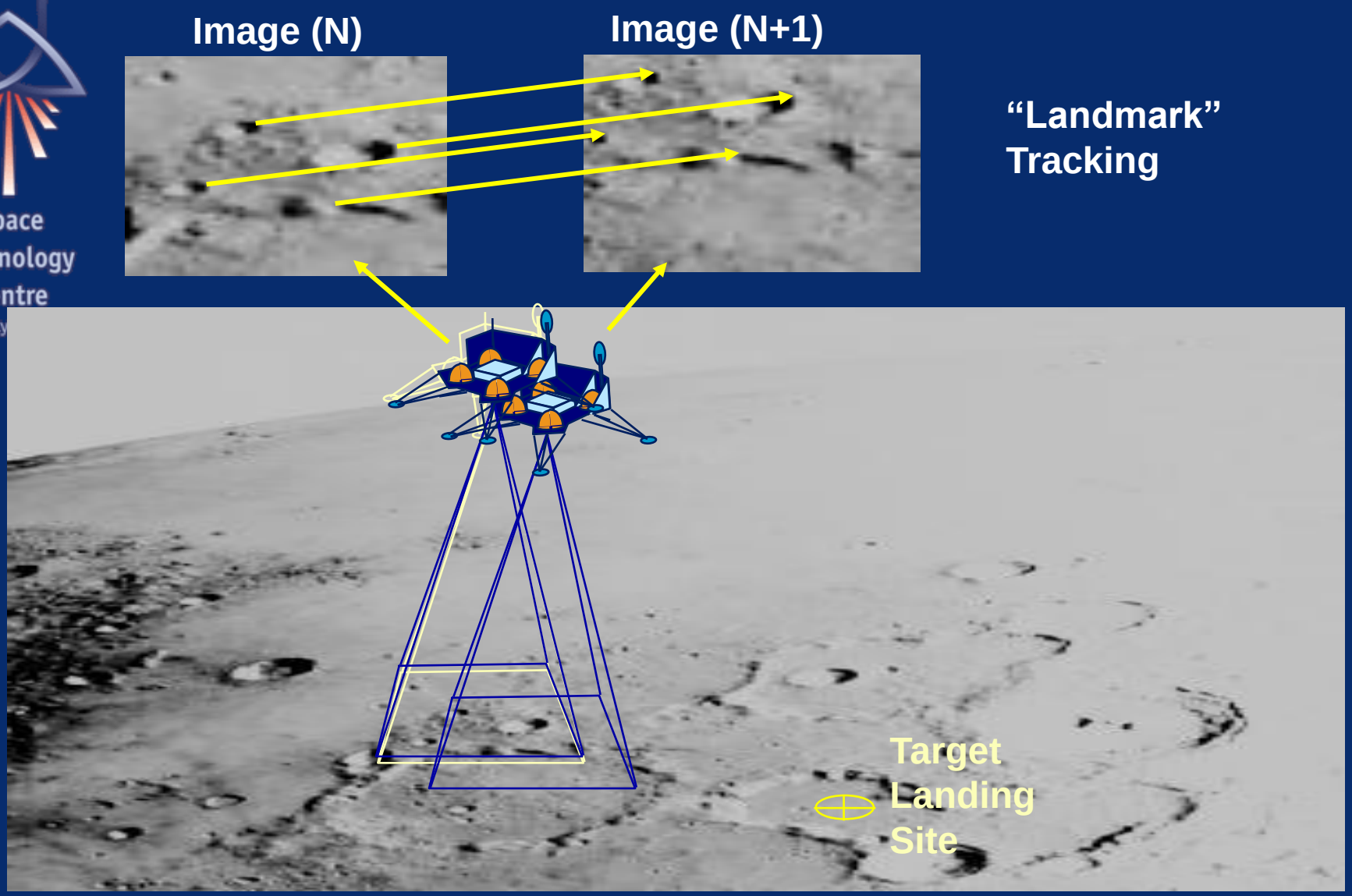
Planetary Landers

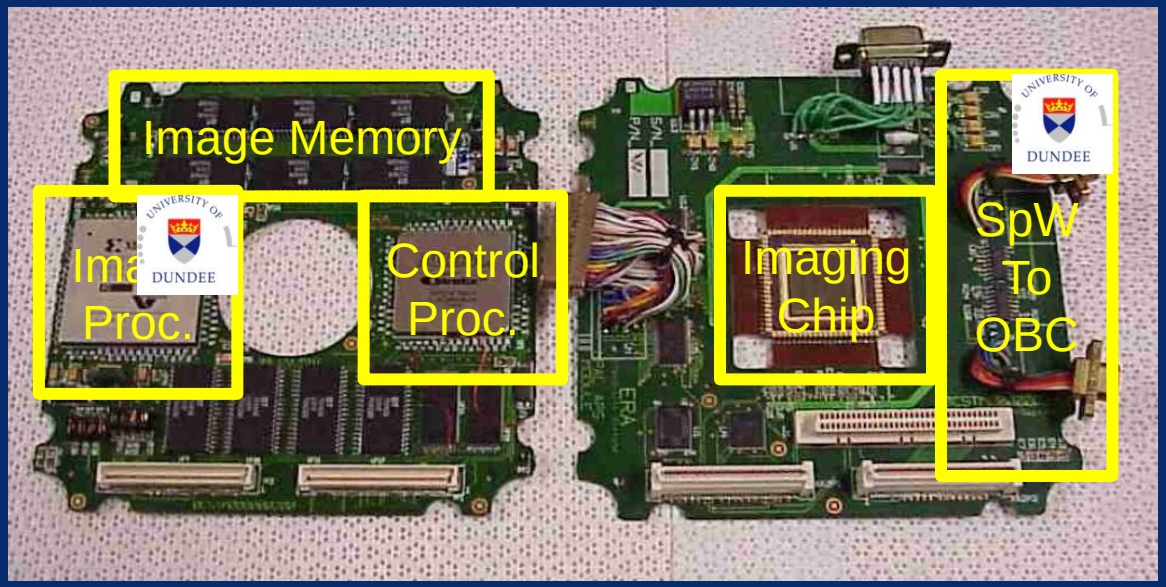
- How to land a spacecraft on a distant planet?
  - Without a pilot on board
  - Long communication delays
  - Precision landing
  - In potentially hazardous terrain
- Robotic pilot
- Eyes of robotic pilot
  - Computer vision
  - Measure spacecraft motion relative to the surface
  - Visual information combined with information from other navigation sensors
  - Used to guide the spacecraft

Feature Tracking



Eyes for Spacecraft Robotic Pilot

- NPAL Camera Prototype
  - Navigation for Planetary Approach and Landing
- Team
  - EADS Astrium (France)
  - Selex Galileo (Italy)
  - University of Dundee



Testing Vision Based Navigation

- Having built a lander navigation system
  - How can we test it?
- Simulation
  - PANGU:
    - Planet and Asteroid Natural-scene Generation Utility
  - Software tool
    - Simulates planets and asteroids
    - Simulates cameras and other sensors viewing those bodies
    - Developed specifically to test vision based GNC algorithms
    - Realistic and high performance
    - Extensively tested and validated so that it can be used for testing space flight systems
  - Being used for lander, rover, orbiter simulation

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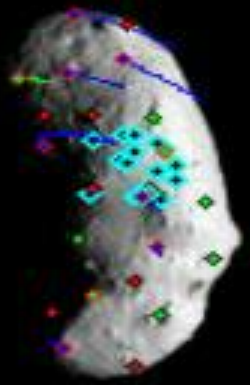

Planetary Landers

- Navigation camera
  - Prototype built and tested
  - Engineering model currently under development
  - Dundee providing image processing chip design
- Test system
  - PANGU simulator designed and built at Dundee
  - Widely used in Europe for testing vision-based navigation systems
    - Descent and landing, e.g. Lunar Polar
    - Asteroid landing, e.g. Marco Polo
    - Rover navigation, e.g. ExoMars
    - Spacecraft rendezvous and docking, e.g. Mars Sample Return

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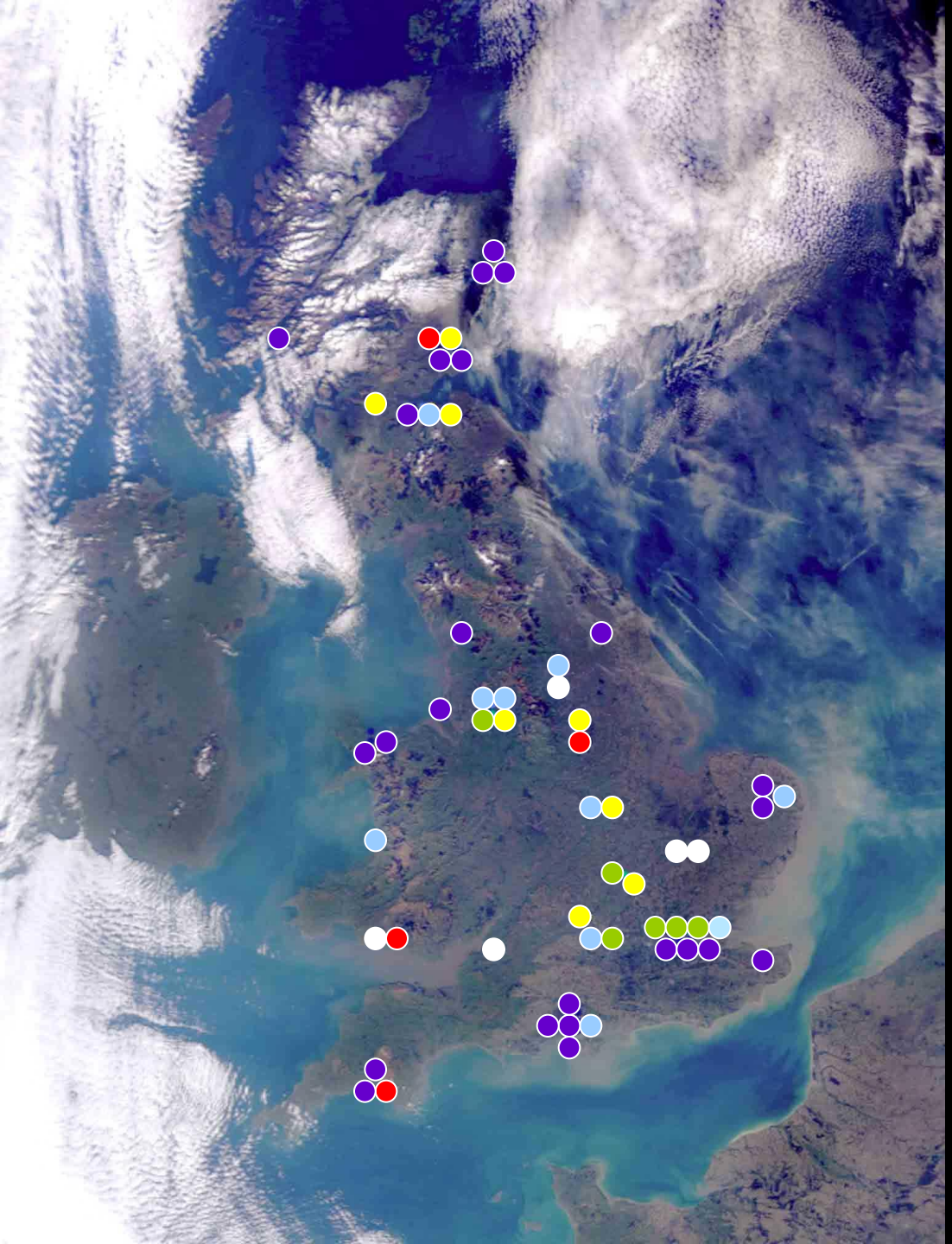
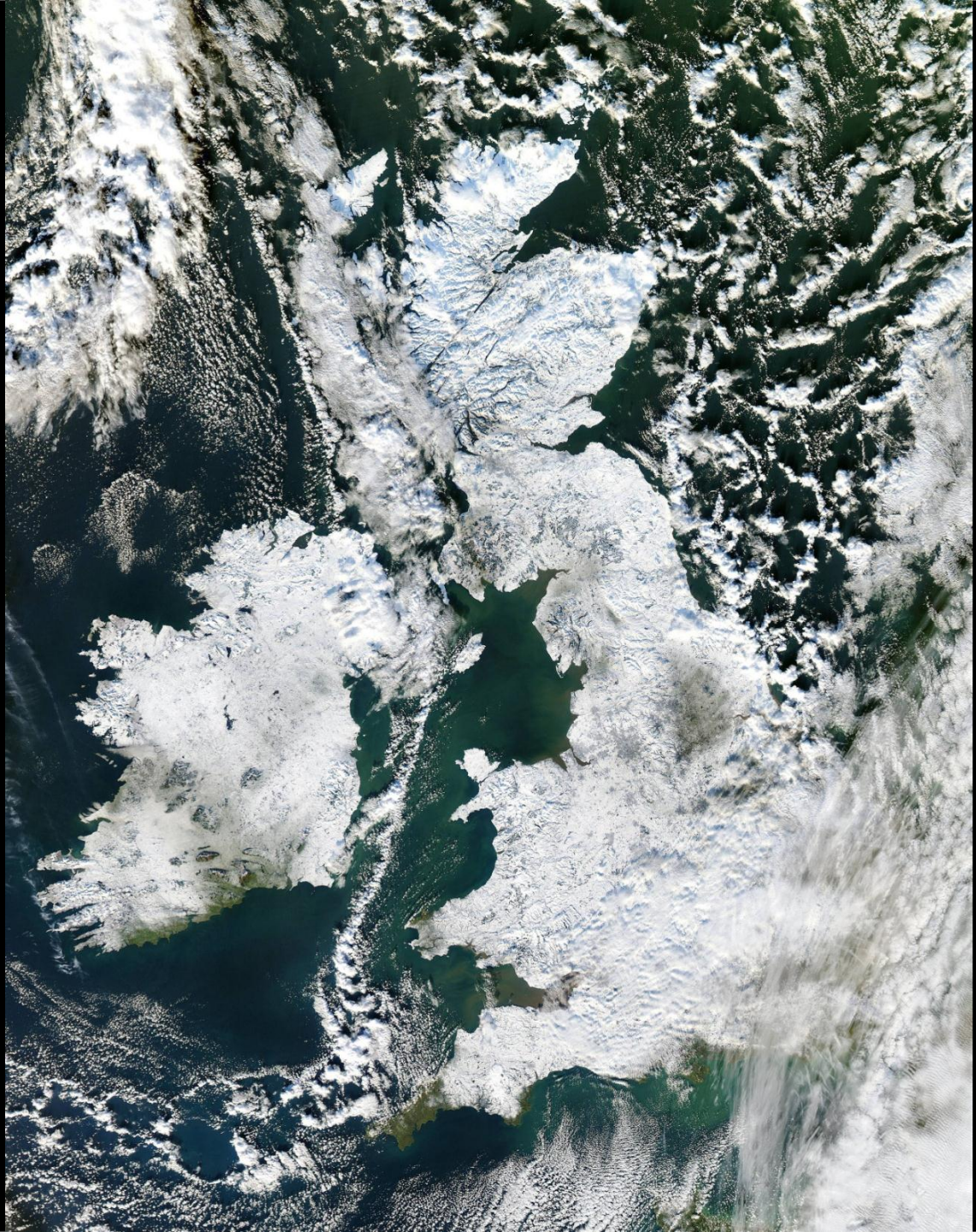
Earth Observation Data Reception

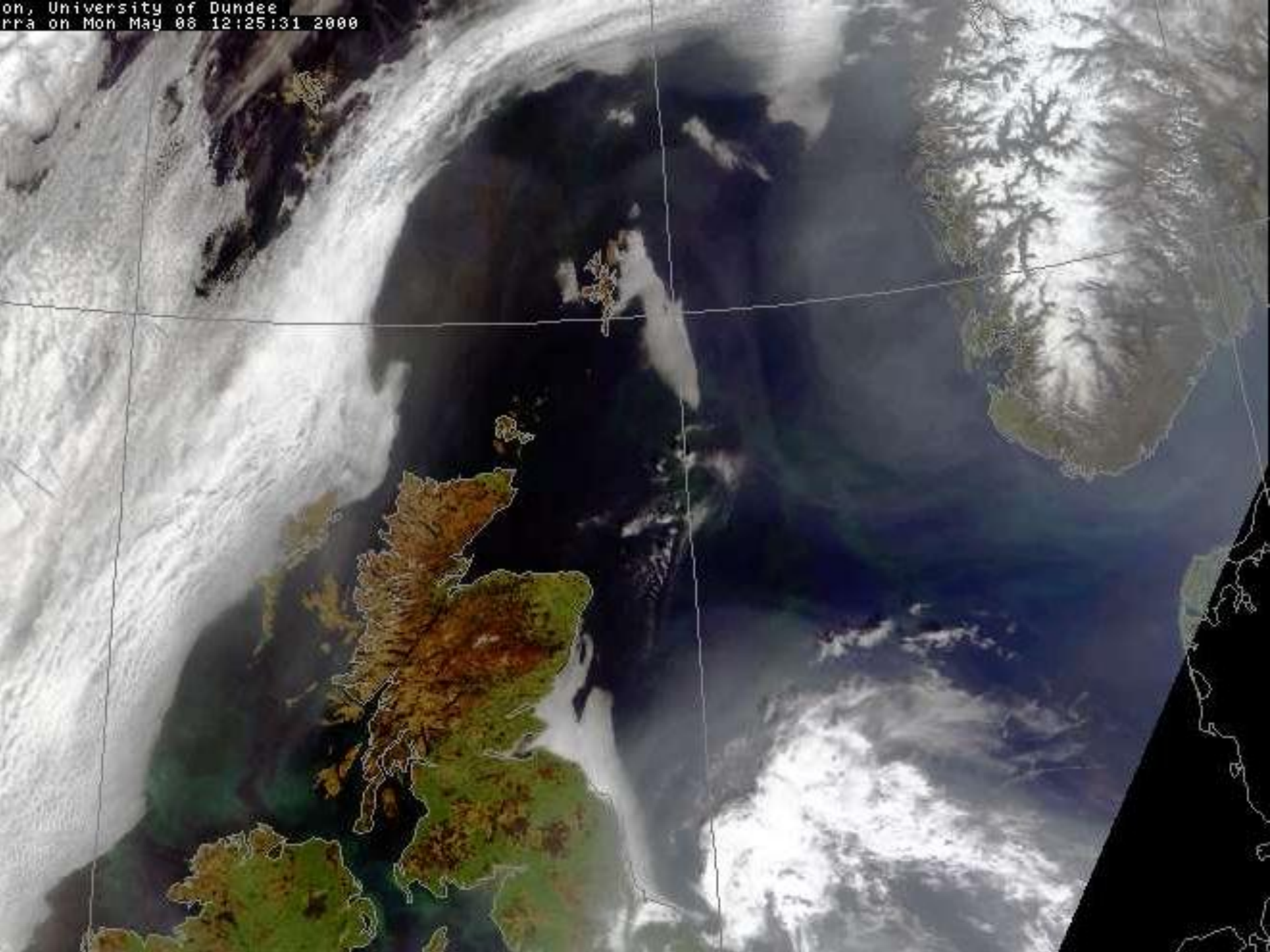
- Dundee Satellite Receiving Station
- One of main receiving stations in UK
- Funded by NERC
  - Natural Environment Research Council
- Part of NEODAAS
  - NERC Earth Observation Data Acquisition and Analysis Service



User community across UK

- Marine
- Atmospheric
- Earth
- Terrestrial & Freshwater
- Polar
- Earth Observation

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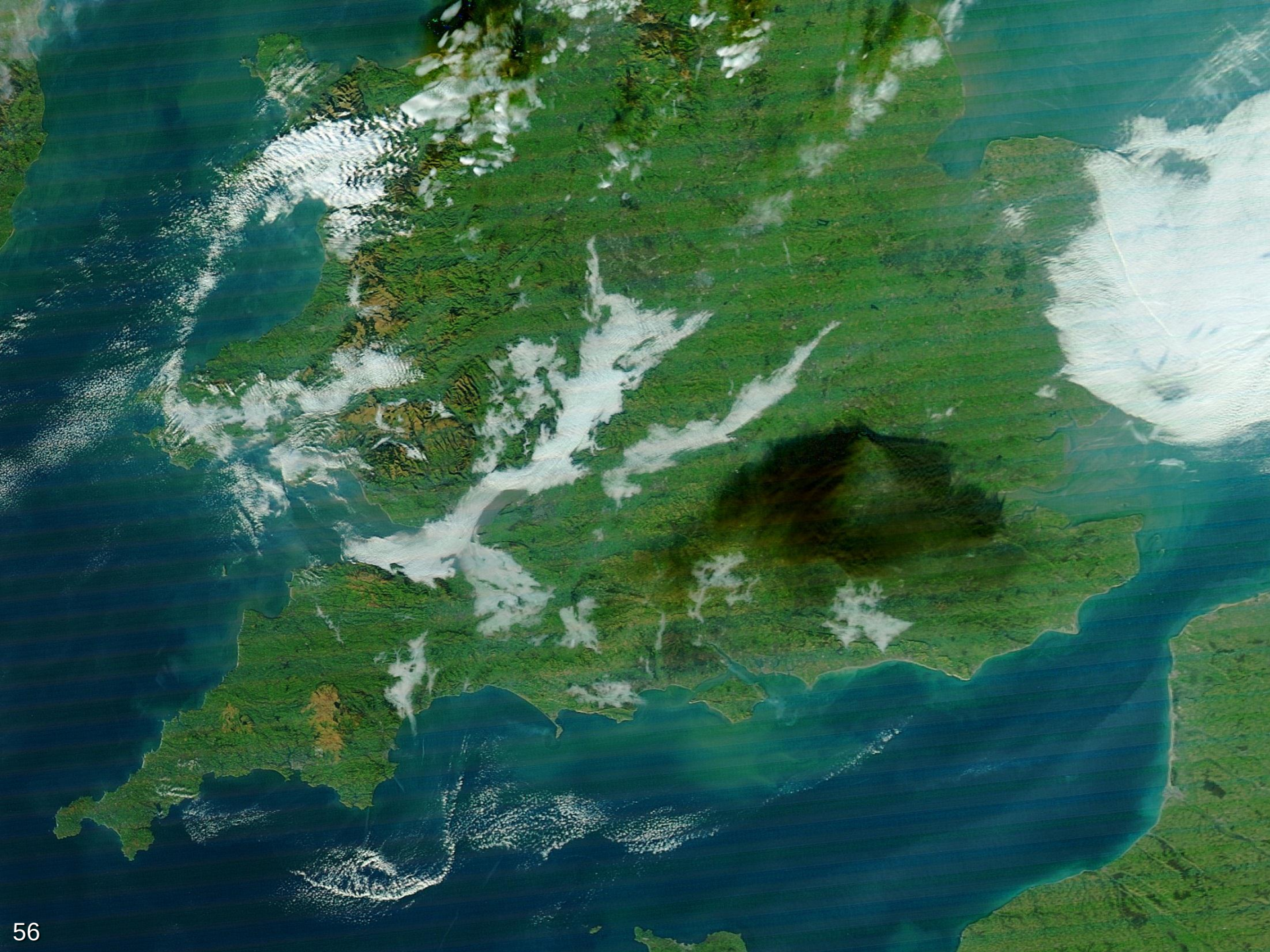

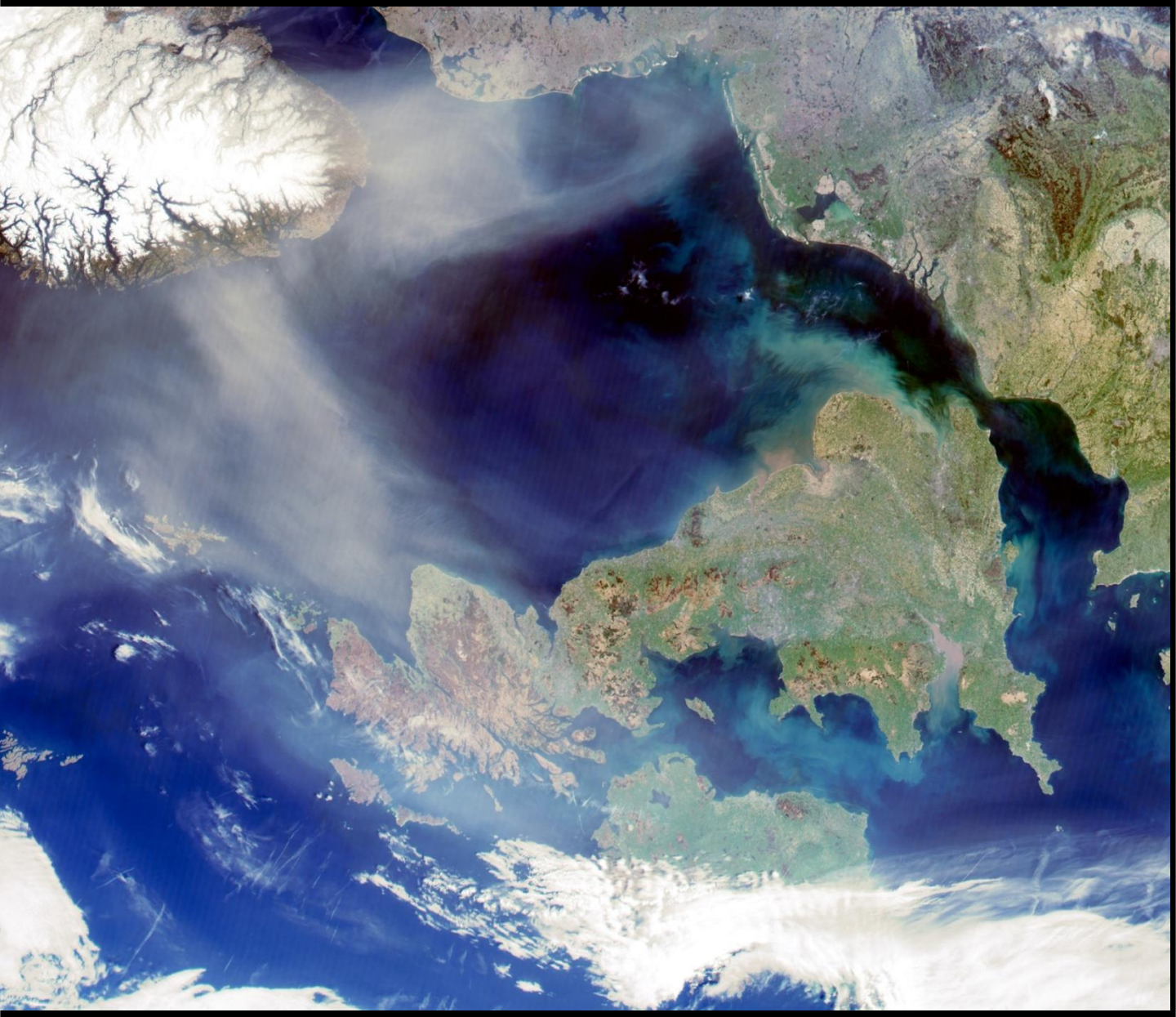

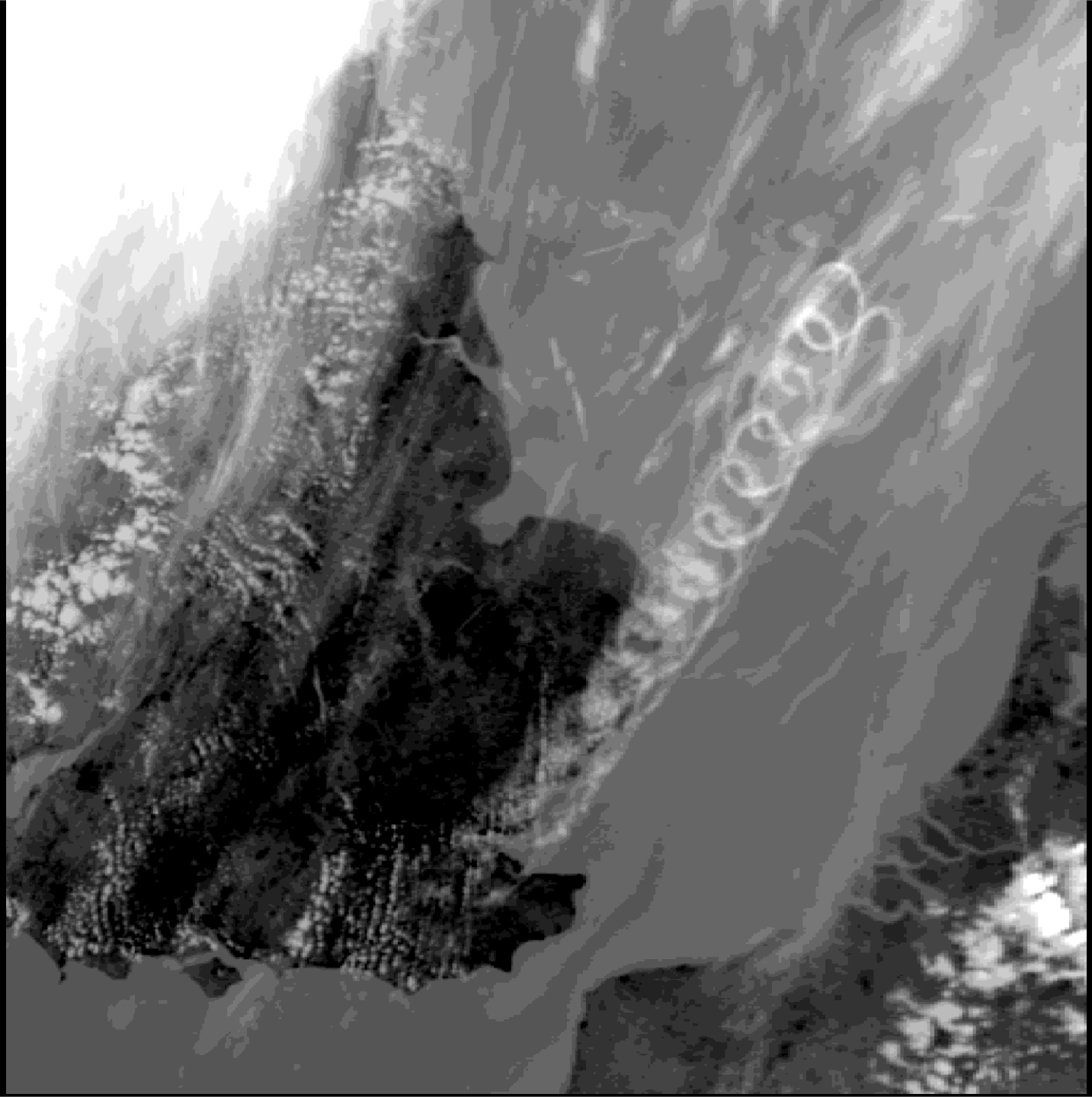

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