Centre for
EO Instrumentation

Feasibility of Passive Bistatic Geosynchronous Radar using Comsats

Cranfield University, University of Birmingham

Dr Steve Hobbs (Principal Investigator)

Prof Marina Gashinova, Prof Mike Cherniakov
Dr Scott Cassidy, Carlo Convenevole

s.e.hobbs@cranfield.ac.uk

CEOI Project Showcase December 2018

www.cranfield.ac.uk

Cranfield
Aerospace

UNIVERSITY OF
BIRMINGHAM

Outline of the talk

1. Introduction and project objectives
2. Analysis of mission requirements
3. System simulation
4. Available signals of opportunity
5. Next steps
6. Conclusions

Reminder: Project Objectives

Pathfinder project – Feasibility of passive bistatic GeoSAR using Comsats

1. Evaluate the technical feasibility of passive bistatic radar (PBR) in geosynchronous orbit using conventional comsat transmissions and a software-defined receiver.
2. Assess the factors affecting the practical implementation of PBR as a hosted payload (technical and operational).
3. Evaluate potential applications for a GEO PBR payload accounting for the expected imaging performance of a PBR hosted payload.
4. Develop a system model for a GEO PBR hosted payload to validate the expected performance and identify mission constraints.

Objectives are designed to address the main uncertainties for the mission concept

- Except for synchronisation and perturbation compensation (under study elsewhere)

Reminder: Success Criteria

Confident answer to the question “Is it feasible (obj 1, 2, 4) and useful (obj 3)?”

Work shared as

Cranfield University	University of Birmingham
System design	Available signals of opportunity
Implementation – hosted payload	Receiver design & technology

System Design: Requirements

Draws on other GeoSAR studies:

GeoSTARe and G-CLASS

GeoSTARe – broad survey

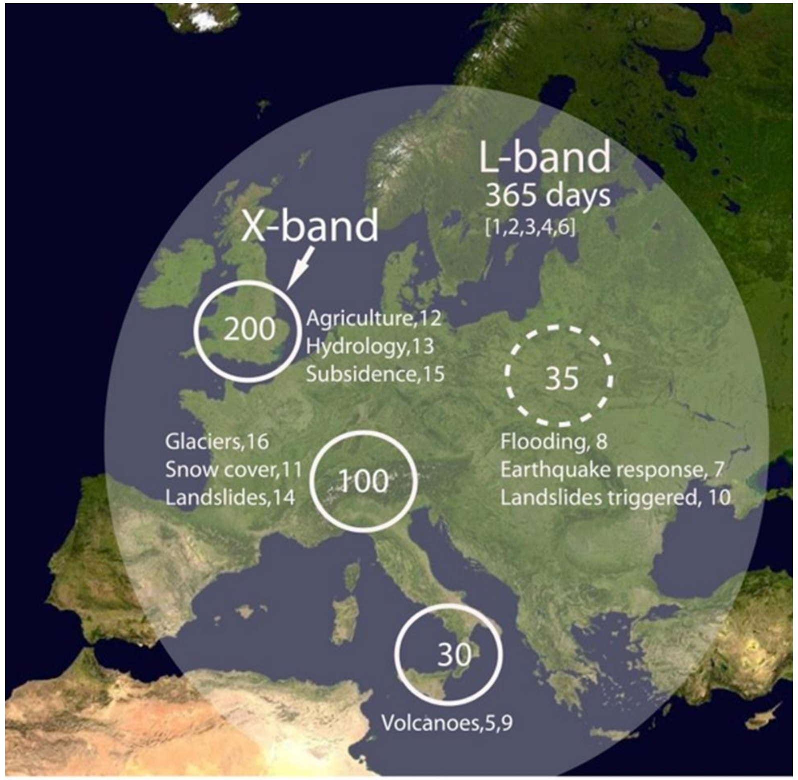
- Identified potential strengths and wide range of applications

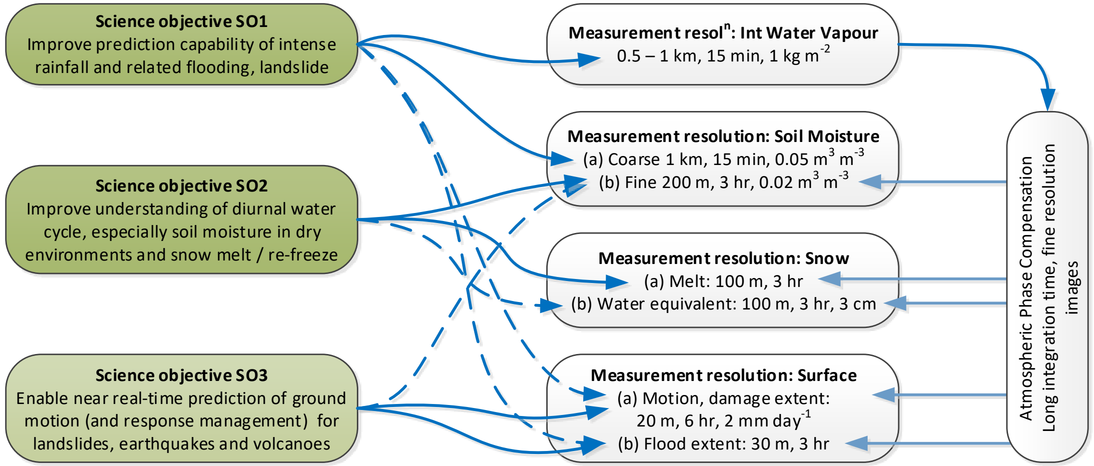
G-CLASS – focus on diurnal water cycle

- Specific science objectives for meteorology, hydrology, cryosphere, solid Earth
- Fine resolution data (100 m or less) are not practical for a PB GeoSAR

Km scale applications seem achieveable

- Atmosphere, catchment scale soil moisture





Requirements summary

Requirements identification is inherently iterative – we need to match observation needs with feasible performance

- Feasible performance
  - Spatial resolution: Ku-band signal bandwidth allows ~10 m imaging; L-band is OK to ~500 m
  - SNR: signals are relatively weak, so can only achieve useful SNR at ~1 km scale

Candidate observation goals:

  - Atmospheric phase screen
  - Catchment-scale soil moisture
  - Surface coherence is an important constraint, especially for short wavelengths, over vegetation: no problem for bare soil / rock, and OK for urban areas

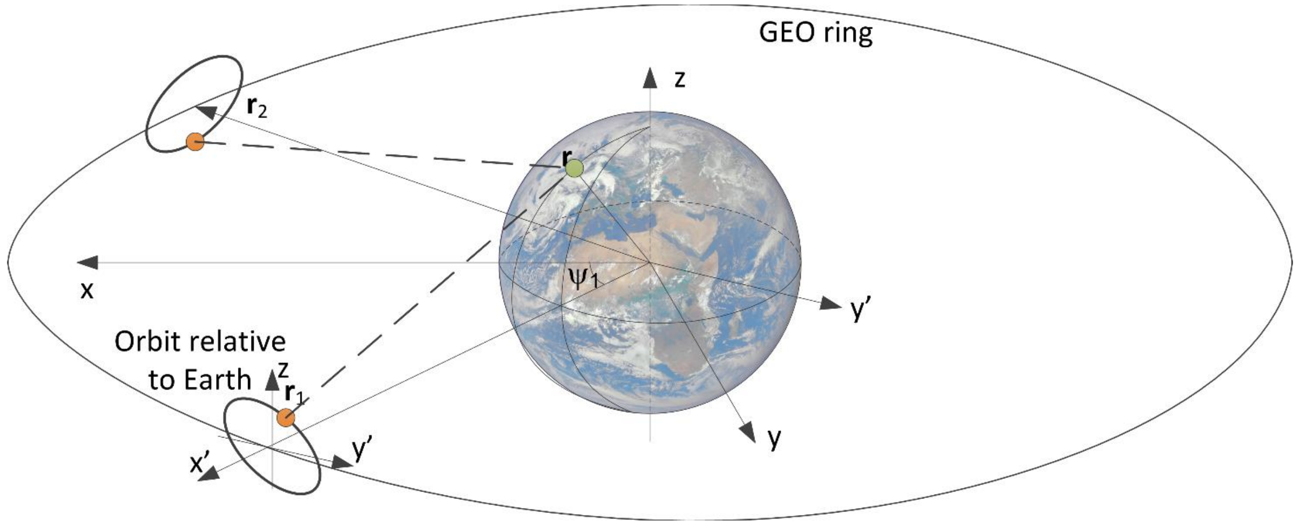
System Model Development and Implementation

Passive Bi-static GeoSAR Simulation

Developed from an existing monostatic simulator

- Focussed attention on the spatial resolution performance
- Analytical and numerical models – for (a) understanding and (b) validation / generalised results

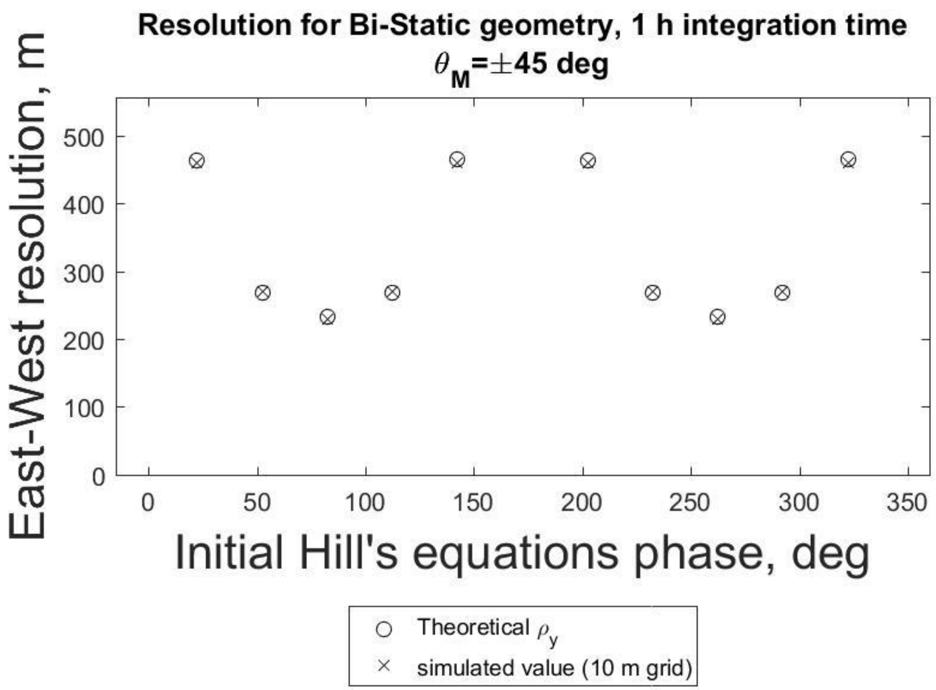
Discussions held with comsat operator to understand practical constraints and opportunities



<u>Azimuth</u> Resolution Projected on East-West direction

$$\rho_y = \frac{\lambda}{t_{int}|\boldsymbol{v}'_{Tx} + \boldsymbol{v}'_{RX}|}$$

$$\rho_{EW} = \frac{\rho_y}{\cos(\theta_{EW})}$$



***v'** is angular "velocity" (= velocity / range)*

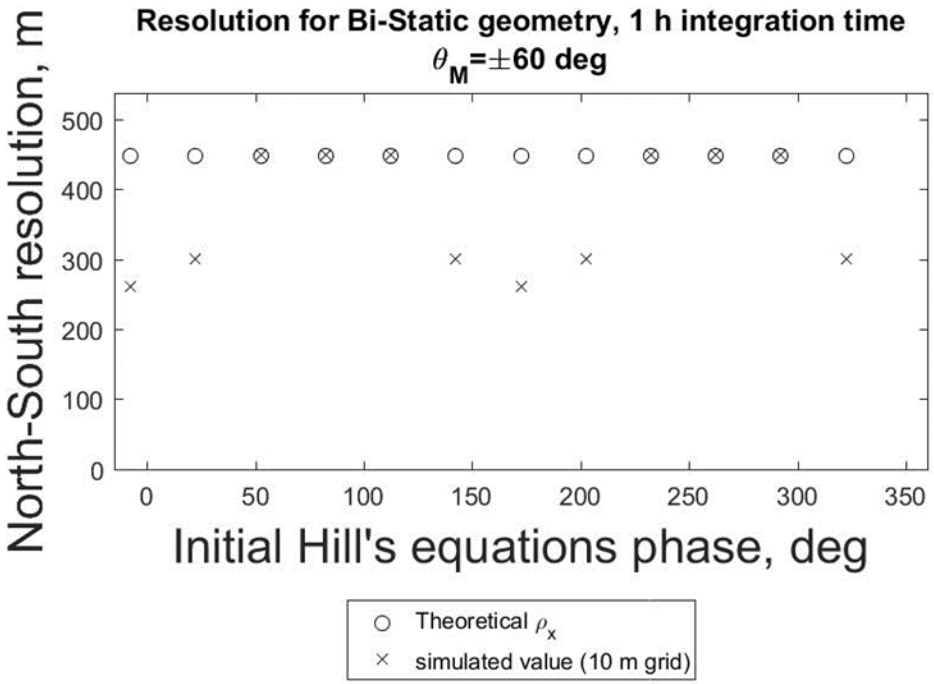
*The **resultant** of **v'** for the transmitter and receiver defines the sensitive direction for aperture synthesis resolution*

Range Resolution

$$L_x = \frac{\Delta r}{2\cos{}^{\beta}/_{2}\sin\theta_b} \qquad e_b = \frac{e_t + e_r}{2\ \cos{}^{\beta}/_{2}}$$

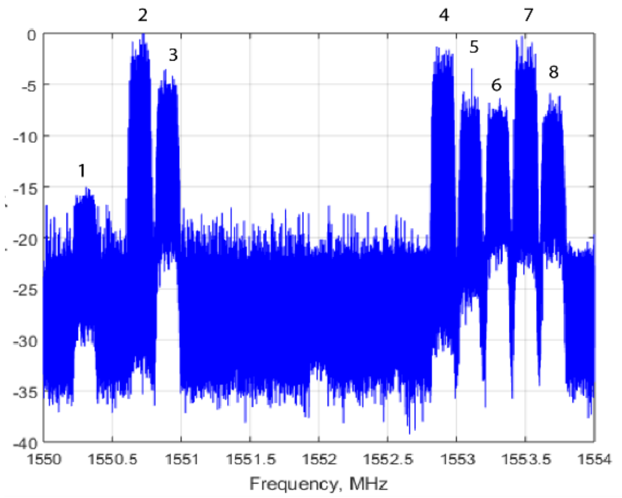
$$B = \frac{1}{\tau_{received}}$$

Where $\tau_{received}$ is the half height width of the received signal, β is the bistatic angle, θ_b is incidence wrt the bisector, and $\mathbf{e}_t$, $\mathbf{e}_r$, $\mathbf{e}_b$ are unit vectors for Tx, Rx and bisector directions from the target

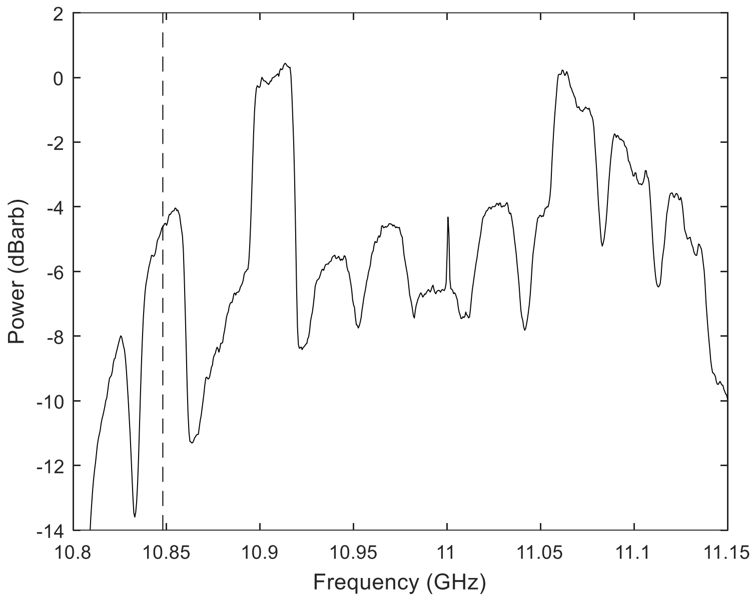


There is a good agreement when the azimuth direction is orthogonal to the range direction; when they become aligned the azimuth resolution improves the range resolution (with the Hill's equation initial phase between 0° and 45°, between 140° and 200° and between 330° and 360°, i.e. near 0° and 180° in the simulation).

Available Signals of Opportunity



Digital data ~ PRN codes

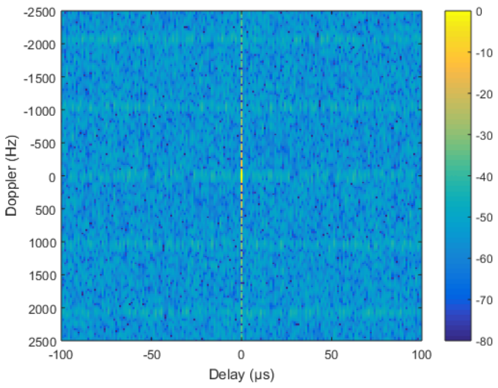


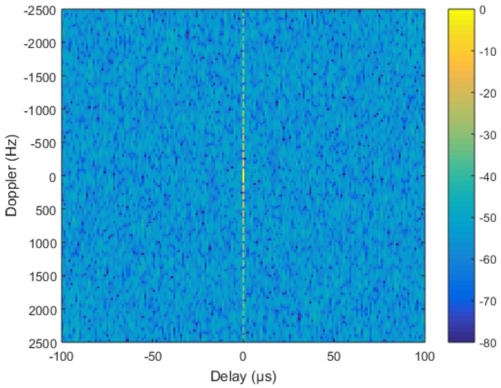
Main candidate signals for UK / Europe:

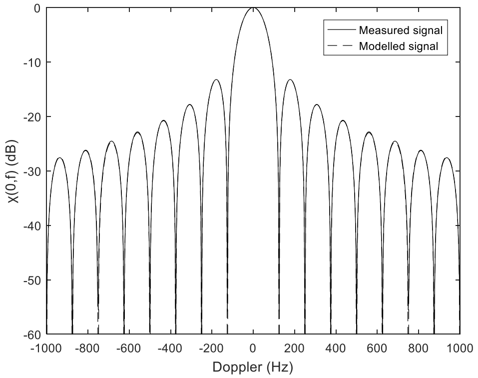
- Inmarsat L-band
- Ku-band satellite TV
- Ka-band data

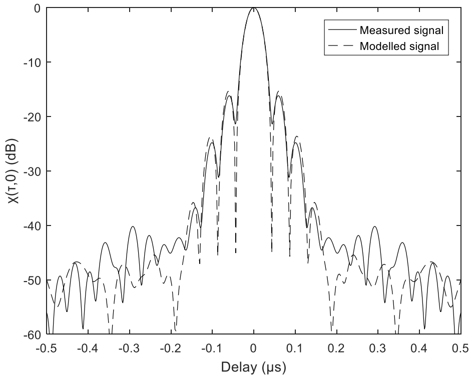
L and Ku-band signals available

Measured and modelled signal properties show good agreement









Previous work / concept validation

PB GeoSAR concept discussed by Krieger (2006) and Prati et al. (1998)

Conclusions are similar to the current study, except

- Increased use of digital transmissions and technology (e.g. SDR) improves the technical feasibility
- We identify potentially useful applications at ~1 km spatial resolution

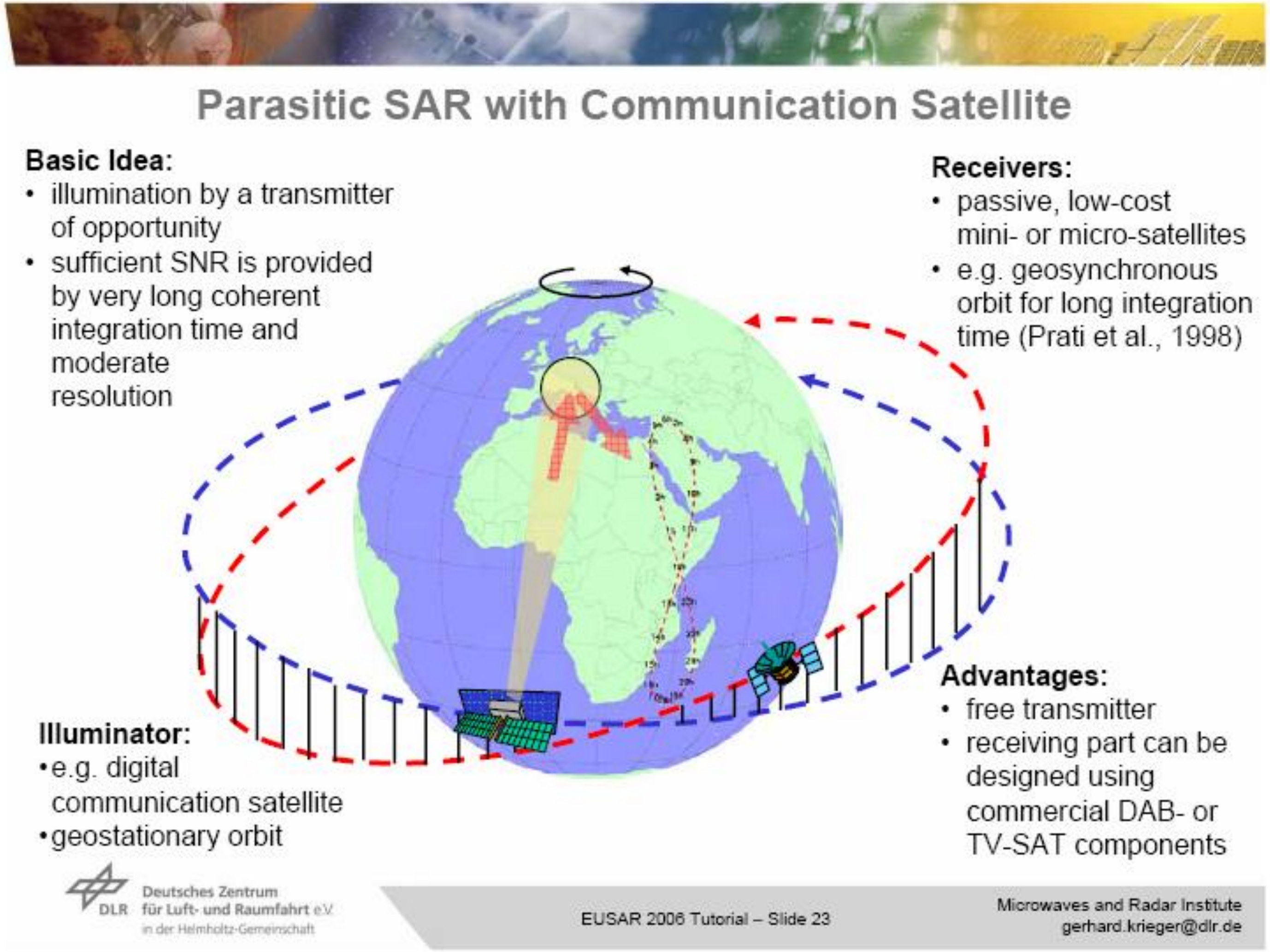


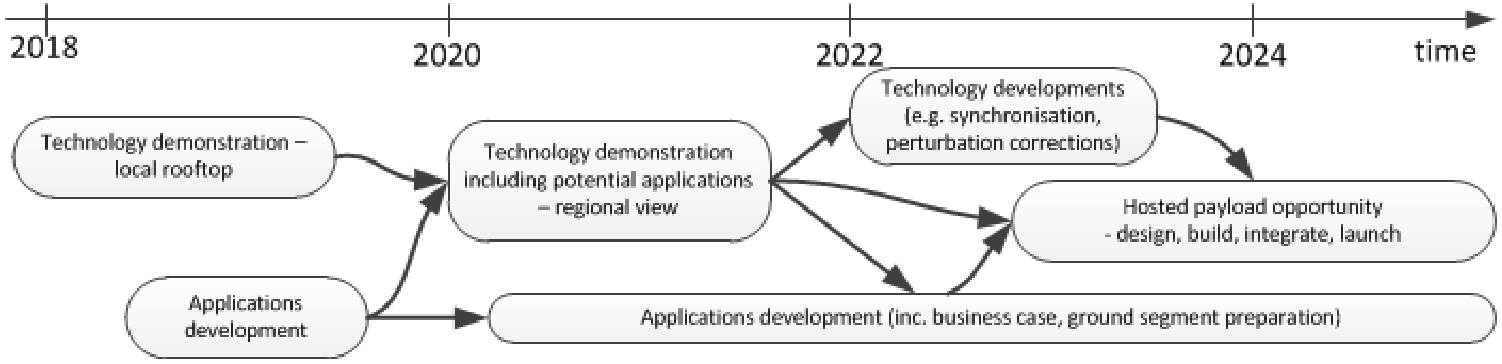
Image: EUSAR 2006 Tutorial - Krieger (2006)

Implementation Roadmap

The bigger picture

Roadmap for eventual implementation

- Highlights the need to develop science readiness once the concept is confirmed



ID	Task Name	Start	Finish	Duration
1	ESA EE10 proposal preparation	25/09/2017	02/03/2018	23w
2	Proposal evaluation	05/03/2018	01/11/2018	34w 4d
3	Phase 0	02/11/2018	26/12/2019	60w
4	Phase0 review	27/12/2019	23/07/2020	30w
5	Phase A	24/07/2020	23/06/2022	100w
6	Phase A review	24/06/2022	19/01/2023	30w
7	Phase B / C / D / E1	20/01/2023	04/11/2027	250w
8	Launch	05/11/2027	13/01/2028	10w
9	Operations	14/01/2028	25/12/2042	780w
10	EOM tasks	26/12/2042	23/07/2043	30w

Conclusions

Feasibility of Passive Bistatic GeoSAR?

- YES – but only at coarse (~1 km) spatial resolution
- Implementation – discussions with an operator suggest that a hosted payload version could be implemented for around $-€-£ 10 million
- Next steps: ground-based demonstrator to validate the system model and technology
- Potential applications need to be cultivated

Thanks to SES and other collaborators

Thank you - Questions welcome