Payloads for SmallSat Missions

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**contact

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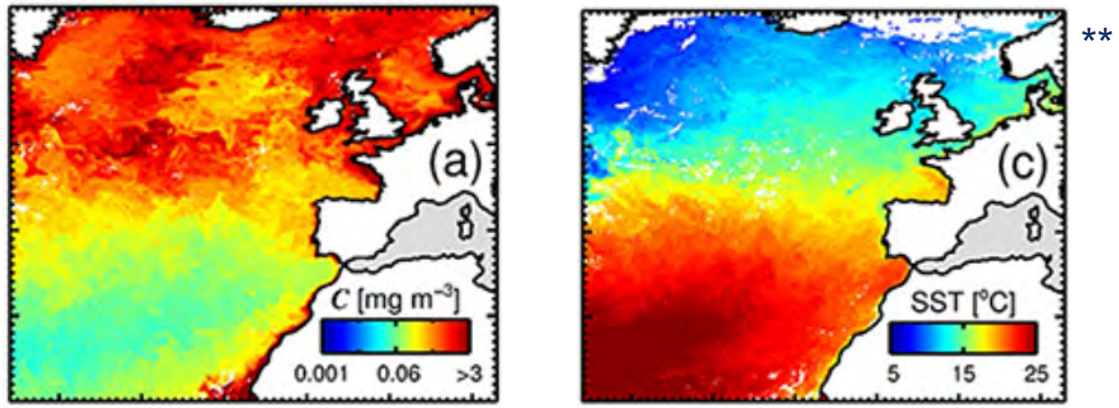
Introduction

- SSTL funded by ESA to develop concepts for future passive optical Earth Observation missions using small (<150Kg) satellites – tailored ECSS compliant
- Partners included:
  - University of Leicester: Eloise Marais & Darren Ghent
  - University of Exeter: Bob Brewin

Concept science case

- Monitor impact of human activity on oceans
- Covariance analysis of sea temperature and chlorophyll: link phytoplankton population change to rising sea temperatures – direct impact of climate change on ocean health



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  - Phytoplankton is a good indicator of ocean health
- Sub-daily retrieval is highly desirable

**Brewin et al (2015)

Requirements

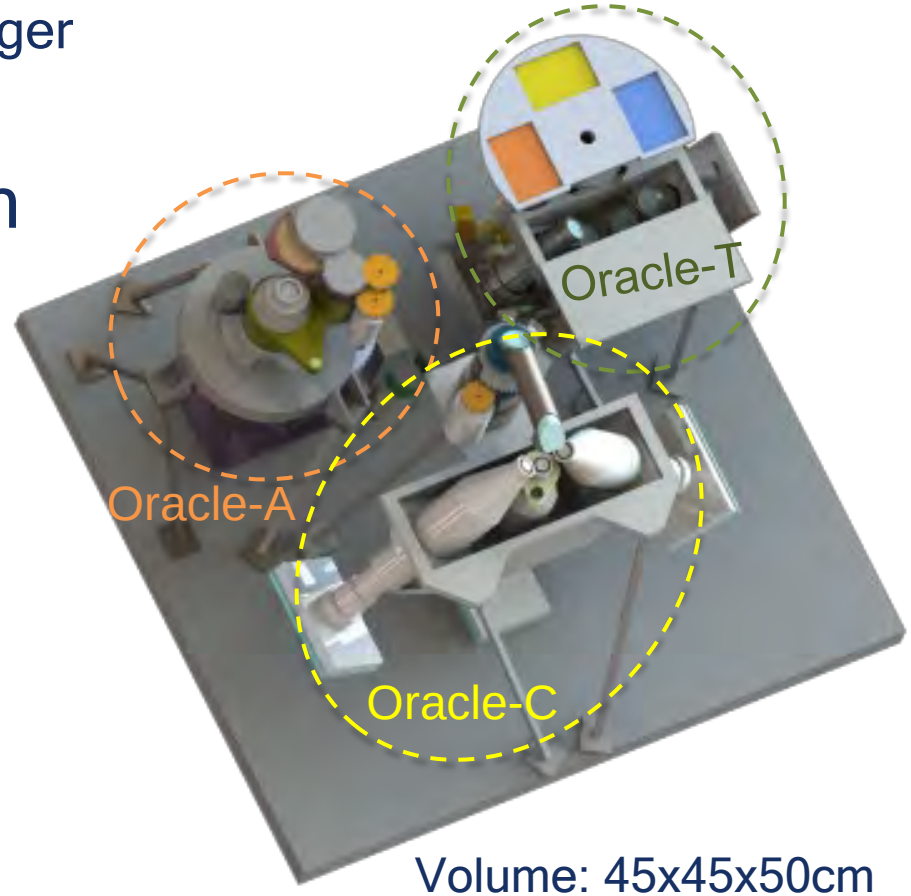
- Ocean colour: SNR>≈400 (Qi et al, 2016)
- Simultaneous AOD retrieval for atmospheric correction: SNR>200 using multi-angle spectro-polarimeter (Frouin et al, 2019)
- Sea skin temperature: uncertainty<0.5K
- Multiple sub-daily retrievals requires use of smallsat constellation
- Five year mission
- Compliance with (tailored) ECSS

Oracle instrument

- Oracle instrument consists of three imagers:
  - Oracle-C: multi-spectral pushbroom colour imager
  - Oracle-T: multi-spectral pushbroom thermal imager
  - Oracle-A: multi-spectral polarimetric imager
- Simultaneous imaging with same swath

Parameter	Oracle-C	Oracle-T	Oracle-A
GSD (m)	100	300	900
Swath (km)	1152	1152	1152
MTF (at Nyquist)	10%	10%	10%
SNR (min. in visible)	>≈400	-	>200
NETD (K)	-	0.21	-
Radiometric accuracy	<2%	<2%	<2%
Multispectral bands	8	3	11*
Mass (Kg)	8.0	7.8	5.7
Viewing angles	-	-	7
Data-rate (Mbps)	84	3	1
Internal calibration	Y	Y	Y

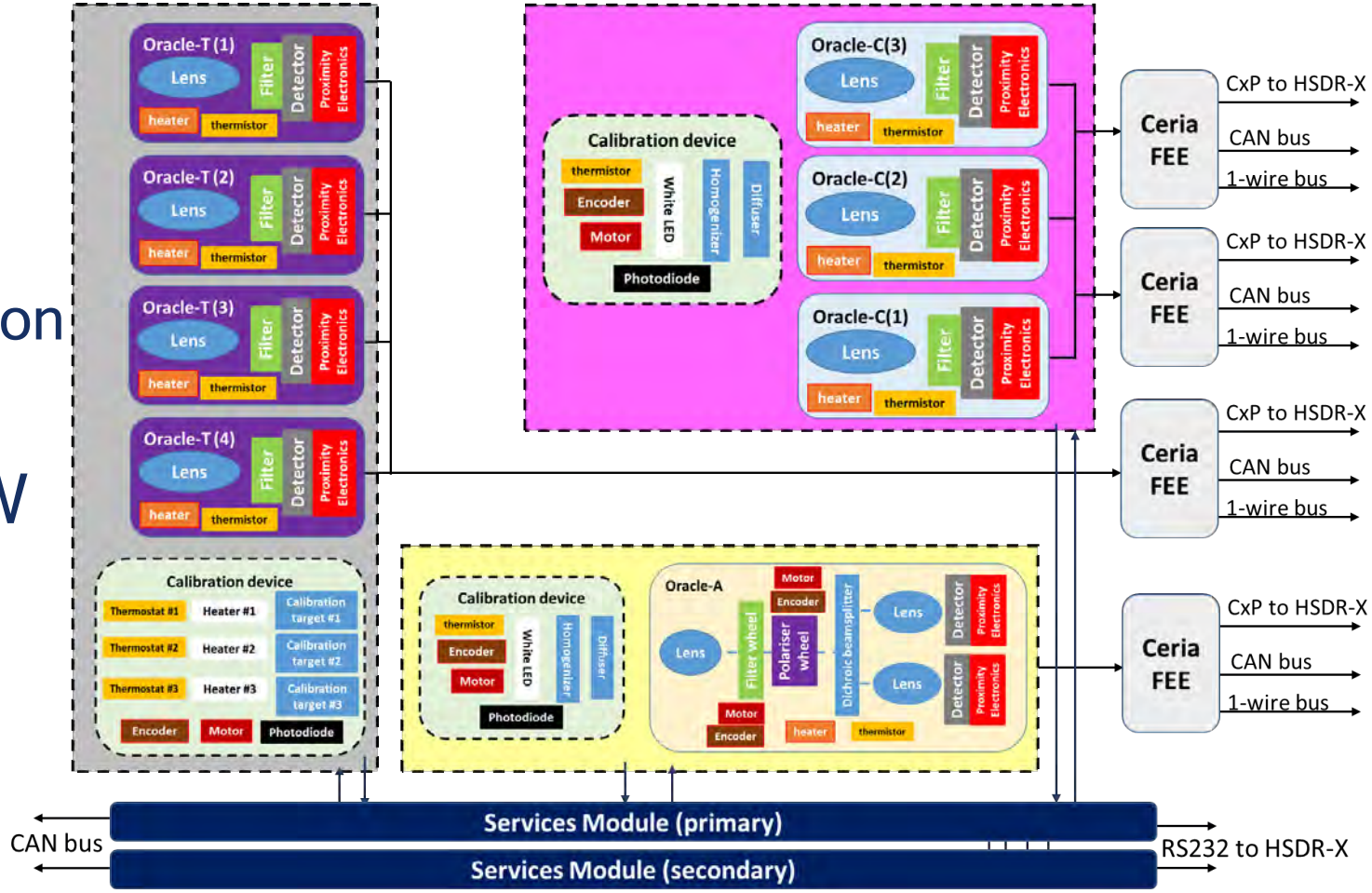
*polarised radiance



Volume: 45x45x50cm

Oracle instrument

- All instruments use:
  - SSTL Ceria FEE
  - SSTL Services Module
  - Individual internal calibration
  - Redundancy in FEE
- Power consumption 61W



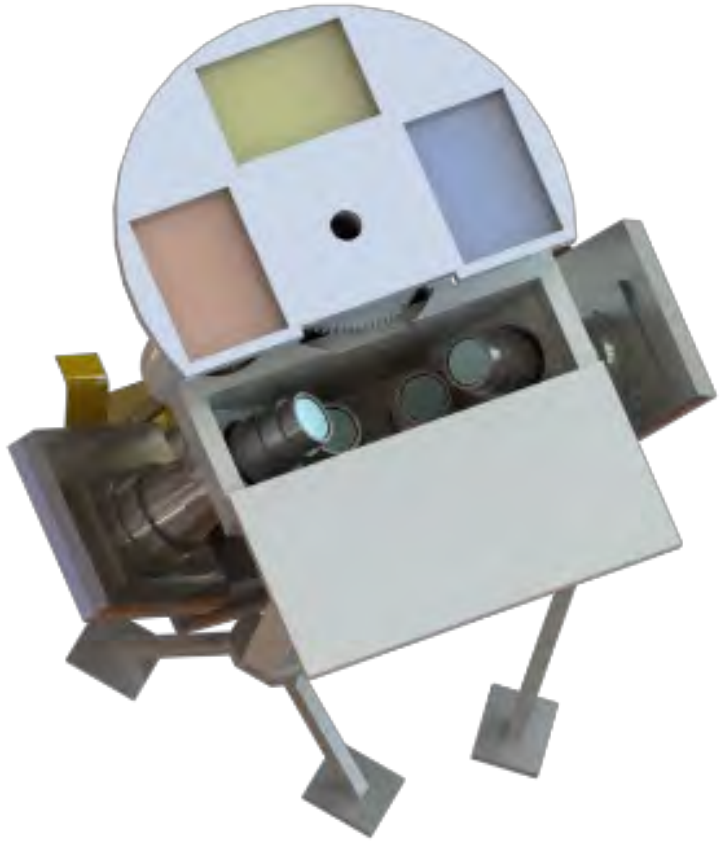
Oracle-C

- Consists of 3 self-contained sub-imagers mounted across track for increased swath
- Internal calibration device is used simultaneously by all 3 sub-imagers and can be moved in/out of field of view near the conjugate stop position
- Calibration device is based on a white light LED

CWL	BWD	SNR	Lref*	Oracle-C Primary use
412	20nm	510	0.074	Yellow substance and turbidity
443	20nm	480	0.066	Chlorophyll absorption maximum
490	20nm	471	0.051	Chlorophyll and other pigments
555	20nm	390	0.032	Turbidity and suspended sediment
660	20nm	284	0.016	Baseline of fluorescence, chlorophyll / suspended sediment
680	10nm	195	0.015	Atmospheric correction and fluorescence signal
745	20nm	258	0.015	Atmospheric correction and baseline fluorescence signal
865	40nm	181	0.062	AOD, vegetation and water vapour reference over ocean

Oracle-T

- Consists of 4 self-contained sub-imagers mounted across track for increased swath
- Internal calibration device is used simultaneously by all 4 sub-imagers and can be moved in/out of field of view near the conjugate stop position
- Calibration device is based on 3 actively controlled hot/cold CNT coated plates

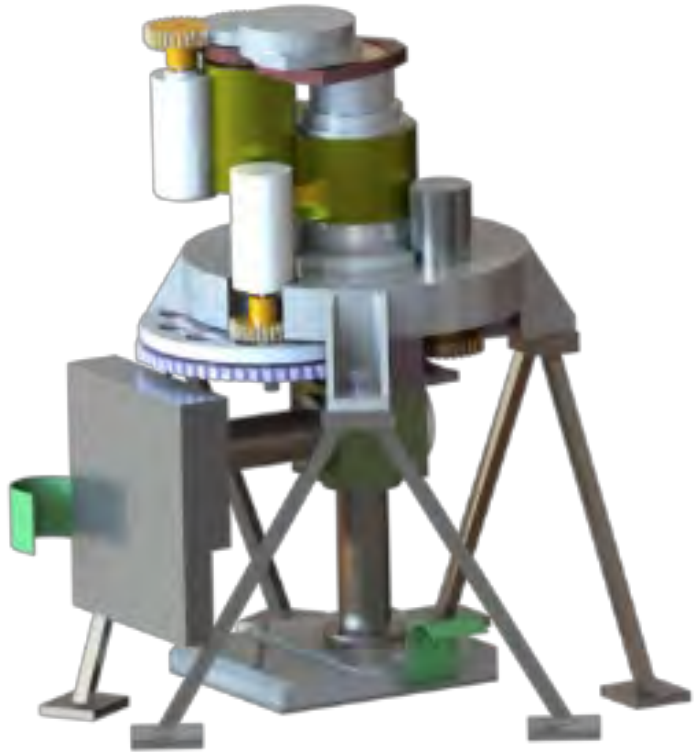


CWL [um]	BWD [um]	NETD
9.2	1.0	<0.2K @300K
10.6	1.0	
12.0	1.0	

Oracle-A

- Calibration device moves in/out of field of view prior to retrieval session
- Operation is same as POLDER/3MI – rotating filters
- VNIR and SWIR channels

Chnl	CWL	BWD	radiance	SNR
	nm	nm	$Wm^{-2}sr^{-1}nm^{-1}$	
VNIR	410P	20	0.047	264
	443P	20	0.057	317
	490P	20	0.058	346
	555P	20	0.055	358
	670P	20	0.045	331
	763	10	0.036	409
	765	40	0.036	298
	865P	40	0.028	261
	910	20	0.025	141
SWIR	910	20	0.025	287
	1370P	40	0.010	377
	1650P	40	0.007	281



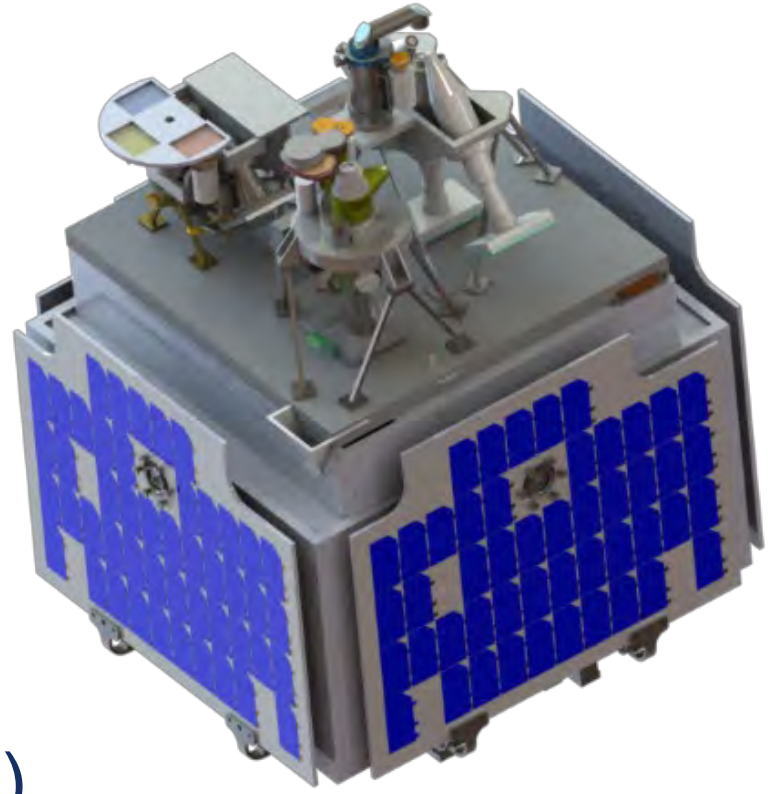
Viewing angles	-52º, -40º, -20º, nadir, +20º, +40º, +52º
Polarisation angles	-45º, 0º, +45º
Polarisation sensitivity	0.976

Performance summary of Oracle instrument

- Oracle meets the user requirement to provide retrieval of ocean colour and sea skin temperature with sufficient radiometric accuracy
- Oracle-C: SNR >≈ 400
- Oracle-T: NETD<0.2K provides a mean L2 temperature measurement uncertainty of <0.5K of SST at 300K
- Oracle-A: SNR >200 (similar to 3MI)
- Five year lifetime

Oracle satellite

- Oracle instrument has been design to fit in the SSTL-42 bus
  - Total wet mass: 77kg
  - Mission lifetime: 5 years
  - On-board memory: 528Gb
  - Data transmission>160Mbps
  - Power consumption<108W
  - Dual redundancy avionics and AOCS
  - SSO 567km
- SSTL 35 year heritage to design (tailored) ECSS compliant satellite



Conclusion

- Oracle concept has been developed to simultaneously retrieve ocean colour, sea skin temperature and aerosol optical depth
  - Mission concept
  - Preliminary instrument design
  - Preliminary platform design
- Allows better understanding of ocean health through examination of phytoplankton populations
- Final presentation of concept to ESA later in the year

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Thank You!
Any questions ?

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Justification of science case

- Many potential benefits of simultaneous retrievals of ocean colour and sea skin temperature:
  - Estimating marine primary productivity (Sathyendranth at al, 1991)
  - Bio-physical feedbacks (Sathyendranth at al, 1991)
  - Satellite phytoplankton group retrievals (Brewin et al 2019, 2017 & Ward et al, 2015)
- Retrieval of ocean colour products:
  - Remote-sensing reflectance (R_{rs})
  - Chlorophyll concentration (C)
  - Particulate organic carbon (POC)