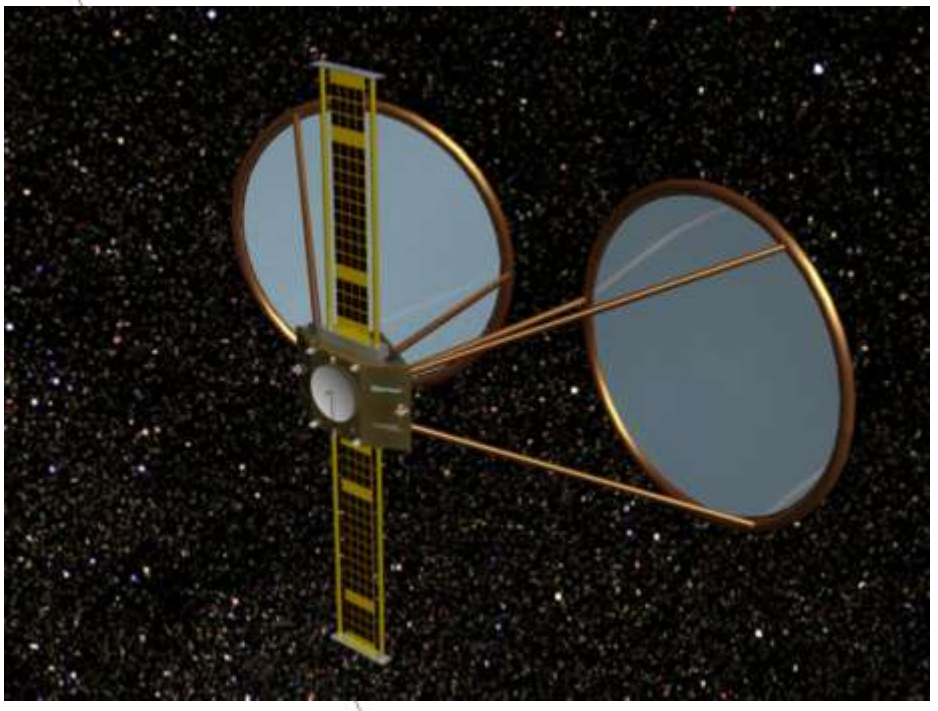
Geosynchronous SAR: System & Applications



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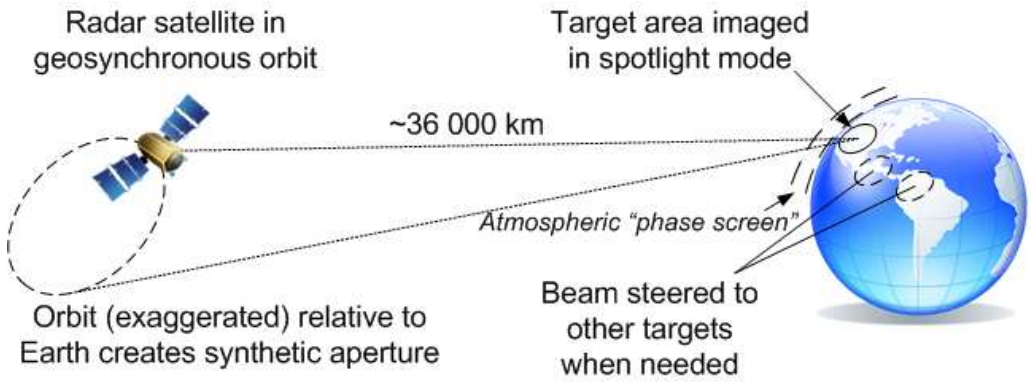
Outline of the presentation



Geosynchronous Radar

1. Background
2. System and Applications Study
3. GeoSAR technologies
4. Applications
5. Mission concepts
6. Summary

1. GeoSAR Background

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	Visible	IR	Radar
LEO	✓	✓	✓
GEO	✓	✓	?

Earth observation uses LEO and GEO orbits, and the whole of the available spectrum – *except* GEO radar (so far)

GEO radar has been discussed for many years

- Excellent temporal sampling + continental coverage
- Powerfully complements LEO: "*system of systems*"

Current research

- USA, China – high power, wide coverage; demanding
- Europe – low power, targetted coverage

2. CEOI System and Applications Study

UK CEOI-funded project to assess GeoSAR mission design and potential applications

Mission Design

- System model – requirements, optimise mission design
- GeoSAR simulator – validate models, quantify performance

Applications

- Ground surface (e.g. subsidence, temporal change)
- Atmosphere: ionosphere (TEC) and / or troposphere (humidity) are measured at high spatial, temporal resolution
- Complementing LEO EO (esp. SAR)

GeoSAR Requirements: Atmosphere

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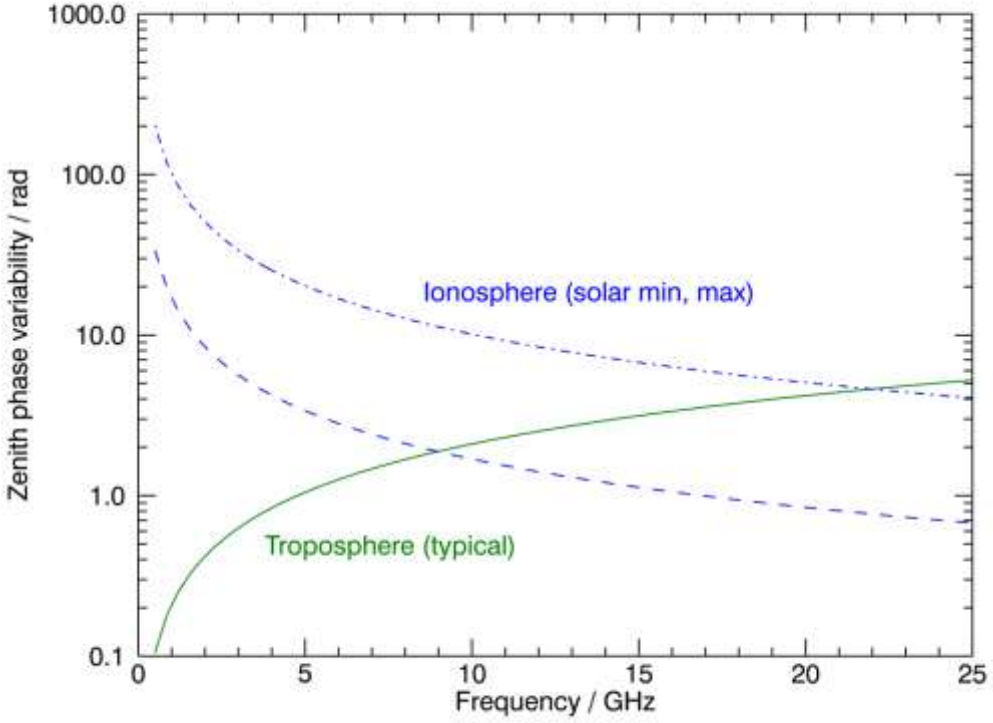
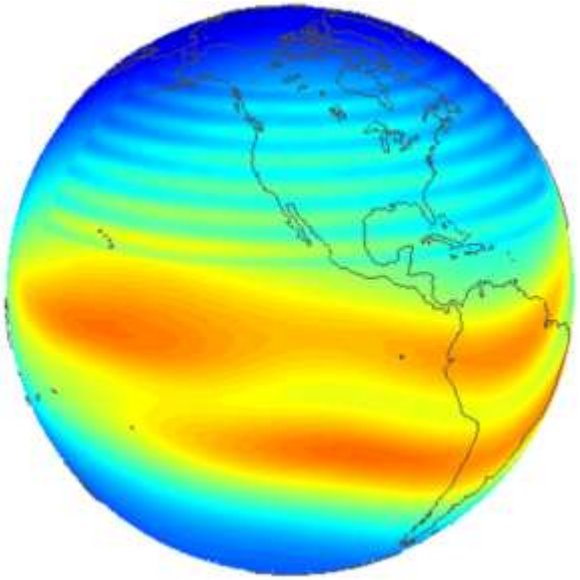
The atmosphere affects GEO SAR imaging (ionospheric TEC, tropospheric humidity)

These therefore become measurable

- Coherent and incoherent methods are available





Measurement length + time-scales

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Atmospheric variability sets measurement length and time-scales

Mission concept:

1. Frequent coarse images (atmosphere quasi-static)
2. Stable targets reveal phase screen changes
3. Compensate phase to focus fine SAR image

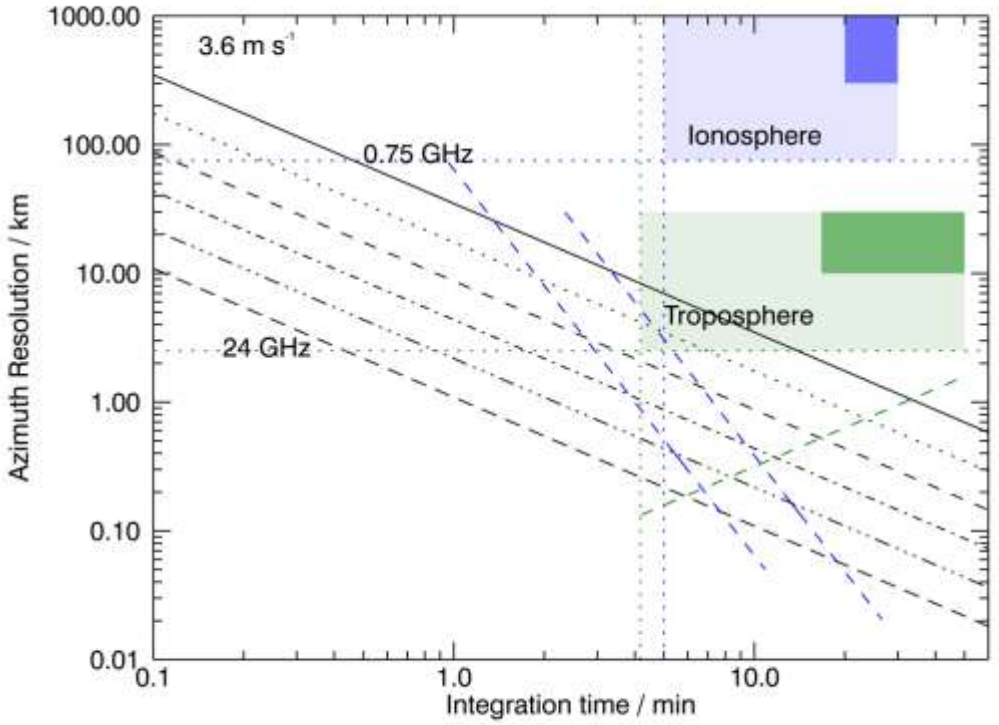
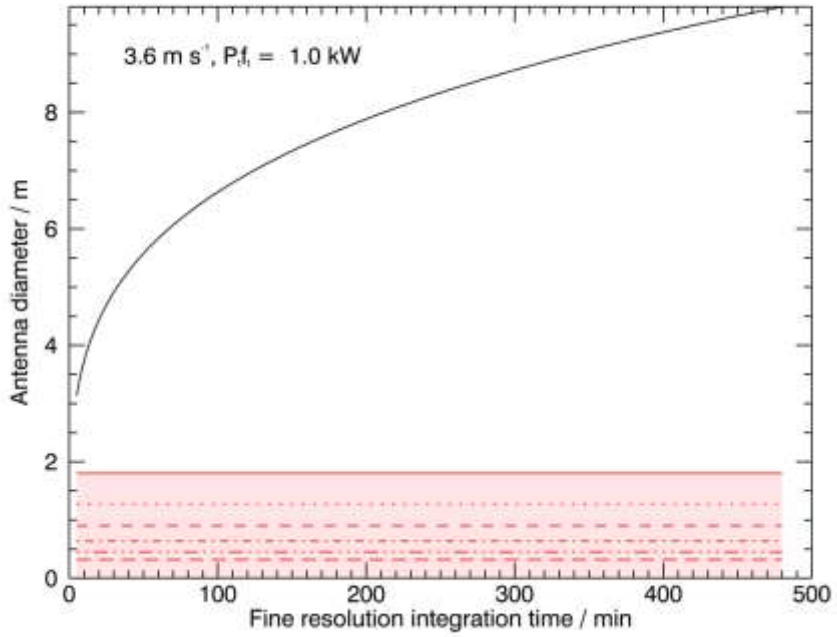


Image shows GeoSAR measurement capability for 100 km relative orbit diameter and various radar frequencies

Antenna sizing
= f(t_{int}, A_{min})



- Coarse resolution images are averaged over ~km and few minutes
  - Phase changes in space and time must be manageable
  - Attenuation due to averaging should be minimised
- Antenna sized by time needed to achieve desired fine resolution
  - Also check antenna large enough to avoid ambiguities

3. GeoSAR technologies

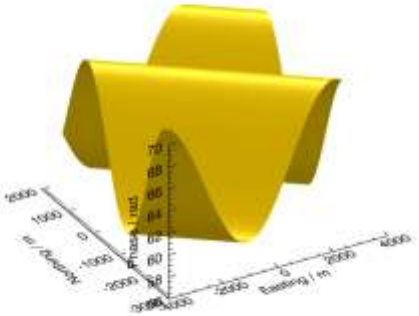
GeoSAR system model – validated ✓

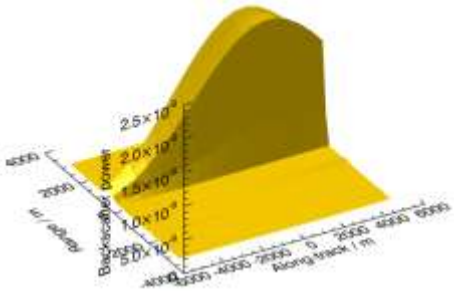
GeoSAR simulator – validated ✓

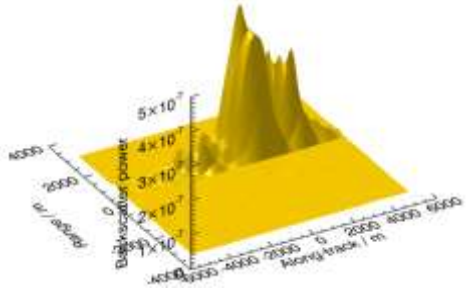
- Captures system physics
- Validates performance calculations
- Evaluates measurement limits

Phase screen autofocus

- Phase correction demonstrated
- Based on data assimilation methodology







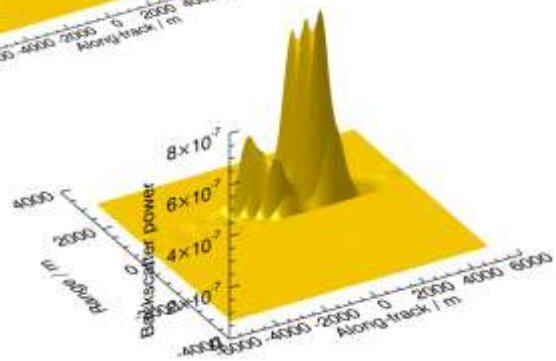
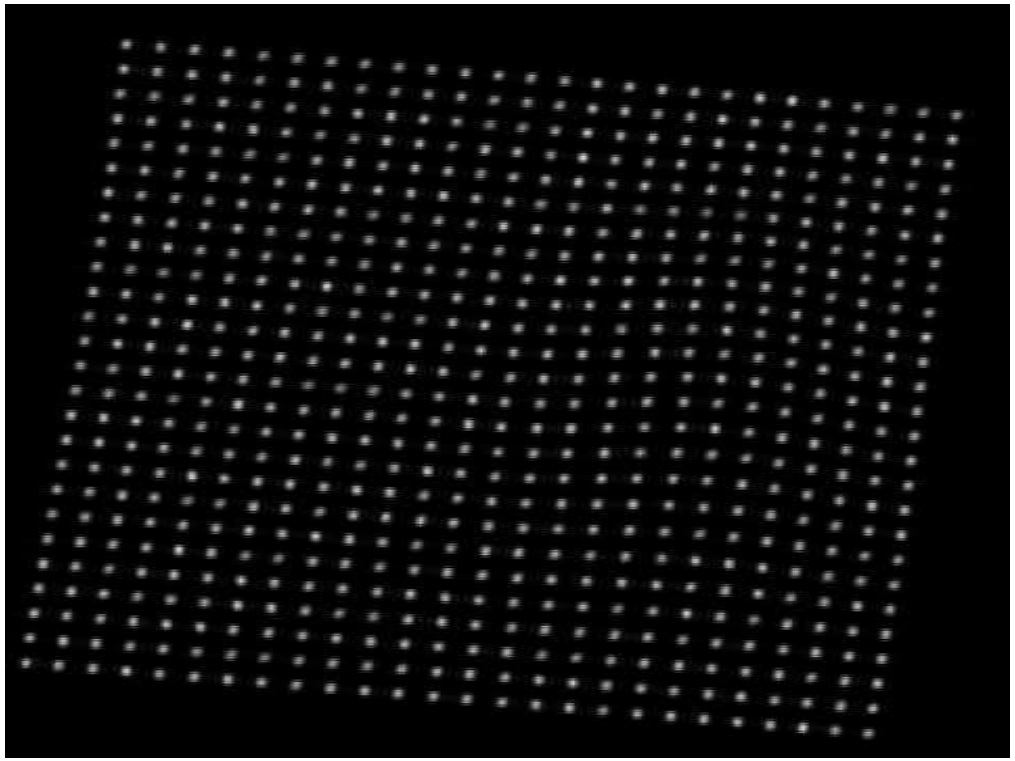


Image distortions



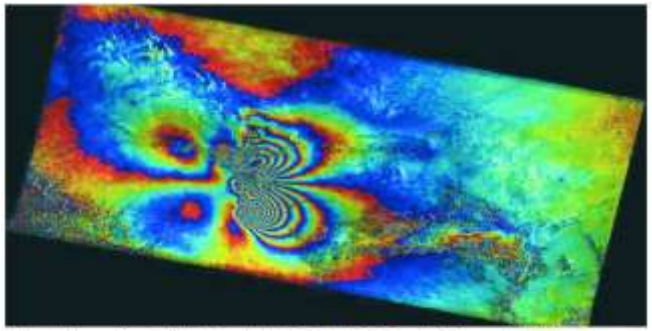
Changing atmosphere shifts target positions

Movie shows simulation of effects of troposphere on a 1 km mesh of point targets (~25 km square)

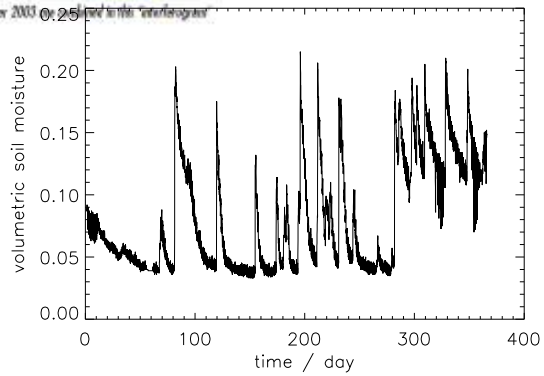
- Uses image every 100 s for 50 minutes

Atmosphere is measured by tracking similar strong targets in the image

4. GeoSAR applications



Envisat radar images of Bam (Iran) from before and after the Earthquake of 26 December 2003 combined in the 'interferogram' to reveal the ground movement. (Polimi/Polito)



Potential applications include

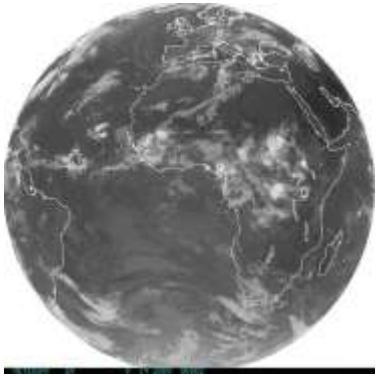
Land surface

- Ground motion: subsidence, landslips
- Soil moisture (*example of process which is too rapid for direct observation with conventional EO*)

Complements LEO SAR, etc.

- High temporal resolution (including daily InSAR)
- Additional targets measured because of viewing geometry
- Target area motion observed in 3D: GeoSAR measures N-S motion, LEO SAR only sees E-W and vertical

GeoSAR Applications - atmosphere



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Frequent images obtained of atmosphere (resolution ~1 km every 3 min); radar frequency determines sensitivity to

- Ionosphere - TEC
- Troposphere – humidity

These images are useful for

- Near-real-time atmospheric corrections, therefore rapid delivery of high quality LEO InSAR data
- Meteorology or space weather; science
- High precision positioning (GPS), etc. …

5. GEO SAR Design Solutions

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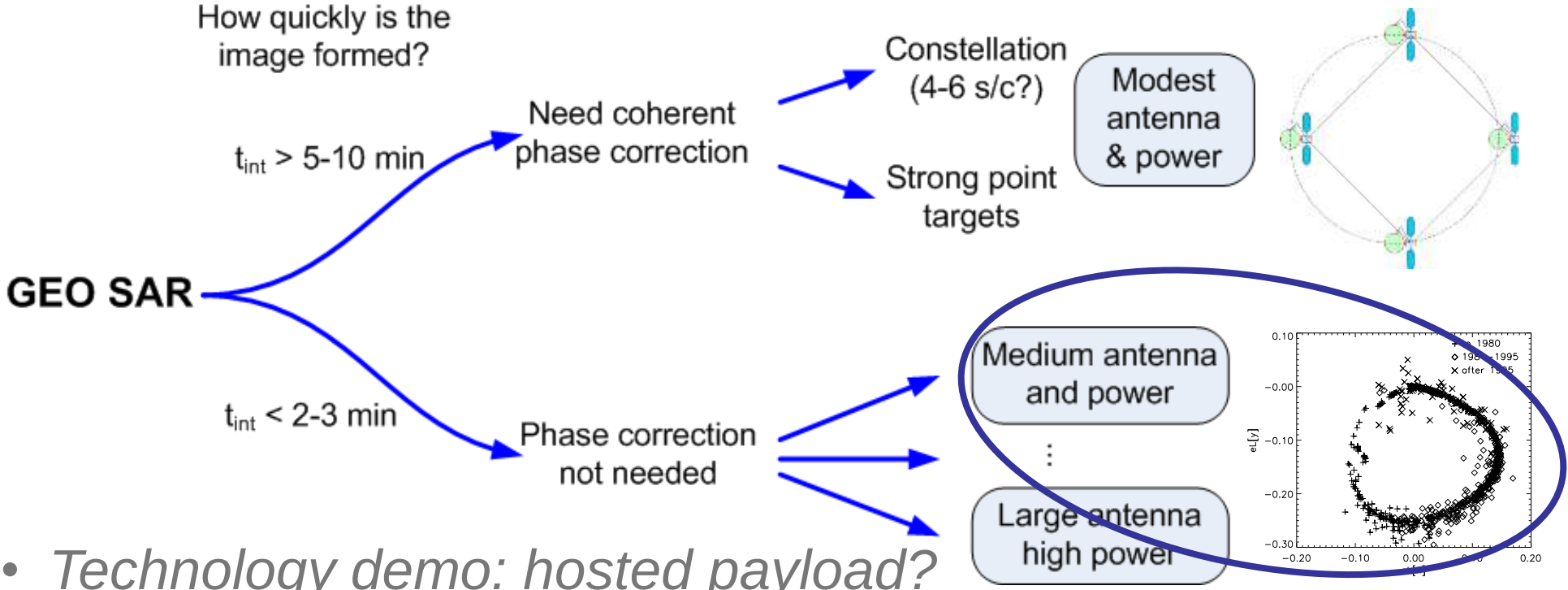
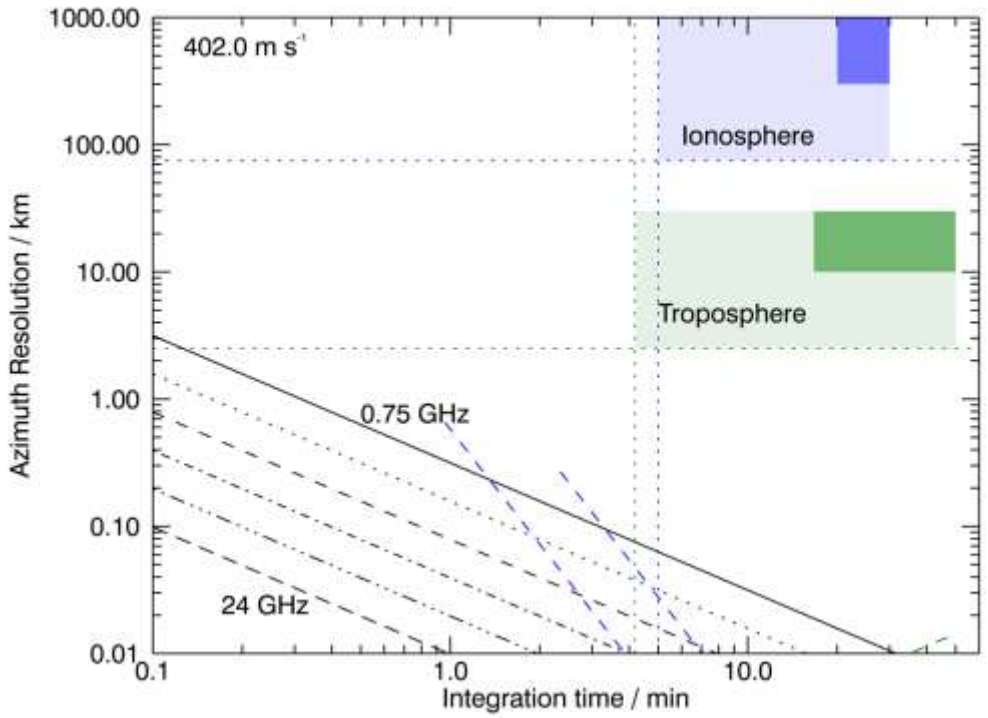
Solution depends on time needed to form the final image

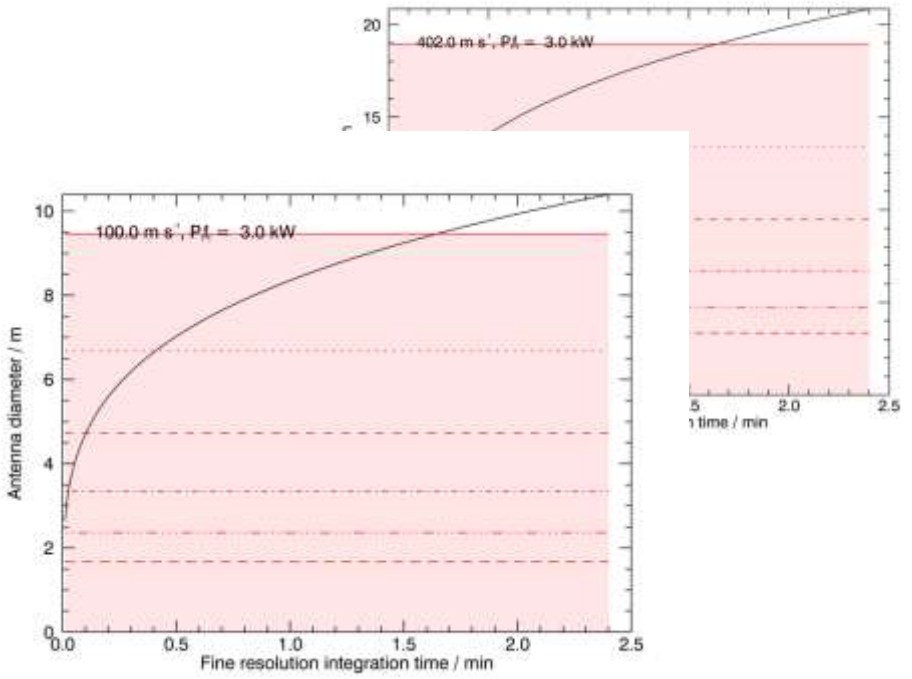


- *Technology demo: hosted payload?*
- *Operational: Medium antenna and power*

System Design Example

Medium Size & Power, e.g. 12 GHz, 10-16 m antenna,
3 kW, t_{int} ~ 1-2 min gives 20-40 m resolution *(+ stable orbit)*





Mission Concepts

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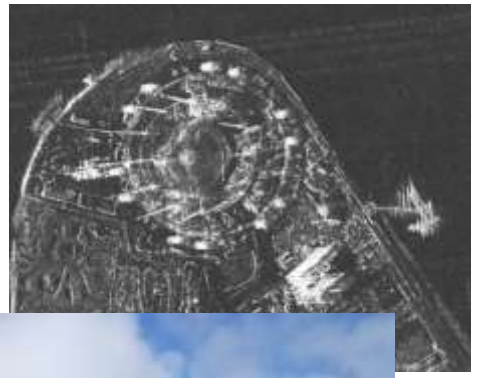


Possible methods of coherent imaging for atmospheric phase compensation:

- Image strong point targets
- Use multiple satellites (constellation)

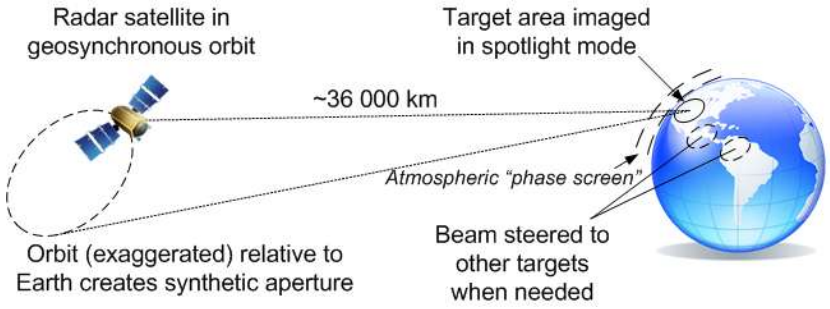
Strong point targets (e.g. Monti Guarnieri et al., 2011)

- Urban areas – natural “corner reflector” returns
- Satellite antennas facing GEO
- Requires small coarse resolution area: favours short λ

Depends strongly on surface properties:

- Short t_{int} options more practical

6. Summary



Radar from geosynchronous orbit

- Concept seems feasible
- Highly versatile imaging modes
  - User can trade spatial coverage and temporal resolution for imaging over continental scales
- Atmospheric data are a valuable by-product
- GeoSAR powerfully complements conventional EO
  - Contributes to a "system of systems"
- UK well-positioned for further work