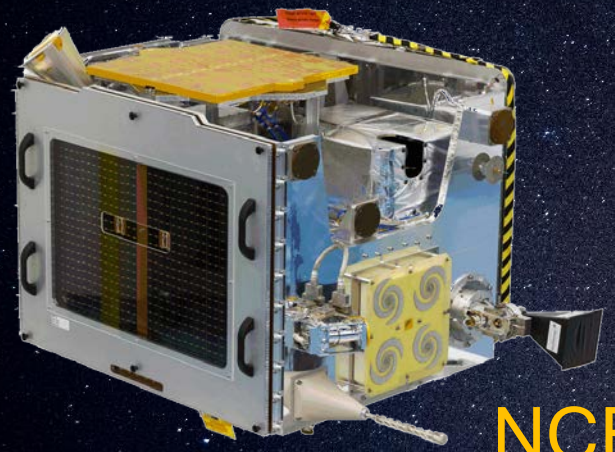
National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

SURREY
CHANGING THE ECONOMICS OF SPACE

esa

GNSS Reflectometry on TechDemoSat-1 and Future Satellites

Martin Unwin, SSTL



NCEO / CEOI Earth Observation Conference 2019
2-5th Sept

#03xxxxxx

© SSTL 2019

ESA Contract: 4000123436
Ack: SSTL, NOC, ESA, Surrey, CEOI, UKSA, InnovateUK, CYGNSS

GNSS Remote Sensing from Space

Weather knowledge more important, globally, than ever before

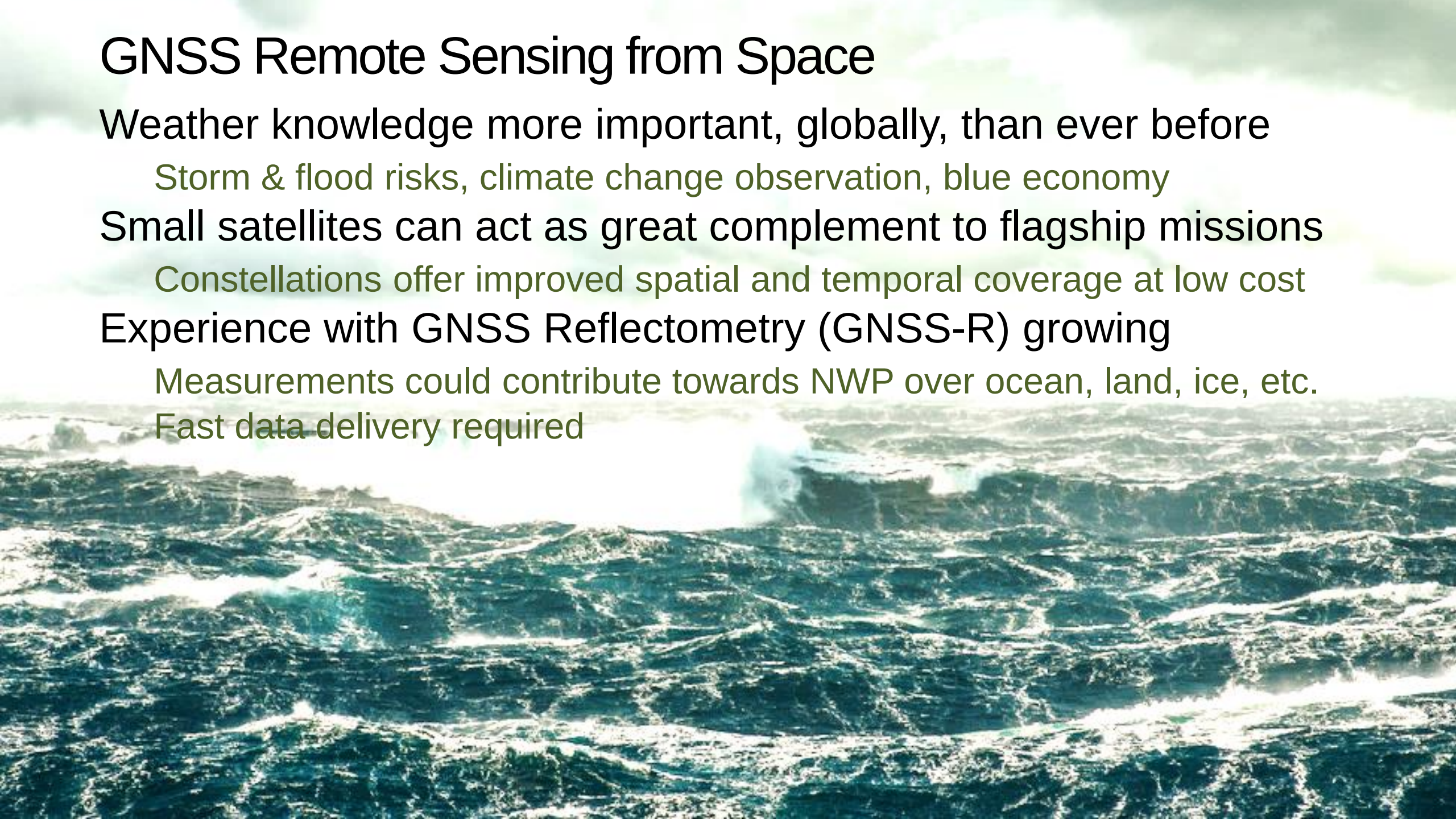
- Storm & flood risks, climate change observation, blue economy

Small satellites can act as great complement to flagship missions

- Constellations offer improved spatial and temporal coverage at low cost

Experience with GNSS Reflectometry (GNSS-R) growing

- Measurements could contribute towards NWP over ocean, land, ice, etc.
- Fast data delivery required

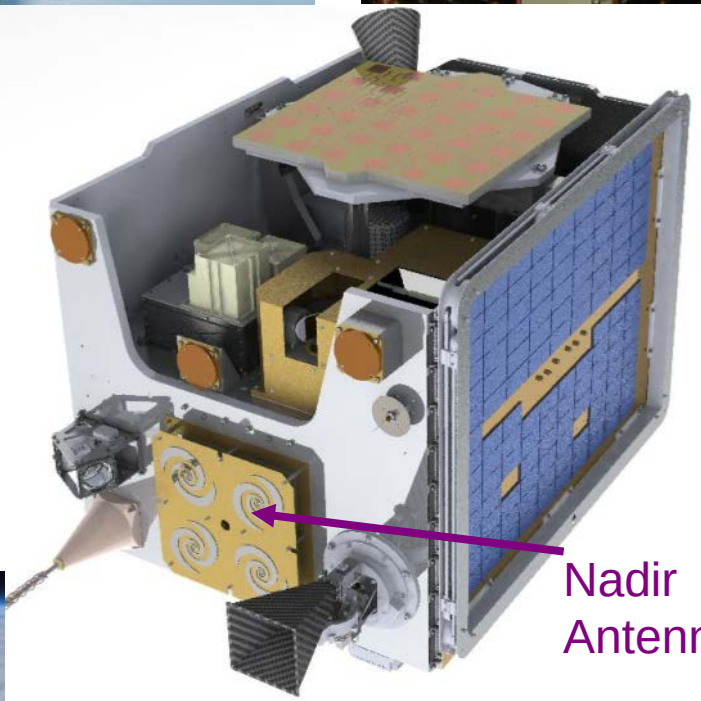


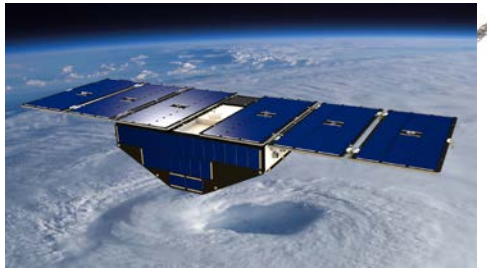
UK TDS-1 and SGR-ReSI

- TechDemoSat-1 Mission (TDS-1)
  - UKSA-sponsored Satellite, approx. 160 kg
  - 8 different payloads from UK
  - Launched July 2014
- **SGR-ReSI – GNSS-R Instrument**
  - COTS Based GNSS Receiver, CEOI project
  - Up and down antennas - using GPS as radar source
  - 5-10 watts, 1.5 kg
- Sponsorship from ESA to exploit experiment on TDS-1
  - Led onto **NASA CYGNSS** project
  - 8 satellites measuring hurricanes using GNSS-R

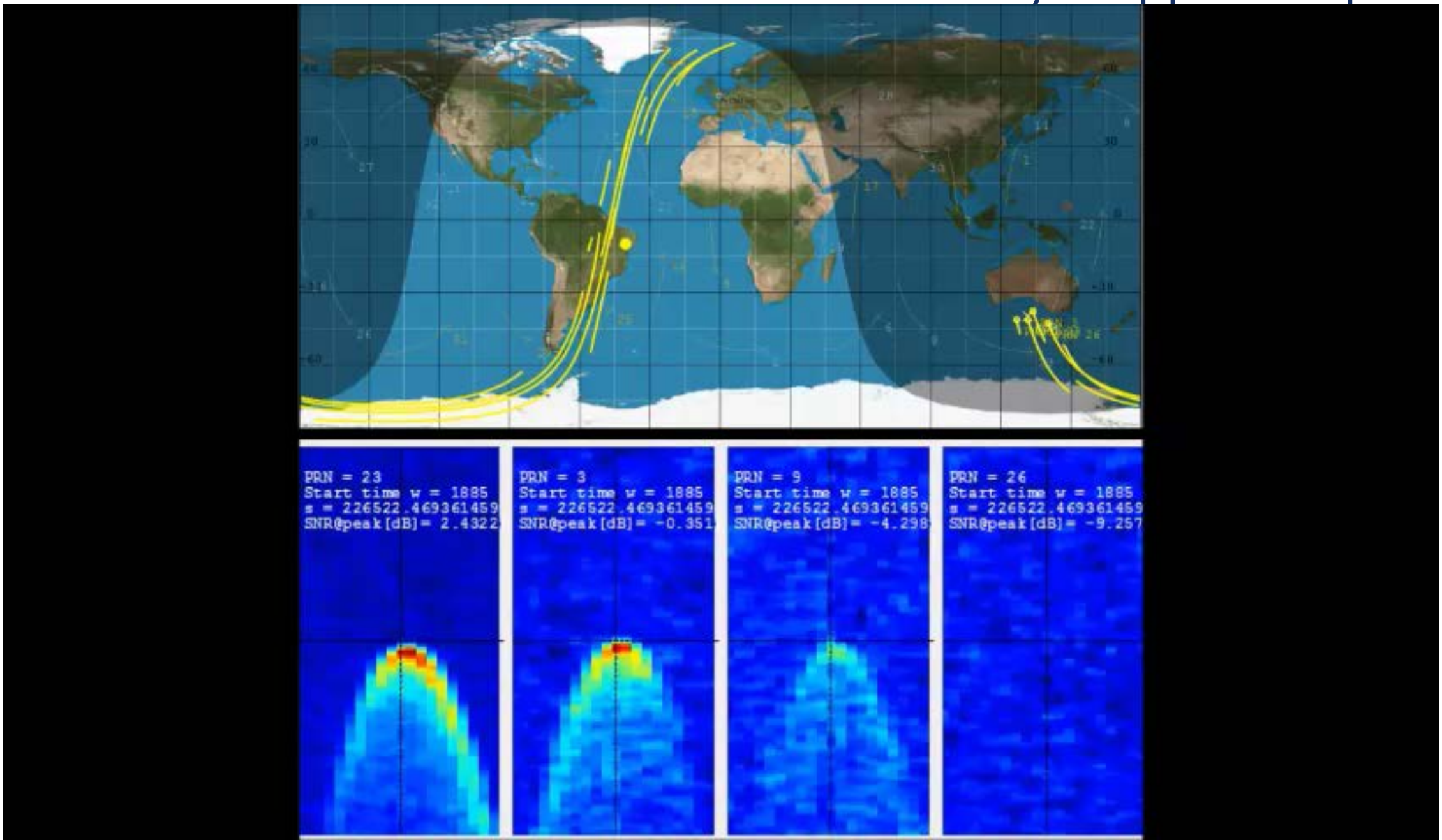
SGR-ReSI Unit

Zenith Antenna

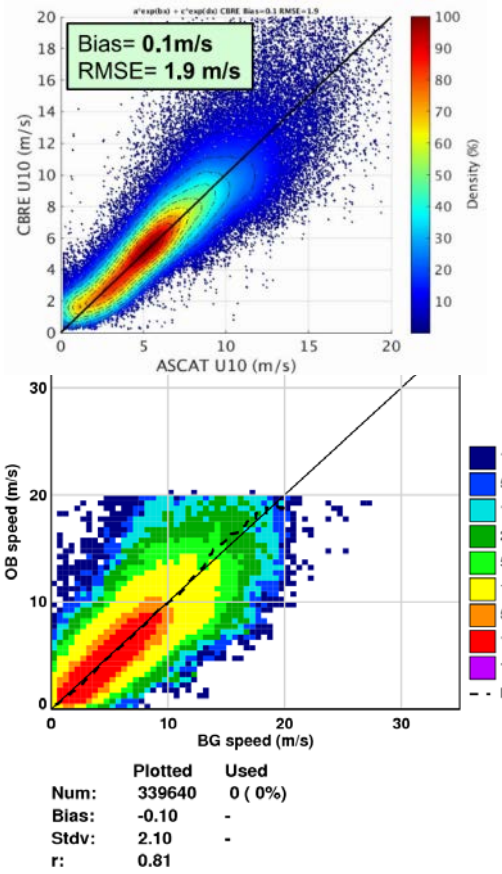




TDS-1 GNSS-R Measurements "Delay Doppler Maps"

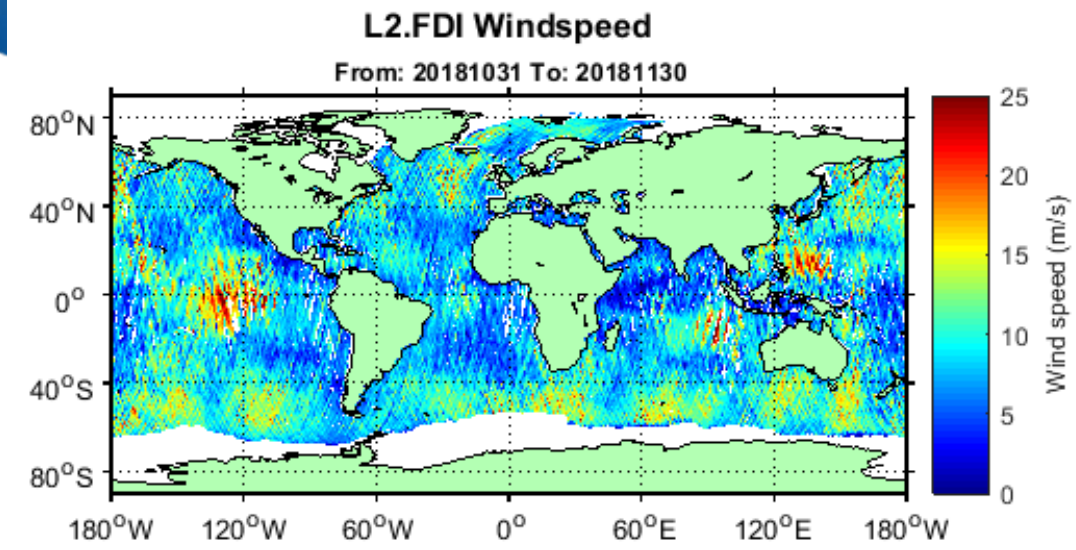


- ESA **TGSCATT** study
  - End-to-end scientific assessment of GNSS reflectometry scatterometric measurements from TDS-1 and data products
  - Seeks to establish the physical relation between GNSS-R signals and ocean wind and roughness properties
- Objectives/tasks
  - Develop simulations and wind speed GMF for GNSS-R
  - Impact analysis on global NWP (O-B, prelim.OSEs & OSSEs)
  - Showed results approached 2 m/s for moderate winds
- Results presented in May 2018 workshop Southampton, UK



Data Access via MERRByS

- www.merrbys.org website for dissemination of GNSS-R data
  - Website and FTP access to netCDF data
  - "**Standard**" and "**Fast**" access to wind speeds
- Also user forum on Google Groups
- Data freely issued - most users have been researchers, scientists, institutions Limited interest from commercial operators

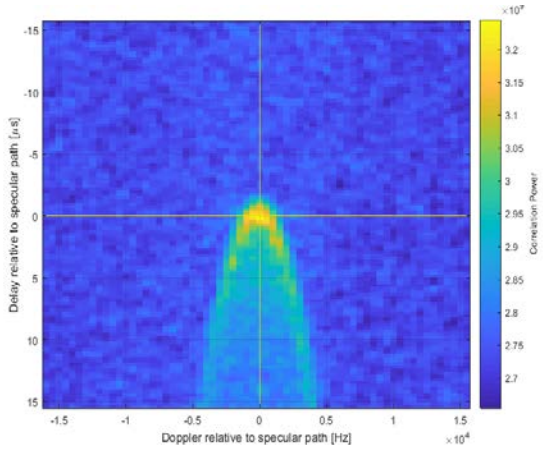


End of TDS-1 – May 2019

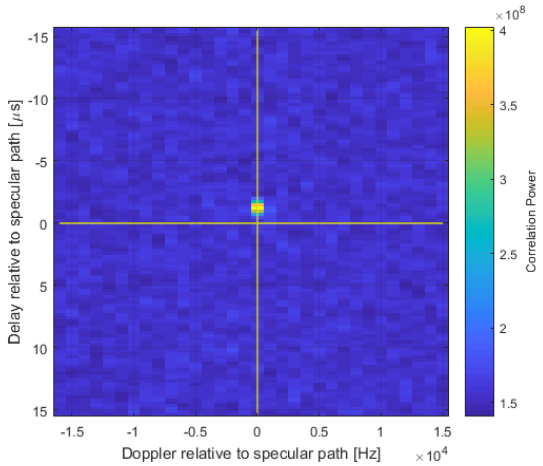
- TDS-1 was granted a 1 year life extension (2018), to support GNSS-R exploitation, but…
- Drag sail was deployed end of May 2019
  - Demonstration sail from Cranfield University
  - Ensures satellite will re-enter within 25 years
  - Image taken of sail on-board
- Last TDS-1 operations

More GNSS Signals Available to Exploit:

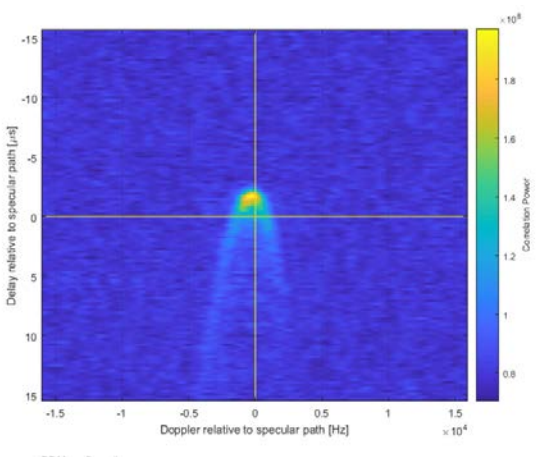
- SGR-ReSI on TDS-1 and CYGNSS only used GPS C/A signals
- Other GNSS signals found in TDS-1 Level 0 raw data
  - Recovered using software receiver on ground
  - Galileo, QZSS, SBAS, GPS III



Galileo E1



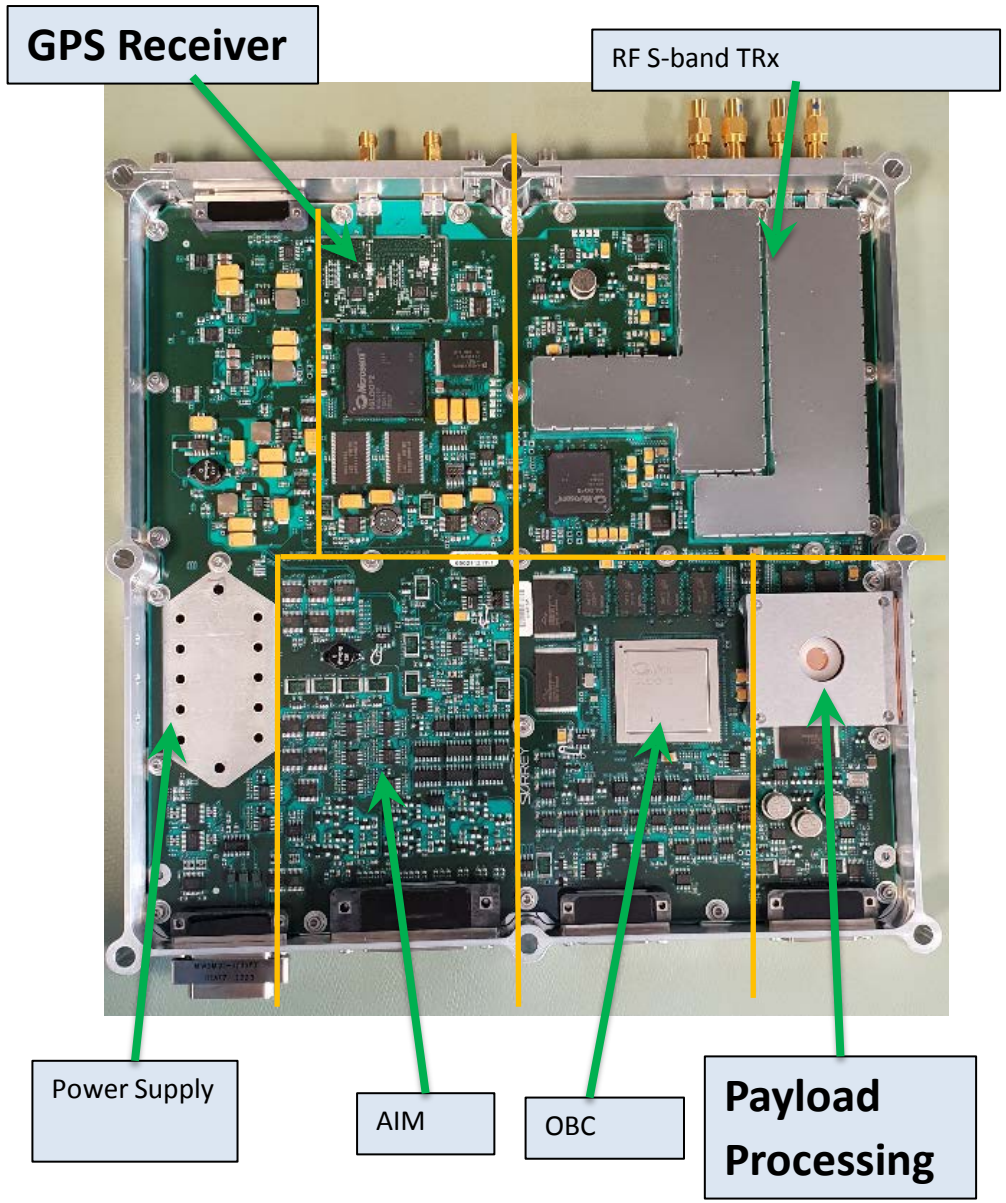
QZSS (Japan)



L1C (GPS III)

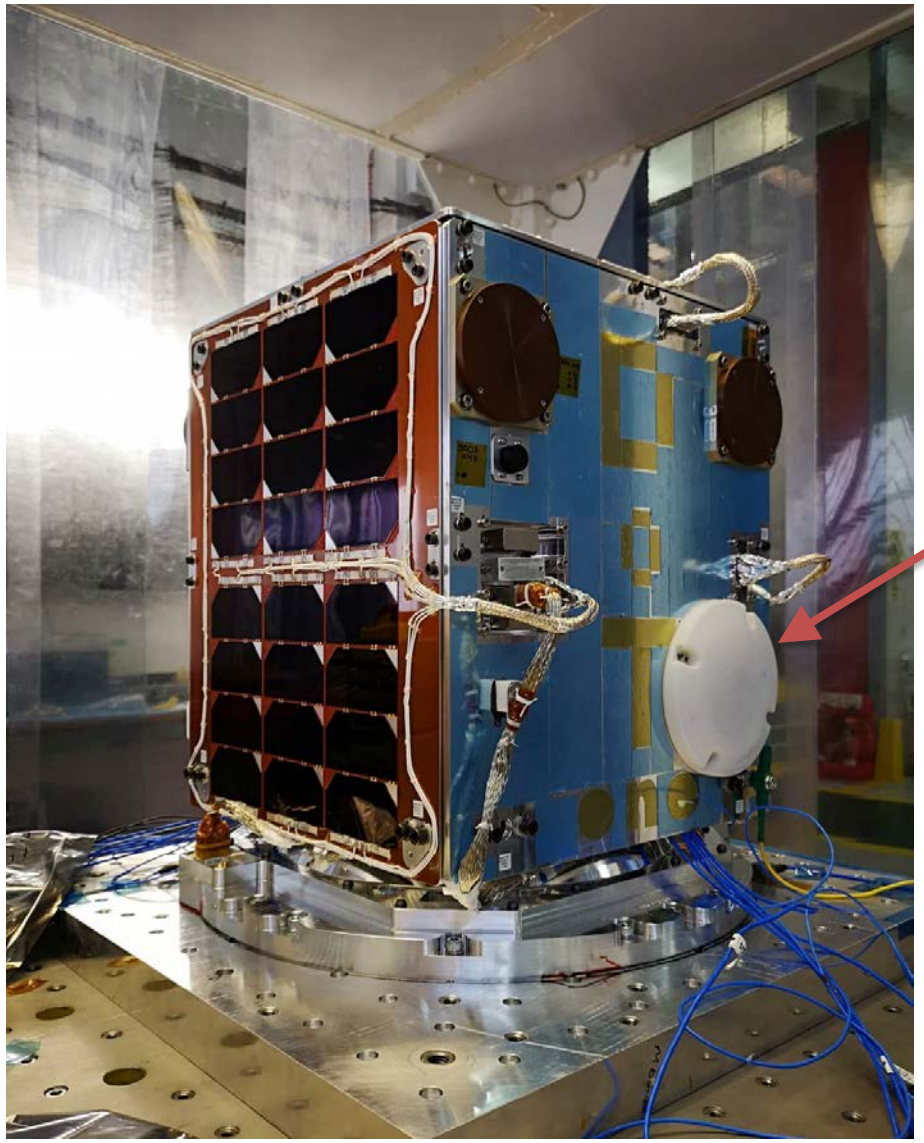
- Other signals to target: Glonass, IRNS, dual frequency, etc.
- Using more signals could increase coverage, increase resolution, allow recovery of coherent measurements (accurate range)
- But – with end of TDS-1, is this last GNSS-R activity?

New SSTL Core Avionics can support GNSS-R



- Core of SSTL's satellite carries SGR-Ligo GNSS receiver
- Dual GNSS front-ends available
- Payload processor could accommodate GNSS/ZTC algorithms
- Just needs nadir antenna

DoT-1 – Avionics Demonstration Satellite

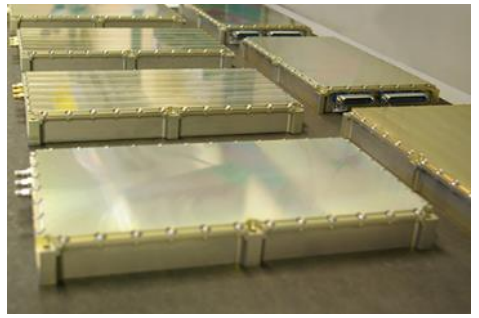


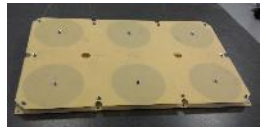
- 21kg SSTL technology satellite
  - Launched end-June 2019
- Main aim is to prove new avionics
- But carries new integrated GNSS- R experimental payload
  - LHCP antenna gain of **8.5 dBi**
  - Wider beamwidth than TDS-1
- ESA study supporting exploitation
  - Part of ORORO study
- Prepare technology for future missions
  - Distribution of GNSS-R data via MERRByS
  - Expand to include on-board Galileo DDMs
  - **Potential to add GNSS-R to all future SSTL satellites**

© SSTL 2018

General Atomics - OTB-3

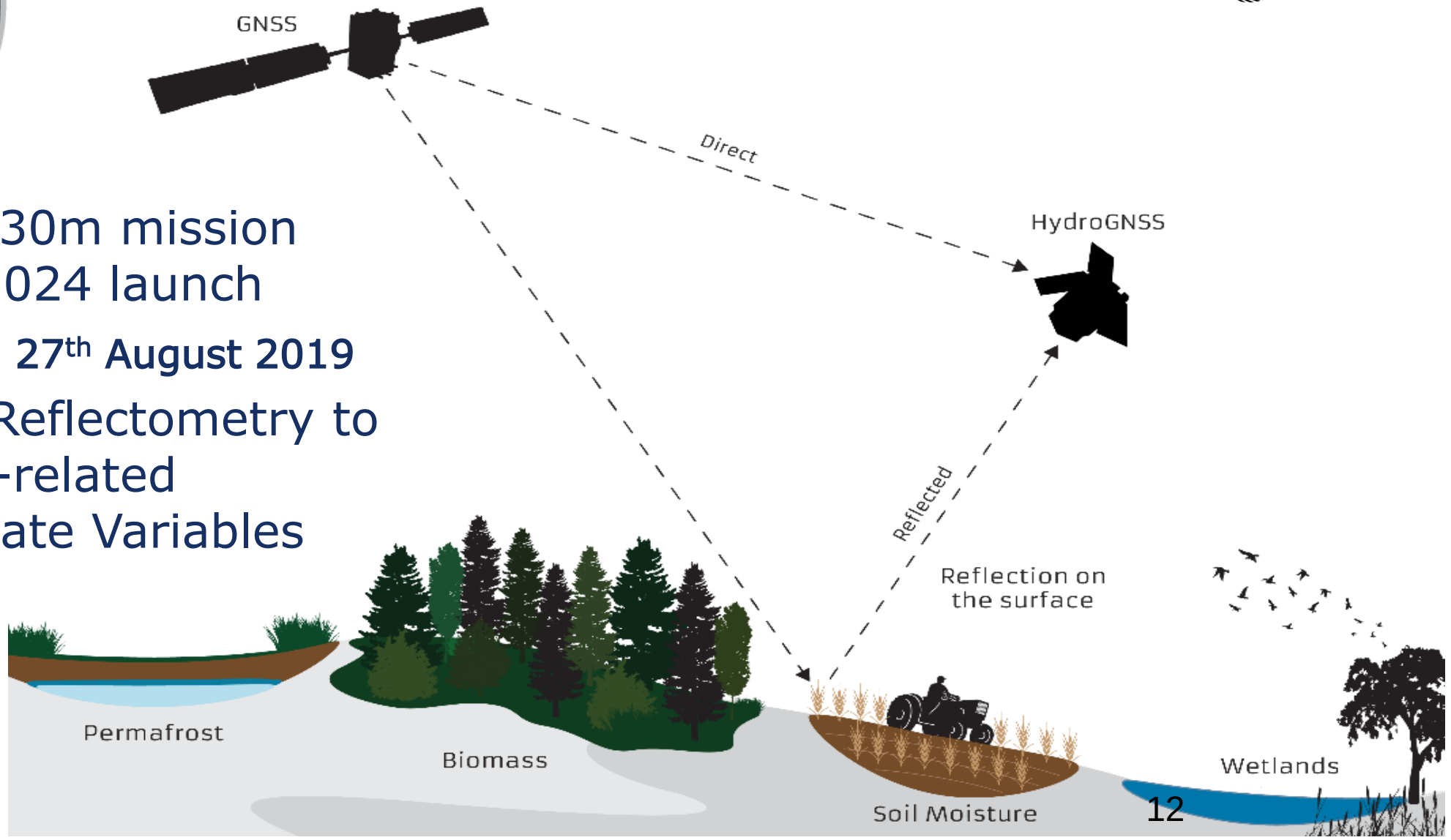
- General Atomics – Electromagnetic Systems (GA-EMS) manufacturing Orbital Test Bed 3 (OTB-3)
- OTB-3, ~110kg, carrying Argos A-DCS
  - Data from transmitters on buoys, wildlife, etc. Payload from CNES, Sponsored by NOAA
- Satellite also to carry SGR-ReSI
  - Former SST-US (US manufacturer of SGR-ReSI) is now part of GA-EMS
  - Using SGR-ReSI in CYGNSS configuration
- Project kicked off early 2019
  - SSTL providing support





ESA Scout bid: HydroGNSS

- ESA Scout - €30m mission opportunity, 2024 launch
- Bid submitted **27th August 2019**
- Use of GNSS Reflectometry to measure land-related Essential Climate Variables



HydroGNSS ECVs

- Essential Climate Variables (ECVs) identified in Global Climate Observing System, GCOS. Four ECVs selected for HydroGNSS:

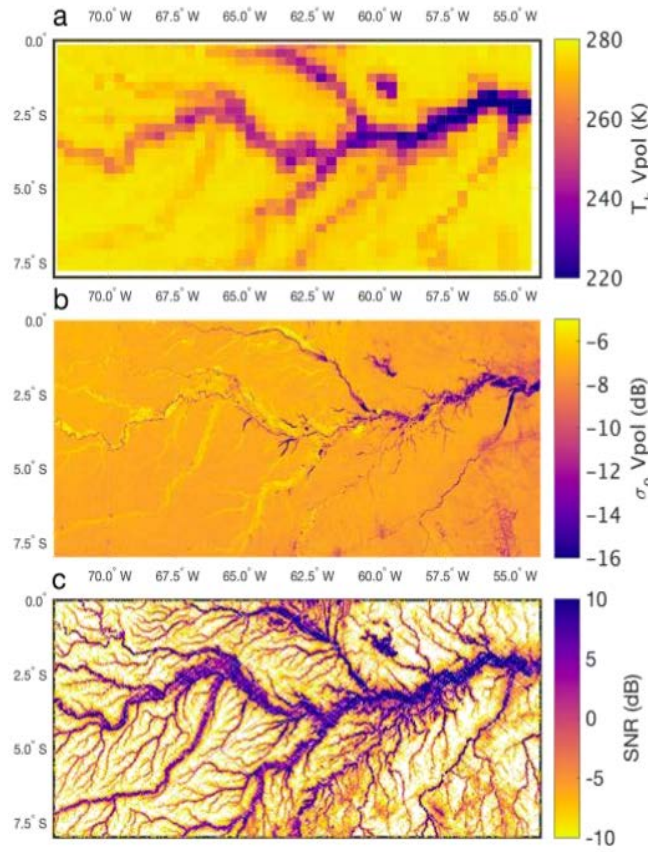
- **Soil Moisture** - vital for weather forecast, climate modelling, agriculture
  - 1-25km res, 0.04 m^3/m^3 uncertainty
- **Inundation / Wetlands** – Methane indicators, agriculture, flood warnings
  - 1-25 km res, 90%
- **Freeze / Thaw** – Permafrost cycles, methane source, CO_2 source/sink
  - 1-25 km res, 90%
- **Biomass** – CO_2 Source/Sink, water & energy exchange with atmosphere
  - 1-25 km res, <20% error, or 10 t/ha for <=50 t/ha

GNSS-R Potential
Compared to SMAP

SMAP Passive

SMAP Active

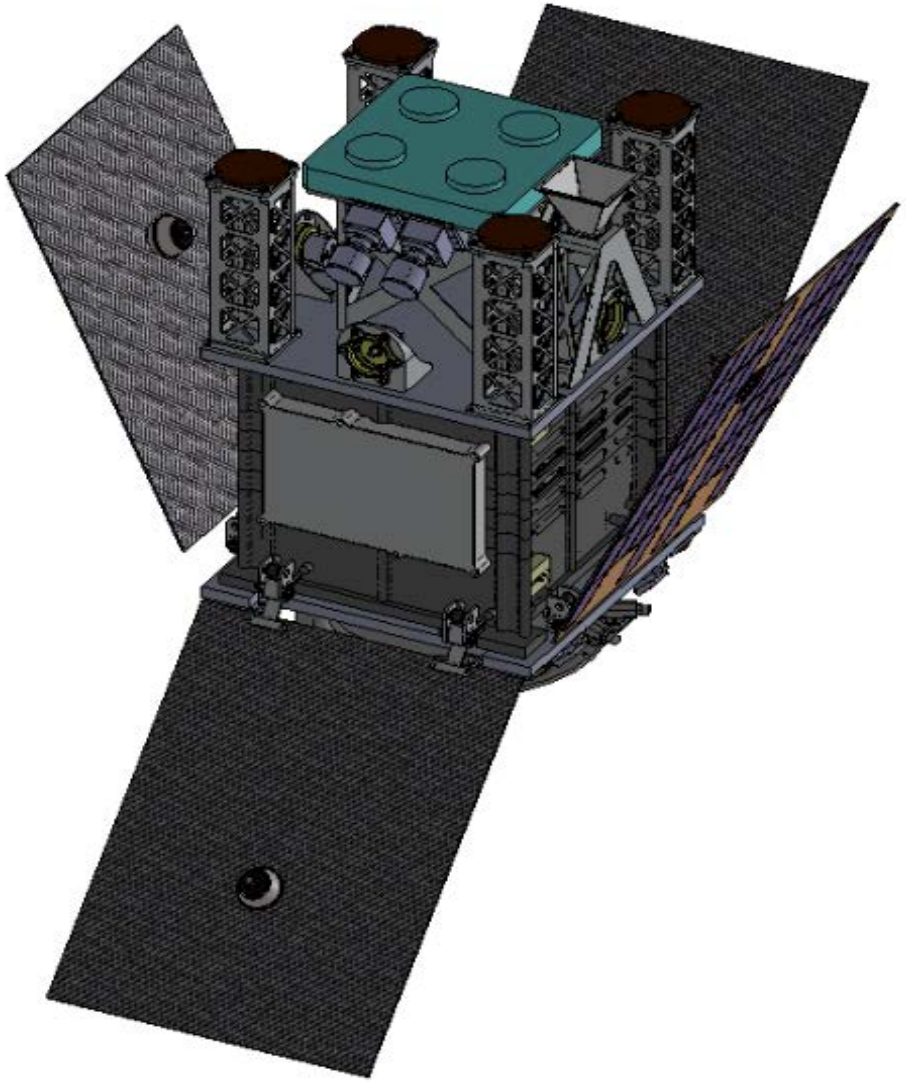
CYGNSS SNR



(Amazon basin, publ. by Clara Chew, UCAR)

HydroGNSS Mission

- Instrument - Upgraded version of SGR-ReSI
  - Same DDMs as TDS / CYGNSS, plus…:
  - Add Galileo E1 capability
    - Increased coverage, wider bandwidth
  - Add dual polarisation antenna
    - Helps separate vegetation from land
  - Add coherent channel (pixel)
    - Very high resolution when coherent
  - Add dual frequency sampling
- Platform – SSTL-Micro(21)
  - 40 kg satellite, high attitude accuracy
  - High data downlink capability, via Svalbard
- Limitation – single satellite demonstrator!
  - Can only get repeat coverage once per month
  - (CYGNSS has 8 in a low inclination orbit)
  - But can add satellites to make constellation



Conclusions

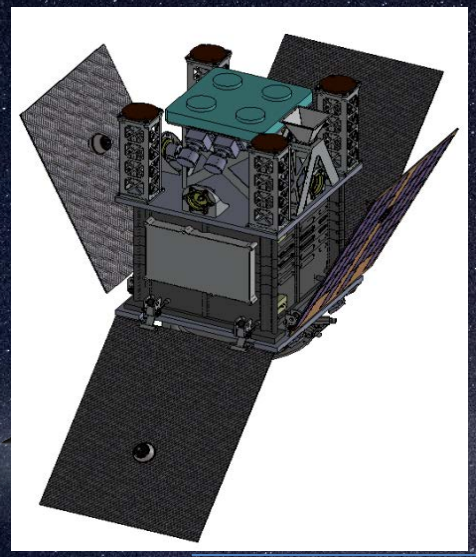
- TDS-1 delivered GNSS-R data and wind service
  - Standard & Fast services, ~ 240 registered data users
  - New signals offering potential – Galileo, etc.
  - But – difficult to pin down commercial case - sparse global data
  - TDS-1 drag sail deployed
- NASA CYGNSS - Successful mission, all 8 satellites still working
  - Showed potential of GNSS-R for land sensing
- DoT-1, SSTL Demonstrator - could lead to low cost hosted payload
- OTB-3 – US mission, SGR-ReSI
- HydroGNSS bid submitted for ESA Scout opportunity
  - Measuring land-related ECVs using GNSS-R, soil moisture, etc.
  - If selected: Study Nov 2019 to May 2020
    - Mission Kick Off Jan 2021

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

SURREY
CHANGING THE ECONOMICS OF SPACE

esa

Thank You



ESA Contract: 4000123436
Ack: SSTL, NOC, ESA, Surrey, CEOI, UKSA, InnovateUK, CYGNSS

MERRBYS

www.merrbys.co.uk

© Surrey Satellite Technology Ltd.
© SSTL 2019
Tycho House, 20 Stephenson Road, Surrey Research Park, Guildford, Surrey, GU27YE, United Kingdom
Tel: +44(0)1483803803 | **Fax**: +44(0)1483803804 | **Email**: info@sstl.co.uk | **Web**: www.sstl.co.uk