SURREY

CHANGING THE ECONOMICS OF SPACE

CEOI ORECO

Summary Presentation

Mission & Business Case

5th April 2019 SSTL#0335668

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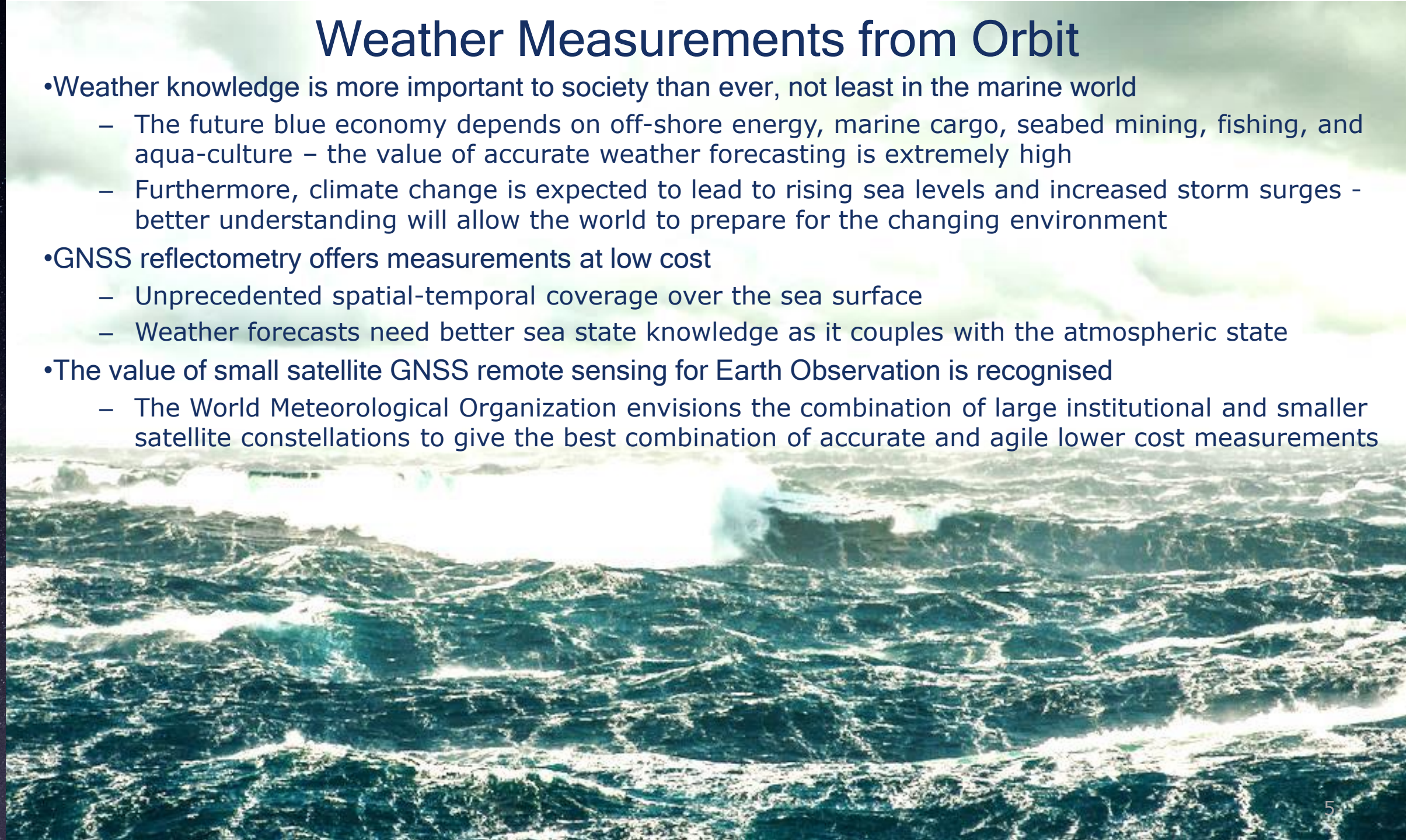
Introduction

User Needs & GNSS Reflectometry

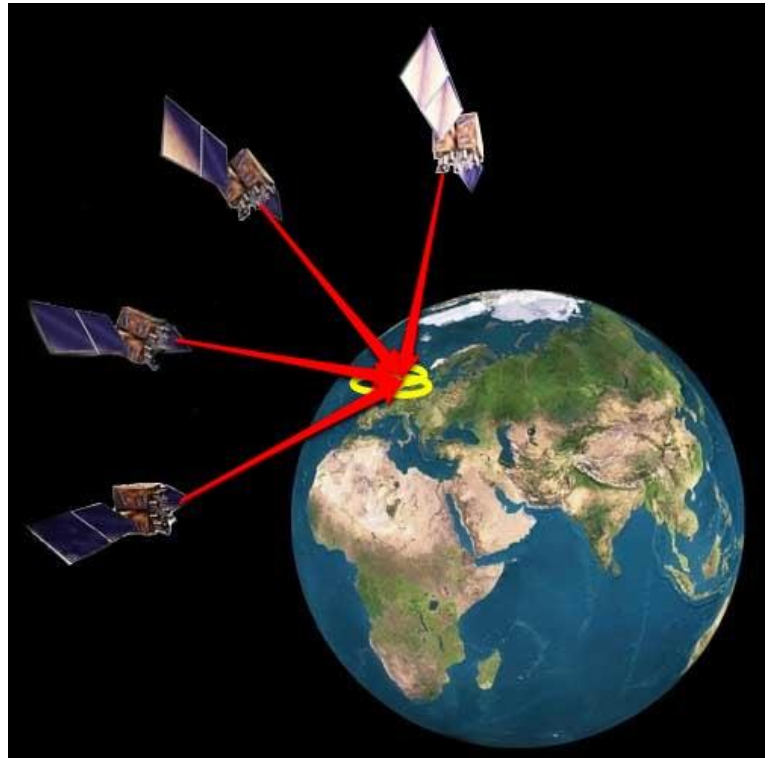
Weather Measurements from Orbit

- Weather knowledge is more important to society than ever, not least in the marine world
  - The future blue economy depends on off-shore energy, marine cargo, seabed mining, fishing, and aqua-culture – the value of accurate weather forecasting is extremely high
  - Furthermore, climate change is expected to lead to rising sea levels and increased storm surges - better understanding will allow the world to prepare for the changing environment
- GNSS reflectometry offers measurements at low cost
  - Unprecedented spatial-temporal coverage over the sea surface
  - Weather forecasts need better sea state knowledge as it couples with the atmospheric state
- The value of small satellite GNSS remote sensing for Earth Observation is recognised
  - The World Meteorological Organization envisions the combination of large institutional and smaller satellite constellations to give the best combination of accurate and agile lower cost measurements



GNSS

- Global Navigation Satellite Systems (GNSS) are used for Satellite Navigation
- Includes GPS (US), Galileo (EU), GLONASS (Russia) and Beidou (China)
- Each system has 20 - 30 active satellites in orbit
- GNSS satellites are in Medium Earth Orbit: 20,000 km altitude
- Constantly transmitting an accurate time signal in L-band (1.6 GHz)
- Used for determining position on Earth
- Also used by Low Earth Orbit satellites to determine their position
    - Very useful for small satellites
    - GNSS receivers are small, low mass and low power

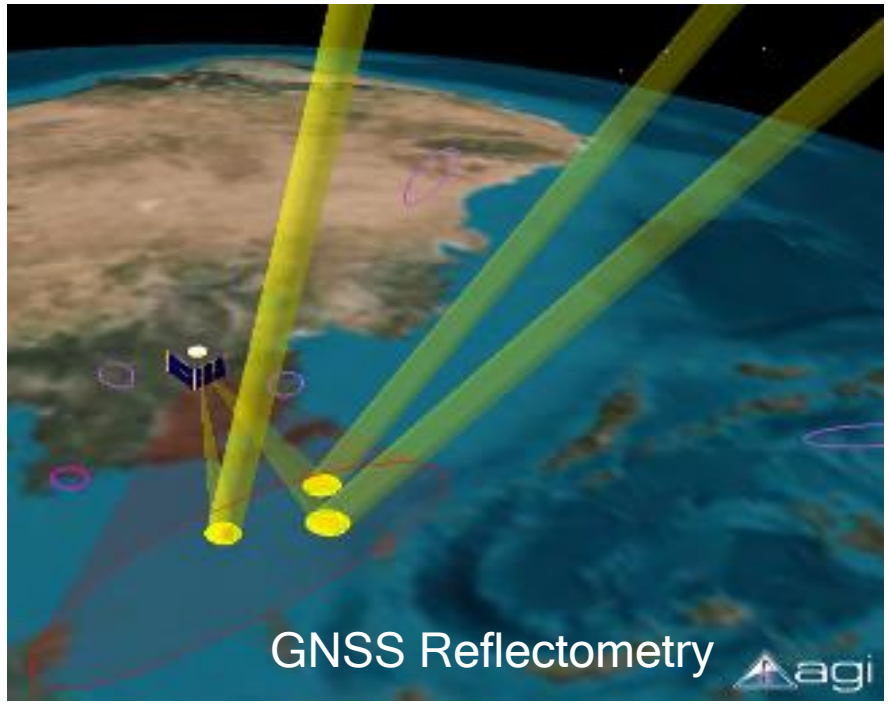


4 GNSS satellite signals needed for position fix

GNSS Signals for Spaceborne Reflectometry

GNSS Reflectometry (GNSS-R)

- A receiver collects GNSS signals reflected off the Earth (like radar)
- The scatter, or spread of the signal is related to ocean roughness
- From roughness, the *wind speed* over the ocean can be estimated
- Roughness, or *mean square slope* is missing parameter – not yet measured from space
- Also signals reflected off ice and land are yielding new measurements
- SSTL proved GNSS Reflectometry using UK TechDemoSat-1 (TDS-1) in 2014
    - Instrument also provided to NASA CYGNSS mission
- Allows for remote sensing at night and through clouds



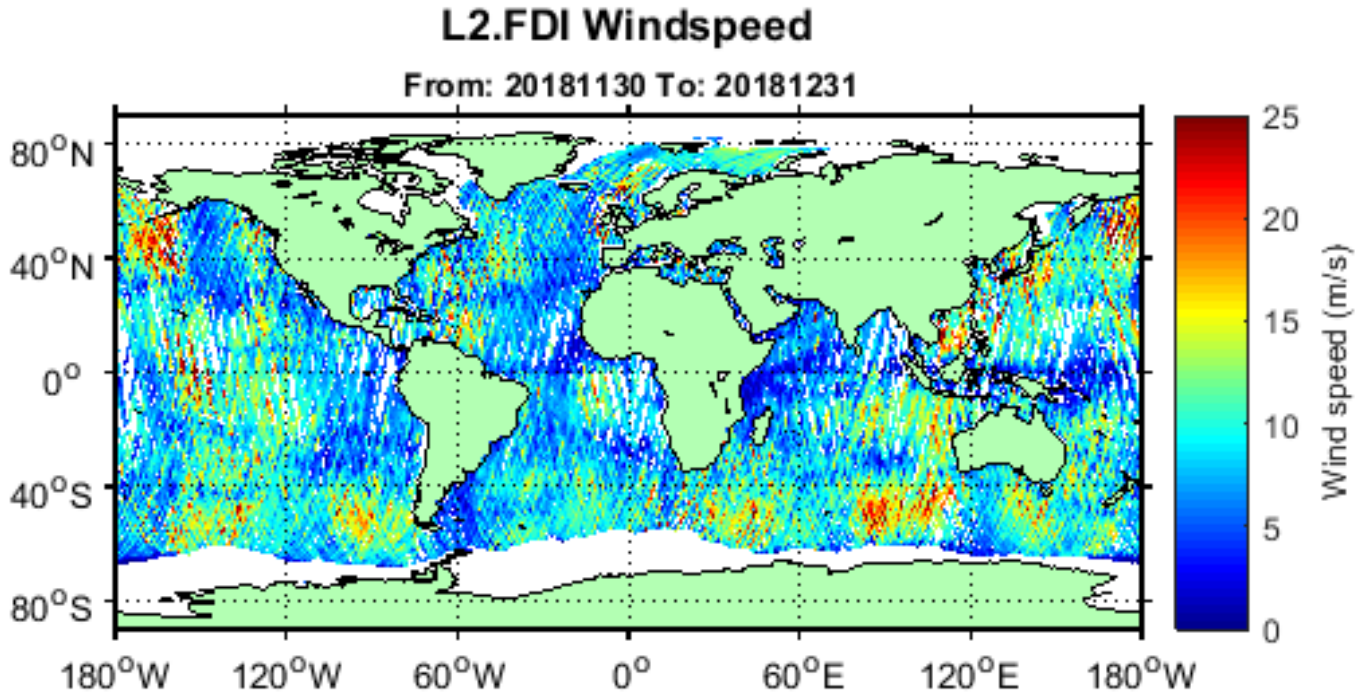
Wind speed measurements are useful for weather forecasting

User Needs

Oceans are significantly under-sampled compared to atmosphere

- Climate change means more storms and flooding – accurate weather forecasting more important than ever
- Limited budgets mean that high impact/low cost solutions are needed

- Data must be timely – available within 3 hours of measurement
- Need for high temporal and spatial coverage



Wind speed data from TDS-1

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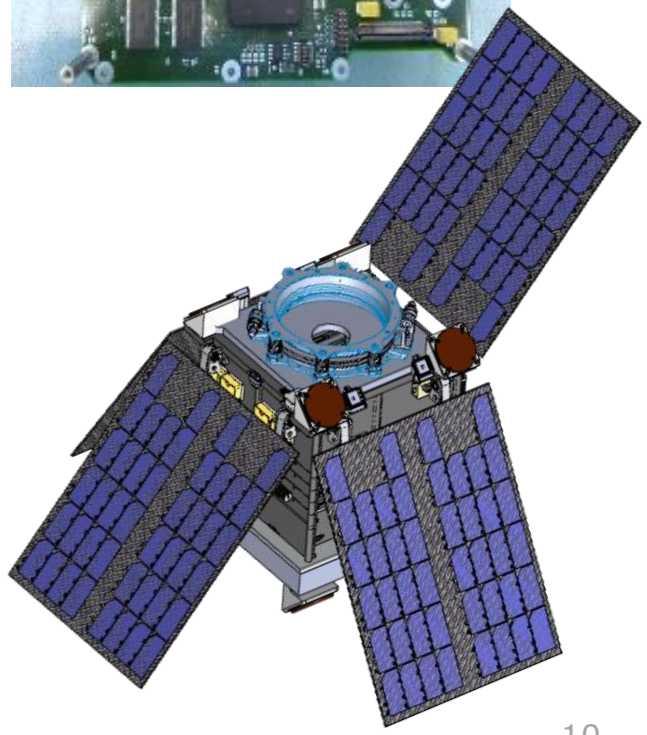
Mission Description

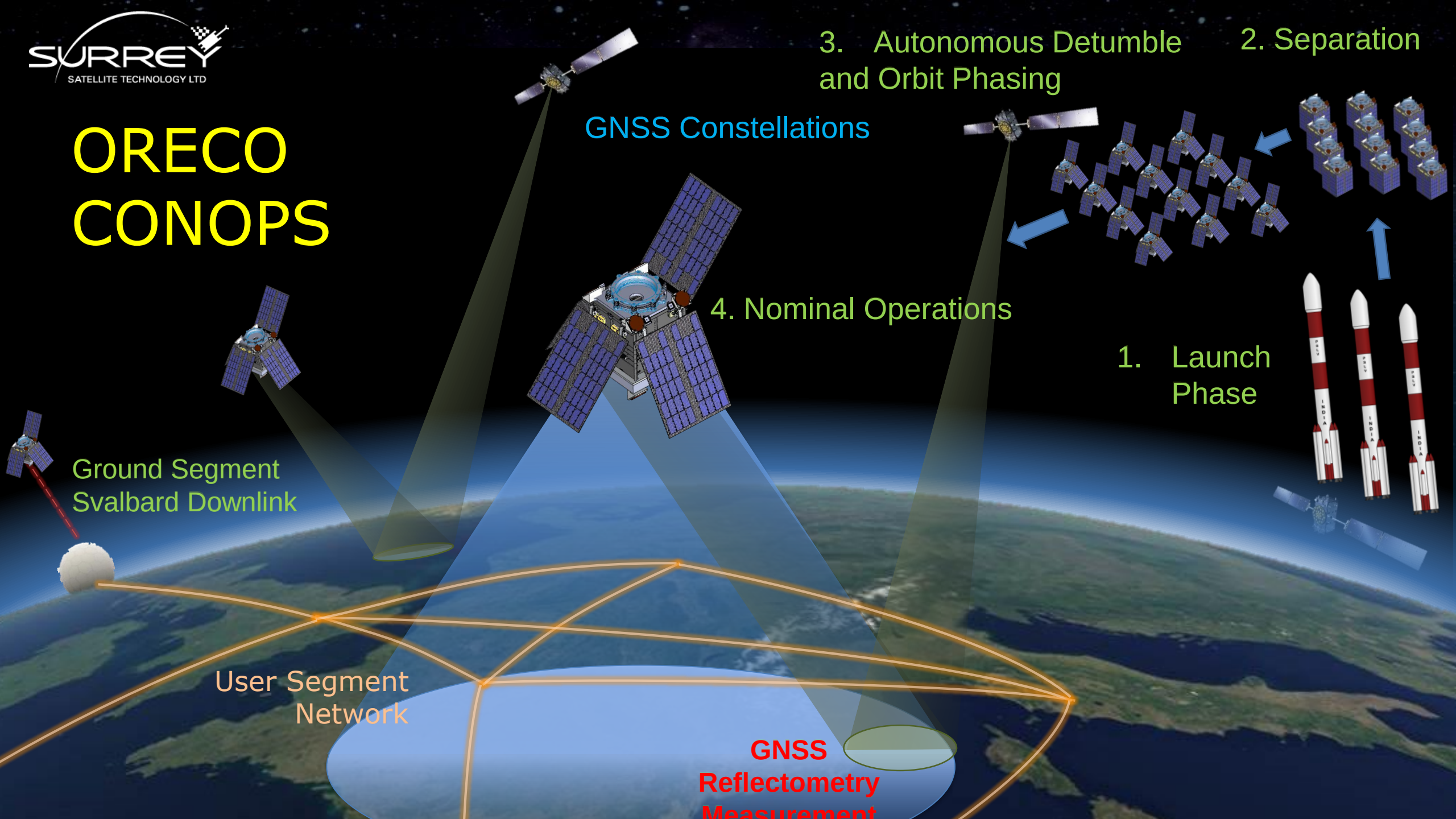
Ocean Reflectometry Constellation

ORECO

ORECO Concept

- Constellation of satellites taking global measurements of ocean wind speed for Numerical Weather Prediction (NWP)
- Data has secondary uses – climate research over land, sea, ice
- Instrument: **ORECO instrument**
  - Upgraded SGR-ReSI
- Dual frequency GNSS Receiver with nadir reflectometry antenna
- Payload: approx. 2-3 kg, 9 watts
- Platform: **SSTL-21**
- Small satellite platform, approx. 45 kg
- 12 satellites (could scale up for better coverage)
- Launched into 3 planes, 550 km altitude
- Data Access: KSAT **Svalbard** & **Inuvik** ground stations
- Rapid download, processing & dissemination in less than 3 hrs

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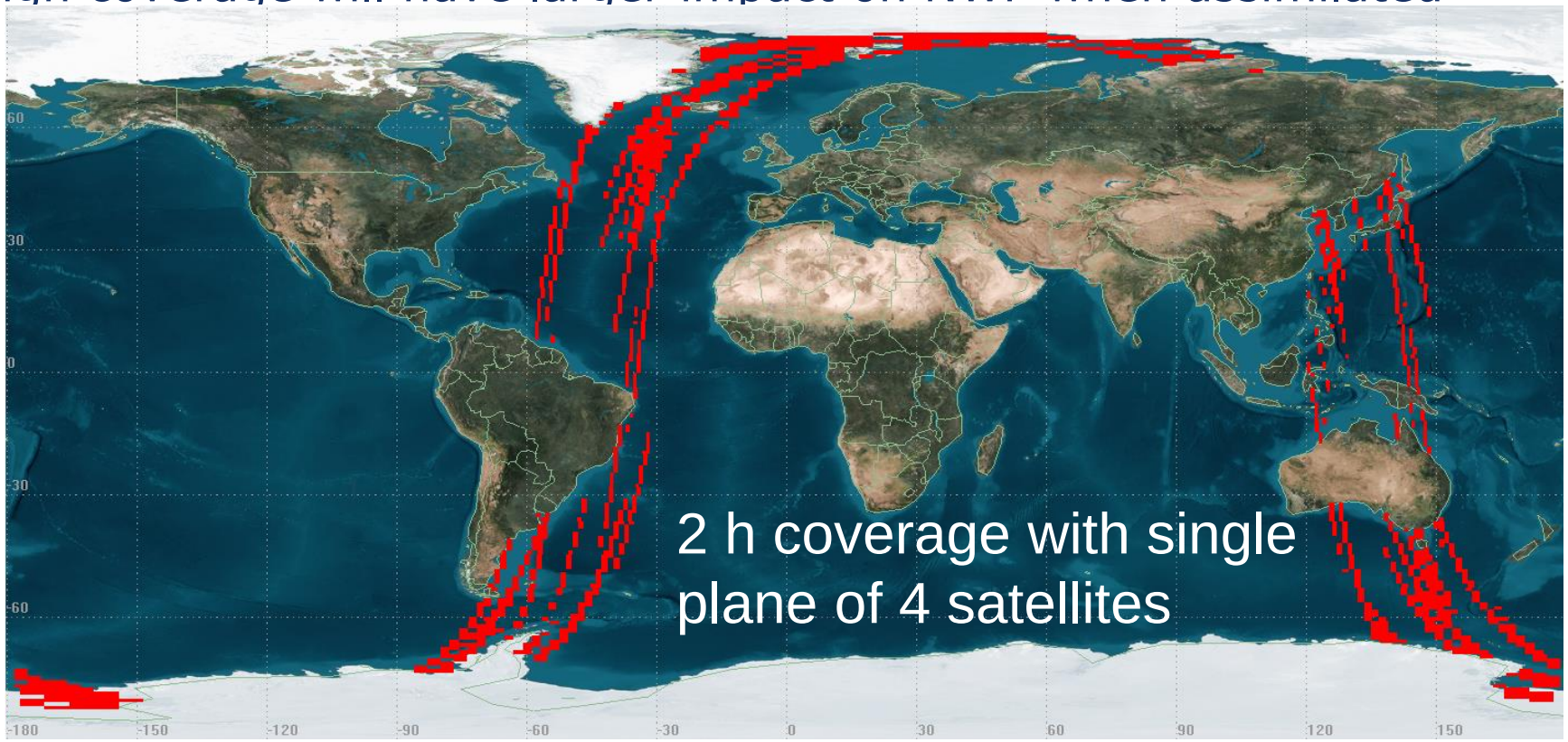
ORECO
CONOPS
GNSS Constellations
3. Autonomous Detumble and Orbit Phasing
2. Separation
4. Nominal Operations
1. Launch Phase
Ground Segment
Svalbard Downlink
User Segment
Network
GNSS
Reflectometry
Measurement

Coverage & Performance

- Assumption of ocean stationarity of 100 km x 100 km, and 2 hours
  - Therefore 3 orbital planes required to cover ocean
- Wind speed measurements shown to be accurate to 2 m/s for lower winds, mean square slope new parameter yet to be quantified
  - High coverage will have larger impact on NWP when assimilated

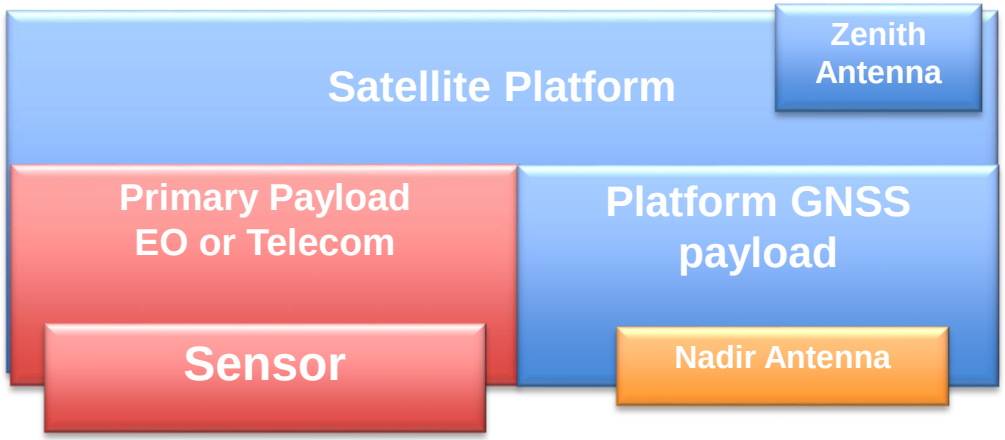


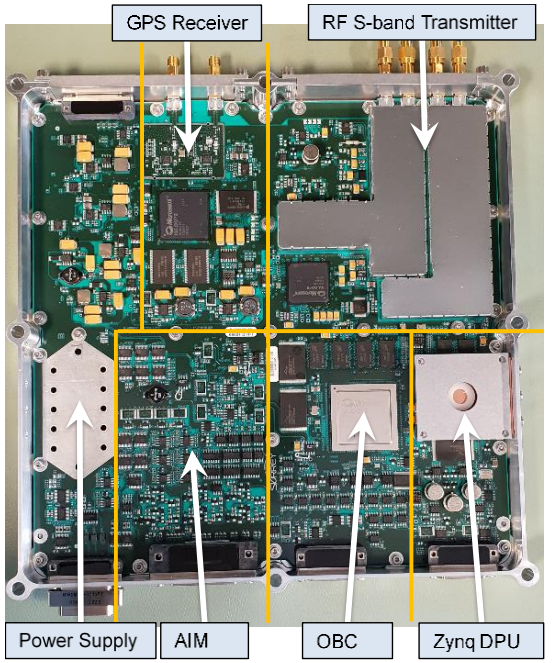
Elements of ORECO

Element	Description
Payload	GNSS Receiver capable of collecting GPS L1 and Galileo E1 Reflections (up to 5 reflections each)
Payload Antennas	Zenith antenna – GPS & Galileo direct signals Nadir antenna – GPS L1 & Galileo E1 reflections
Platform	SSTL-21 satellite platform x 12 (plus 1 spare on ground)
Launch	3 launches of 4 satellites each, equidistant hour angles 550 km sun-synchronous orbits, Smallsat launch, e.g Orbex
Ground Station TTC	Svalbard with Guildford and Harwell as backups
Download Station	KSAT Svalbard datalink with KSAT Inuvik for covering gaps in Svalbard access - to allow measurement download every orbit (96 min) Potential to add KSAT Troll to further reduce latency to 48 min (not including time to get data to users)
Mission Operation Centre	Rapid processing of measurements data into released Level 1 product – Delay Doppler Maps Generation of Level 2 products include ocean wind speed

Hosted Payload Option

- SSTL's new platforms include GNSS receiver & coprocessor
  - Two front-ends already integrated
  - GNSS Reflectometry potentially could be implemented on every SSTL satellite
  - Only requirement is to add Nadir antenna and LNA
- GNSS Reflectometry could be hosted as secondary payload on EO or Telecom constellation
  - Full global coverage at very low cost





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Business Case Summary

ORECO Mission

Strategic Case

- Free data will create a thriving downstream applications sector
- GNSS-R will improve NWM and benefit weather forecast users
- Complement SAR, scatterometry, altimetry and microwave radiometry measurements at low cost
- SSTL is experienced with GNSS-R: UK-DMC1, TDS-1 and CYGNSS carried SSTL payloads
- Very little GNSS-R data available but after TDS-1, US, China are showing interest in making their own constellations

Strategic Risks & Constraints

- Supply chain – early buy of long lead items and back up suppliers
- Scheduling – careful management and planning required for large constellation batch build
- Personnel consistency – core team needed to oversee design from cradle to grave to provide continuity and knowledge
- Limitations provided by UK and international export regulations
- Launch availability and launch slot resources
- ITU filings and regulations for space-to-ground comms.
- It is expected this programme will be at a minimum a bilateral, or potentially a European partnership from more than one country. Funding and legislation for partner nations to proceed is considered the top dependency to mission success.

Economic Case

- Blue economy is growing in importance
  - Off-shore energy, auto-shipping, aquaculture, etc.
- Sea state is under-measured
  - Knowledge of wind and waves, hourly forecasts, very valuable for off-shore operations
- ORECO offers improvement to NWP
  - Unprecedented wind speed spatio-temporal sampling over globe, and addition of new parameter, mss
  - Better sea state knowledge couples into weather modelling
  - Moisture in soil is also poorly sampled, has effect on operational NWP
- Improving prediction saves money with disaster mitigation
  - Forewarning of storms, storm surges
  - Soil moisture affects flooding risk
- Commercial downstream startups will benefit
  - Ship routing, insurance, risk management

Financial Case

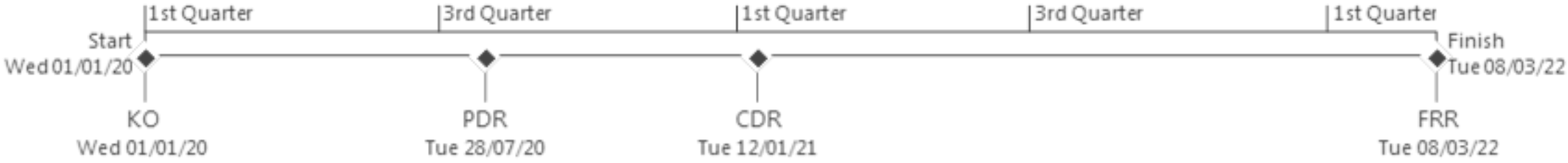
- Preliminary costing includes
  - Satellite platform and payload
  - LEOP, Commissioning and 5 years of Operations
  - Launch campaign
  - Some science & operations activities
- Total cost **<£100m incl. VAT**
- Not included in this estimate:
  - Launch – based on public information, €30,000/kg
    - This gives approx. €16m in total, at 12 x 45 kg satellites
  - Insurance costs – typically valued as 15% of mission costs
  - Mission Operation Infrastructure – still to be scoped and costed
  - This costing was performed for earlier ORORO proposal & has not been updated for ORECO. ORECO is expected to cost less due to having only a single payload.

Commercial Case

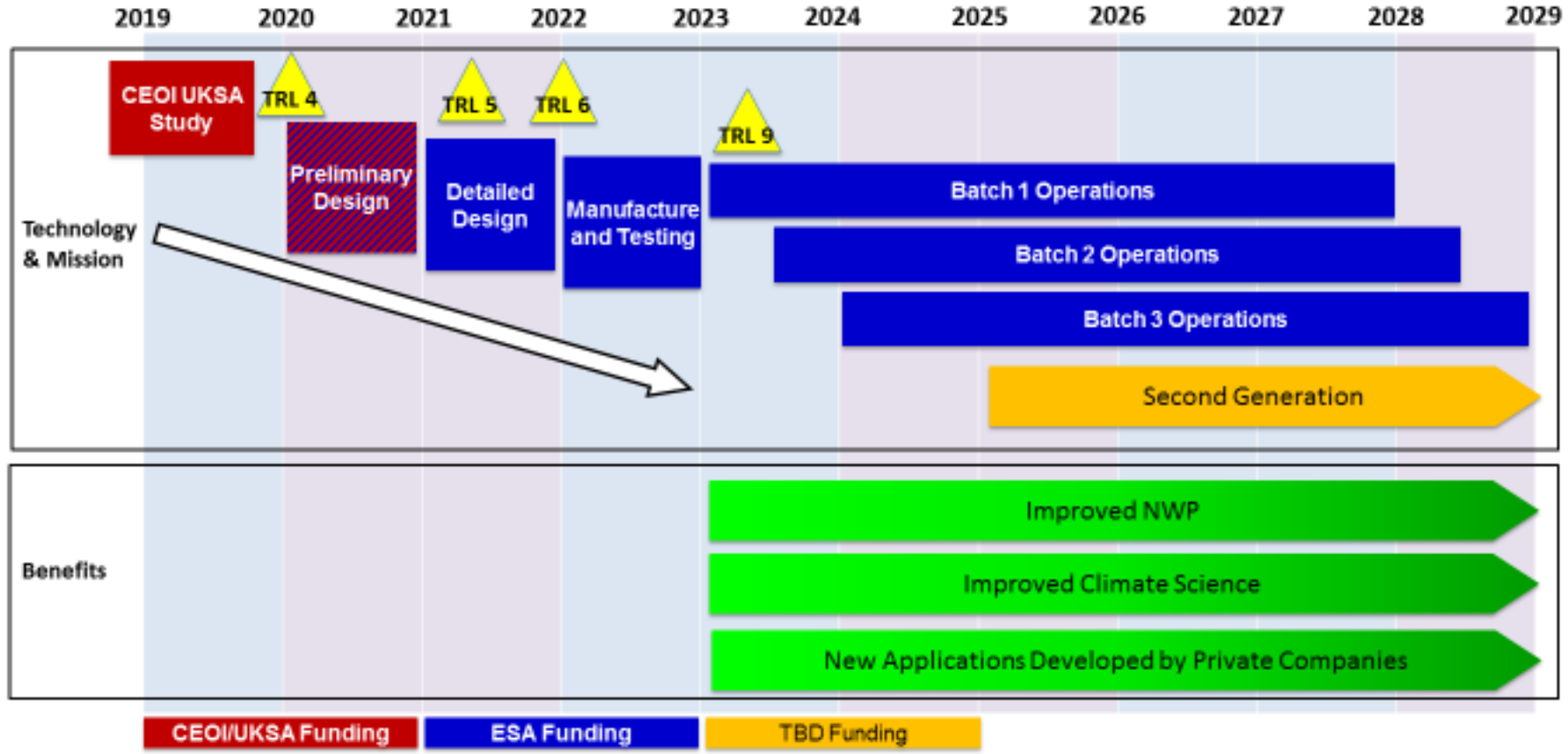
- Commercial considerations include: Launch, sub-contracts, scientific advisory group, long lead items
- Space licences and radio-frequency requirements to be addressed
- Separation of elements of ORECO may be necessary to allow for ‘Lean prime’ rule if invoked by ESA
- ORECO may highlight regions of GNSS jamming – nominal measurements heavily processed so not collecting signal intelligence material

Management Case / Roadmap

- Outline initial schedule presented here



- Roadmap for future allows for second generation constellation



Potential Partnerships

- Many potential partners for mission within UK
  - National Oceanography Centre, Met Office, National Physical Laboratory
  - UK Space companies (for antennas, ground segment, launch, etc.)
  - Universities – Nottingham, Newcastle and Bath
  - CEH, Reading – soil moisture, & other land applications; CPOM - ice applications
- Potential European Partners
  - Eastern European countries – possible manufacturing partner
  - Service & subsystem providers, e.g. KSAT for ground stations
  - GNSS-R scientists and processing experts
    - Spain (IEEC, UAB, ICM), Germany (GFZ), Italy, France, Portugal and others
  - Institutes: ECMWF, EUMETSAT, national weather centres
- Worldwide Partners
  - Taiwan, possible manufacturing partners (collaborators on Formosat-7)
  - US (collaborated on CYGNSS)
  - Institutes: WMO, NOAA, other weather agencies

Earth Watch Compatibility

- The aim of ESA's Earth Watch [ESA2018] is to secure for Europe an independent sustainable capability in operational Earth Observation supporting both institutional needs and commercial initiatives
  - ORECO directly addresses this Earth Watch aim
- To be compatible, UKSA has stated a maximum of £280m
  - The initial costing of ORECO suggests the total costs will be well within this figure
- UKSA suggests at least 10% involvement from European partner(s)
  - Several potential partners have been identified by SSTL
  - Significant external elements could be shared, including: launch, calibration, downlink, applications

Conclusions

- ORECO (Ocean Reflectometry Constellation) consists of 12 microsatellites taking global near-real time weather measurements using GNSS Reflectometry at an unprecedented temporal and spatial resolution.
- ORECO is a low cost small satellite concept, improving UK and international weather forecasting capability, giving a significant cost benefit
- Other benefits include improved flooding assessment, soil moisture, ice extent, concentration and other measured parameters relevant for climate research.
- The mission will be publicly funded, and data will be freely distributed to encourage downstream exploitation. User data management will allow the potential for commercialisation of high value low latency data.
- The concept builds upon world leading expertise at SSTL in both GNSS payloads (payload provider for the 8 satellite NASA CYGNSS mission) and small satellite constellations (DMC, RapidEye constellation providers).
- The business case for ORECO is developed and presented in these slides, addressing Strategic, Economic, Financial, Commercial, and Management aspects and risks in these respective areas.
- Costs fall within boundaries for implementation under an ESA Earth Watch programme.

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