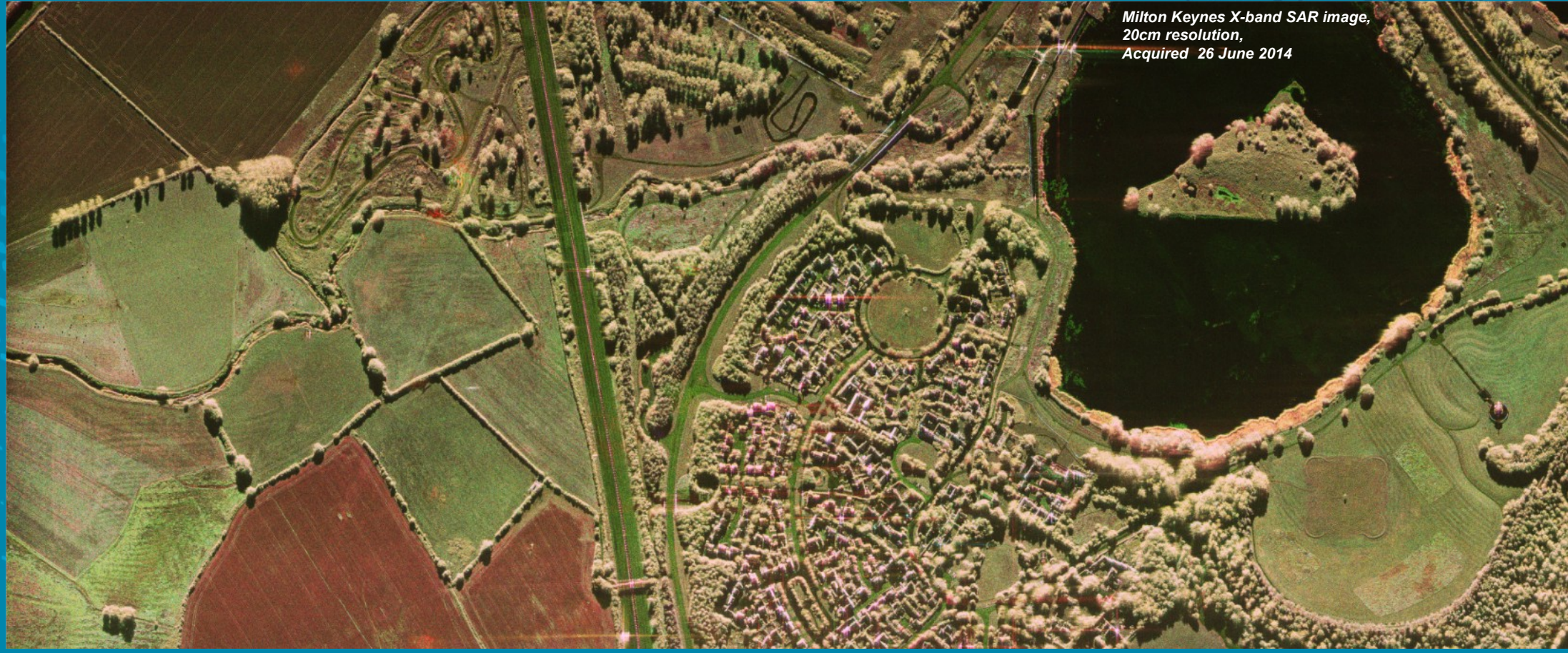

Airborne SAR Demonstrator Flight Trials – Challenges & Opportunities

CEOI-ST Challenge Workshop : Airborne Demonstrator Opportunities

Geoff Burbidge, Airbus Defence and Space, Portsmouth

7 October 2015

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Airborne SAR: **Challenges** & **Opportunities**

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The **challenges**…

- **Availability of host survey aircraft platform**
- **Sensor accommodation and airworthiness certification**
- **Sensor robustness and reliability in platform environment**
- **Aircraft flight levels and flight line control**
- **Flight planning and data acquisition**
- **Flight trials coordination with users**
- **Data processing and product generation / delivery**

The **opportunities**…

- **All weather, day-night remote sensing capability**
- **Bespoke, tailored data gathering for users**
- **Flexible and diverse image acquisition**
- **Fusion of SAR data with other sensor types**
- **Image/data product and/or sensor technology demonstration**
- **Complementary or precursor data to current or future spaceborne systems**
- **An asset/capability to be traded**

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Availability of host aircraft platform

Continuity of access to suitable airborne platform

Aircraft technical compatibility

NRE of sensor installation and certification

Funding of cost of operations

Commercial vs institutional operators

Business model and science case

Previous platforms to have hosted SAR sensor

Potential future candidate platforms

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Sensor accommodation and certification

Side-looking SAR sensor

Motion compensation

Need for suitable radome

Field-of-view (RF transparency, antenna beamwidth)

Aircraft modifications and certification

Twin Otter installation in cargo door aperture

Dornier 228 with belly radome

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Sensor robustness and reliability on platform

Temperature and vibration

Risk of ingress of water, humidity

Installation/mounting of in-board and out-board hardware

Handling of sensor equipments during fit/de-fit

Reliability issues during operations

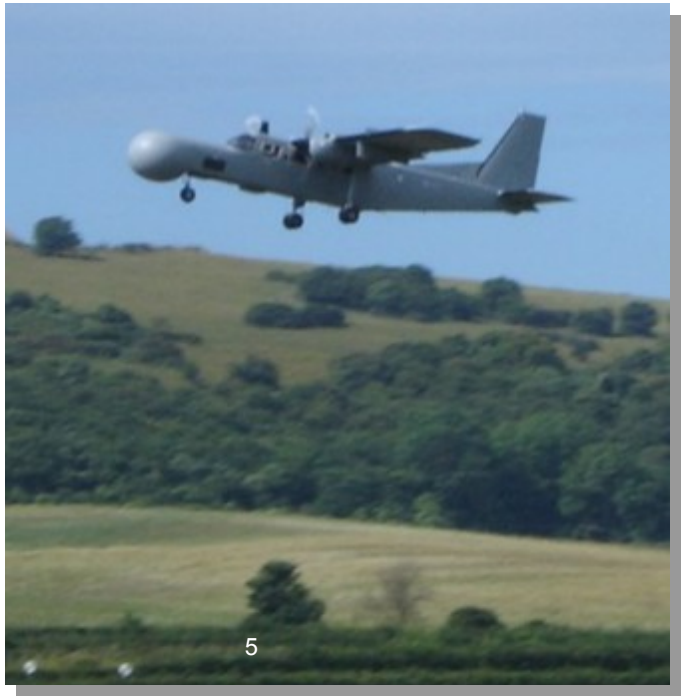
Sources of RF interference

DC-3 inboard equipment fit

DC-3 radome configuration

Sensor operations with no radome on Twin Otter

Britten Norman Island radome configuration



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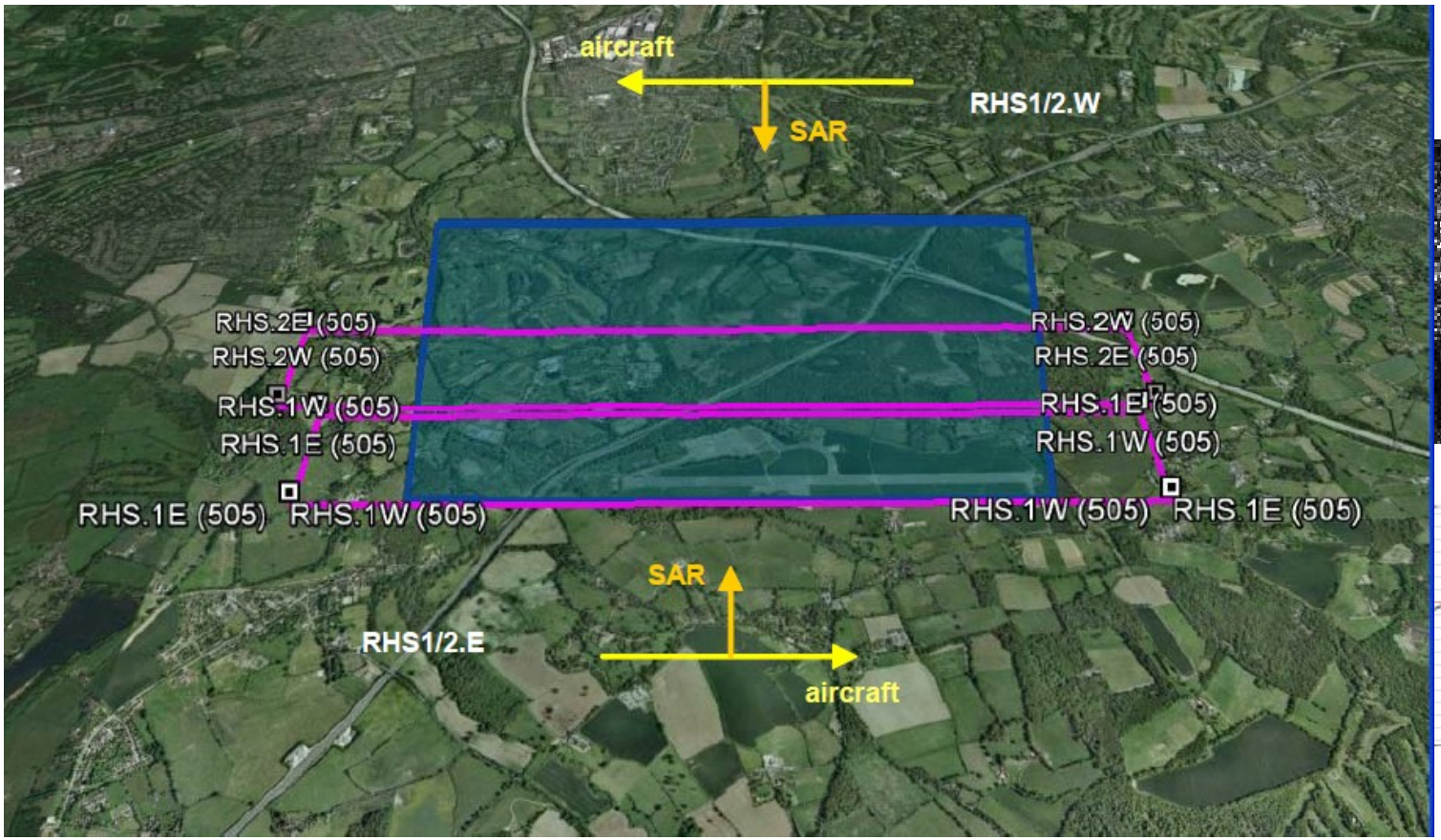
Aircraft flight levels and flight line control for SAR operations

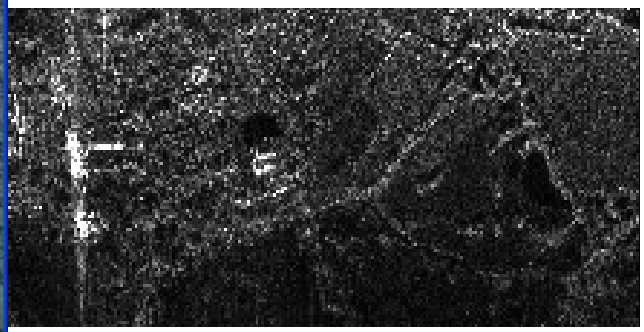
Permitted flight levels from ATC and available flight paths

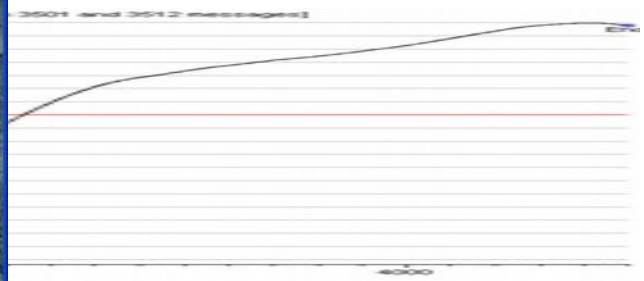
Imaging geometry for SAR operations within defined mode

Tolerance of aircraft flying within ”tube”

RHS Wisley passes June 2014







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Flight planning and data acquisition

Planning of acquisitions for multiple users

Transmit time between sites

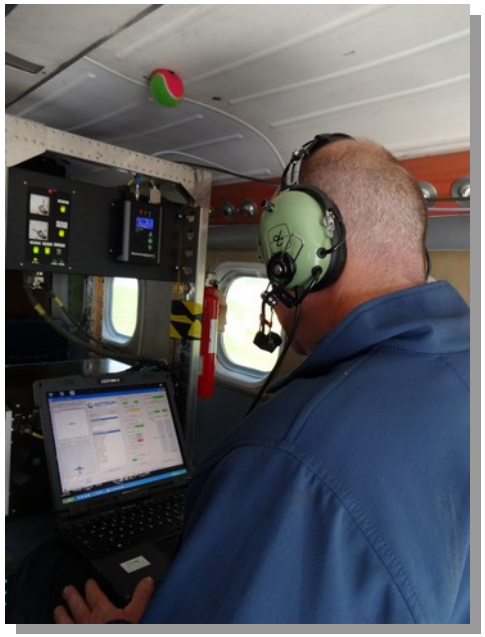
SAR operating time and data storage

Aircraft endurance and range

Calibration from ground references

Operator communications and comfort

Sensor operator interface



NERC BAS Twin Otter VP-FAZ with Airbus DS SAR instrument during AirSAR 2014 flight trials

Calibration target for AirSAR flight trials

Reference target in X-band image enabling radiometric calibration

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Flight trials coordination with users

Communications with ground teams

Deployment of calibration reference targets

Acquisition of ground truth

Synchronisation with other sensor acquisitions

Coordination regarding acquisition time

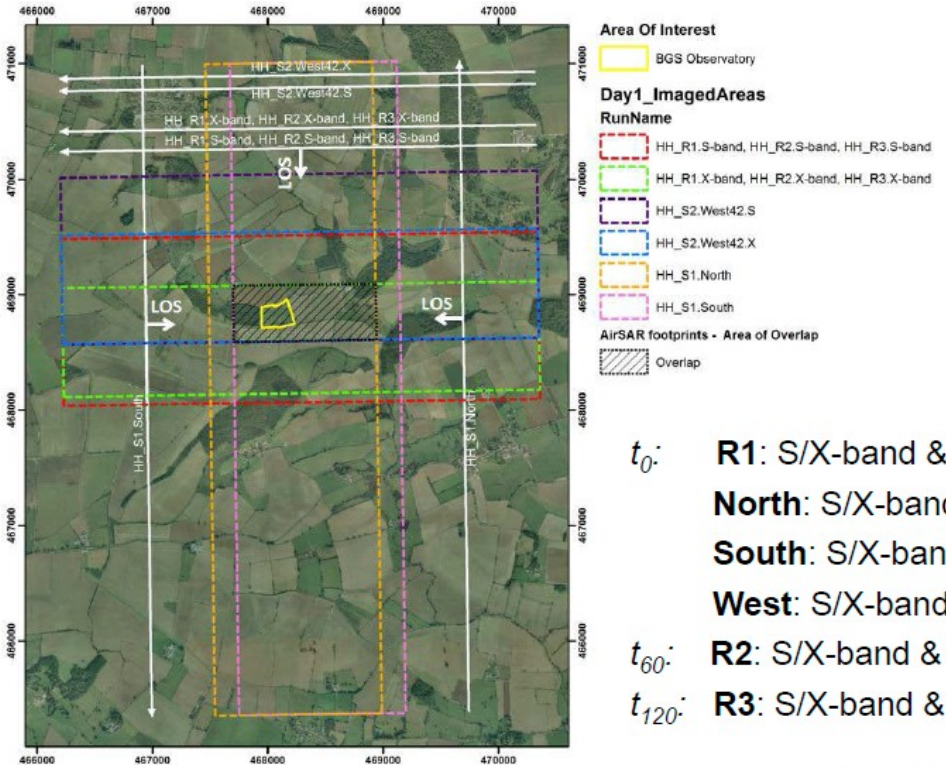
Delivery of processed data

Demonstration Flights – AirSAR trials Day 4, 26 June 2014

Number of successful imaging runs	**28**
Number of swaths gathered	23 S-band , 28 X-band
Operating altitudes	3000 ft / 4500 ft / 7500 ft / 10000 ft
Total flying time - **Take off time** - **Landing time**	03:26+1:52 = 5:18 hours - 13:19 / 17:28 - 16:45 / 19:20
Conditions	Variable: Partial cloud (25-50%) for NYM and Peak, 90% cloud for HH, heavy cloud and rain for CAL and clear for MK and Crop runs (the aircraft flew below the clouds)

Hollin Hill instrumented control site

Hollin Hill planned passes



t_0: **R1**: S/X-band & X-band
North: S/X-band [*NovaSAR*]
South: S/X-band [*NovaSAR*]
West: S/X-band & X-band

t_{60}: **R2**: S/X-band & X-band

t_{120}: **R3**: S/X-band & X-band

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Data processing and product generation/delivery

Required formats, need for map-ready product

Processing options and product variants

Cataloguing and repository of acquired data sets

Field work / ground truth and information extraction

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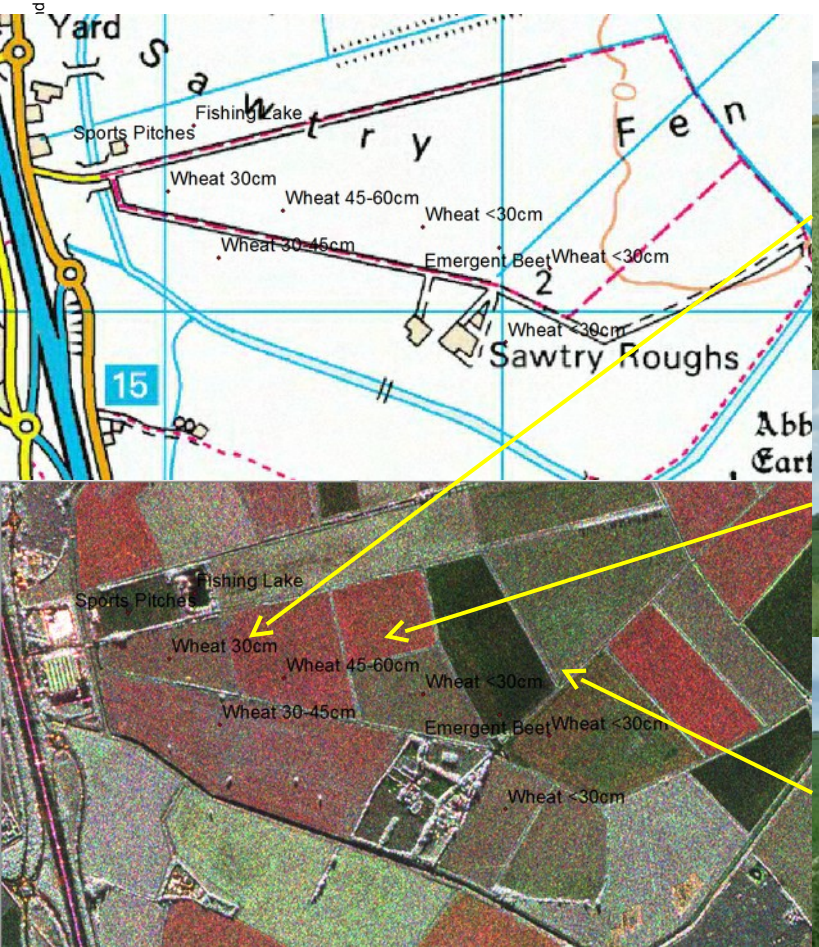
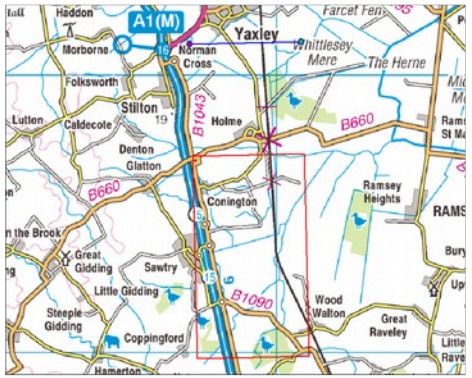


Ground truth from Sawtry area

Acquisition summary from AirSAR Flight Trials Results



All weather, day-night remote sensing capability

- **Product acquisition independent of solar illumination**
- **Imaging through cloud and rain**
- **Fine resolution image products (to 15cm)**
- **Good signal-to-noise ratio**
- **Negligible impact of ambiguities**
- **Range of viewing geometries and incidence angle**
- **Information content in polarimetric SAR data**
- **Coherent change detection**

Bespoke, tailored data gathering for users

Time of acquisition

Viewing geometries

Incidence angles

Single or multi-frequency data

Repeat pass imaging

Flexible swath widths

Multiple areas of interest within short time interval

Responsive to user acquisition requirements & changes

Example: 28 July 2010, over ~2 hour period

- Swansea region
- >20 swaths of S+X-band co-temporal product acquisitions
- 400-500km^2 of SAR products during one sortie

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Flexible and diverse product acquisition

Airborne SAR (AirSAR) campaign (2014)

Acquired data during 5 days of operations in May, June

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Product acquisition example

Charmouth, Dorset

AS14-21	**24-25/06/14**	**Charmouth, Black Ven**	**Bournemouth University**	**Slope stability**	**8 swaths**

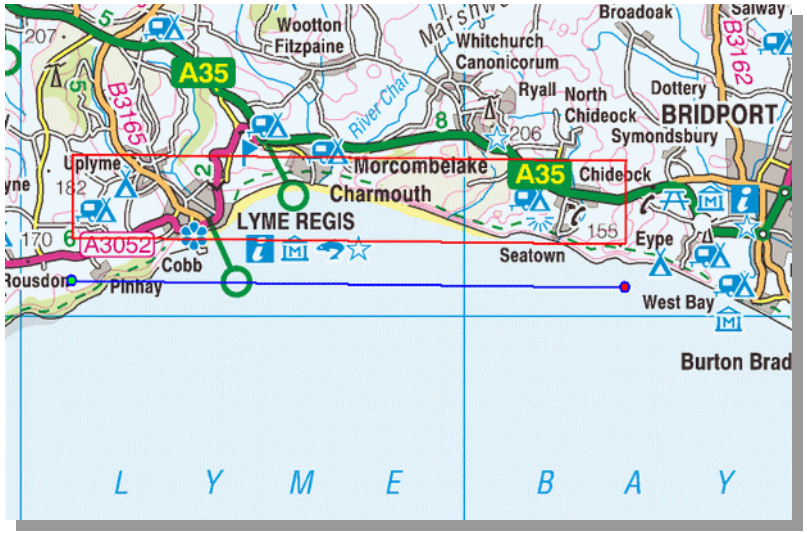
Data requirements

- Data type: S and X-band, VV, HH, VH
- Location: West Dorset coastline, near Lyme Regis and Charmouth
- Data requirements: Repeat passes for airborne InSAR of mass-movement hazard (surface displacement) over Black Ven and Charmouth landslides with variable temporal baselines

Flight planning

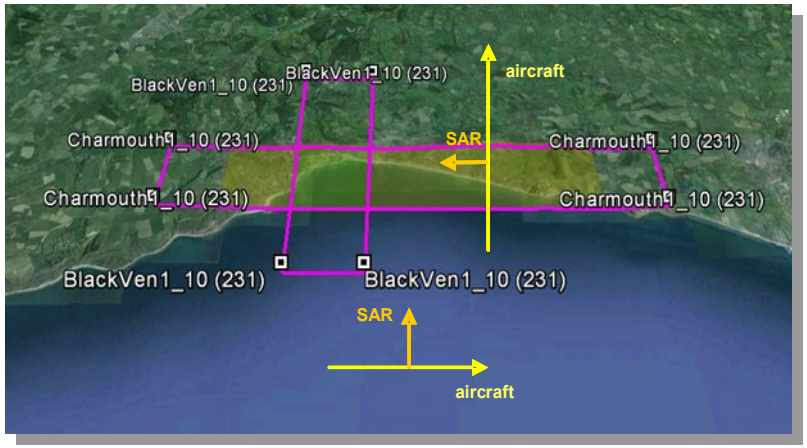
- Mode definition:
  - Frequency bands: S-band (3.1-3.3GHz) + X-band (9.5-9.7GHz)
  - Altitude above ground: 10,000ft
  - Swath width: 1.92km
  - Incidence angle range: 16° to 42.5°
  - Polarisation: Quad
- Location definition:
  - Altitude above sea level: 10,000ft
  - Heading: 90°
  - Aircraft waypoints:
    Lon/Lat 1: 2.97641W 50.7164N
    Lon/Lat 2: 2.79973E 50.7164N

Charmouth run in OS maps



Charmouth area seen from operator window

Charmouth and Black Ven swaths projected on Google maps



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Product acquisition example

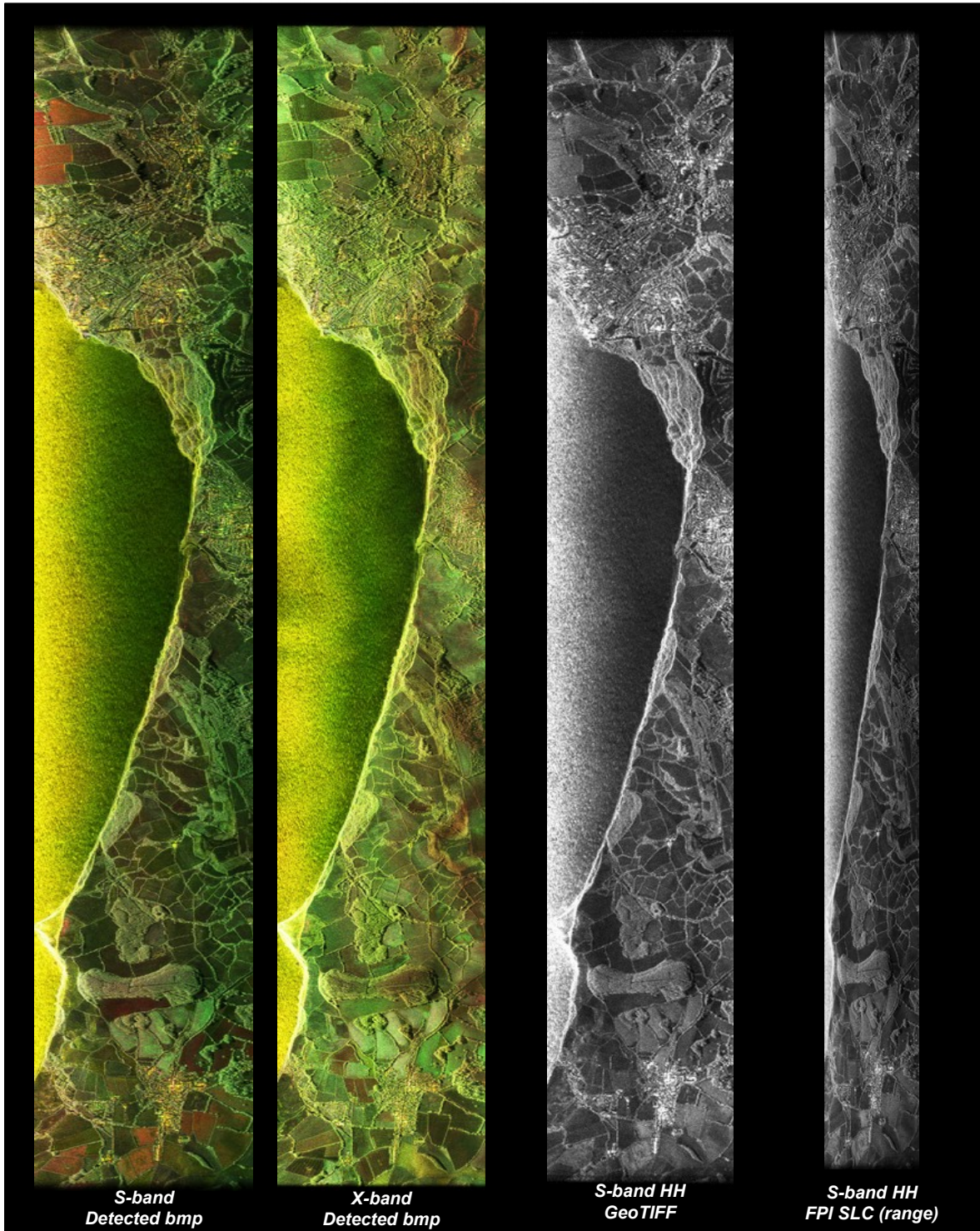
Charmouth, Dorset

Image product *(Charmouth 2)*

- Image:
  - Actual AG: 10005ft
  - Time: 2:26:36 PM - 2:29:03 PM
  - Length: 12419 m
  - Near edge pixel: 2°58.924'W 50°43.287'N
  - Far edge pixel: 2°48.351'W 50°44.289'N

End product parameters *(Charmouth 2)*

- Product characteristics:
  - Raw data (including GPS and both bands): **22.3 Gb**
  - FPI detected: 39.8 Mb per polarisation
    → Resolution (azimuth x range)= 3m x 3m, Pixel spacing= 1m x 1m, Number of looks: 3 x 1
  - FPI SLC: 373 Mb per polarisation
    → Resolution (azimuth x range)= 1m x 1m, Pixel spacing= 0.5m x 0.5m, Number of looks: 1 x 1
  - IDF: 472 Mb per polarisation
  - GeoTIFF: 22.5 Mb per polarisation
  - BMP file: 29.9 MB



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Fusion of SAR data with other sensor types

Prospect of multi-frequency SAR + lidar + multi/hyper-spectral + optical from single platform

Significant science and commercial potential from co or near co-temporal acquisitions

Planned sensor fit on ARSF Dornier 228 would have offered this capability… aspirations remains to delivery this capability

Integration of airborne SAR data sets with other information sources (remote sensing, ground-based)

Integration of SAR with AIS and other maritime monitoring tools for marine and coastal surveillance

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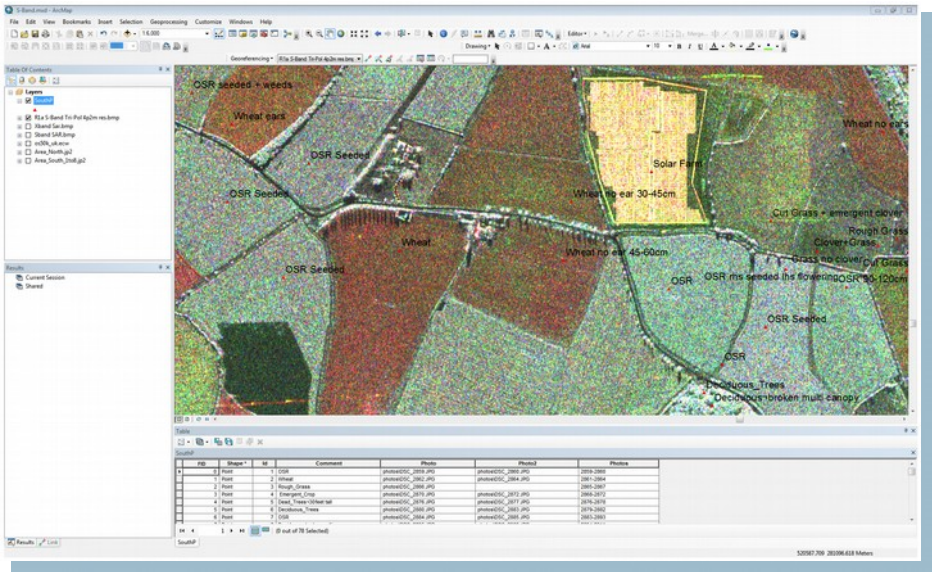
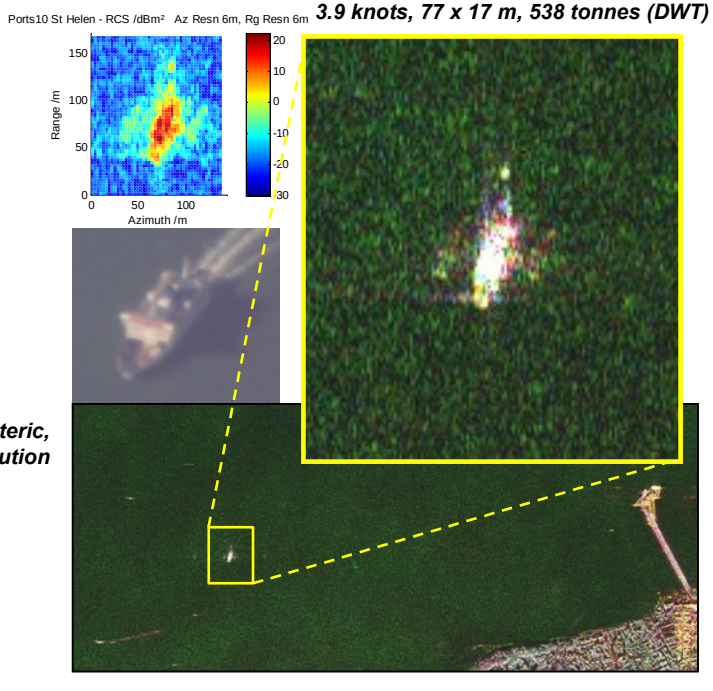
Image/data product and/or sensor technology demonstration

Crop classification using S-band airborne SAR data



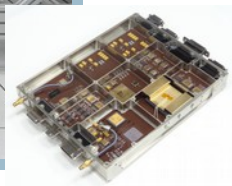
Isle of Wight Ferry
3.9 knots, 77 x 17 m, 538 tonnes (DWT)



S-band fully polarimteric, 3m resolution

NIA / NovaSAR-S Payload & Equipments

NovaSAR-S FM Antenna & Back Ends



CTG Module

Digitiser Module

NovaSAR-S FM Antenna integration

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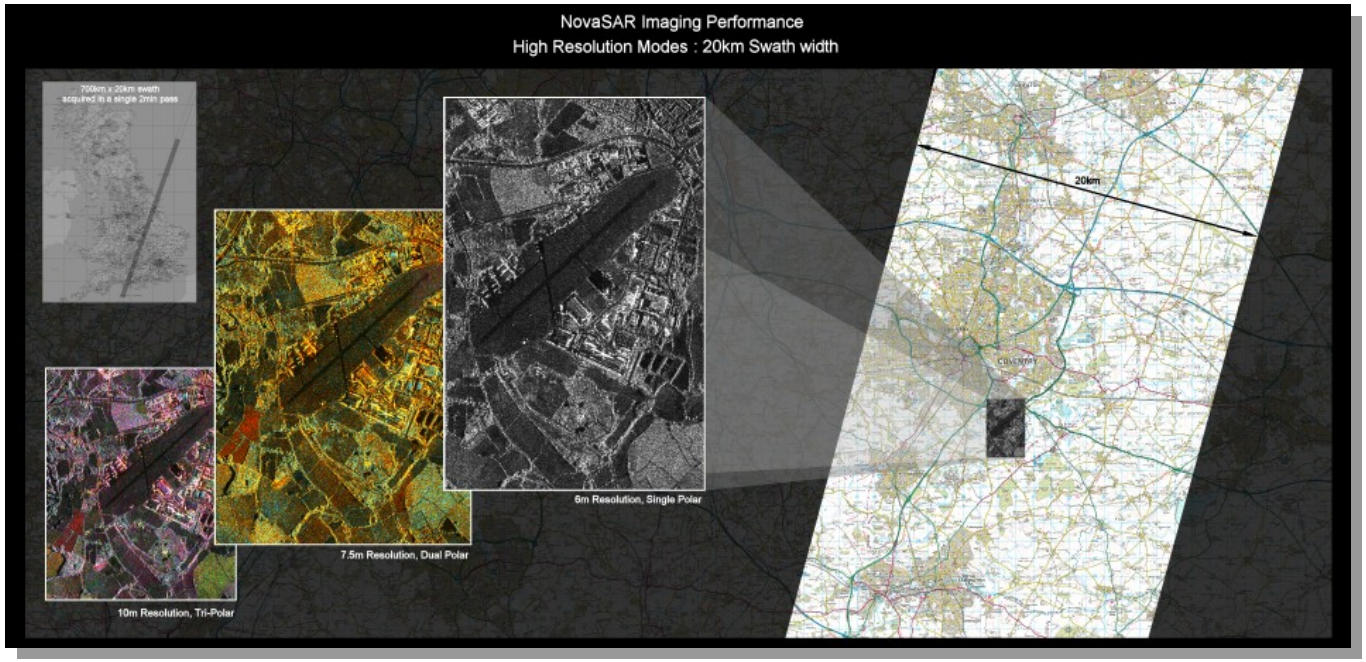
Complementary or precursor data to current or future spaceborne systems

Pre-launch: Gather data and garner support for mission; developing applications and/or market
Post-launch: Continue to acquire airborne data in concert with spaceborne system

Example of NovaSAR-S:
S-band airborne capability to generate representative products;
S+X-band co-temporal acquisitions to enable data comparison across two frequency bands

Synthesis of NovaSAR-S representative products from airborne data



Increasing global interest in use of EO remote sensing tools

- emerging nations with aspirations in spaceborne systems
- existing partners looking for UK technology or capability

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An asset/capability to be traded

A range of approaches to Airbus DS regarding airborne SAR over the last 2 years:

- for gathering of specific data sets for user needs (research, commercial, security)
- for provision of airborne SAR as a capability and service
- for operation of the system as a complement to spaceborne SARs to gather precursor or parallel data
- as a tool to demonstrate and develop customer opportunities
- to develop and deliver demonstrator and operational sensor systems for the military

Airborne SAR capability is therefore not only technology development to support future space-based SAR… it is also an asset which can be exploited for service delivery, technology transfer, marketing, product development

However, to date, few of these prospects have developed due to a lack of availability of:

1. a suitable and available airborne platform
2. a robust and supported instrument capable of meeting user operations requirements
3. funding needed to realise a capability/product that could be offered to clients

such that an enduring national capability has not been delivered

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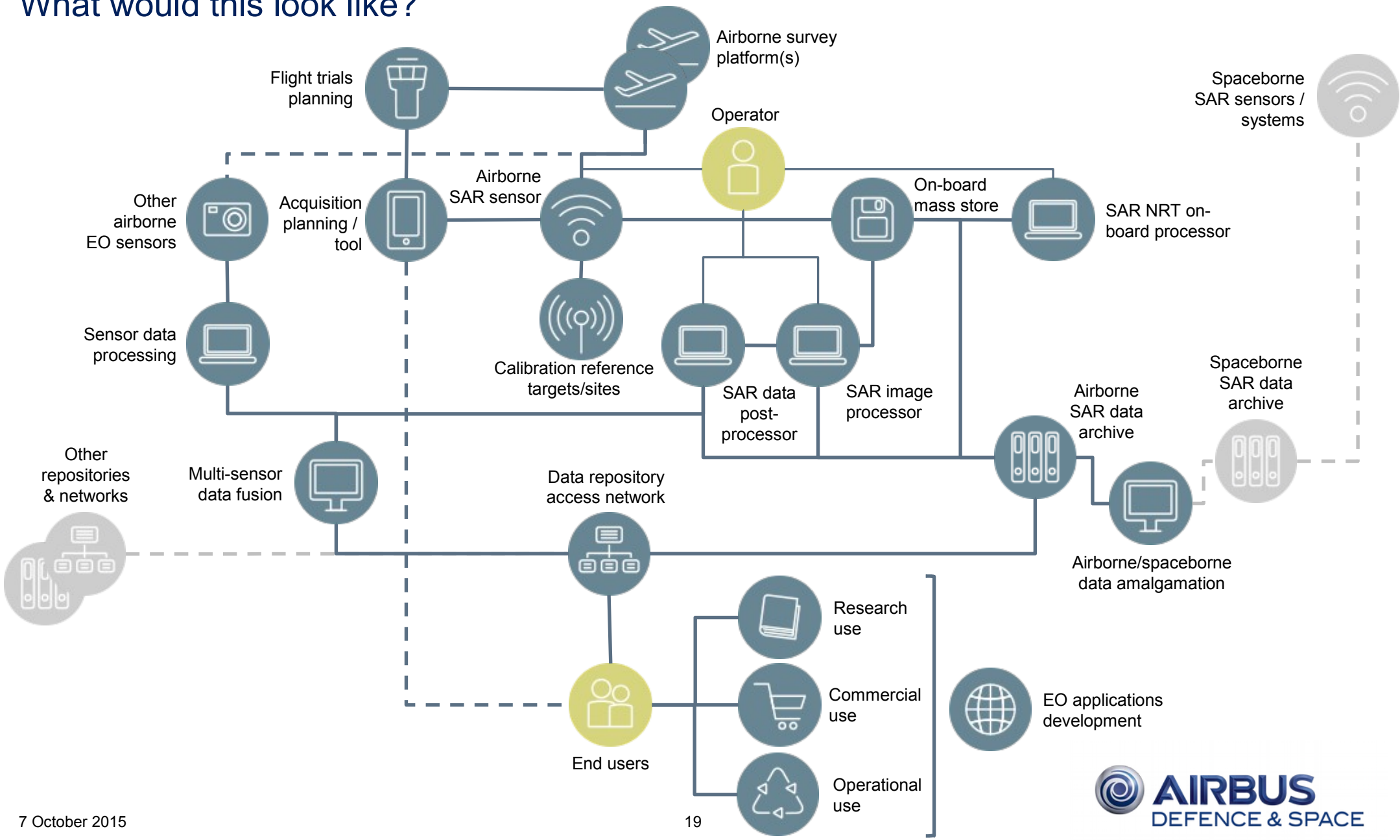
A UK national airborne SAR capability

What would this look like?



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A UK national airborne SAR capability

What is required to deliver this?

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1. **Investment in sensor capability:** take demonstrator system forward to provide robust reliable product suitable for wider exploitation

2. **Investment in other infrastructure elements:** to support generation of suitable products and delivery to users

3. **Access to compatible airborne platforms:** addressing sensor fit and certification; guaranteed continuity of access/availability

4. **Follow-on project opportunities:** to provide continuity of system operations and data acquisition; project funding for research and commercial users to analyse and develop downstream products

Requires…

- **a joined up strategy involving all stakeholders, with a plan to collectively benefit from the system**
- **a whole-of-government approach, incorporating the full range of requirements from public/agency users**
- **recognition that development of airborne SAR systems can be integral to the success of spaceborne remote sensing**

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Potential airborne SAR products

Range of airborne image products based on previous trials:

- **Very fine resolution** (X-band, 15-20cm resolution)
- **Multi-frequency co-temporal** (S+X-band, +L-band)
- **NovaSAR-S representative products** (S-band , 6m)
- **Low-frequency wideband** (P-L-band, fine resolution)
- **Hybrid along- /across-track interferometric** (X-band)
- **Single-pass and repeat-pass InSAR**

Access via future airborne SAR data repository from a UK owned and operated asset:

- UK data archive: NEODC? Harwell? other?
- AirSAR 2014 campaign data and previously acquired data sets from multiple campaigns
- newly derived products from future campaigns

How best to exploit existing and future airborne SAR data sets and products to foster strong user interest?

X-band, fully polarimetric, 20cm resolution Harwell, acquired

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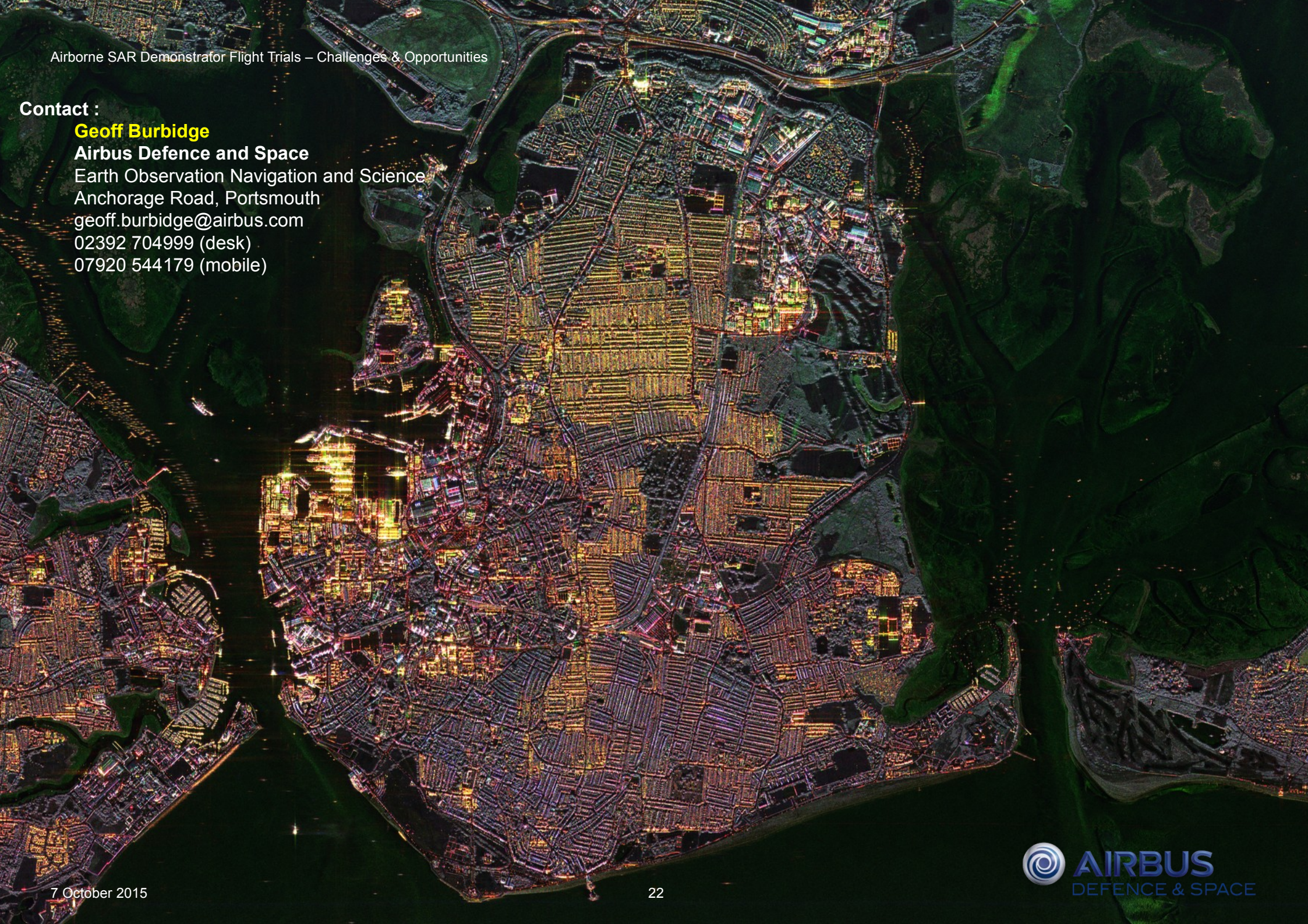

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