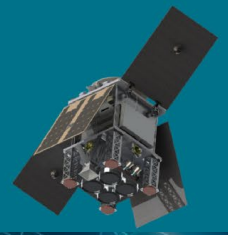
DLR



SURREY SATELLITE TECHNOLOGY LTD

esa

esa hydrognss

living planet symposium | BONN 23–27 May 2022

SSTL is supported by a team of Science partners, comprising:

FINNISH METEOROLOGICAL INSTITUTE

Institute of Space Sciences CSIC IEEC

IFAC

National Oceanography Centre

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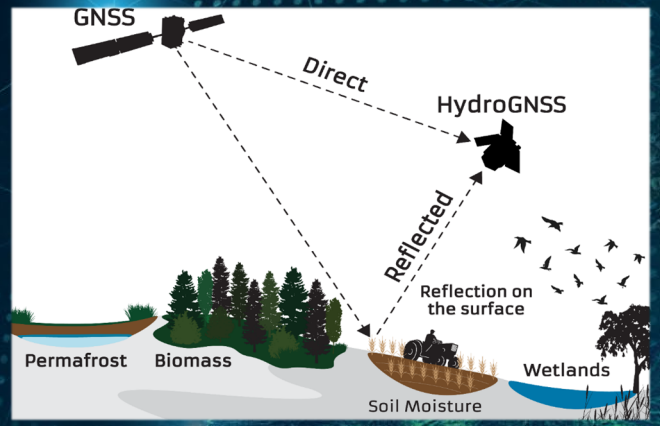
SAPIENZA UNIVERSITÀ DI ROMA

TOR VERGATA UNIVERSITÀ DEGLI STUDI DI ROMA

University of Nottingham UK | CHINA | MALAYSIA



TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

Preparations for the Scout-2 HydroGNSS Mission

Martin Unwin, Pete Garner, Serena Donati, Reynolt De Vos van Steenwijk, Jonathan Rawlinson, Nazzareno Pierdicca, Estel Cardellach, Kimmo Rautiainen, Leila Guerreiro, Emanuele Santi, Giuseppe Foti, Paul Blunt, Jean Pascal Lejault, Massimiliano Pastena

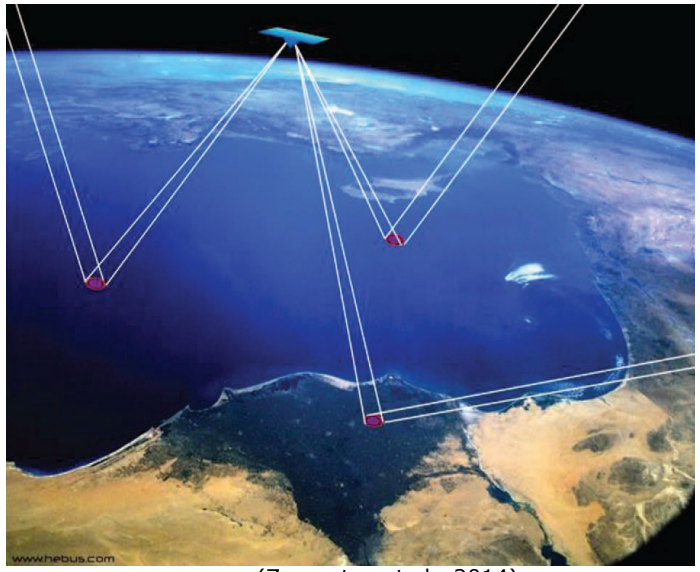
B7.01 Scout: ESA NewSpace Science Missions. Wed 25th May 2022

European Space Agency - Scout Programme

- New initiative from ESA's Earth Observation directorate
- Small satellite missions, demonstrating science with small budget and rapid schedule
- Missions fully funded by ESA, characterised by an agile and low-cost development process to prove new concepts for future ESA endeavours
- Aiming to tap into New Space approach to achieve a launch within 36 months after KO, budget < €30m
  - Managing higher risks, use of COTS components, reuse of existing designs, lower cost, faster to service
- Free, full and open data, delivered using service-based approach
- **HydroGNSS** selected as one of first two Scout missions in Feb 2021
  - Project kicked off, October 2021

GNSS Reflectometry Concept and Heritage

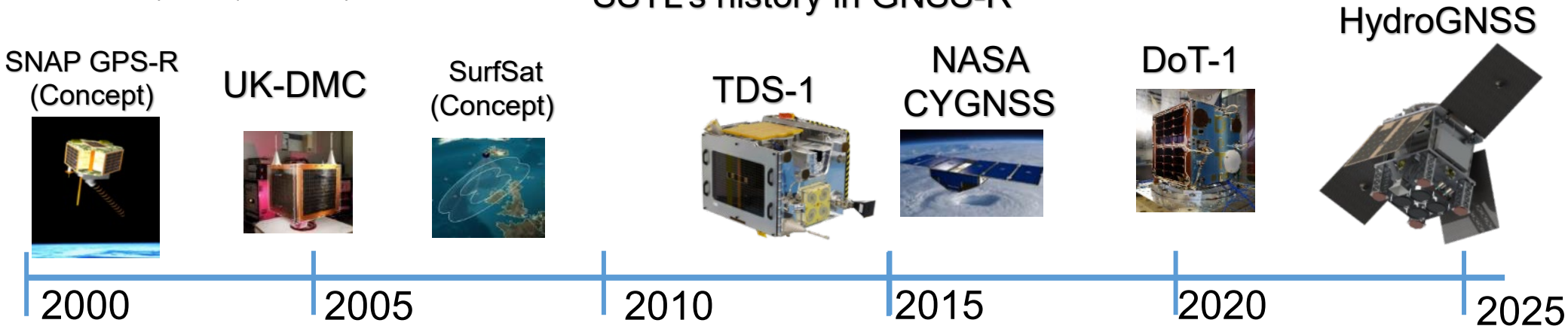
GNSS Reflectometry (GNSS-R) surface reflections collected from LEO of *Global Navigation Satellite Systems*, including GPS and Galileo



(Zavorotny et al., 2014)

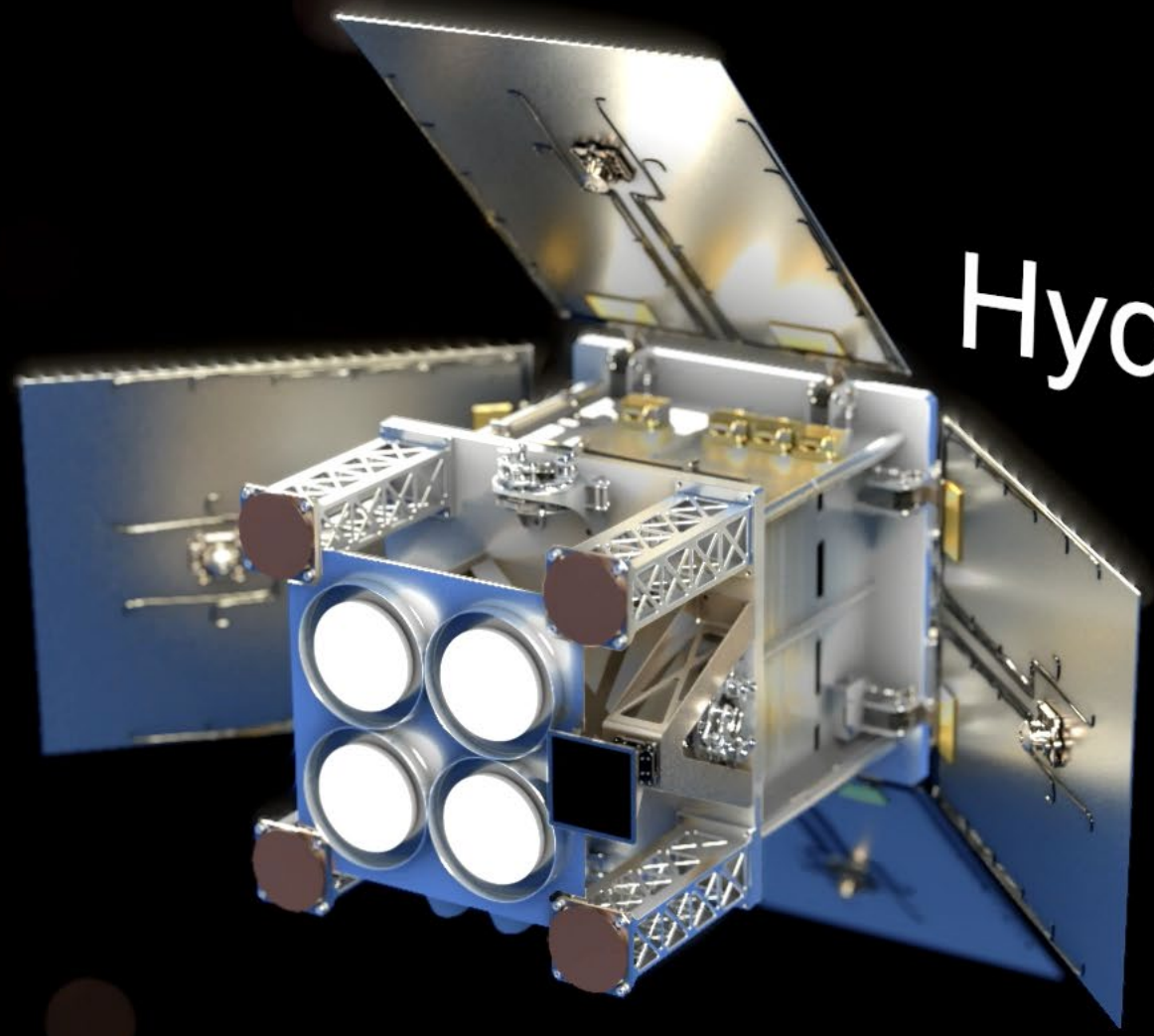
- >100 sources of L-Band signals in orbit
- Forward specular reflection, i.e. bistatic radar
- Early concepts led to key in-orbit demonstration on TechDemoSat-1, CEOI and UKSA funding,
- Subsequent support from ESA, showing:
  - Ocean wind and wave sensing
  - Sea ice extent and ice concentration
  - Land – now addressed by HydroGNSS

SSTL's history in GNSS-R



Importance of Hydrological Knowledge

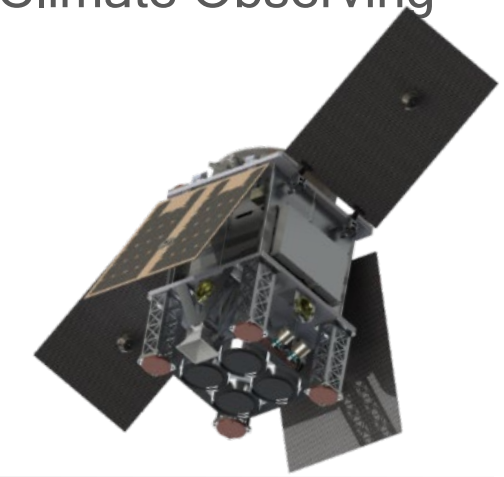
- Water: natural resource vital to climate, weather, life on Earth
  - Present *on* or *in* land in form of soil moisture, wetlands and rivers, snow and ice, and vegetation
  - World Economic Forum identifies land water-related issues as amongst greatest challenges facing population for future
- Global knowledge of land water vital
  - Soil moisture (weather, agriculture, storage in land, subsidence)
  - High latitude permafrost (methane emissions, climate impact)
  - Biomass (carbon stock, biodiversity, fire disturbances)
  - Inundation (Flooding, wetlands, methane emissions, biodiversity)
- Models need measurements for understanding and predictions, planning for the future, tackling climate change
  - Earth System Models (ESM) – for climate
  - Numerical Weather Prediction (NWP) – for weather
- Monitoring outcome of actions taken following COP26 pledges

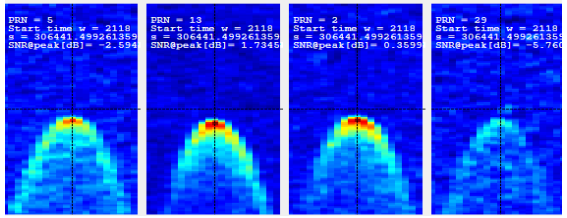


HydroGNSS

HydroGNSS Mission & Science Objectives

- Exploit L-band satellite navigation signals to monitor Earth's water systems to a finer resolution and derive measurements linked to ECVs defined by the Global Climate Observing System.
- **Soil Moisture**
  - Requirement 0.08 m^3/m^3, Goal 0.04 m^3/m^3
- **Inundation,** also wetlands
  - Requirement 90% classification
- **Soil Freeze/Thaw state,** incl. permafrost regions,
  - Requirement 90% classification
- **Forest Biomass**
  - Requirement 30%, goal 20%
- **Resolution** requirement 25 km, goal 1 km
  - Achievable resolution expected strong dependency on signal coherency
- (Secondary objectives) **Ocean wind speed and ice extent**
- Level 2 and Level 1 (**Delay Doppler Maps)** will be made freely available
- Timeliness – 31 days standard and <7 days goal for faster service, view towards <24 hours
- Coverage – >80% of globe in 30 days
- Requirements captured in MRD - more on science in subsequent presentation

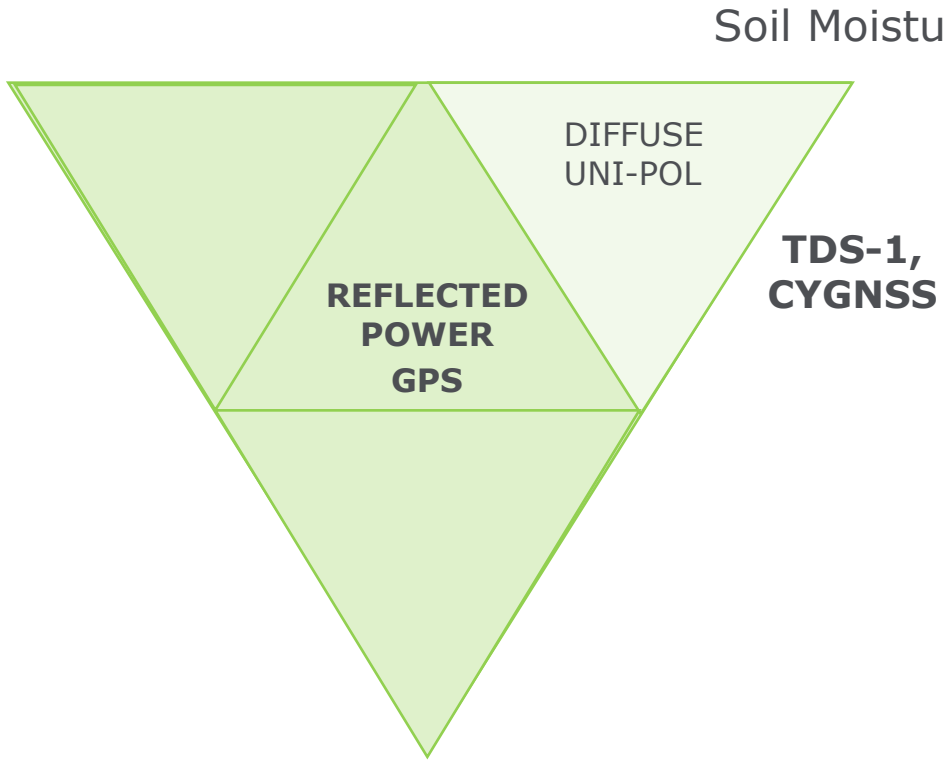




HydroGNSS offers New Technology and Measurements

Established GNSS-R Approach:

- Incoherent Delay Doppler Maps (DDMs) from GPS L1 at 1 Hz



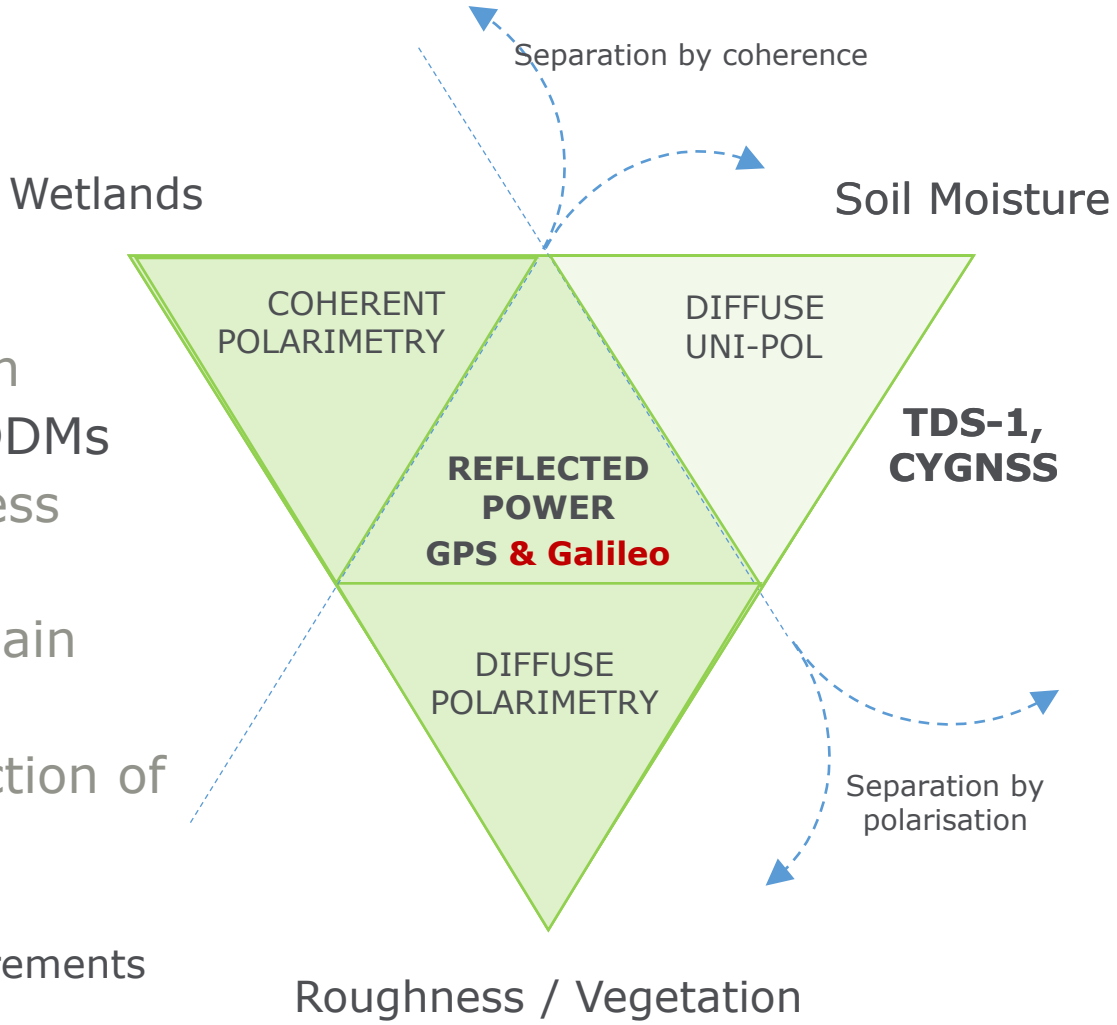
HydroGNSS offers New Technology and Measurements

Established GNSS-R Approach:

- Incoherent Delay Doppler Maps (DDMs) from GPS L1 at 1 Hz

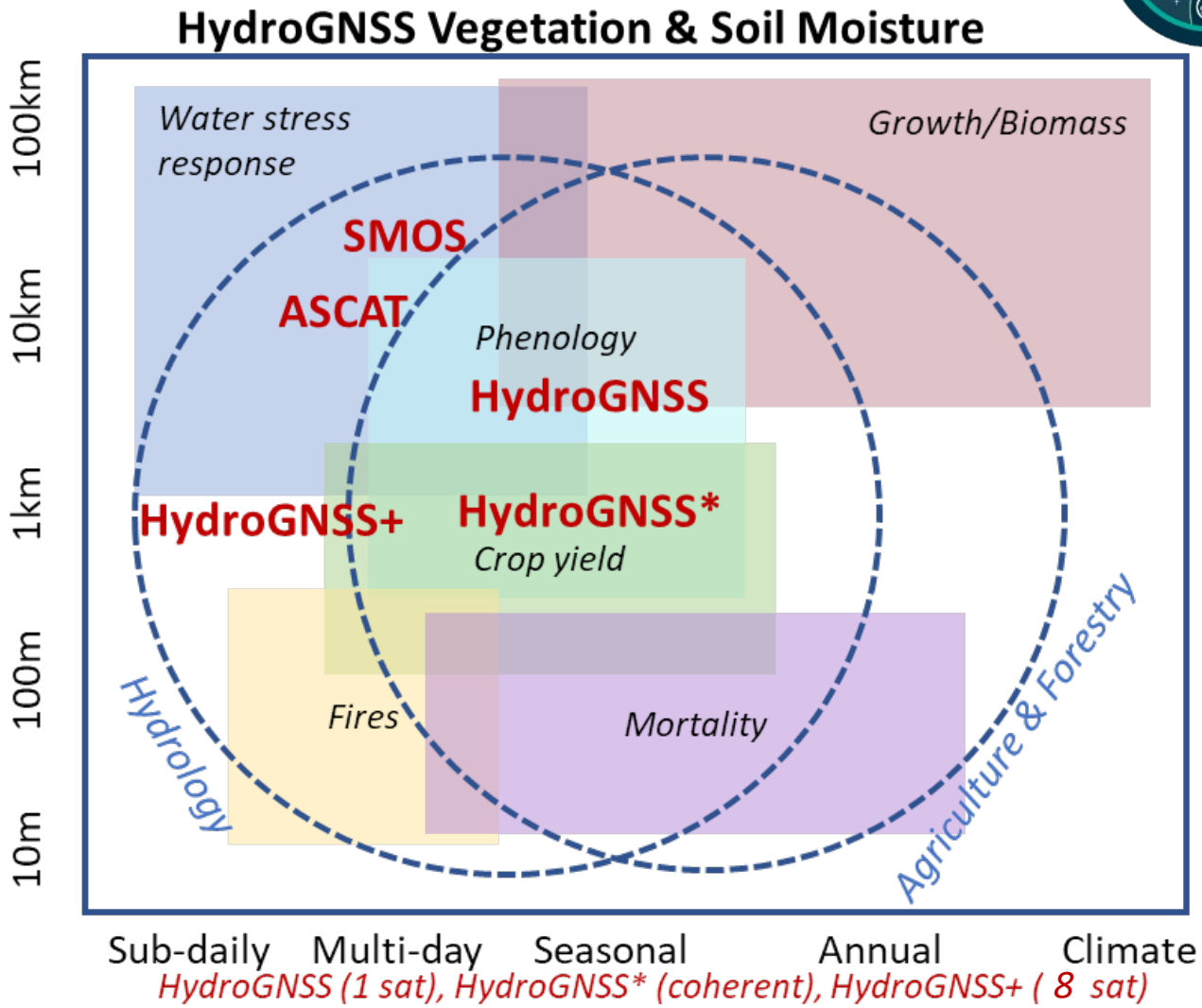
Plus New GNSS-R Measurements (firsts):

- DDMs from **Galileo** Signals
  - Increased coverage, longer codes for increased coherent gain
- **Polarisation** - Left and Right Hand Circular DDMs
  - Separation of moisture and soil roughness
- **Coherent** complex channel
  - Improved resolution, more processing gain
- **Second frequency**, L5/E5 Sampling
  - Wideband signals may offer better selection of coherent surfaces, feature separation
- New measurements backed up by simulations
  - End to End simulator addressing old and new measurements



HydroGNSS Addresses Niche in Applications

- Spatial-Temporal Resolution good for Hydrology, Agriculture and Forestry
- GNSS-R resolution higher than SMOS and SMAP
  - Further improves with new coherent channel
- Special capability in sensing water under canopies
- Revisit can be increased by adding further satellites



HydroGNSS Instrument & Mission

Payload

- New GNSS-R Instrument based on TDS-1 and CYGNSS missions
- Nadir antenna ~13 dBi dual polarised, dual frequency
- Instrument compatible with Galileo and GPS, reconfigurable in orbit, supporting new GNSS-R measurements

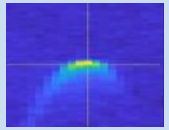
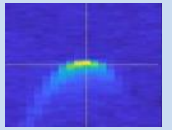
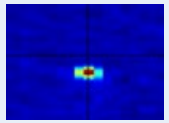
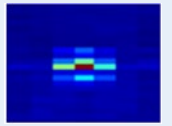
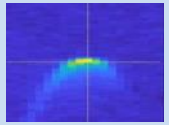
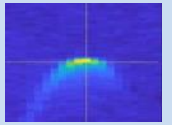
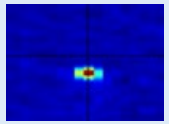
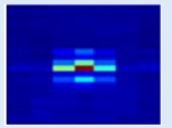
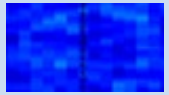
Platform

- 65 kg SSTL-Microsatellite,
  2.5 year operational life plus 2 year extension
- 3-axis attitude stabilised with star tracker
- Propulsion for orbit phasing and collision avoidance
- Spacecraft MOC and PDGS located in Guildford
- Up to 200 Mbps X-band downlink via Svalbard, Guildford
- Payload Data Ground Segment (PDGS) built upon www.merrbys.org disseminating Level 1 and Level 2 data
- SSTL prime, supported by Sapienza, IEEC, Tor Vergata, FMI, IFAC, NOC, Nottingham, Vienna as science team members

Constellation

- HydroGNSS comprises 1 satellite
  - Global coverage every 30 days
- Option for 2nd satellite
- Suitable for upscaling to larger constellation of 8 to achieve coverage every 3 days

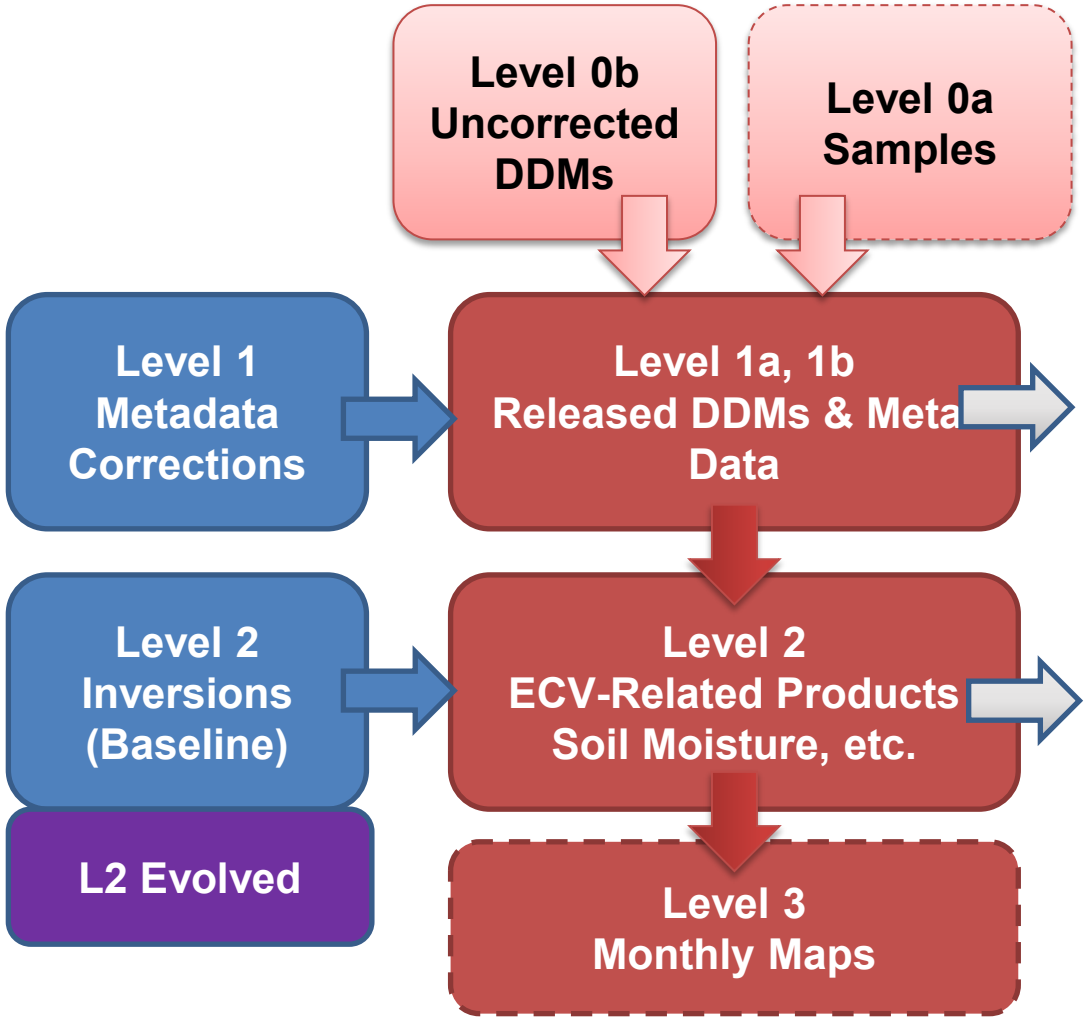
Observational Requirements – Old & New Products

Level 0b, near continuous	GPS - LHCP	GPS - RHCP	Galileo - LHCP	Galileo - RHCP
L1 Band Non-coherent DDMs 4 satellites every 1 sec	 *	*	 *	*
Coherent Channel 4 complex ch., 250 Hz	 *	*	 *	*
L5 Band Non-coherent DDMs 4 satellites every 1 sec	 *	*	 *	*
Coherent Channel 4 complex ch., 250 Hz	 *	*	 *	*
Black Body, L1 and L5 Bands x 1, each LNA	 * *	* *	(Same)	(Same)
MetaData	Incl. Settings of Instrument, temperatures, zenith measurements GNSS position, velocity and time – Used for Level 1 corrections			

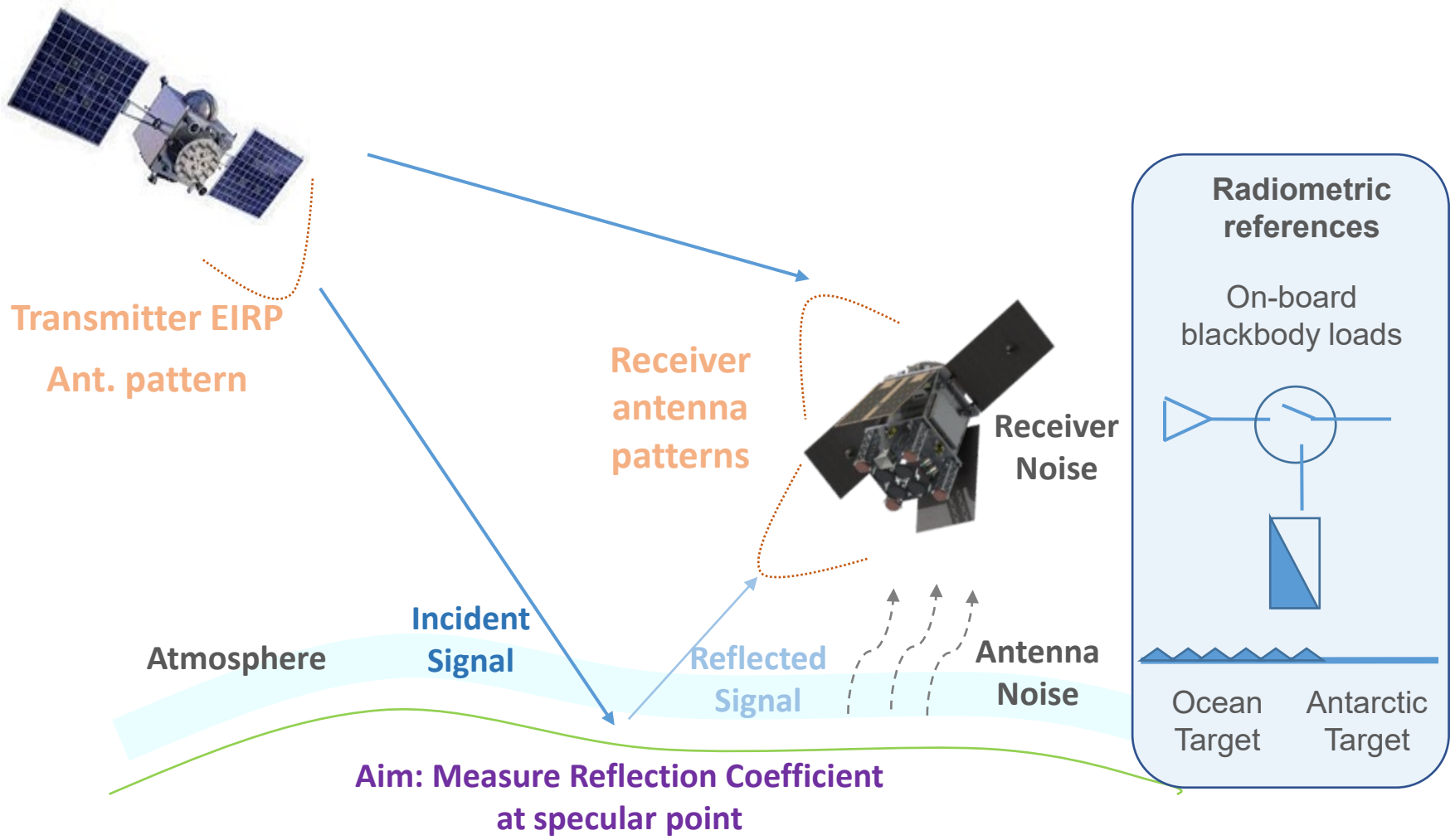
Level 0a (Typ. 60 seconds)	LHCP (All GNSS)	RHCP (All GNSS)	Previous / New Products
L1 Band Sampled data	 *	 *	* Previously available on TDS-1
L5 Band Sampled data	 *	 *	* Indicates new to HydroGNSS

Measurements Feed into Data Levels

- On **spacecraft,** either
  - **Level 0a (raw IF)** samples scheduled (60 seconds, nominal)
  - **Level 0b** Continuous DDMs
- On **ground**
  - **Level 1a**, DDMs with collated Meta-data
  - **Level 1b**, DDMs with derived corrections (including receiver corrections, and estimated transmit powers)
  - **Level 2**, Products related to Essential Climate Variables
- Reuse of TDS-1 MERRByS processing architecture
- Data property of ESA – free, full and open L1, L2 data available to users via **HydroGNSS Web Portal**



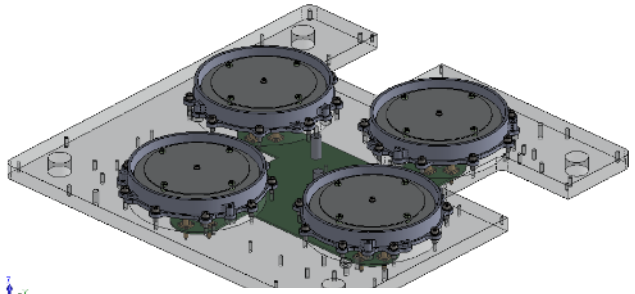
Radiometric Calibration Approach



- Factors include
  - Transmit power,
  - Variation with time, Transmit and receiver antenna patterns, Attitude knowledge,
  - Antenna noise
  - Thermal effects
- Makes use of
  - Av. ocean reflections
  - Direct signal acquisition
  - Blackbody loads
- New measurements pose new challenges
  - Dual pol/frequency

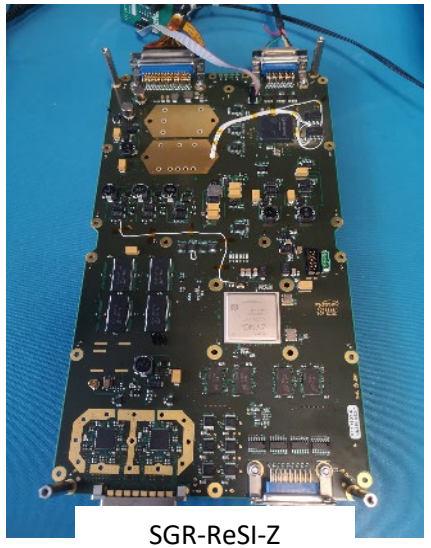
Progress on Project

- Preliminary Design Review – May-June 2022
- Designs for satellite presented
- First hardware being produced
  - Engineering Models
  - Representative testing => TRL-6
- Progress with Payload
  - Complex antenna – dual frequency (L1,L5), dual polarisation
  - Very low noise amplifiers – with filtering to mitigate interference
  - Development of signal processing
  - Engineering Models becoming available

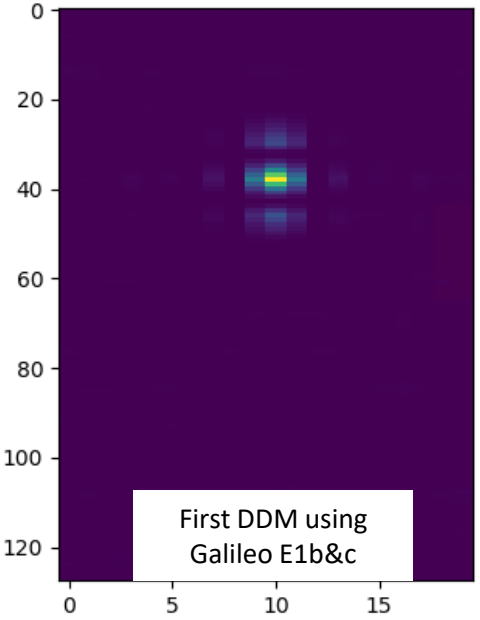


Nadir Antenna Panel

Low Noise Amplifiers

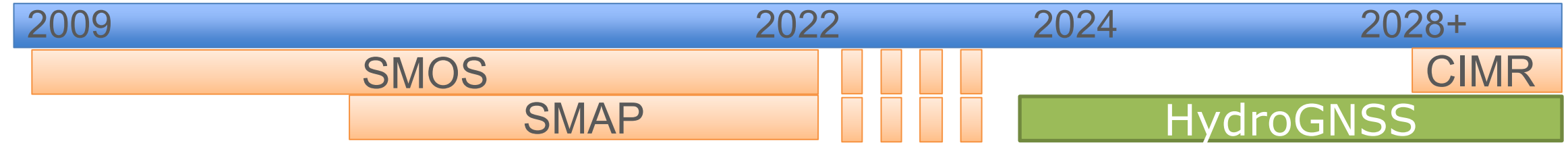


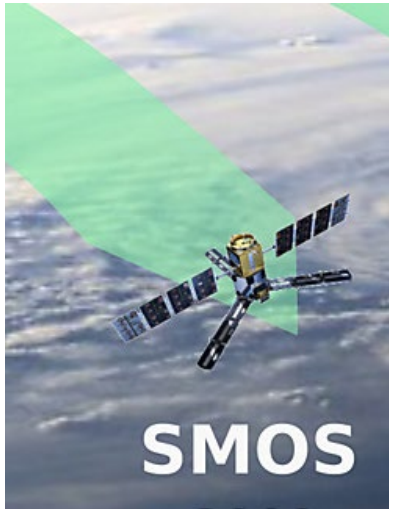
SGR-ReSI-Z



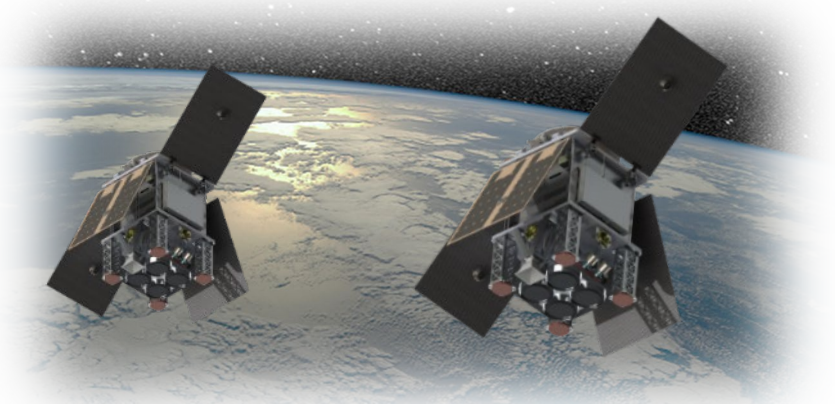
First DDM using Galileo E1b&c

HydroGNSS Gap Filler using a low cost approach





Small Size & Cost-Efficient L-Band Continuity Mission



SMOS (2009)
Resolution: 35-50 km
Mass: **670 kg**
Cost: €315m (2009)
(c.f. NASA SMAP ~**1 tonne**, $1b)
Operating beyond end of life

HydroGNSS (2024)
Resolution: 1-25 km
Mass: **65 kg** per craft
Scout Budget < €30m
(8 craft would match SMOS coverage)

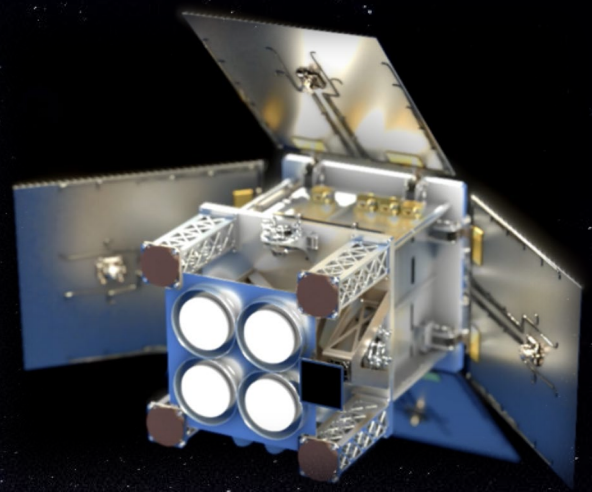
CIMR (2028+)
L-Band (plus others)
Resolution: 36 x 64 km
Mass: **>700 kg**
(7 metre antenna)
Budget: >€500m

- Urgent need recognised- sustainable continuity of SMOS / SMAP services to support ECV sensing

Conclusions

- HydroGNSS uses GNSS-Reflectometry to target key variables – soil moisture, inundation, freeze / thaw, and biomass
  - Addresses identified user needs, including WMO (WIGOS), GCOS ECVs, C3V
  - HydroGNSS observes boreal forests & disturbances, where ESA Biomass Explorer cannot
  - Some urgency, Soil moisture and Freeze thaw not adequately measured in long term (SMAP and SMOS now operating past design life, facing potential gap)
- HydroGNSS showcase for GNSS-Reflectometry and new measurements for hydrology – Launch scheduled for 2024
  - **Second ESA Scout satellite option** will double coverage, efficiently improve return
  - Sets framework for constellation – orbit phasing, cross-satellite calibration and data merging
- Prepares way for constellation of 8 satellites to cover globe every 3 days
  - More sustainable in cost compared to existing approaches
  - Immediate benefits for weather forecast and flood alerting
  - Monitoring of outcome of actions following COP26 pledges

DOING SPACE DIFFERENTLY



Thank you

Workshop videos at tinyurl.com/hydrognss-ws
Contact merrbys@sstl.co.uk to stay informed
HydroGNSS intro paper can be found via IEEE Xplore

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