DEFENCE AND SPACE

SPIDER (Ship Position and Detection Radar) Proof of Concept Campaign

UK NEO Conference, Birmingham, 05/09/18

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Background

- Inherent **challenges** of Maritime Surveillance increasing and predicted to accelerate due to expansion of maritime traffic, growing issues with illegal fishing, piracy and migration.
- Maritime Surveillance is traditionally performed using a **fragmented, expensive and inefficient** array of sensor networks managed by Maritime Authorities and, Defence and Security Agencies.
- Current systems still suffer from poor revisit time and latency for wide areas which are increasingly required.

Typical Maritime Surveillance Requirements

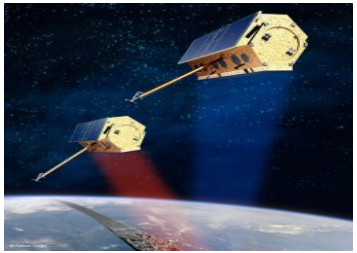
Re-visit Time	• Threshold < 1h • Target: <15 min
Latency	• < 15 minutes
Ship size	• Threshold: 25m • Target: 10-15m
Performance	• Prob. of detection > 0.9 • Prob. False alarm < 10^{-6} • Sea State <4-5

*These figures depend on global, regional or local coverage.

Land-based Radars

Maritime Patrols

Air Patrols



EO Satellites

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Opportunity: Airbus Zephyr

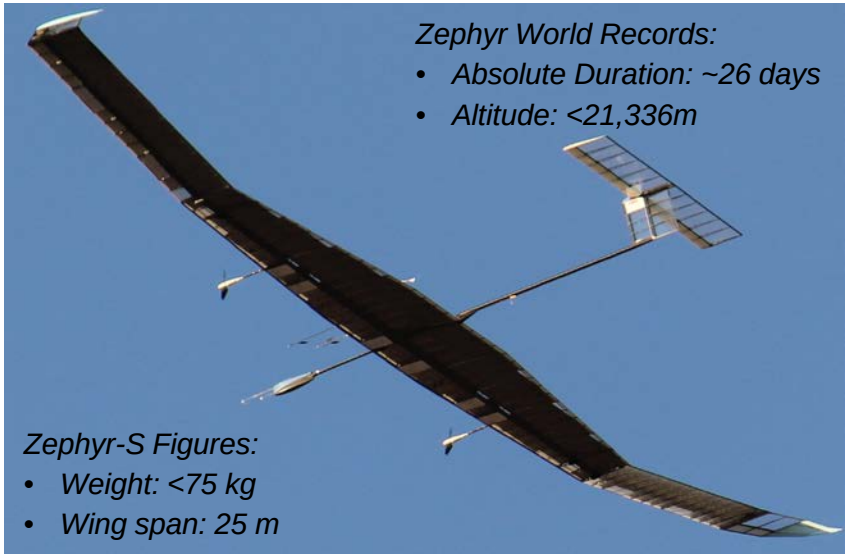
- Zephyr is a High Altitude Pseudo-Satellite (HAPS) running exclusively on solar power that:
  - Endures like a satellite;
  - Focusses like an aircraft and;
  - Is cheaper than both of them.

- Very brief Zephyr program status:
  - 3 Zephyr-S purchased by UK-MoD in production.

- **Zephyr opens new market opportunities for permanent maritime surveillance at regional scale.**

The challenge is to develop a radar sensor meeting the stringent SWaP, operational, and environmental constraints.

(*We like challenges.)



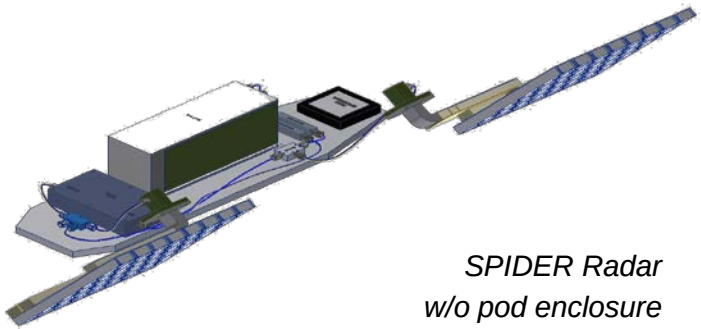
Typical Zephyr-S Requirements on Payload

Total Mass	< 5 kg
Total DC power	< 50 W (day avg.) < 200 W (peak)
Volume	< 0.15 L
Environmental	Temp & Pressure Stratos.
Data Link	BLOS < 1kbps (SATCOM)

SPIDER Zephyr-S Radar Payload

Payload Characteristics

- Total mass < 5kg
- Centre frequency: X-Band
- Bandwidth: up to 1200 MHz
- CW Operation: Chirp & Coded pulses
- Antenna size < 0.2 m x 0.2 m
- Beam Scanning capabilities for extended coverage
- Beyond Line-of-Sight Operation in Maritime Mode



SPIDER Radar w/o pod enclosure

Payload Datasheet

System Parameter	Maritime Mode	Stripmap SAR
Coverage	>40km	>40km
Product Swath	>40km	5km
Resolution	0.5m x 100 m	<1m x 1m
Data Rate*	1-2 bytes/ship	<30 MB/s
Duty Cycle	100%	<3%
Avg. Power	<40 W	<140 W
Integration Time	0.05-0.5 s	30-60 s
Operation mode	LOS & BLOS	LOS / DL
Performance	PD>0.9 PFA<10^{-6}	NESZ<-20dB
N. of Sub-swaths	8	8

**Excludes data packaging information*

SPIDER Proof-of-Concept Campaign

- SPIDER Concept was proposed to the UK CEOI within the 10th Earth Observation Technology Call.
- Proposal was approved for funding in April 2017 and campaign was completed in November 2017.
- CEOI Program with 50% Airbus DS co-funding.

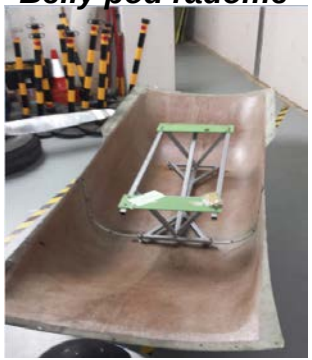
Campaign Objectives:

- Design, Implementation, validation, and verification of a SPIDER PoCC demonstrator.
- Demonstration of SPIDER radar concept on an airplane (“controlled” environment).
- Demonstration of processing principle and radar operation for maritime surveillance.
- **Zephyr’s radar design with mostly same COTS components but without PCB integration.**

From Radar Design to Flights in <10 months.

Scimitar G-BEZL Piper Navajo

Belly pod radome



Mission Rack

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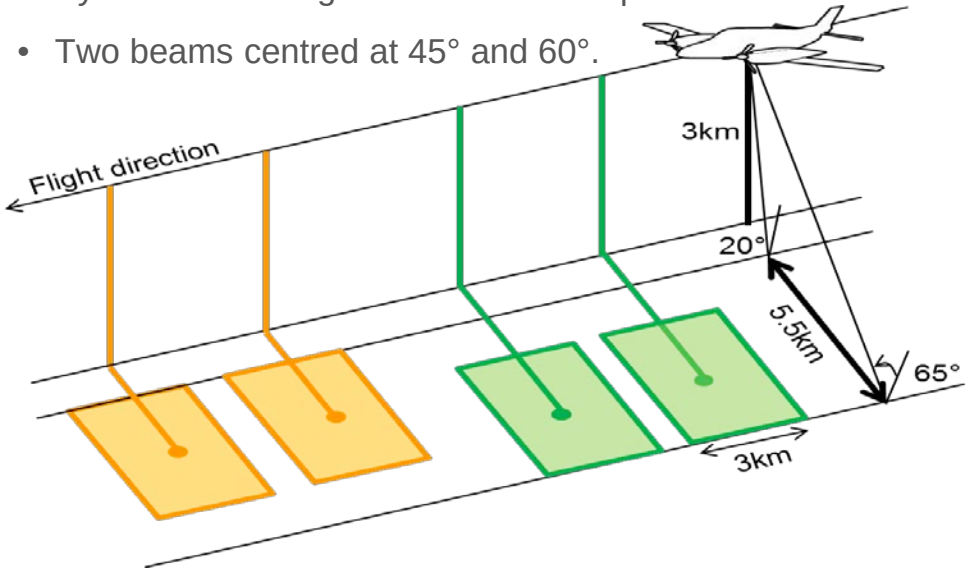
PoCC Instrument Definition

- System is operated in CW mode with FM and Coded modulations.
- Burst mode “imaging” of 0.37s duration with 240MHz and 485MHz bandwidth.
- System in active gimbal stabilised in pan and tilt.
- Two beams centred at 45° and 60°.



Parameter	Value
Platform Height	1.7 – 3 km
Carrier Frequency	10.1 GHz
Bandwidth	< 485 MHz
Sampling Freq.	1440 MHz
Operation	Burst CW
Burst duration	0.37 s
Pulse Modulation	FM & Coded
Peak Tx Power	12.5 W
Noise Figure	2.2 dB
System Losses	5 dB
Antennas’ Size*	7 x 7 cm
Resolution	< 2 x 2 m
Swath	> 3 km

**COTS WG16 Standard 15dBi Gain Horn*

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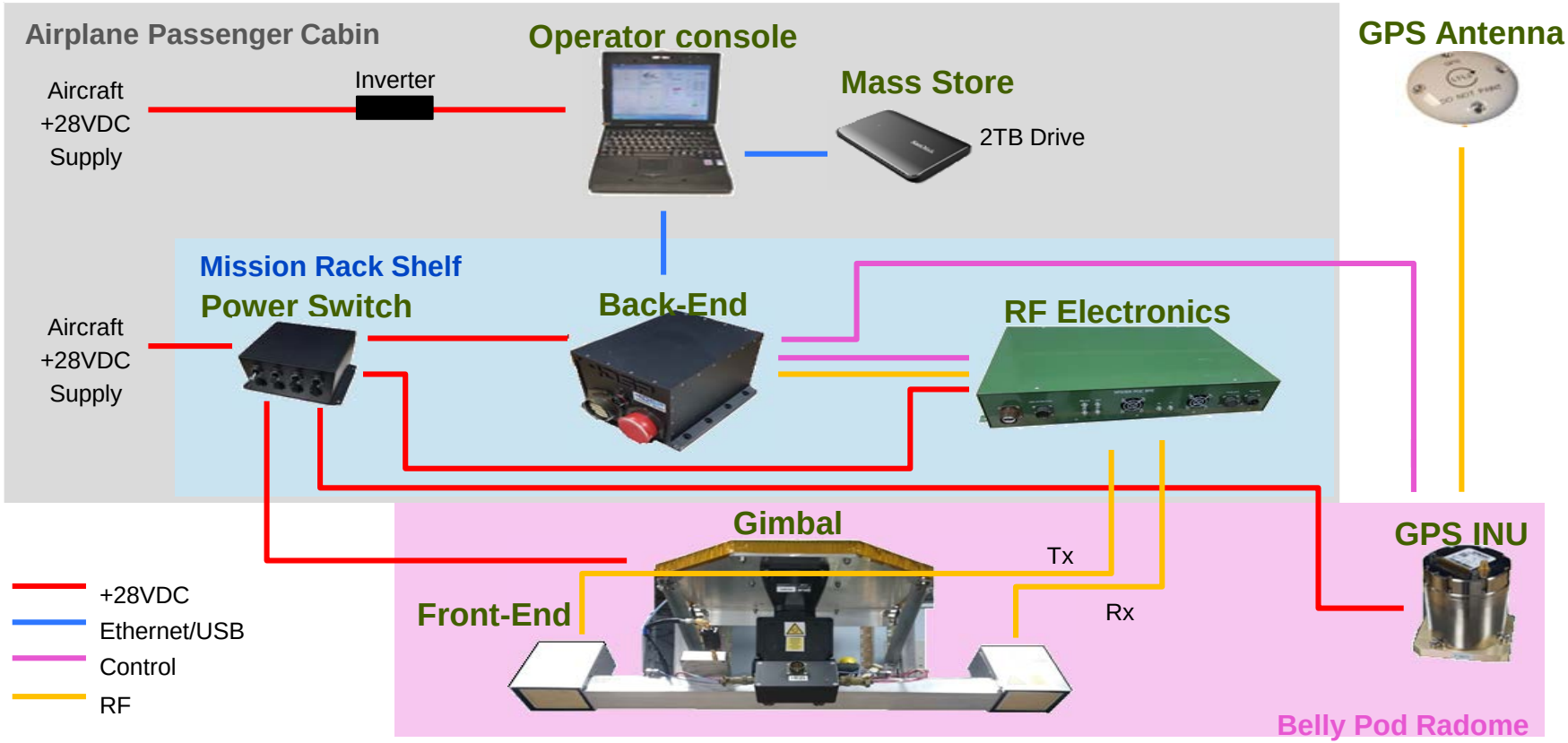
Instrument Interfaces



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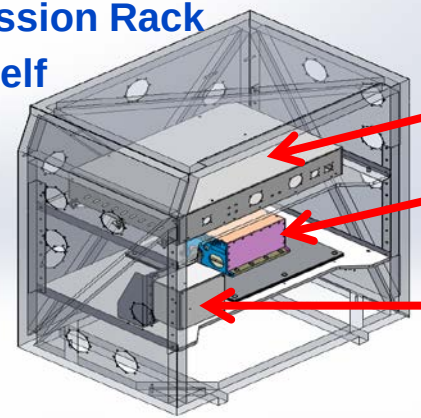
Instrument Accommodation

Mission Rack Shelf



RF Electronics

Back End Electronics on heat sink plate

Power Switch Box on Bracket

Gimbal Motion:

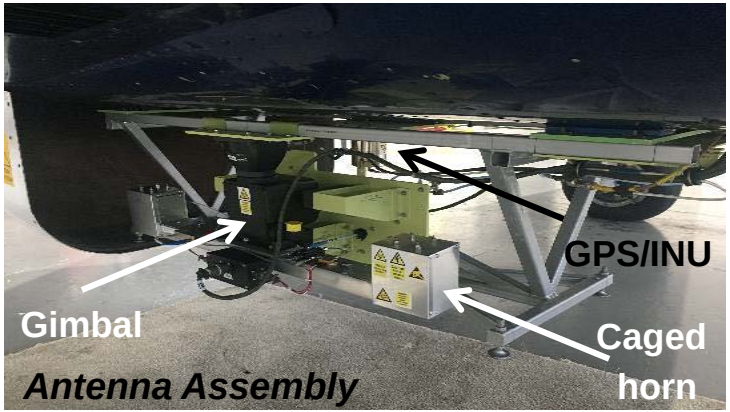
- Includes SW and HW stops.
- Pan motion: ±15°
- Tilt motion: -10° to +90°
- Pointing corrected on-the-fly.

Belly Radome

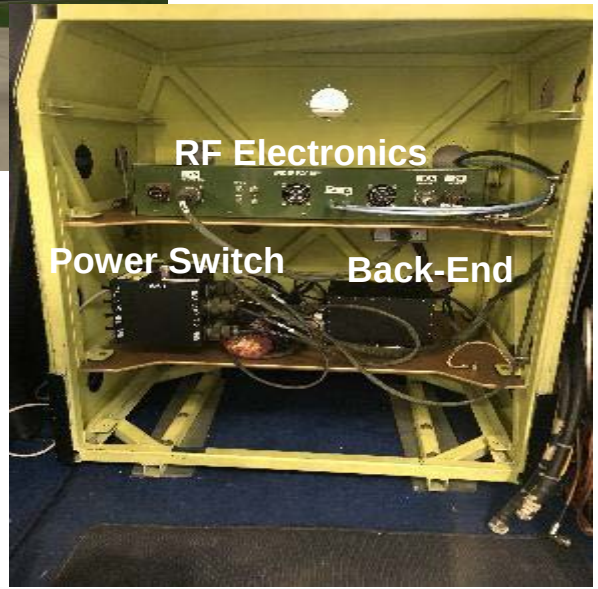
Gimbal

Caged Horns to improve isolation

Instrument Accommodation (2)



Mission Rack



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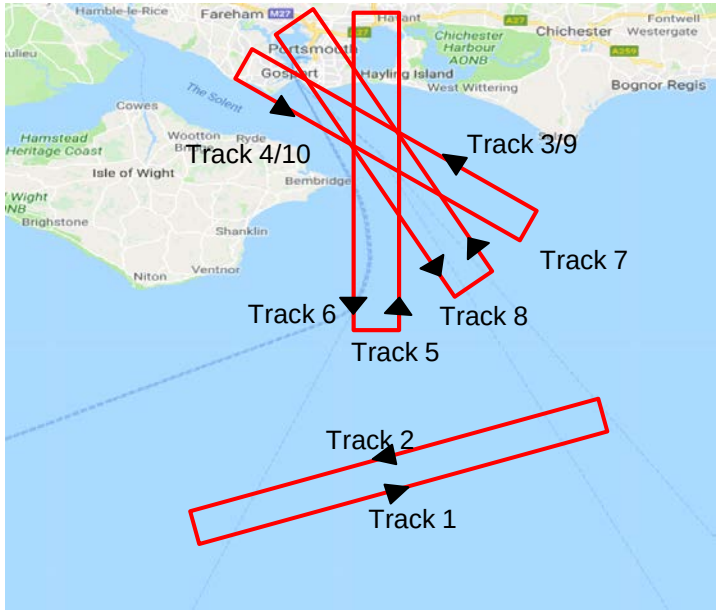
Campaign Definition

- SPIDER PoCC took place from 21-29 November 2017.
- 4 Flights in total, each of ~4h, 8-10 tracks each day.
- Test site: The Solent, near Portsmouth, UK.
- AIS data acquired as ground truth, also CR deployed.

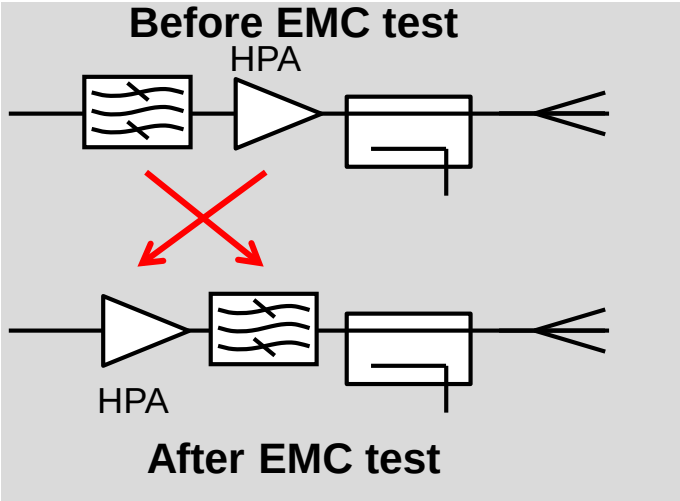


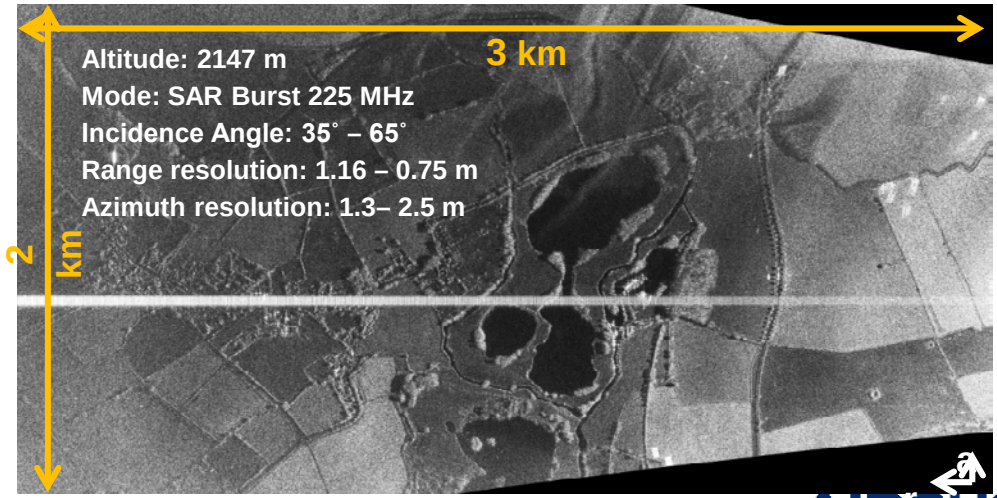
Campaign Blog

Day	Comments
21st	• Sywell • Elevation: 45˚ / 60˚ • SAR 225 MHz • Coded 240 MHz • Coded 480 MHz
22nd	• Bad day!
23rd	• The Solent • Elevation: 45˚ • SAR 225 MHz • Coded 240 MHz
28th	• The Solent • Elevation: 60˚ • SAR 225 MHz • Coded 240 MHz
29th	• The Solent • Elevation: 45˚ • SAR 480 MHz • Coded 240 MHz

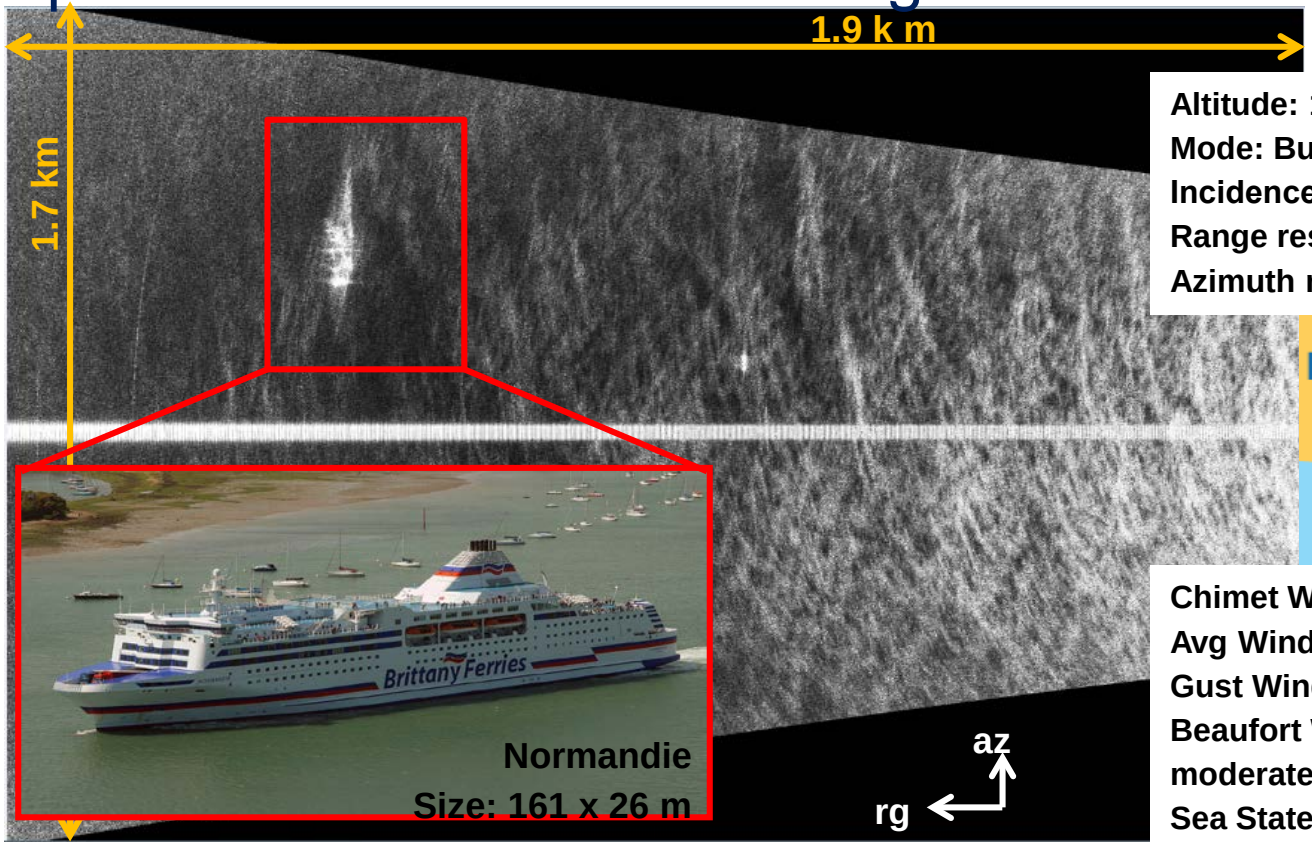
EMC Problems

- During EMC test it was noticed that the radar was interfering with the airplane GPS navigation system when using coded signals (SAR was fine).
- Filter was moved after HPA to avoid interferers due to spectral regrowth in coded modulation.
- Unfortunately, cavity filter (not designed for high power) was leaking affecting system isolation and producing a **white stripe** in the SAR imagery.
- No other filters were available and lead time > 8 weeks so campaign went ahead anyway.

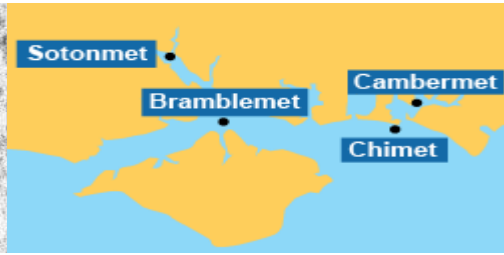




Ship Detection Results – Boresight 45˚

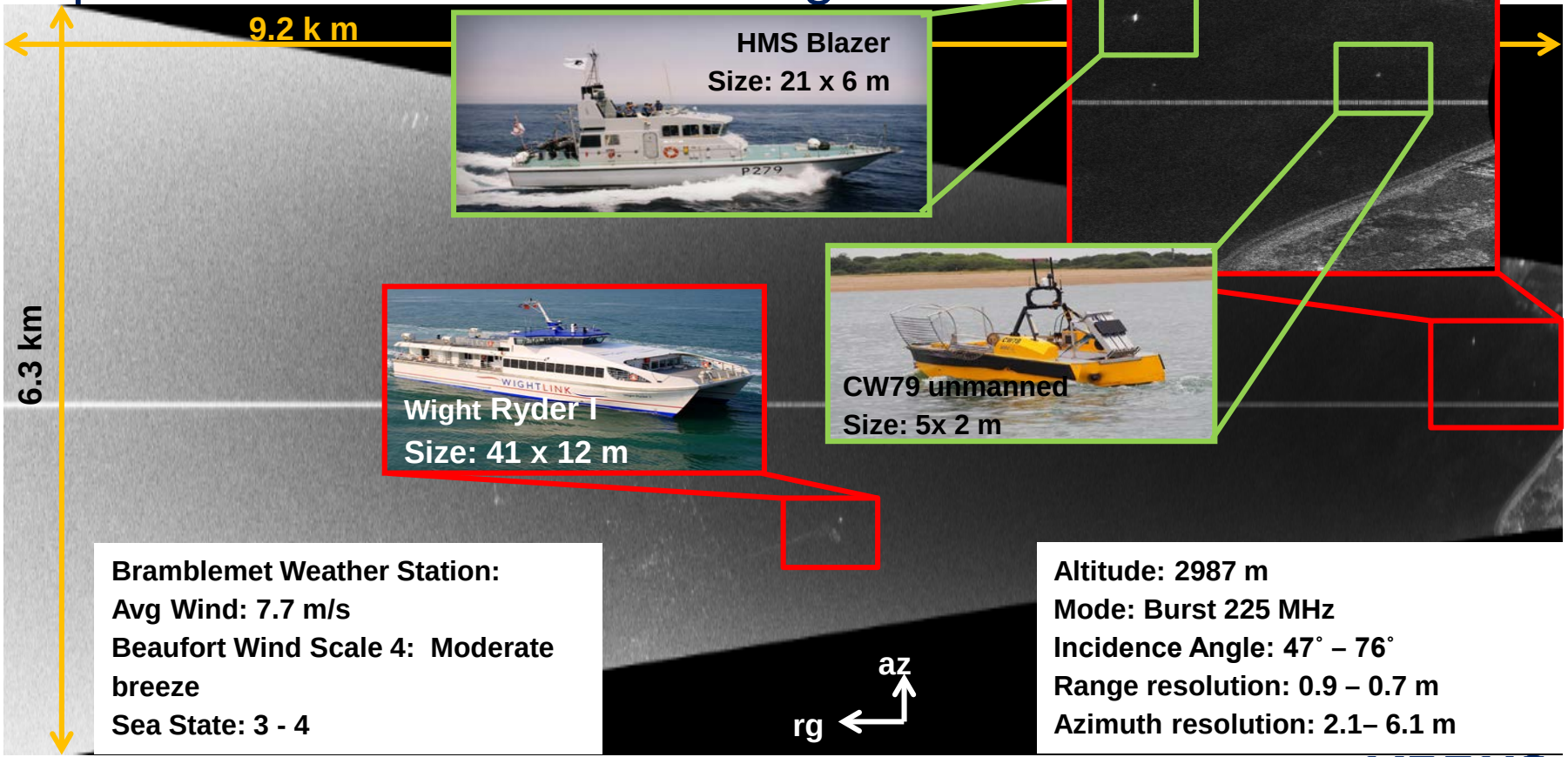


Altitude: 1569 m
Mode: Burst 225 MHz
Incidence Angle: 32˚ – 62˚
Range resolution: 1.2 – 0.75 m
Azimuth resolution: 0.9– 1.7 m



Chimet Weather Station:
Avg Wind: 14.4 m/s
Gust Wind: 18 m/s
Beaufort Wind Scale 7: High wind, moderate gale, near gale
Sea State: 5-6

Ship Detection Results – Boresight 60˚

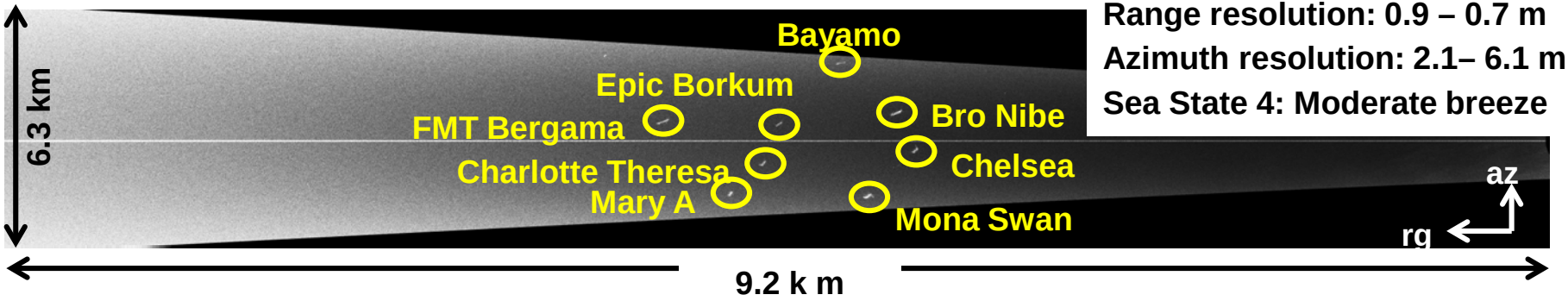


Bramblemet Weather Station:
Avg Wind: 7.7 m/s
Beaufort Wind Scale 4: Moderate breeze
Sea State: 3 - 4

Altitude: 2987 m
Mode: Burst 225 MHz
Incidence Angle: 47˚ – 76˚
Range resolution: 0.9 – 0.7 m
Azimuth resolution: 2.1– 6.1 m

Ship Detection Results – Boresight 60˚

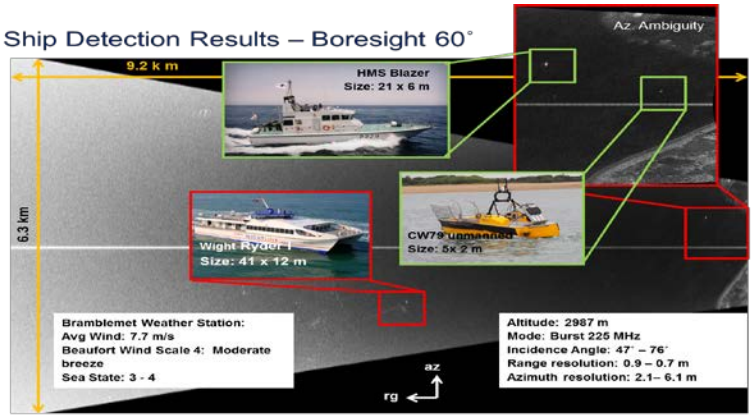
Altitude: 2987 m
Mode: Burst 225 MHz
Incidence Angle: 47˚ – 76˚
Range resolution: 0.9 – 0.7 m
Azimuth resolution: 2.1– 6.1 m
Sea State 4: Moderate breeze



All these are oil/gas tankers!

Conclusions

- SPIDER prototype designed and developed in 2017 to demonstrate operational concept (but not optimised for mass & without on-board processing).
- SPIDER Proof-of-Concept Campaign successfully conducted in November 2017 with a conventional airplane at 3000m altitude.
- Campaign results confirmed expected ship detection and land imaging capabilities with a modified burst-mode SAR operation mode



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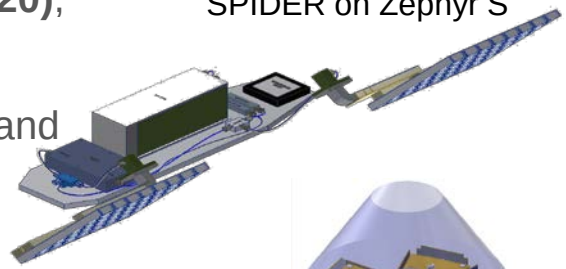
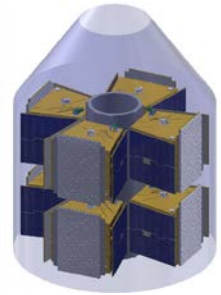
Next Steps

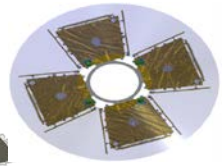
- In order to prepare the system for **Zephyr flights (available Q1 2020)**, the following steps required:
  - Integration of the RF components on dedicated PCB for mass and volume optimisation.
  - Manufacturing of bespoke lightweight antennas.
  - Development of on-board processor.
- In order to prepare for a OneWeb SPIDER payload, the following steps are required:
  - Development of front-end phased array network and W/G antenna.
  - Development of on-board processor
  - Back-end integration of RF Electronics (commonality with ZS).

SPIDER on Zephyr S





8 SPIDER SAT on Vega-C



Upper view

SPIDER on OneWeb

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Any questions?

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