German Aerospace Center
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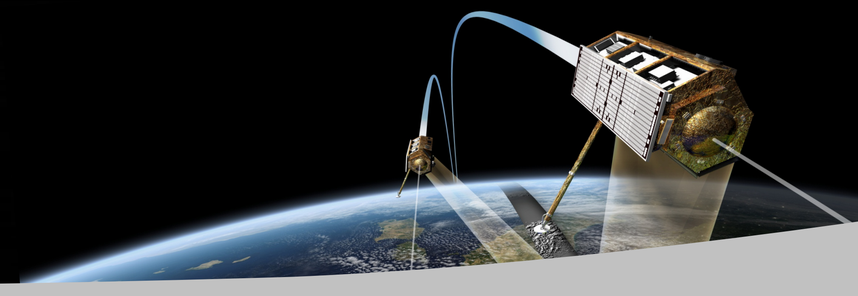
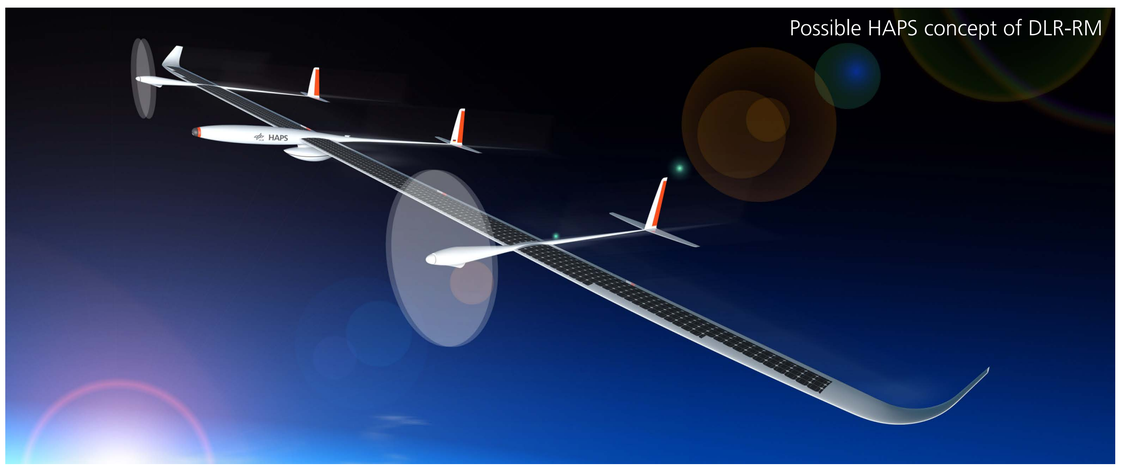


HAPS: Potentials, Applications and Requirements for Radar Remote Sensing

Stefan V. Baumgartner, Rolf Scheiber, Federica Bordoni, Gerhard Krieger, Markus Peichl

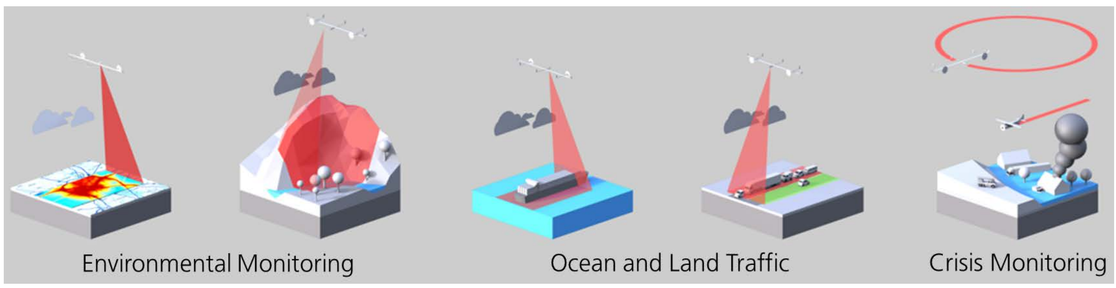
Advantages for Remote Sensing

- **Long endurance** → missions over days / weeks / months
- **Repeated observations** of large ROIs with **short revisit times** → monitoring of dynamic processes
- **Circular flight tracks** → continuous observation of regional hotspots and hazard areas



Synthetic Aperture Radar Applications

- **Disaster and crisis** management
- **Borderline, coastline and pipeline** surveillance
- Continuous imaging of **critical infrastructure**
- **Traffic and traffic infrastructure** monitoring
- **Trafficability** of maritime routes → sea ice, icebergs
- **Tomography and holography** with circular flights
- **Established** synthetic aperture radar **applications**

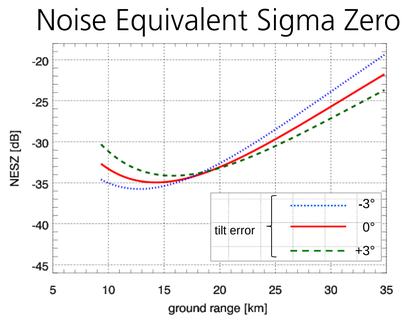


Performance of an Exemplary Low Power X-Band Synthetic Aperture Radar (SAR)

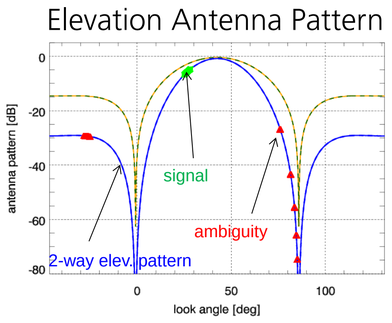
- **Platform assumptions:** Solar-powered fixed-wing HAPS platform in **20 km altitude** , slowly flying with **20 m/s**
- **Major challenges for radar design:** limited payload weight and limited available electrical power

System Parameter	Scenario		
	SAR Imaging	MTI	Open-Sea Long-Range
Radar center frequency [GHz]	9.6		
Range chirp bandwidth [MHz]	500	100	30
Peak transmit power [W]	**50**		
Duty cycle [%]	24	10	
System noise temperature [K]	438.447		
Losses [dB]	2.5		
Antenna overall length [m]	1.0	2 x 1.25	
Antenna height [m]	0.046	0.04	0.07
Pulse repetition frequency [Hz]	2400	4000	780

Noise Equivalent Sigma Zero



Elevation Antenna Pattern



SAR Imaging Performance

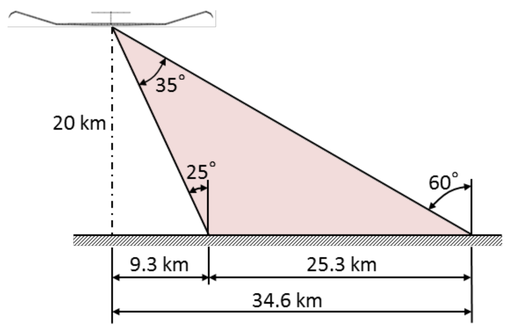
- Swath width 25.3 km
- Resolution ≤ 1 m (8 mm limit @ circular SAR)
- Ambiguity-to-Signal Ratio ≤ -22 dB
- NESZ ≤ -22 dB

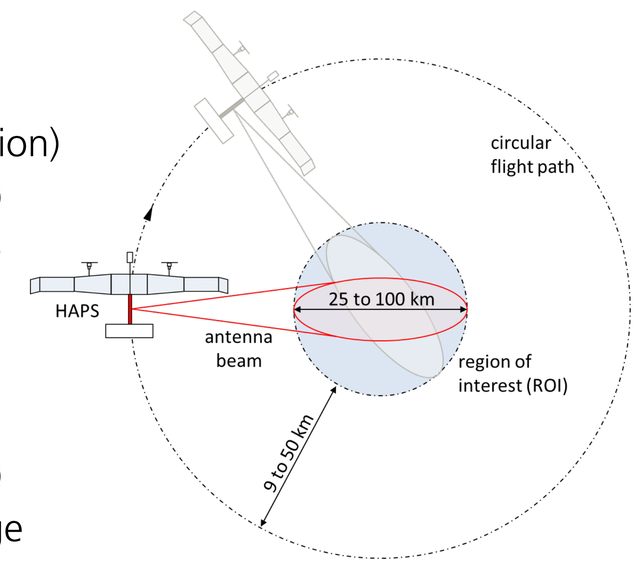
MTI (Moving Target Indication) Performance

- Swath width 25.3 km
- RCS = 7 dBm², false alarm rate 10^{-6}
- MDV ≤ 0.11 m/s (over land, no clutter motion)
- MDV ≈ 0.89 m/s (over ocean, 10 m/s wind)
- Repositioning accuracy ≤ 42 m in far range

Open-Sea Long-Range MTI Performance

- Swath width 100 km
- RCS = 22 dBm², false alarm rate 10^{-6}
- MDV ≈ 0.89 m/s (over ocean, 10 m/s wind)
- Repositioning accuracy ≤ 140 m in far range





Navigation Data Accuracy Requirements

- Relative position knowledge ≤ 0.4 cm for SAR imaging
- Roll angle accuracy ≤ 0.005° for ≤ 3 m height error for single-pass interferometry with 8 m baseline
- Absolute position knowledge ≤ 0.2 cm for 1 m height error for repeat-pass interferometry with 50 m baseline
- MEMS inertial navigation systems are too inaccurate ⇒ star trackers (?) + laser for accurate SAR interferometry

Conclusions

- A limited electrical peak power of only 50 W is sufficient for high-quality SAR imaging and MTI, when a sufficiently large antenna and long duty cycles are used
- The achievable SAR imaging swath width of 25.3 km is comparable to stripmap swath widths of state-of-the-art satellite SAR systems like TerraSAR-X/TanDEM-X
- For SAR interferometry an accurate navigation system is mandatory

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