The ‘Other’ Earth Explorers

Explorer opportunities for the UK?

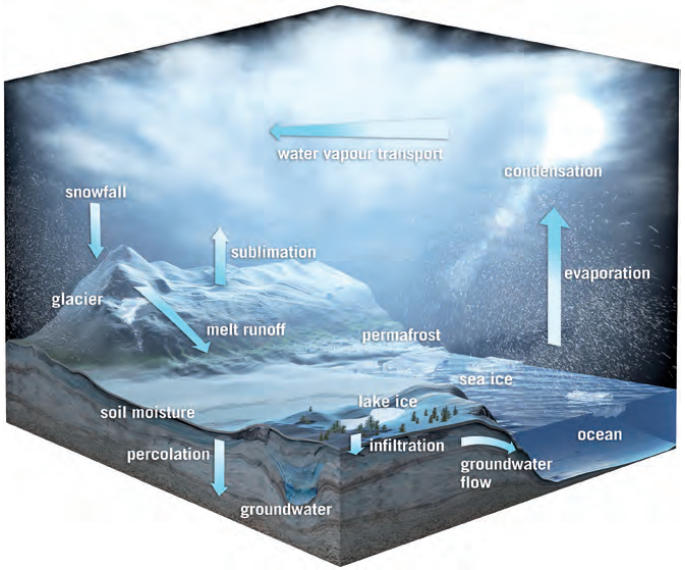
Rob Scott

$CoReH_2O$

Cold Regions Hydrology high-resolution Observatory

- Snow cover dominates the Earth's cryosphere, therefore understanding of the global water cycle demands accurate, high-resolution observations of freshwater stored as snow.

- CoReH2O will make measurements in support of:
  - Quantification of the role of snow and glaciers in influencing the global water cycle and regional water resources.
  - Parameterisation and downscaling of snow and ice processes in atmospheric circulation and climate models.
  - Quantification of the effects of snow regimes on boundary conditions for carbon exchange, trace-gas exchange and preservation of biodiversity.
  - Processes in high-latitude ocean circulation and thermodynamics related to sea-ice formation and freshwater fluxes from high-latitude rivers.
  - Improved representation of hydrological processes in NWP models

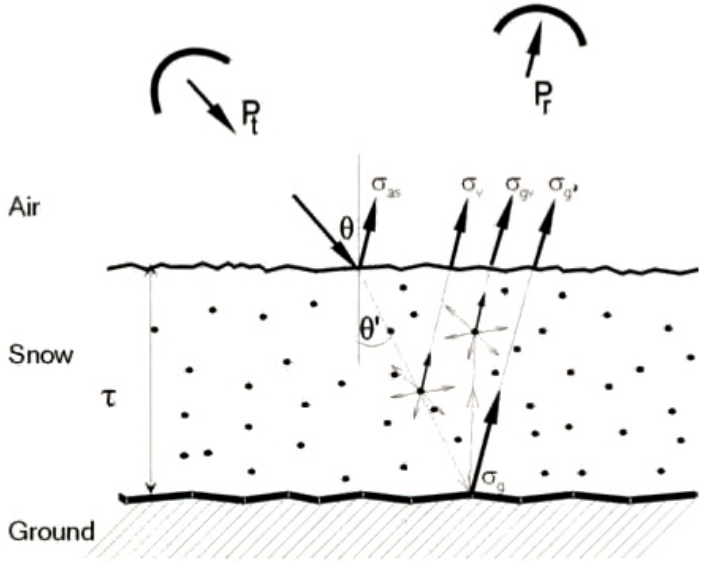


CoReH$_2$O Principle

- CoReH$_2$O is a wide-swath, high resolution SAR mission, using dual-band, dual-polarisation measurements. This allows:
  - Observation of extent and water equivalent of seasonal snow-cover and winter snow-accumulation on glaciers.
  - Observation of ice type (with the emphasis on thin ice) and snow depth on sea ice and freshwater ice.
- SAR operates in Ku and X band, with VV-VH polarisations, over a 100km swath width
- Ku-band (17.2 GHz) is a first for space SAR
- Complementary to and synergistic with C-band SAR on SENTINEL-1
- Will support measurements of altimeters such as Cryosat II and SENTINEL-3

CoReH$_2$O Interactions (1)

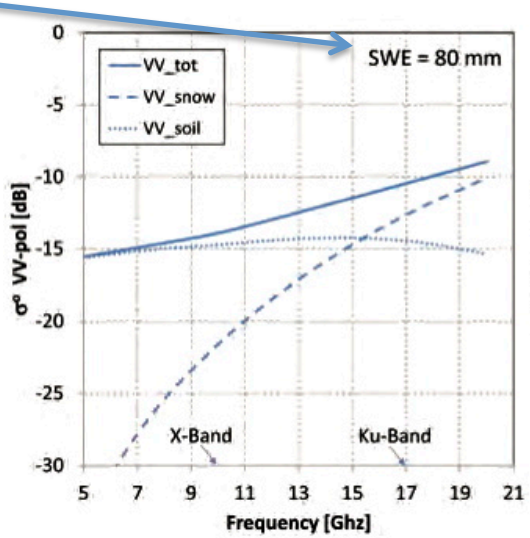
- Total backscatter σ^t from snow covered surfaces is made up of contributions from:
  - Air-snow (small for dry snow)
  - Direct volume (significant)
  - Ground/Volume & Volume/ Ground (small)
  - Direct Ground (significant)
- The snow water equivalent is derived mainly from the volume scattering.
- Note that dry snow is relatively transparent at C-band (5.3GHz), and so only the snow/substrate interface contributes

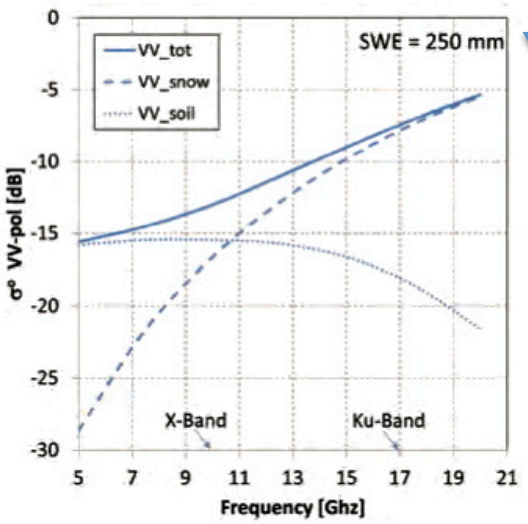


$$\sigma_{pq}^{t} = \sigma_{pq}^{as} + \sigma_{pq}^{v} + \sigma_{pq}^{gv} + \sigma_{pq}^{g'}$$

CoReH$_2$O Interactions (2)

Thin snow

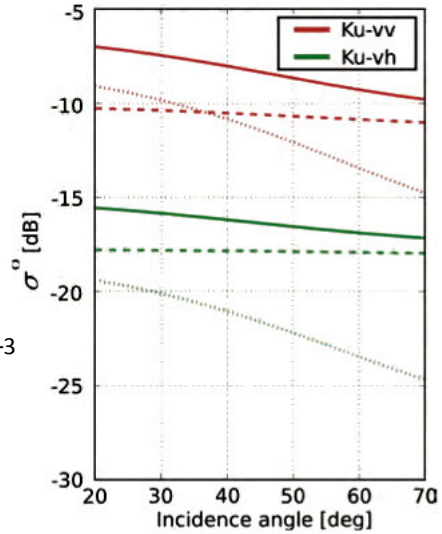


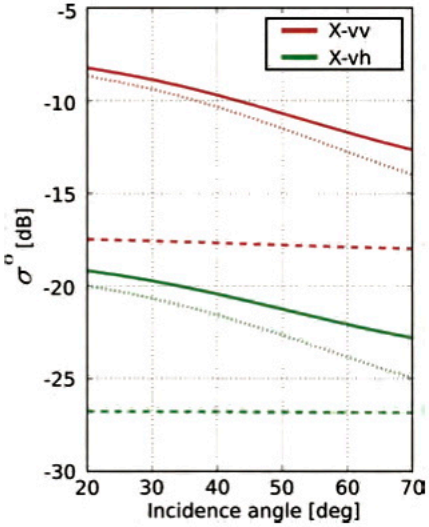


Thick snow

Solid – Total backscatter
Dashed – volume signal
Dotted – ground signal

Ku-band





X-band

Both cases:
SWE=150 mm
snow density=250 kg/m^{-3}
Snow ~ 0.6m deep

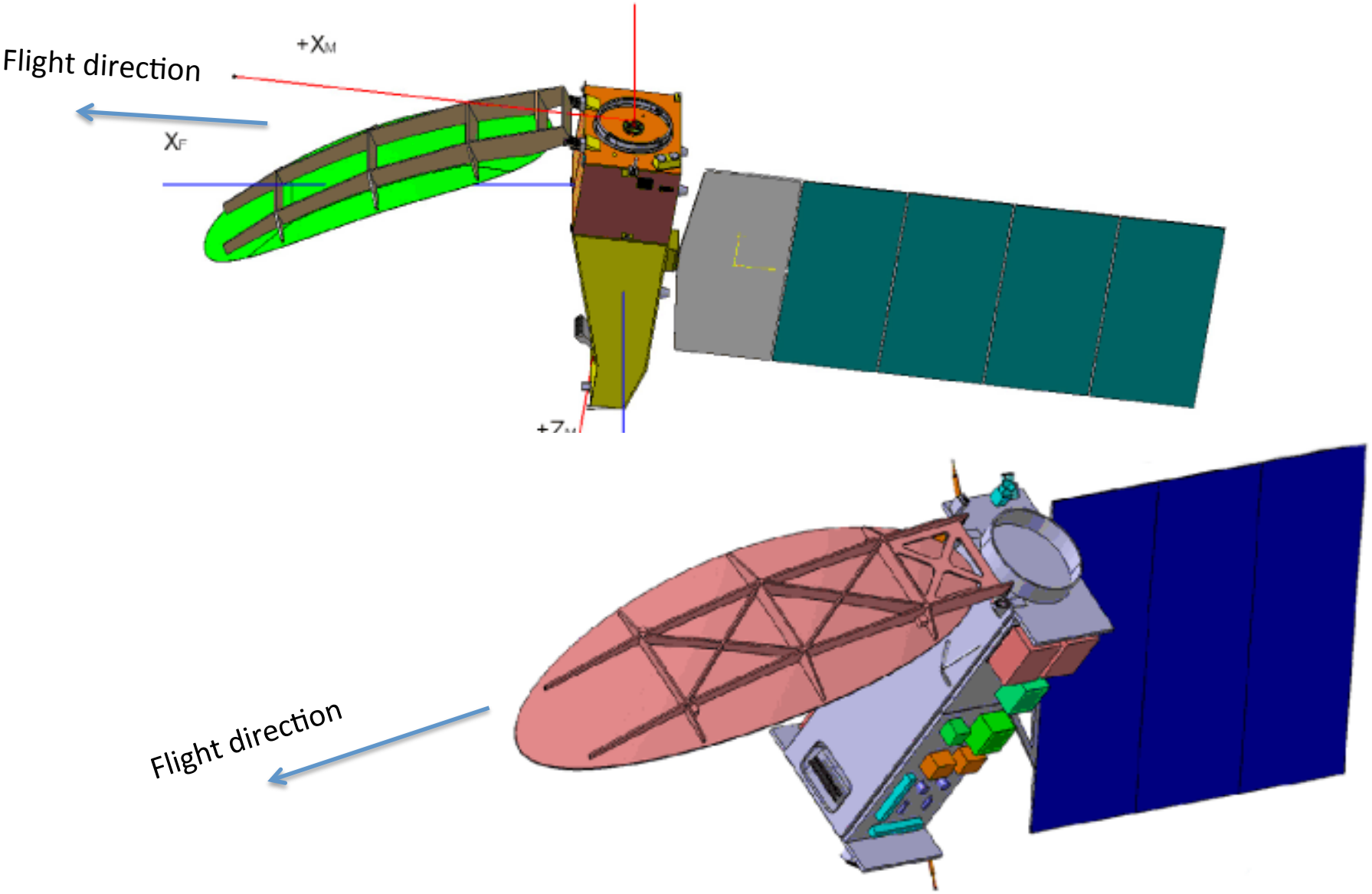
Solid – Total backscatter
Dashed – volume signal
Dotted – ground signal

CoReH$_2$O mission

- 2 mission Phases envisaged:
  - Phase 1 (2 years): 3-day repeat (~666 km)
  - Phase 2 (year 3 onwards): 15-day repeat)~645km)
  - SAR operates in ScanSAR mode (5 or 6 sub-swaths)

Parameter	Requirement
SAR frequency	9.6 GHz and 17.2 GHz bands
Polarisations	VV and VH
Incidence angle (at horizontal surface)	30–45° (swath within this range)
Spatial resolution	≤50 m × 50 m (≥4 equivalent number of looks)
Swath width	≥100 km
Noise equivalent σ^0	X-band: ≤–23 dB for VV; ≤–27 dB for VH Ku-band: ≤–20 dB for VV; ≤–25 dB for VH
Radiometric stability	≤0.5 dB
Absolute radiometric bias	≤1.0 dB
Dynamic range	≥30 dB
Total ambiguity ratio	≤–20 dB

CoReH$_2$O Spacecraft Concepts



FLEX – Fluorescence Explorer

- FLEX is a mission to map chlorophyll fluorescence of vegetation from orbit.
  - Used to make quantitative estimates of photosynthesis
  - Will provide an indicator of carbon storage in vegetation, and give insights into the carbon and water cycles.
- FLEX in Explorer 8 is an evolution of the mission studied at Phase 0 in EE7, and features a smaller spacecraft flying in tandem with Sentinel-3.
- FLEX is now in parallel competitive Phase A study, and so up-to-date designs are under wraps at present. We may expect further evolution from information presented today.
- Some details of a scientific study to identify optimal retrieval schemes are available from the University of Valencia. See: http://ipl.uv.es/flex-parcs/

- A single payload: FLuORescence Imaging Spectrometer (FLORIS - formerly FIMAS) - a VIS-NIR instrument (500-800 nm).
- Mission will use co-registered data from 2 instruments on Sentinel-3 which will fly in tandem with a few seconds separation:
  - Sea and Land Surface Temperature Radiometer - SLSTR
  - Ocean and Land Colour Instrument – OLCI

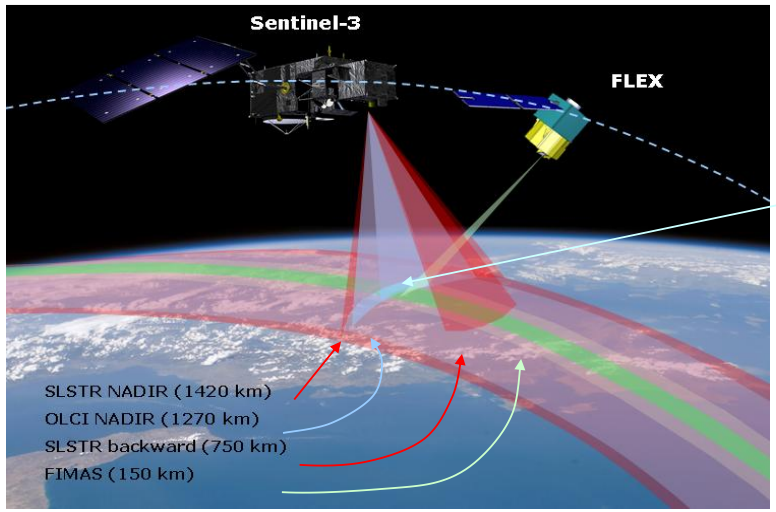


Image: ESA & University of Valencia

FLEX – Principle (1)

- Chlorophyll fluorescence is a close proxy for vegetation physiology.
- A very small component of sunlight returned from foliage is due to chlorophyll fluorescence in the red and far-red spectral regions.
- In parts of the solar spectrum where light is attenuated by absorption, and which overlap the fluorescence features, the fluorescence signal can be separated.
- The O_2-A and O_2-B atmospheric absorption features and Fraunhofer lines can be used to separate the fluorescence signal, provided effects are strong enough at the top of atmosphere.

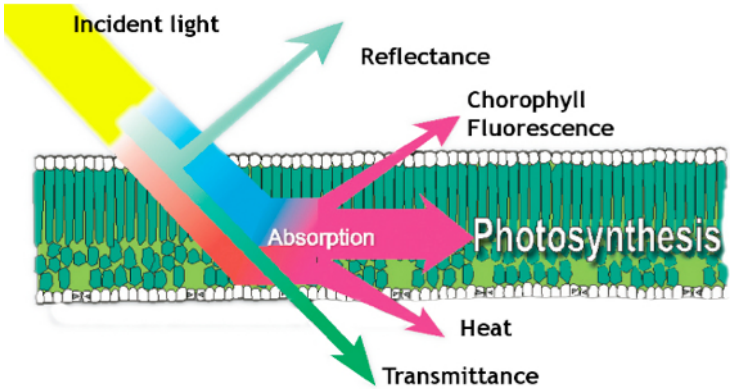


Image: University of Valencia

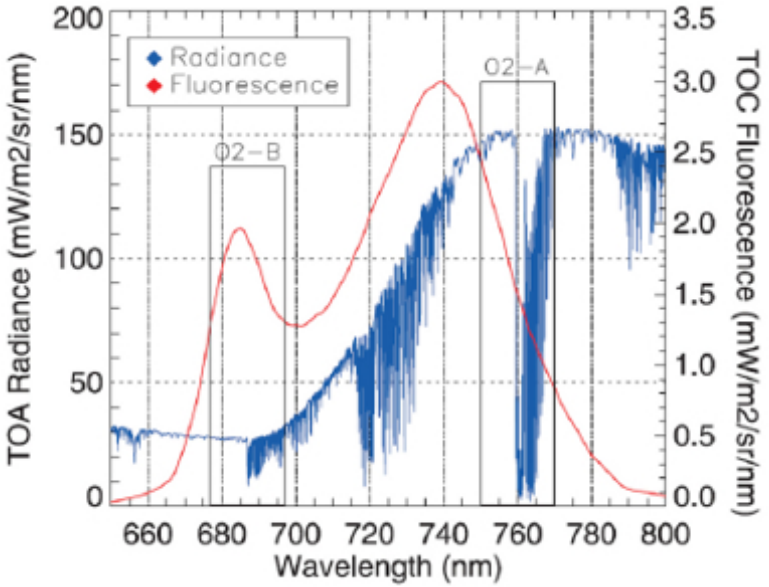


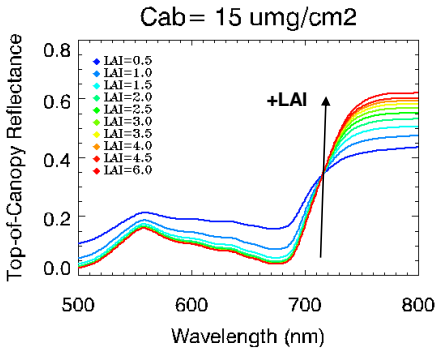
Image: University of Valencia

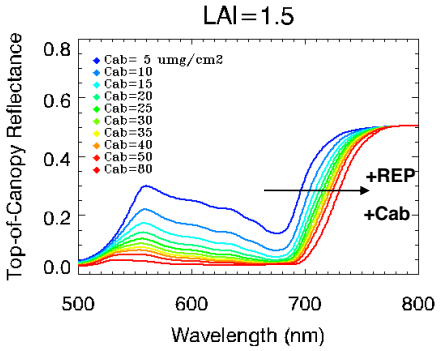
Principle (2)

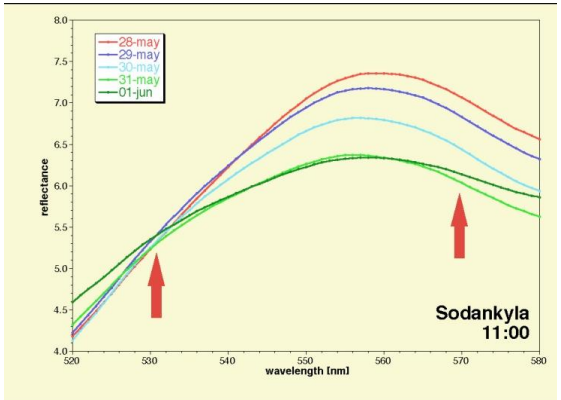
- Red edge and photochemical reflectance index (PRI) bands are also recorded.

Band	Range	Resolution
O_2-A	750-777 nm	0.1 nm
Red edge	714-750 nm	0.5 to 2 nm
O_2-B	660-714 nm	0.1 nm
PRI	520-660 nm	0.5 to 2 nm

- Slope of red edge is related to Leaf Area Index
- Position of red edge is related to chlorophyll content



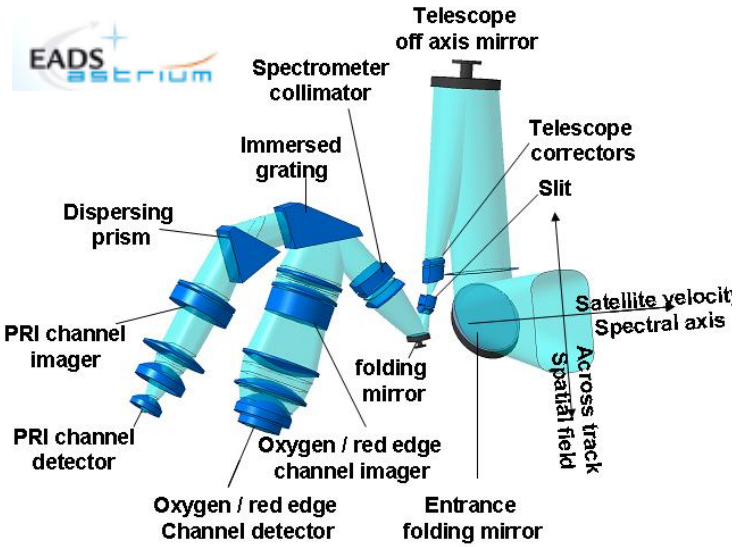


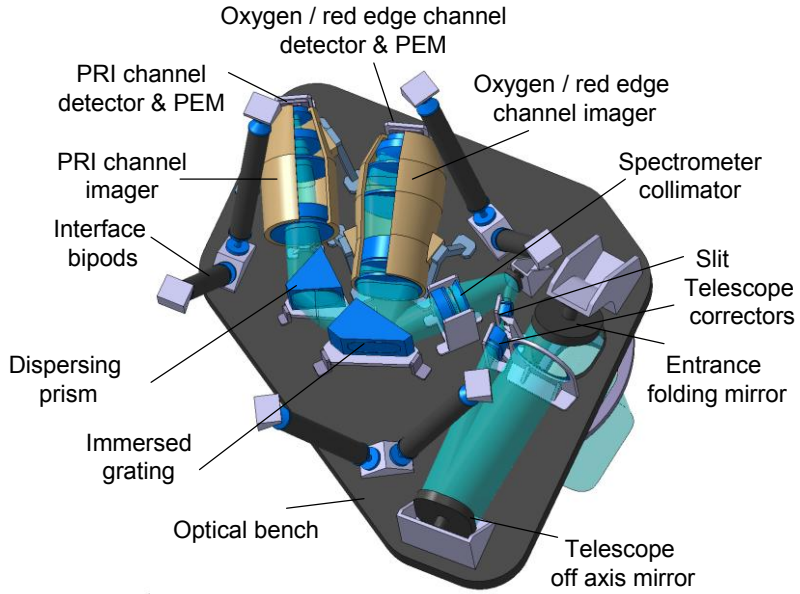


Early Instrument concepts

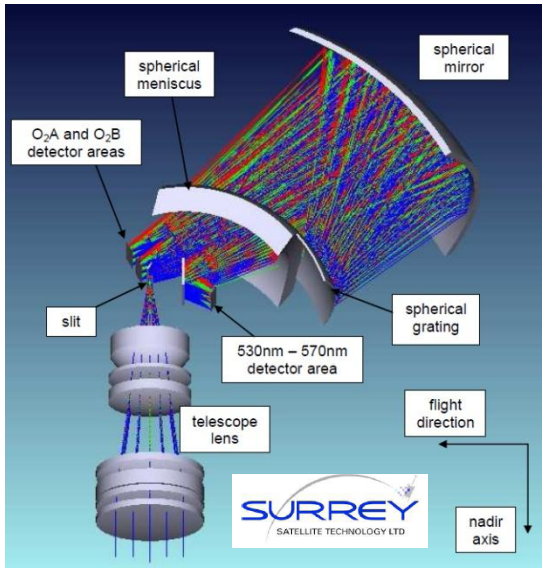
Centre for eo Instrumentation

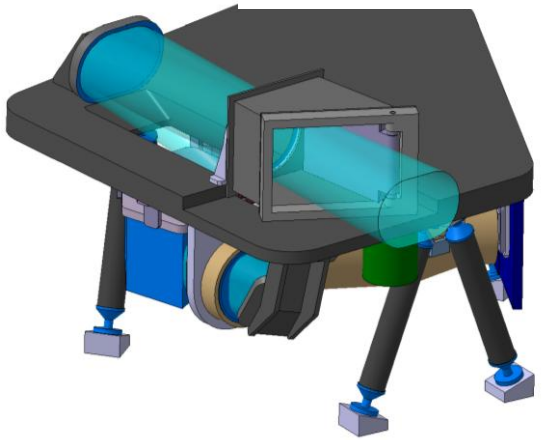
Immersed grating design





Concentric design with spherical grating





EADS astrium

Mission

- FLORIS uses the push-broom technique with a swath of 100-150km (within the swaths of the Sentinel-3 instruments)
- Pixel size is 0.3 x 0.3 km^2
- Co-registered OLCI and the SLSTR data are needed in support of fluorescence measurement and cross-calibration.

UK Interests – non exhaustive!

- **NB All missions subject to competition and down selection.**
- **PREMIER**
  - STEAM-R – STFC RAL & Astrium aspire to provision of SSB Mixer technology as UK contribution to the Swedish STEAM-R mm-wave imaging limb sounder instrument
  - Science interest – STFC RAL
- **BIOMASS**
  - Astrium UK Phase A study lead + aspiration for P-Band SAR
  - Science interest at U of Sheffield and U of Edinburgh
  - SEA aspire to end to end calibration, inc effects of ionosphere.
- **CarbonSat**
  - SSTL is involved in instrument design in one of the study consortia
  - Science Interest U of Leicester
- **CoReH2O UK Interest**
  - Astrium aspire to SAR electronics etc
  - COM DEV Europe aspire to provide several 1:8 switch matrix feeds at X and Ku-band
  - The also aspire to supply of high peak and CW power handling subsystems using ferrite-based latching circulators and phase-shifter switches
  - SEA aspire to end to end calibration, inc effects of ionosphere.
- **FLEX UK Interest:**
  - SSTL is involved in instrument design in one of the study consortia
  - Oxford University involved in the science

UK in the ESA Explorer programme

- Unless one is already embedded in the EE7,8 consortia, it will now be difficult to secure a major instrument role.
  - *However UK SMEs and other interested organisations are encouraged to contact the mission consortia, as there are likely to be subsystem and equipment roles – subject to geo-return issues!*
  - *Keep an eye on the politics! Opportunities can become available unexpectedly as a result of changes in the international funding landscape.*
- For the future, ESA have commented that Explorer proposals from the UK still lack maturity in some areas, namely:
  - *TRL level of technologies*
  - *Maturity of cost models*
  - *Maturity of systems engineering*
- For Explorer 9 & 10 and EE-X etc., CEOI may be able to help.
- Schedule for 9, 10 and EE-X etc. is dependent on EOEP-4 outcome at the Ministerial in November.

CEOI support (1)

- CEOI can provide:
  - Funds for proposition/proposal development;
    - *See current CEOI open call – aimed at small studies (capped at £30k each) for new mission concepts, instruments, and technologies. Closing date noon on 28th September 2012. Still time, but hurry! www.ceoi.ac.uk*
    - *Competitive bids - normally for seedcorn activities up to £50k.*
  - Funds for instrument development and TRL raising
    - *Competitive bids for seedcorn (£50k) and mainstream instrument technology development (£50 to ~£250k)*
  - Note that the existence of a real and credible flight opportunity is a key success criterion for a CEOI 'mainstream' bid.

CEOI Support (2)

- In addition, CEOI may be able to provide:
  - Seminars to discuss preparation of bids for Earth Explorers, perhaps exploiting experiences from past successful consortium members, or those with insight into ESA's processes;
  - Proposal 'flight-checks' in collaboration with UKSA.
- Discussions are taking place as to how these services might be provided.