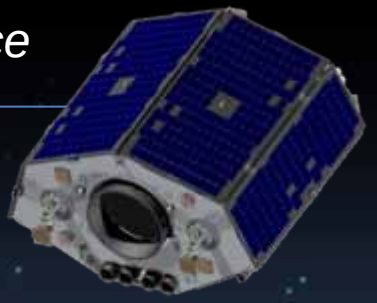
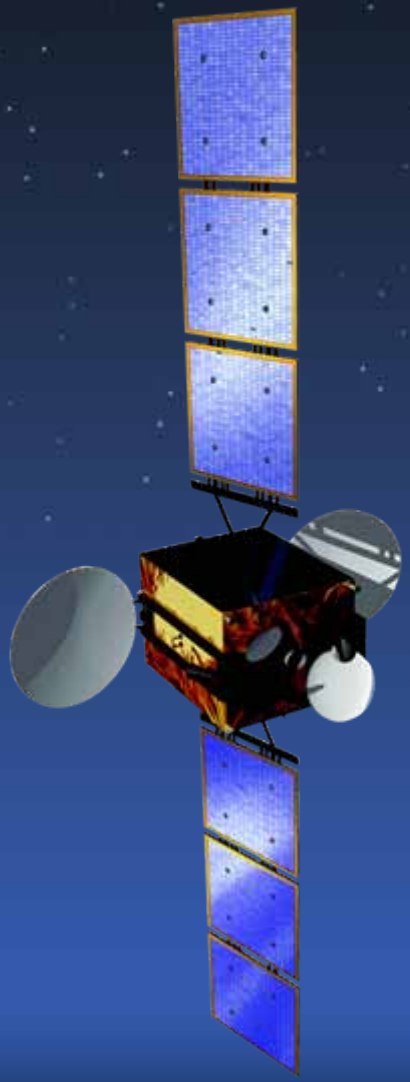
SURREY SATELLITE TECHNOLOGY LTD

Changing the economics of space





Sea State Payload on TechDemoSat-1

Martin Unwin

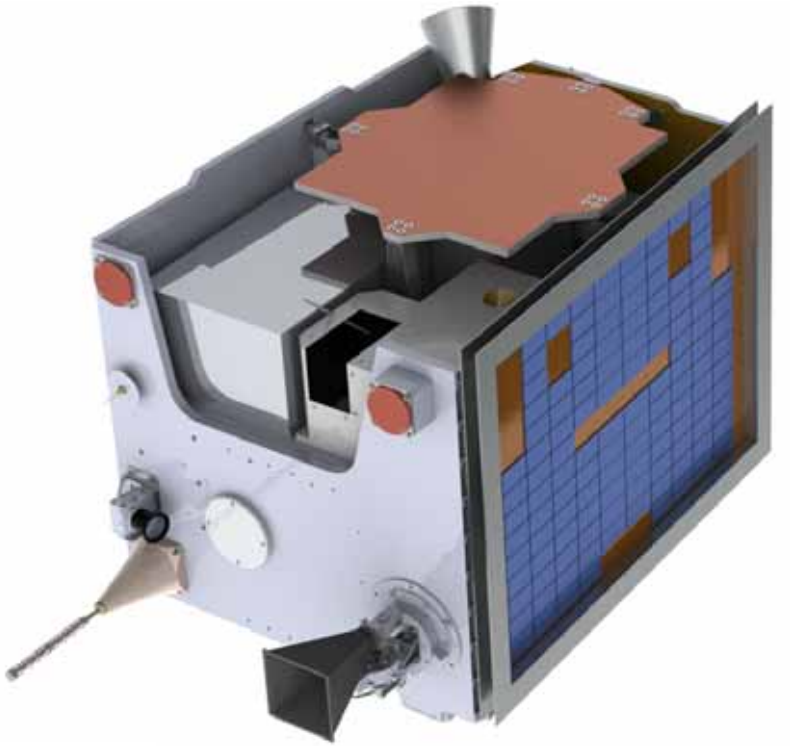
Satellite Constellations and Sea State

- Ocean remote sensing achieved from high accuracy spaceborne satellite-based radar
  - Jason, GEOSAT, Envisat, QuikSCAT
- Satellite constellation opportunities open new doors in ocean remote sensing
  - E.g. Iridium NEXT opportunity – 66 satellites
  - SSTL's small satellites: RapidEye x 5, DMC x 5
- Implications for sea state determination
  - High temporal, high spatial coverage feasible
  - Validation of near real-time wind and wave models
  - Long term observations for climate models
  - Ice edge and concentration monitoring
  - Operational monitoring service – sea state, cyclones, storm surge, tsunamis, etc.
- To be feasible, need low cost, low power instruments, with "adequate" accuracy
  - Target is for constellation to cost same as high-spec satellite

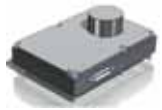
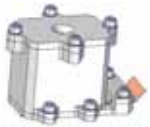
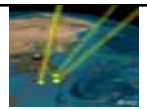
TechDemoSat-1 (TDS-1)

- Provide in-orbit facility to demonstrate new space tech.
  - Rapid access to orbit
  - Low risk space and ground facilities to host and operate the payloads
  - Demonstrate payloads operationally => commercialisation step
- Funding from TSB / SEEDA & Payload Suppliers

- SSTL-150 platform
  Accommodates 8 physical payloads
- Total Mass ~160 kg
- Power - 52 W orbit average
- Data storage - Up to 128 GB
- Downlink - S- & X-Band
  - Up to 400 Mbps
- Attitude Det. & Control
  - 4 wheels, New star tracker, New gyro, MTMs and MTRs



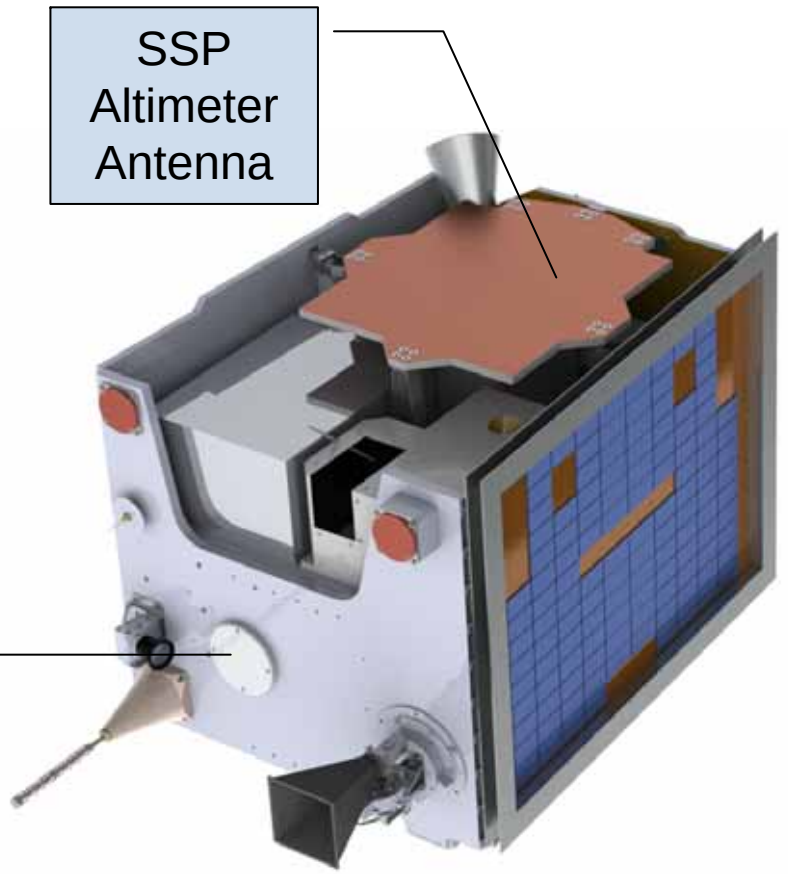
TDS-1 Payload Overview

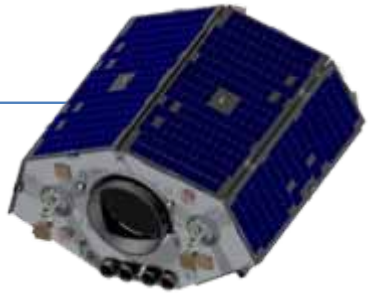
Payload	Supplier	Description	Illustration
MuREM	University of Surrey (Surrey Space Centre)	The Micro (μ) Radiation Environment Monitor (MuREM) is a miniature radiation environment and effects monitoring payload.	
ChaPS	Mullard Space Science Laboratory (MSSL)	The Charged Particle Spectrometer (ChaPS) is designed to measure electron and ion populations in the orbit of the host spacecraft.	
LUCID	Langton Star Centre	The Langton Ultimate Cosmic ray Intensity Detector (LUCID) allows characterisation of the energy, type, intensity and directionality of high energy particles.	
CMS	University of Oxford / RAL	The Compact Modular Sounder (CMS) is a set of compatible optical, detector, cooling and electronic sub-systems which can be used to implement miniature infrared remote sensing spectrometers or radiometers.	
HMRM	Rutherford Appleton Laboratory	The Highly Miniaturised Radiation Monitor (HMRM) is a an ultra-compact, low power radiation monitor developed for re-use on future ESA missions.	
CubeSAT ACS	Satellite Services Ltd	The CubeSAT ACS payload is a complete 3-axes attitude determination and control subsystem for Cubesats.	
DOS	Cranfield University	The De-Orbit Sail (DOS) is intended to demonstrate a novel means for de-orbiting a satellite at the end of its mission lifetime through deploying a sail to increase aerodynamic drag.	
Sea State Payload	Surrey Satellite Technology Limited (SSTL)	a) Experimental Altimeter, b) SGR-ReSI - GNSS Remote Sensing Instrument – Measures ocean roughness using reflected GNSS signals	

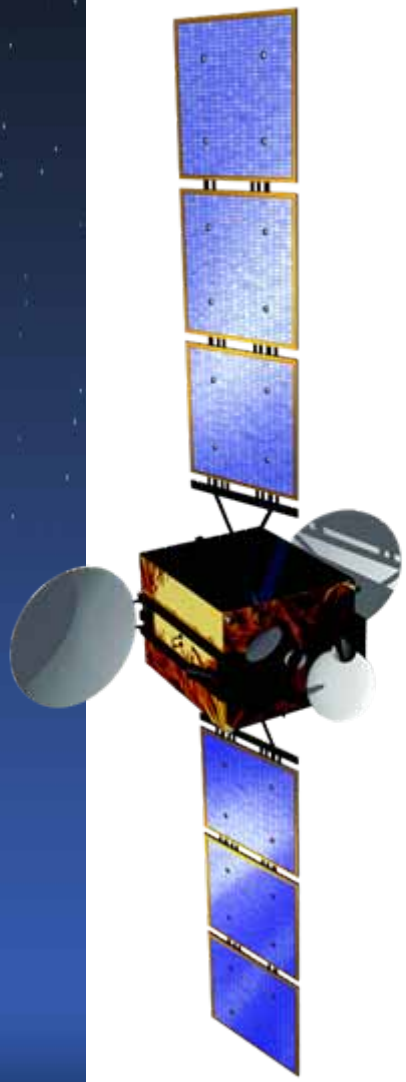
Sea State Payload on TechDemoSat-1

- Sea State Payload has two components
  - SSP Altimeter - Demonstration of low cost altimeter
  - SGR-ReSI - Space GNSS Receiver - Remote Sensing Instrument

- Both targeted at determining Sea State
  - Possible future use on satellite constellations
  - Not limited to sea state, secondary objectives







SSP Altimeter

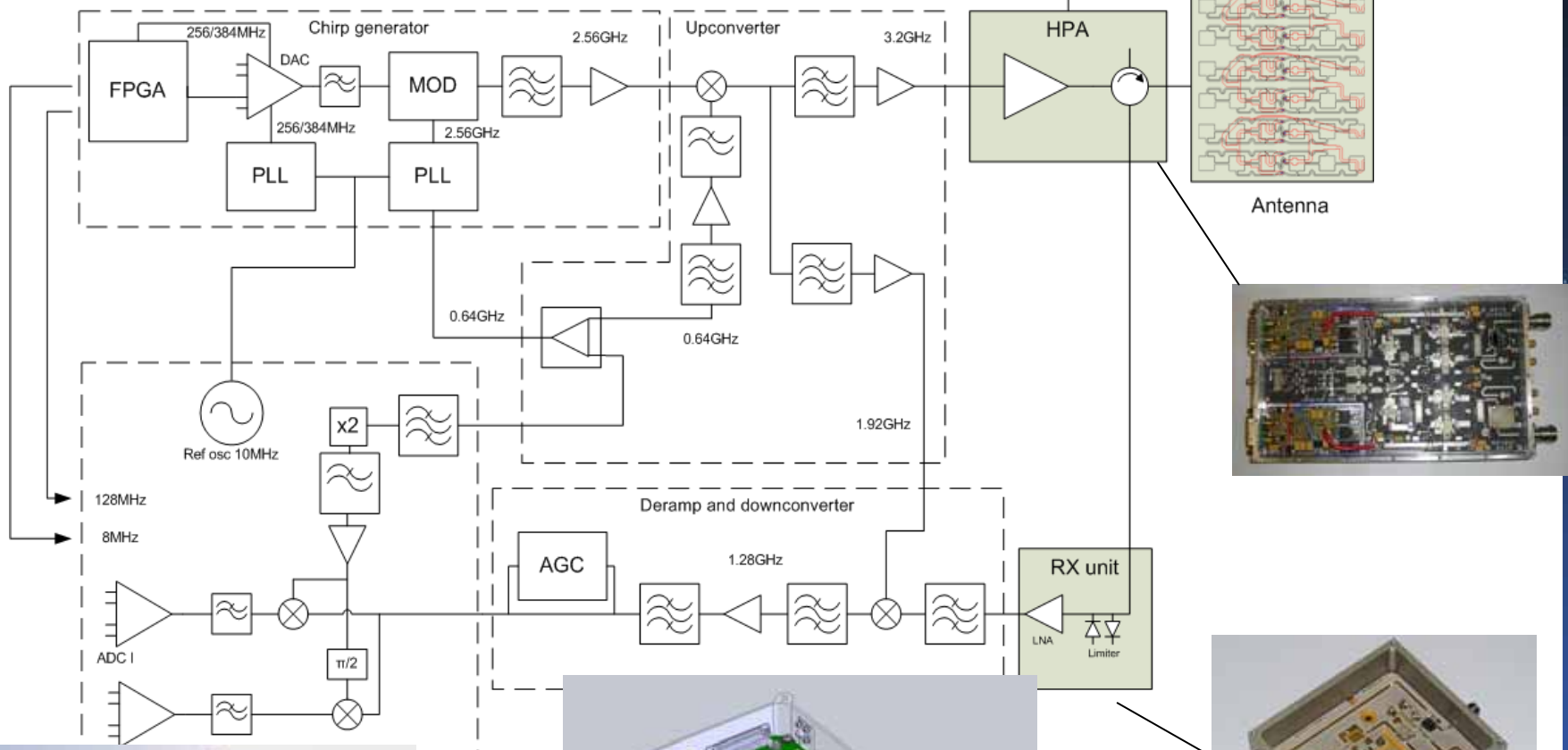
SSP Altimeter

- SSTL-funded instrument
  - With equipment contributions from Astrium, Portsmouth
- Experimental instrument - aims:
  - Demonstration of radar altimeter in small satellite package
    - S-Band with dual polarimetric capability
  - Sea-state measurement targets
    - Significant wave height
    - Wind speed
    - Relative sea height / geostrophic current sensing
  - Stepping stone for future altimetry mission / constellations
    - GANDER business case, GAMBLE study, ESA/GMES study
- Technology: new subsystem but with leverage from other developments
  - Early flight heritage for SAR payload RF units
  - Using SSTL X-band transmit modulator for signal generator
  - Maximum use of heritage technology/components where possible

Altimeter RF Block Diagram

Chirp, S-Band upconversion, Amplify, Transmit

Receive, Downconversion, Demodulate, Store/proc.



SSP Altimeter – Vital Statistics

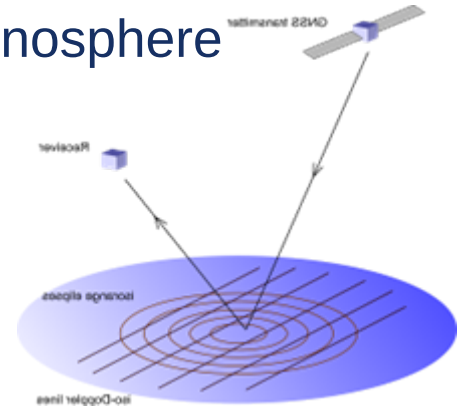
TDS-1 Implementation:

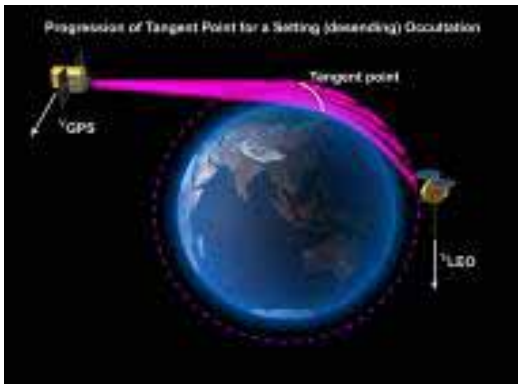
- Power – 90 Watt DC peak
- Transmit - 100 W pulsed at S-Band
  - Pulse Repetition Frequency: 2 kHz
- Total Mass – Approx 5 kg
- Antenna Size ~ 50 cm x 50 cm
- Operational Modes planned
  - Primary mode – data collection over ocean
  - Post processing data on ground for validation
  - Experimental Delay Doppler Mode
  - Experimental Receive-only RF Surveying Mode

SGR-ReSI
GNSS Remote Sensing Instrument

Remote Sensing with GNSS

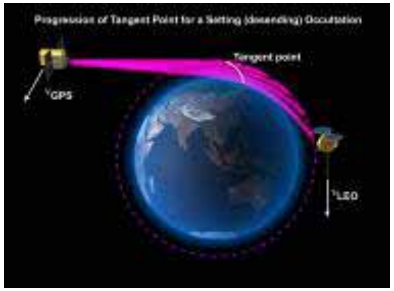
- GNSS comprises GPS, Galileo, Glonass and others
  - 60+ Satellites in Medium Earth Orbit (20,000+km) transmitting L-Band navigation signals
- Remote sensing - GNSS signals as “radar transmissions”
  - No extra transmitter is required – only antenna and receiver
  - Potentially small, low cost remote sensing instrumentation
  - Dual frequency available – mitigate/measure ionosphere
- GNSS Reflectometry
  - Use GNSS reflections off ocean / land
  - Measure scattering of signal
  - Demonstrated on UK-DMC
- GNSS Radio-Occultation
  - Measure refraction of signals through
    - Troposphere – meteorological weather
    - Ionosphere – space weather
  - Proven on COSMIC, Eumetsat, others
  - Used by Met Office, near-operational status





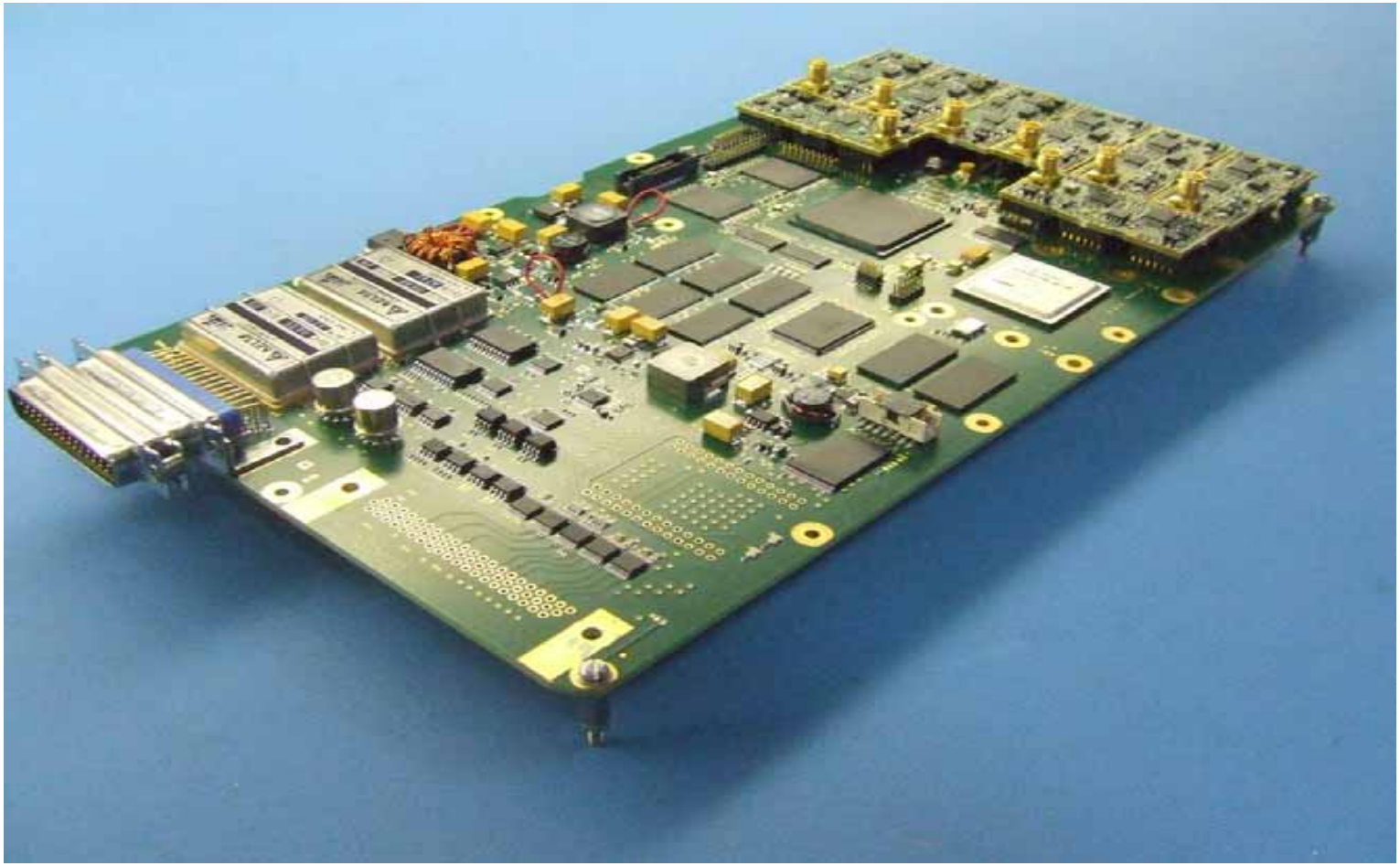
Science Needs

- SGR-ReSI development intended to address needs:
- Ocean Sensing (driver)
  - Wind and Waves – More GNSS-R data required to verify inversion models
  - Applications both near real-time, and long term
  - science models, SMOS calibration
- Atmosphere
  - Tropospheric for weather, and research
  - Ionospheric monitoring, mapping, scintillation
- Ice sensing
  - Ice edge detection, ice concentration
  - Dual Frequency may allow free-board measurement
- Soil Moisure potential
  - Soil mapping and crop management

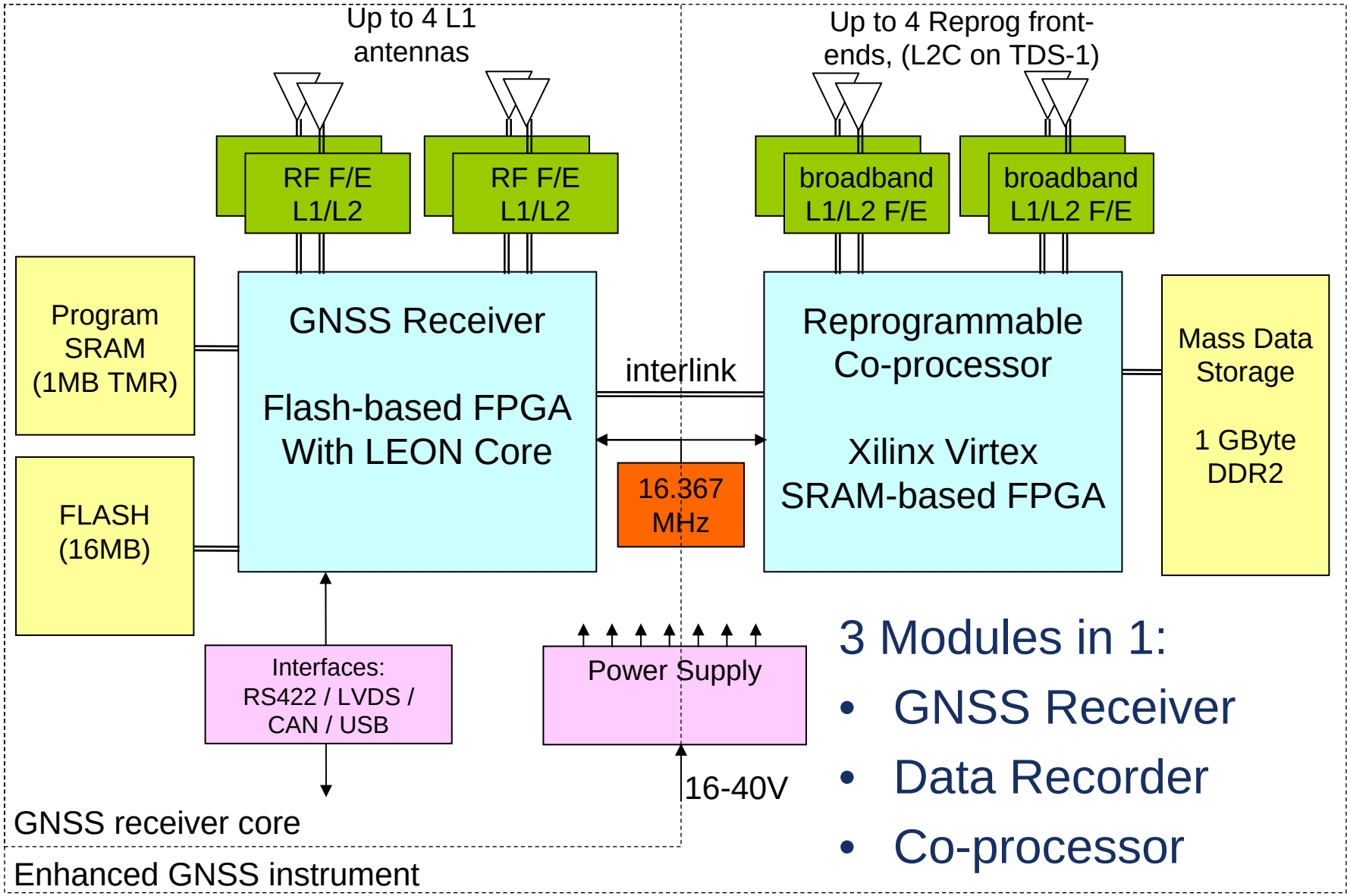


SGR-ReSI Prototype

- CEOI matched funding for instrument development
  - Funded from Call 2 and Call 3
- Consortium Partners – NOC, Uni. Bath, Uni. Surrey, PIL
  - Output was Prototype and Engineering model SGR-ReSI



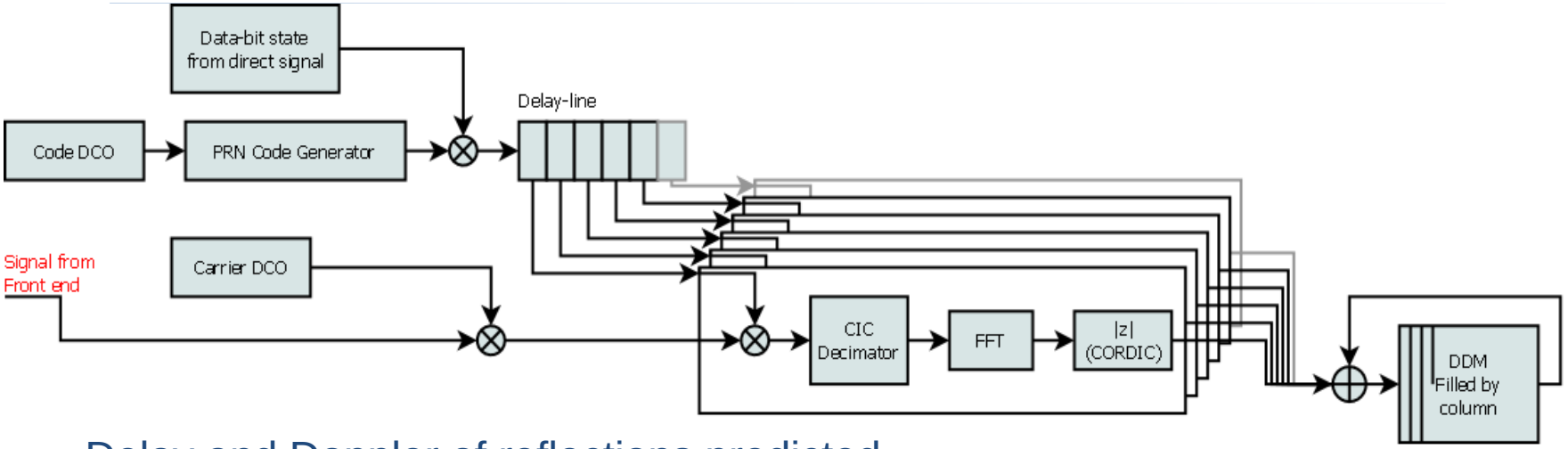
Instrument Description



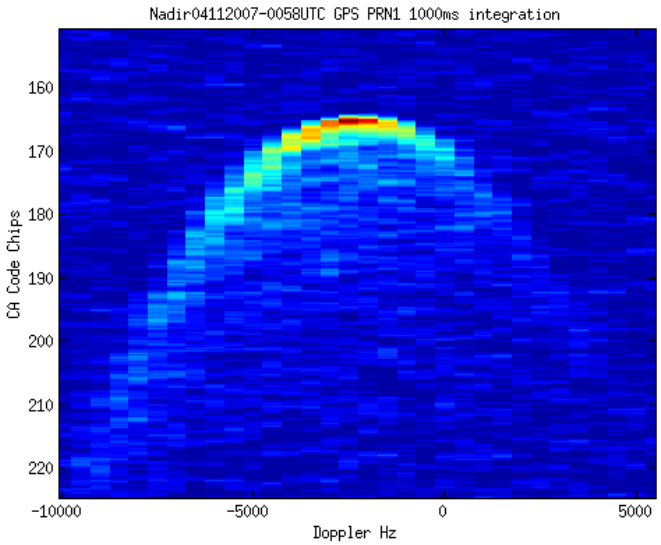
3 Modules in 1:

- GNSS Receiver
- Data Recorder
- Co-processor

Delay Doppler Co-processing



- Delay and Doppler of reflections predicted
  - Based on current position & signals tracked
- Sampled reflected signals processed in Virtex
  - Using in-built RAM and multipliers in Xilinx Virtex FPGAs
  - Time-shared hardware (131MHz processing clock)
- Current realisation:
  - Coherent correlation for 1ms
  - Accumulated incoherently for about 20ms to 2s (run-time configurable)
- Generation of Delay Doppler maps of reflections
  - Equivalent of nearly 7000 GPS channels correlated in real time



SGR-ReSI – Vital Statistics

- Power – 10 Watts
  - Continuous reflection processing mode
  - Approx 5 W for GNSS receiver only
- Mass – 1.5 kg (incl antennas)
- Nadir Antenna Size ~ 30 cm x 30 cm
  - Gain approx 12 dBi, dual frequency
- Zenith Antenna - Dual Freq, Gain ~4 dBi
  - Plus 2 Small Single Frequency Antennas
- Receives – GPS L1 and L2C
  - Also reconfigurable for Galileo, Glonass
- Operational Modes planned
  - Primary mode – data processing over ocean
    - Data gathering for cross over & in situ data model validation
    - Prototype marine service mode
  - Raw data collection over targets for post processing
    - Cyclones, ice edge, snow, coast, land
  - Demonstration Radio-Occultation mode – iono- & troposphere
  - Experimental GNSS RF Surveying Mode

TDS-1 Status & Schedule

- Launch – Mid/End 2012
  - Negotiations underway with provider
  - Current orbit assumption:
    - LEO, Sun synchronous, 670 km, 10 am [TBC]
- Internal Critical Design Review successful
  - August 2011
- Spacecraft manufacture commenced
  - Spacecraft harness undergoing assembly
  - Platform systems under test
  - First Payload for Spacecraft Assembly due mid-Oct
  - Spacecraft Environmental Test - early 2012

Summary

- Sea State Payload on TDS-1
  - SSP Altimeter
    - Major step towards low cost altimetry technology
  - SGR-ReSI
    - Instrument for exploiting GNSS signals for remote sensing
    - Ocean sensing – also ice, land & atmosphere
- Progress towards *constellation paradigm* in ocean remote sensing
  - High spatial / temporal resolution of sea state
  - Fine scale altimetry, scatterometry
  - Operational and scientific / climate users

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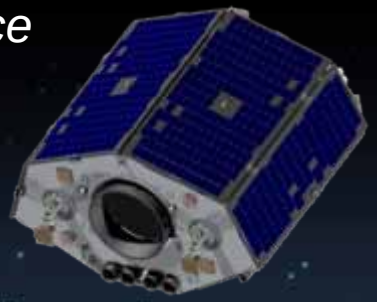

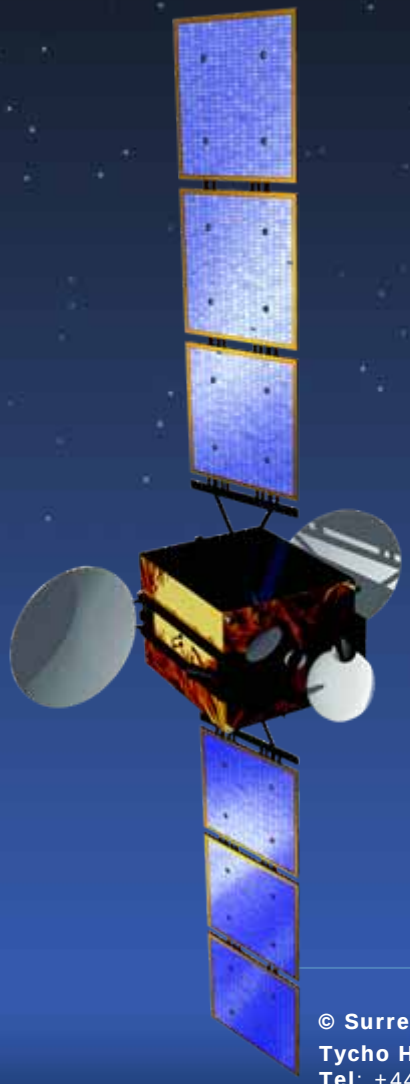

Thank You

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SGR-ReSI Reflectometry Performance

	SGR-ReSI
Signals	1) GPS L1 2) GPS L2C a) Ice & Ionosphere measurements 3) Galileo + GLONASS L1 a) Optional extras! b) more signals for gap filling
Sampling Rate	16.367MHz, 2 bits (I & Q)
Storage	60 seconds raw data (1 GByte storage)
Calibration of Power Received	AGC monitoring & on-board thermal noise source
Direct Tracking	Reprogrammable to other signals
Reflected Tracking	Reprogrammable in SRAM FPGA
Continuous output	Yes - Delay Doppler outputs

Equipment Specification

Parameter	SGR-ReSI specifications
Number of channels	24 (extra channel can be configured in Virtex 4)
Mass	<1 kg
Size	300 x 195 x 48 mm
Isolated operation off 28V	Yes
Input Voltage	28 +/- 10 Vdc
Power (typical value)	10 W at 28V
Data Interfaces	CAN
PPS outputs	CAN
Flight Heritage	New development
Qualification Testing	No
Parts Quality	COTS based with Rad testing
EDAC protection	Yes – Cyclical EDAC on Flash and SRAM, TMR of critical registers in FPGAs
GPS Function (Zenith antenna)	**Specified max in reference orbit conditions**
Position accuracy	< 20m (95%) (L1 only)
Velocity accuracy	< 0.25m/s (95%)
Time (UTC)	< 1µs
Dynamic capability	> 8 kms-1, 2g
TTFF (when all almanacs are available in NVRAM)	90-180s
Raw measurements	L1 pseudorange, carrier phase, SNR L2C pseudorange, carrier phase, SNR
Other constellations (Option)	Configurable L1 / L2

TechDemoSat-1 Payload overview

- **Maritime Suite -** Sea State Payload (SSTL)
  - SGR-RESI plus SSP Altimeter
- **Space Environment Suite**
  - Micro (μ) Radiation Environment Monitor (University of Surrey)
  - Charged Particle Spectrometer (MSSL)
  - Langton Ultimate Cosmic ray Intensity Detector (Langton Star Centre)
  - Highly Miniaturised Radiation Monitor (RAL)
- **Air and Land Monitoring Suite**
  - Compact Modular Sounder (Oxford University / RAL)
- **Platform Technology Suite**
  - De-Orbiting Sail (Cranfield University)
    - Deployable sail to increase aerodynamic drag and lower the orbit
  - CubeSAT ACS (SSL) - Miniaturised attitude, orbit sensors
  - Software experiments (SciSys / Logica)