



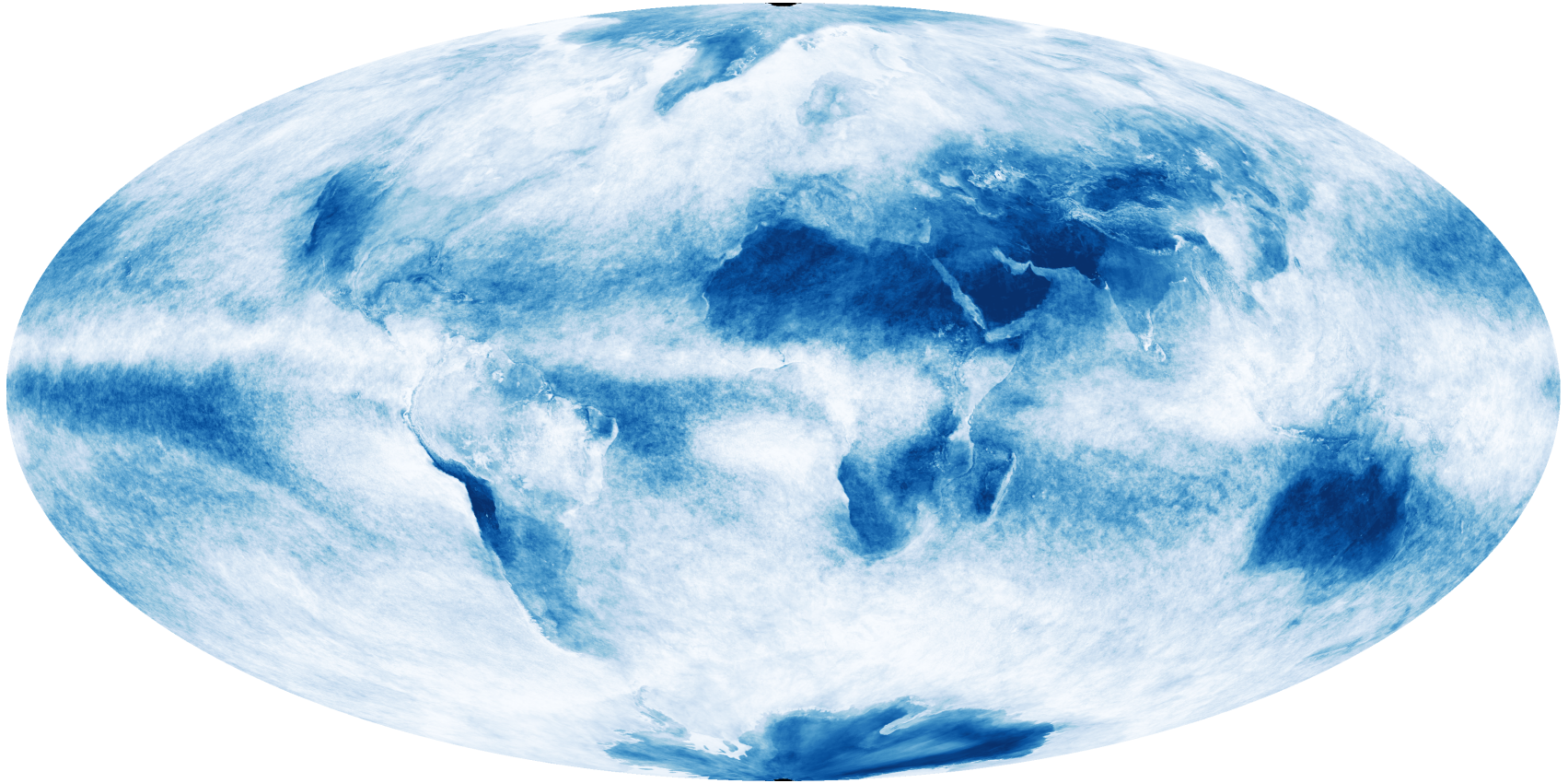
Doing Space differently.

Business Under The Clouds

SSC19-XI-07

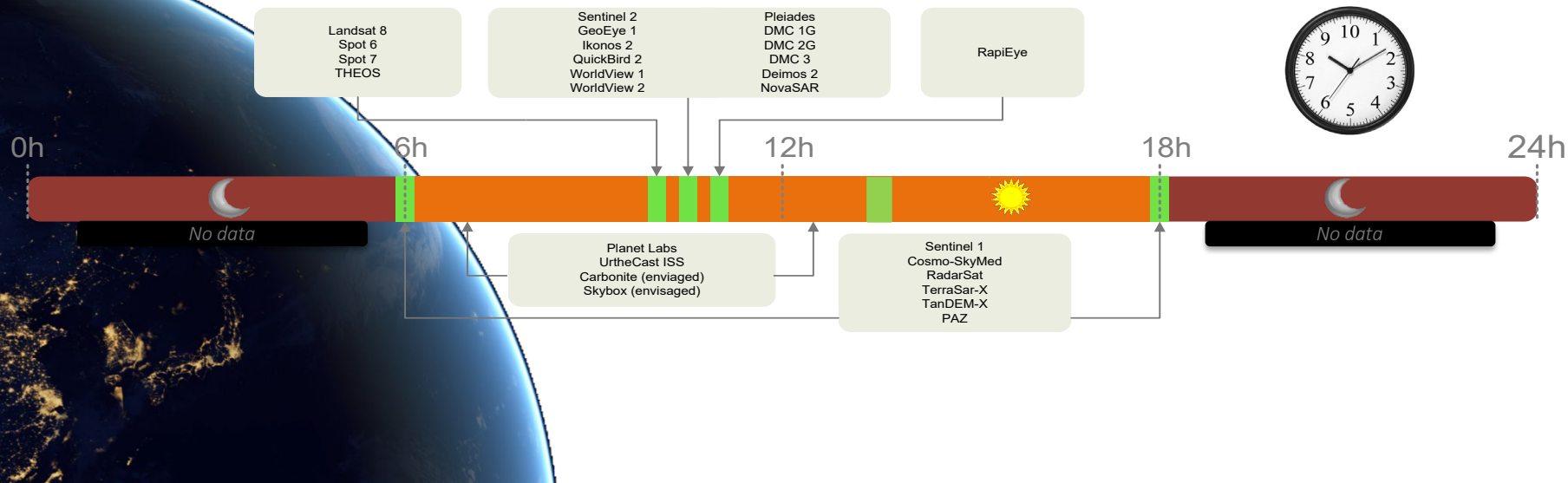
Alex da Silva Curiel,
Phil Whittaker, Rachel Bird, Glen Evans, Andrew Haslehurst,
Victoria Irwin, Andrew Cawthorne, Martin Sweeting

Why the need for satellite SAR?

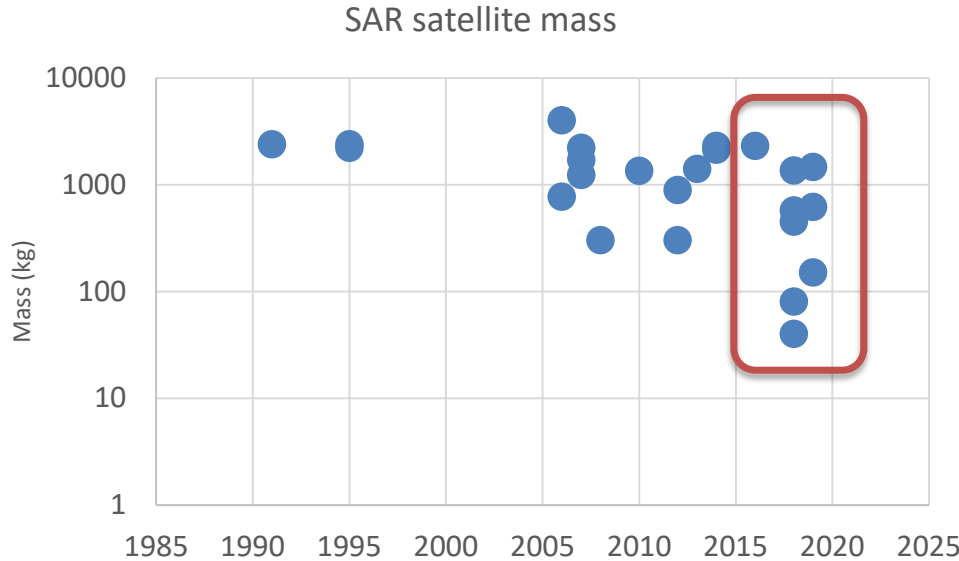


The dark side of the Earth

- Optical missions mostly operate around 10:30 and 13:30 during daytime
- SAR assets typically operate at 06:00 and 18:00 local time.
- As a result, **almost no EO products are available for the period between 18:00 and 06:00**



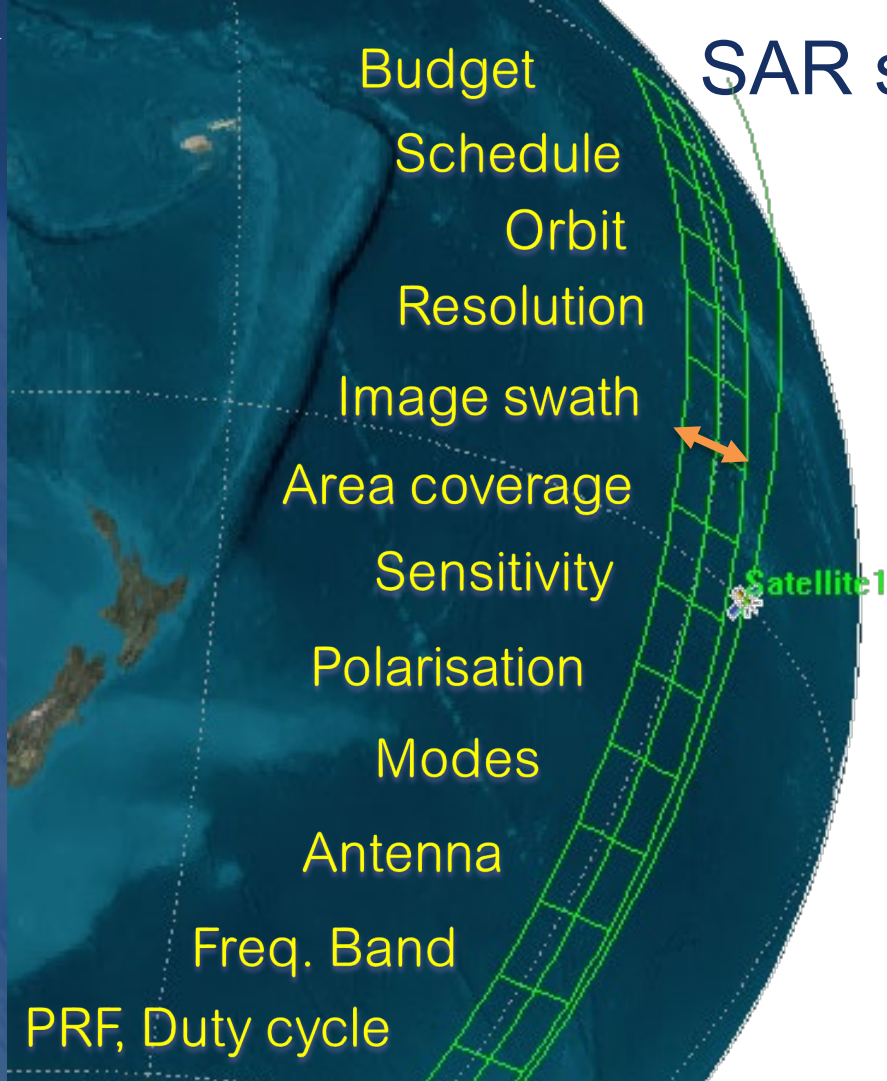
SAR mission trends



SAR mission	Year	Mass (kg)	Band
ERS-1/2	1991-1995	2384	C
RadarSat-1	1995	2200	C
SARLupe	2006-	770	X
ALOS-1	2006	4000	L
TerraSAR-X	2007	1230	X
RadarSAT-2	2007	2200	C
Cosmo-Skymed	2007-	1700	X
TecSAR	2008	300	X
Tandem-X	2010	1340	X
HJ-1c	2012	890	S
RISAT-1	2012	300	X
KompSat-5	2013	1400	X
Sentinel-1a/b	2014/16	2300	C
ALOS-2	2014	2120	L
IceEye-1	2018	80	X
NovaSAR-1	2018	450	S
Capella	2018	40	X
Paz	2018	1350	X
Asnaro-2	2018	570	X
RiSAT-2B	2019	615	X
Harbinger	2019	150	X
RCM	2019	1460	C



SAR satellite design trades



Small?



Large?

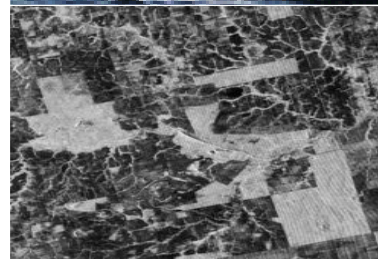
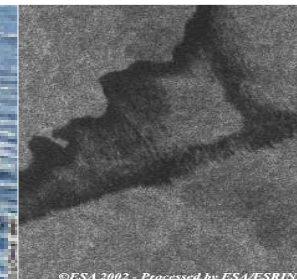
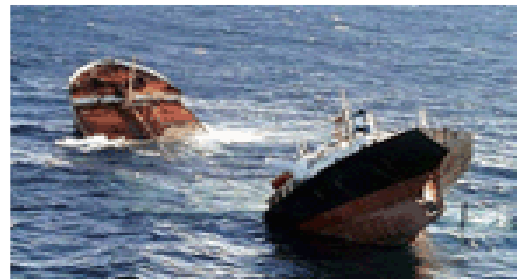


Constellation?

It's all about the Applications



- Most thorough will be
- SAR data interpret.
- Users



 22

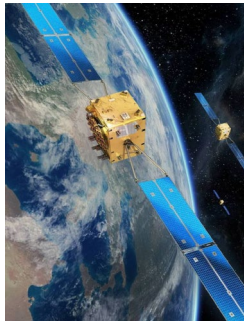
Satellites launched

9 

Launches

2018/9 – busy years for SSTL

*Galileo
FOCx4*



KazSTSAF-1



Carbonite-2



SSTL-300 S1 4, NovaSAR



FORMOSAT-7 (x6)



DoT-1



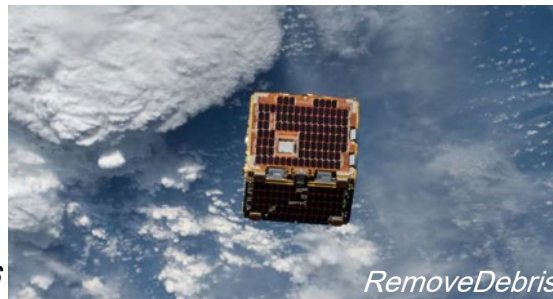
Leo Phase One



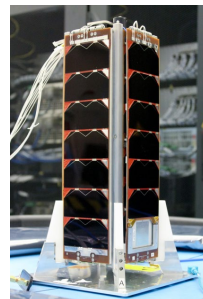
OTB-1



Kanus-V IK3,4 5,6



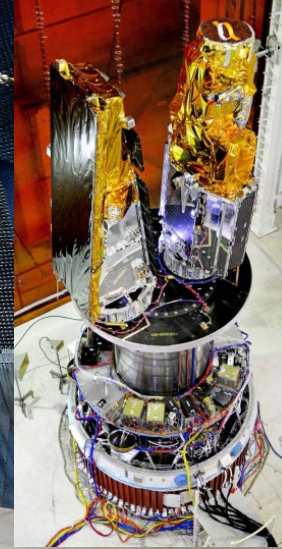
RemoveDebris



VESTA-1

NovaSAR – affordable radar imaging + AIS

- Maritime Surveillance
- Forestry
- Agriculture
- Disaster monitoring



Launch
Sep 2018
10:30 SSO
430kg

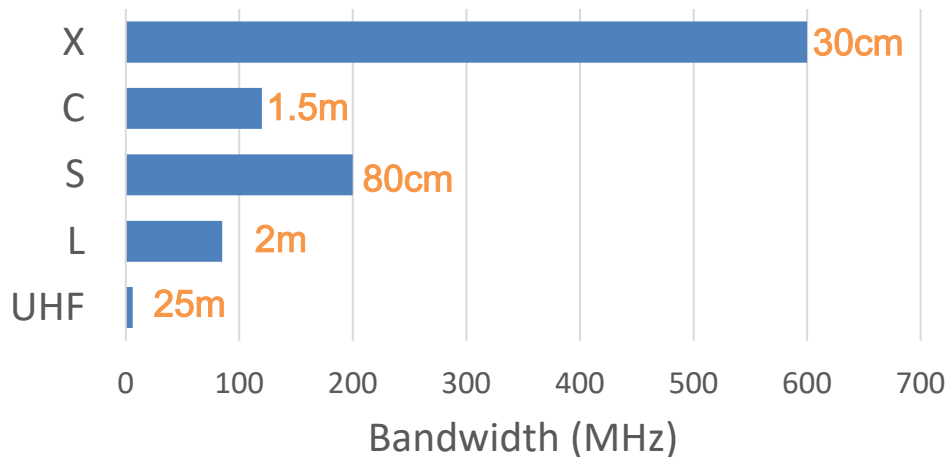
Capability
6m
Quad band
S-band
+AIS

4-6 mission
partners

Band of operation



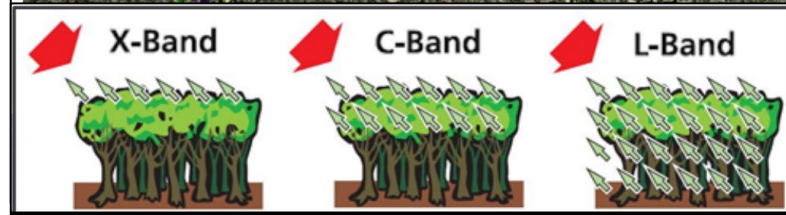
- Bands fixed by ITU
 - L, S, C, X mostly used
 - Most bandwidth at X-band (relates to **range resolution**)



Space Archaeologist Wants Your Help To Find Ancient Sites

February 17, 2016 · 6:54 PM ET
Heard on All Things Considered

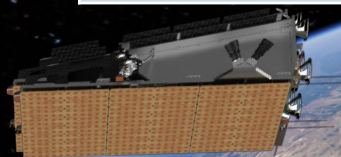
NPR STAFF



- Choice of band strongly linked to applications
- Available technology can also become a driver

NovaSAR - Modes of Operation

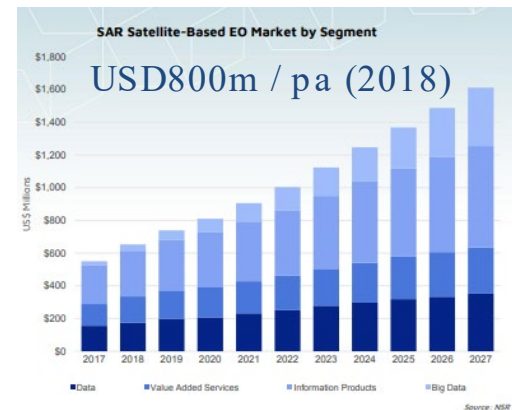
Type	Resolution	Swath	Polarisation
Stripmap	6m	13-20km	HH or VV
Stripmap (wide swath)	6m	18-25km	HH
Stripmap (x-pol)	6x10m	20km	HV
Maritime (scanSAR)	6x14m	400km	HH
ScanSAR	20m	50-100km	HH or VV
ScanSAR	30m	55-150km	HH or VV
ScanSAR	33m	195km	HH
Dual pol	20m	50-60km	HH+VV
Dual pol	20m	20-30km	HH+HV
Dual pol	40m	195km	HH+HV
Dual pol	45m	195km	HH+HV
Tri-pol	30m	50-56km	HH+VV+HV
Tri-pol	35m	100km	HH+VV+HV



How big is the SAR market?

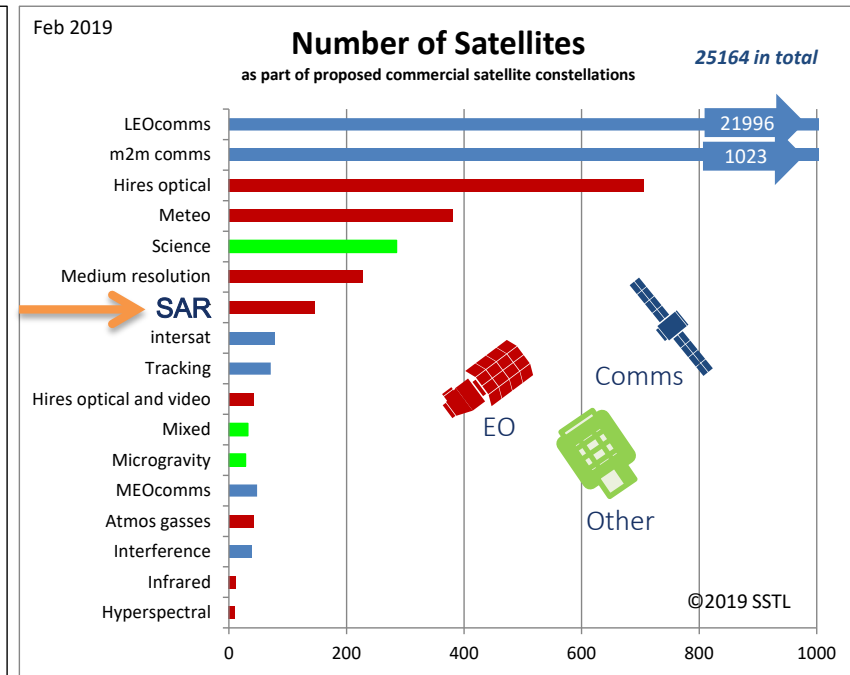
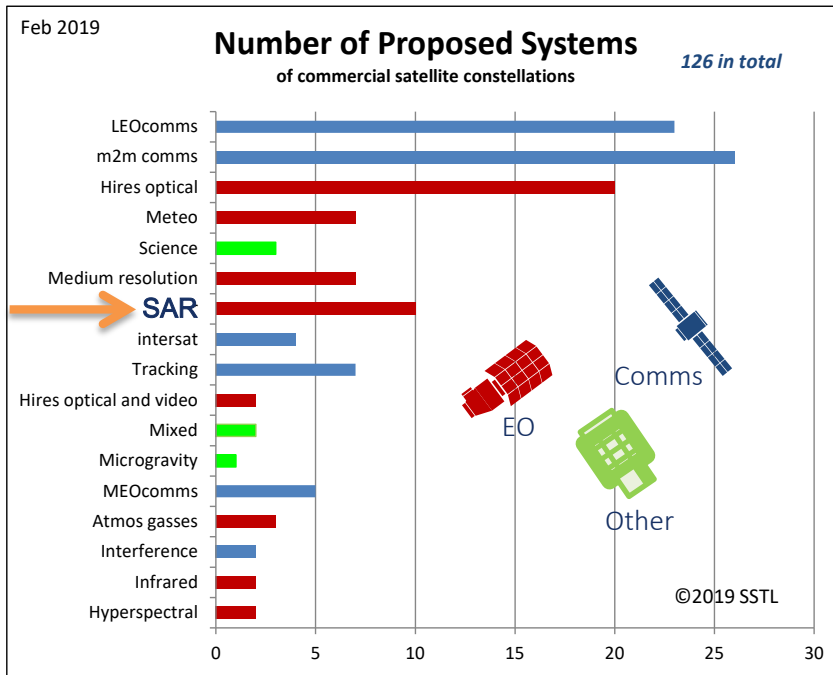


- Projected SAR market over next 10 years
 - Worldwide data and value added services to double.
 - Data cost-per-km² to halve
 - SAR systems must become 4x more cost effective
- Food for thought - NovaSAR
 - 4min operation per orbit, 14.9 orbits/day
 - 20 x 1600km (6m) \approx 500,000 km² per day
 - No losses due to cloud!
 - Potential value generation \approx USD5m per day!
- Market is highly distorted due to government missions.
 - E,g, Sentinel-1a,b “free” data
 - Some governments buy spacecraft instead of data
- Value is based on “Useful” data
- Missions will have to be cheaper, and address new markets and applications.



Source: Satellite-Based Earth Observation, Northern Sky Research, 10th Edition October 2018

New markets in constellations



- Analysts predict 5,000-10,000 to be launched in coming decade
 - ~25,000 LEOcomms announced
 - ~1,000 IOT comms announced
 - ~1,000 EO and Meteo announced

➤ Plans for ~10 SAR constellations comprising 180 satellites

Payload trades 1/2



- Orbit choices
 - 06:00 - 18:00 nice for *single* SAR spacecraft
 - Altitude vs power/sensitivity/aperture size trades
- Using an off-the-shelf platform?
 - Payload power almost always drives ROI / mission returns
 - SAR pulsed and high peak power demand requires consideration (battery, power system, solar panels, EMC)
 - SAR antenna and solar panels can drive AOCS beyond design parameters
 - Significant area for radiators may be required
 - Data storage and downlinking



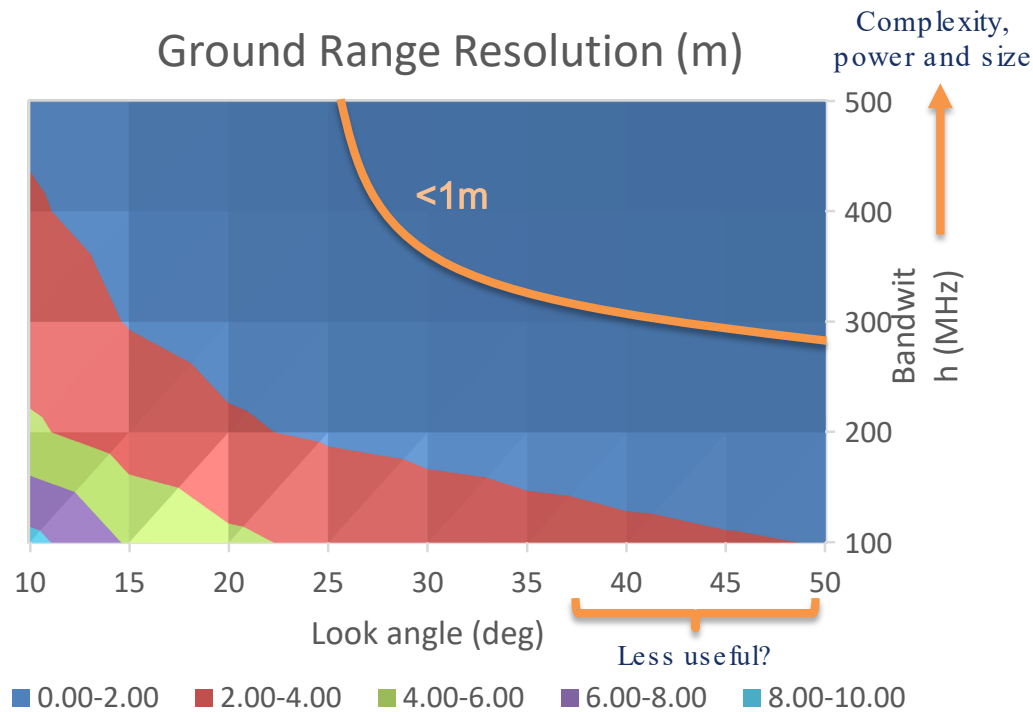
Sun direction
in orbit normal



Payload trades 2/2



- Pulsed operation instead of CW!
- Complex interactions between many parameters.
- **Azimuth resolution** relates to length of SAR antenna
- **Range Resolution**, relates to RX bandwidth and Look angle
- **Swath Width** not a free choice and subject to pulse scheme



- Choose the parameter you want and you are probably doomed on being able to meet the others!

Business Trades 1/2



“Lifetime and heritage are not important”

“Technology will soon be superseded”

“Moore’s law”

- Moore’s law
 - + Computing
 - + Data storage
 - + Data Processing
 - Power generation
 - Power storage
 - Data downlink
 - Radiating heat
 - Your target market

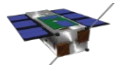


- **Investors limit their exposure if market / returns are uncertain**
 - Doubling performance usually does not double the mission cost → lifetime
 - COTS technology **can** support 5-10 year design life → heritage
 - Risk of systematic design faults must be considered for constellations → heritage
 - Data customers value sustainability → lifetime
-
- Lifetime is probably important
 - Heritage is probably important

Business Trades 2/2



"Make spacecraft simple and quick"



Investment (CAPEX)

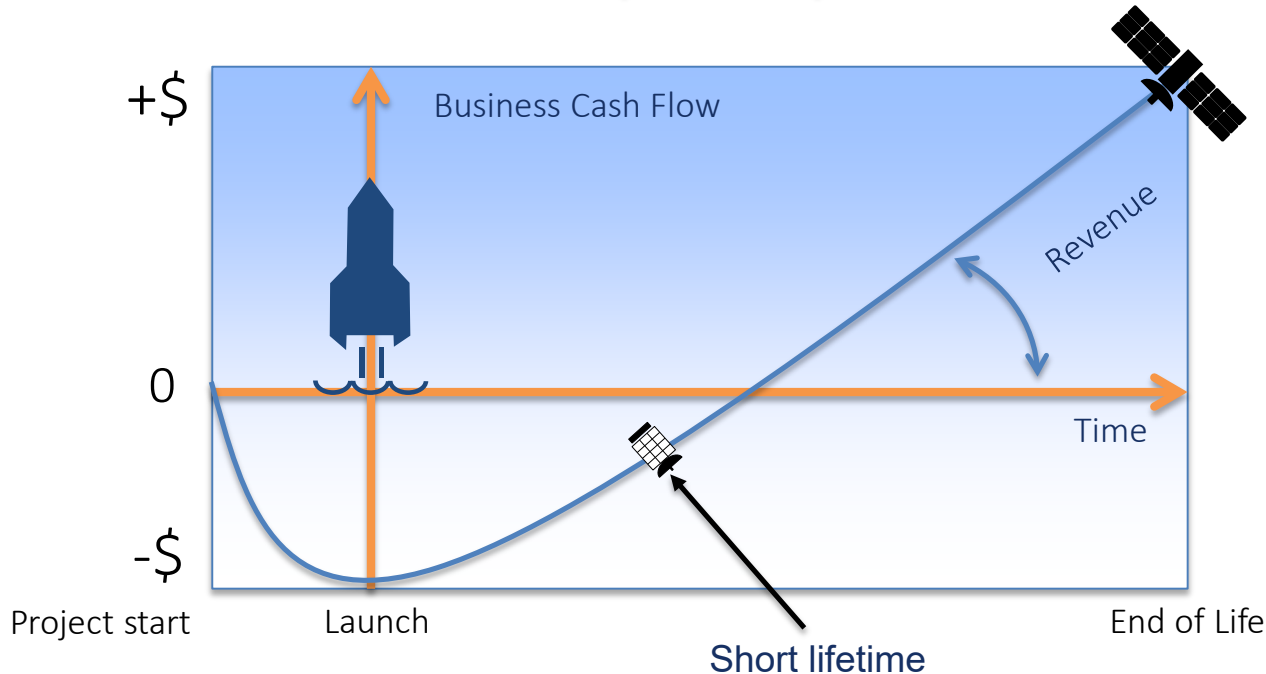
Time to bring into operation



"Make spacecraft capable"

Performance / Applications

Mission lifetime



NovaSAR results

Some Examples

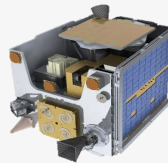
Design and Validation

NovaSAR uses a modified SSTL-300 bus, and new solid state amplifier technology (GaN).

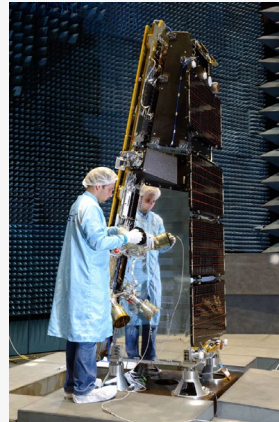
Over the years, several activities took place to ensure the success of the mission.



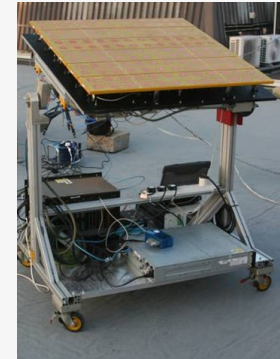
Airborne demonstrators



Altimeter on TDS-1



Extensive testing in antenna range



Ground demonstrator

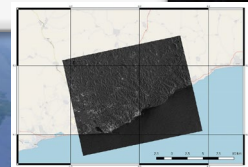
Mission



UK
SPACE
AGENCY



- Raising the budget to launch and operate NovaSAR turned out to be the most challenging aspect



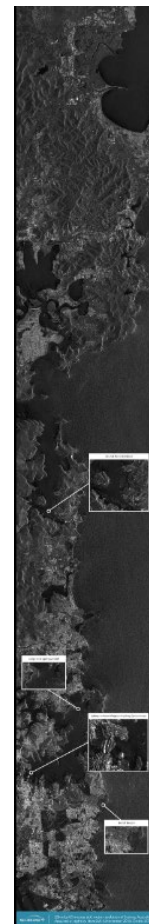
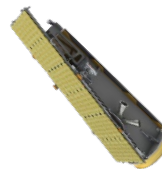
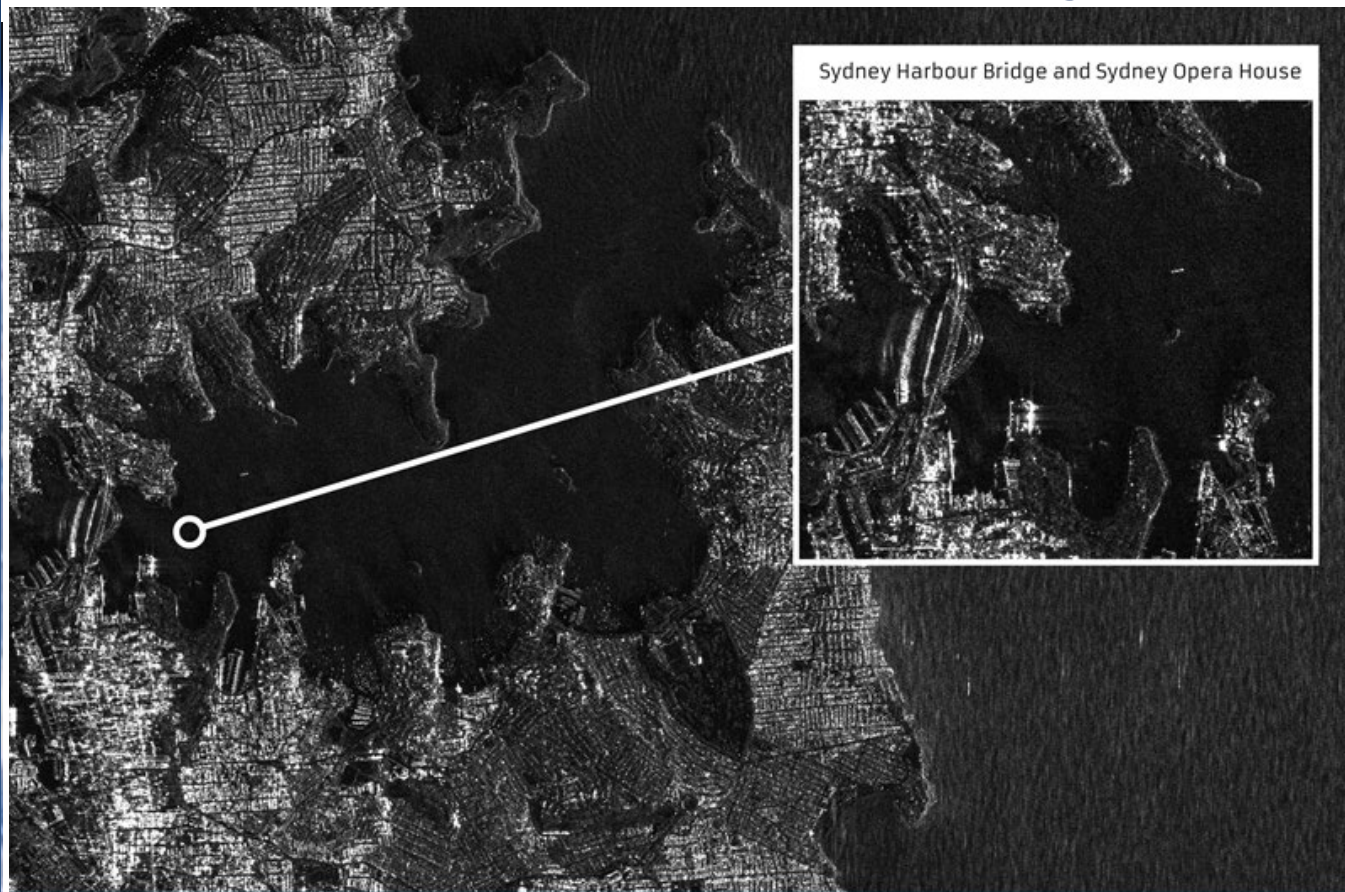
NovaSAR – fractional ownership



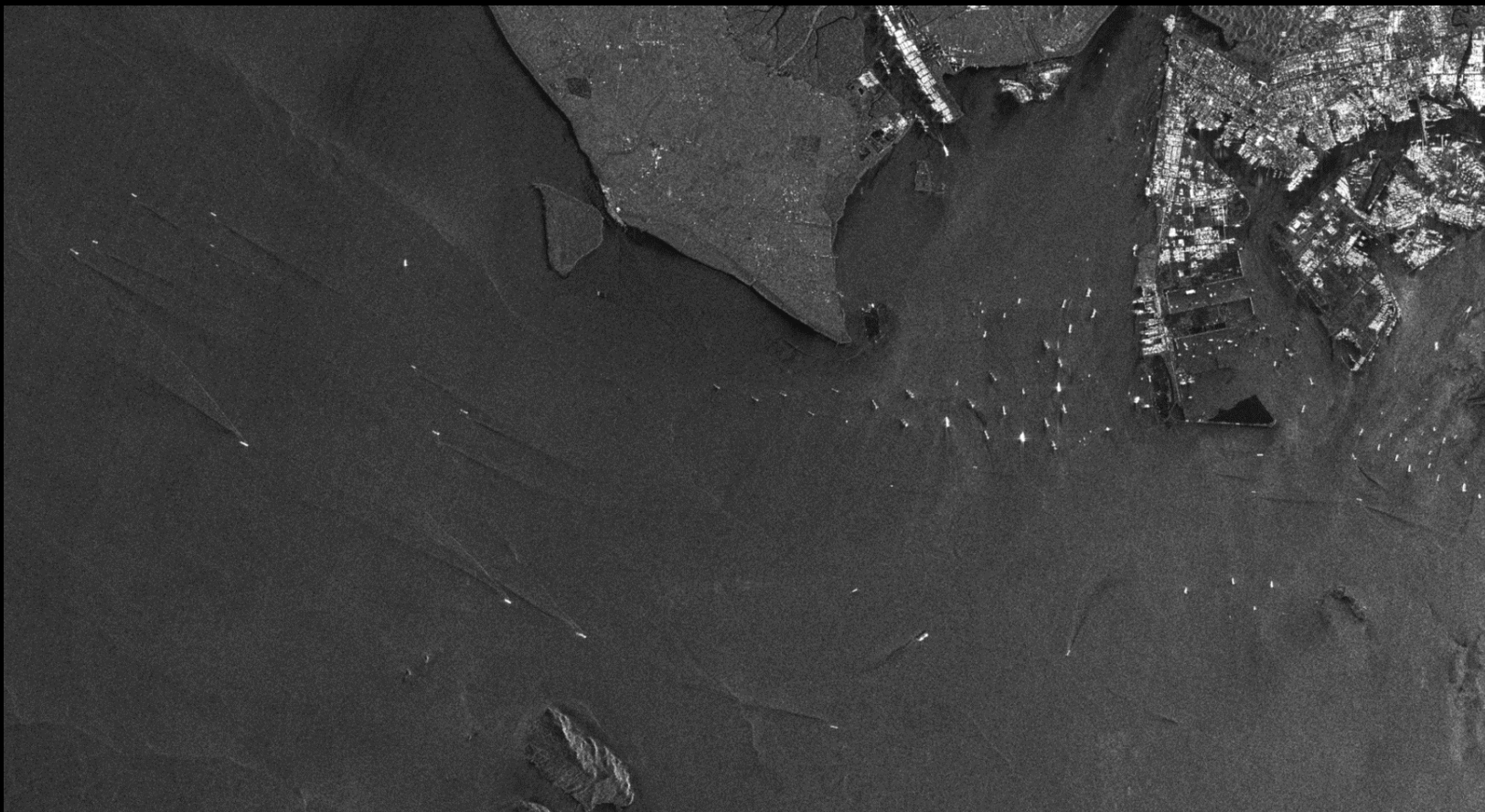
Example:

- Governments typically interested in small fraction of the orbit
- Commercial operators interested in specific worldwide targets

NovaSAR images



Singapore - 20m HH Pol ScanSAR



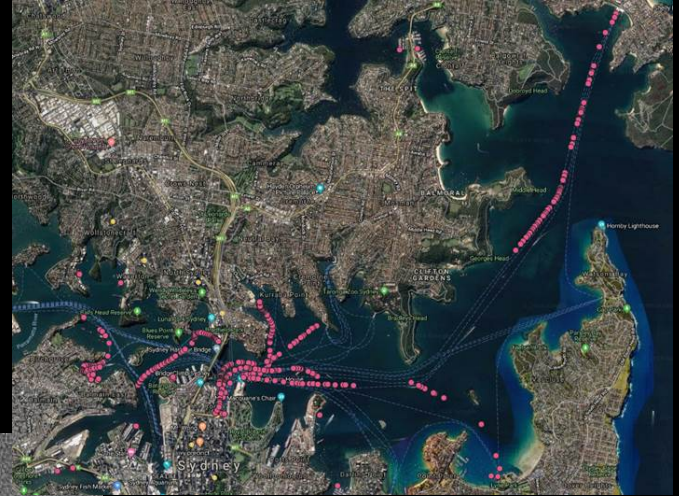
NovaSAR – AIS + SAR data fusion



NovaSAR
ship detection mode



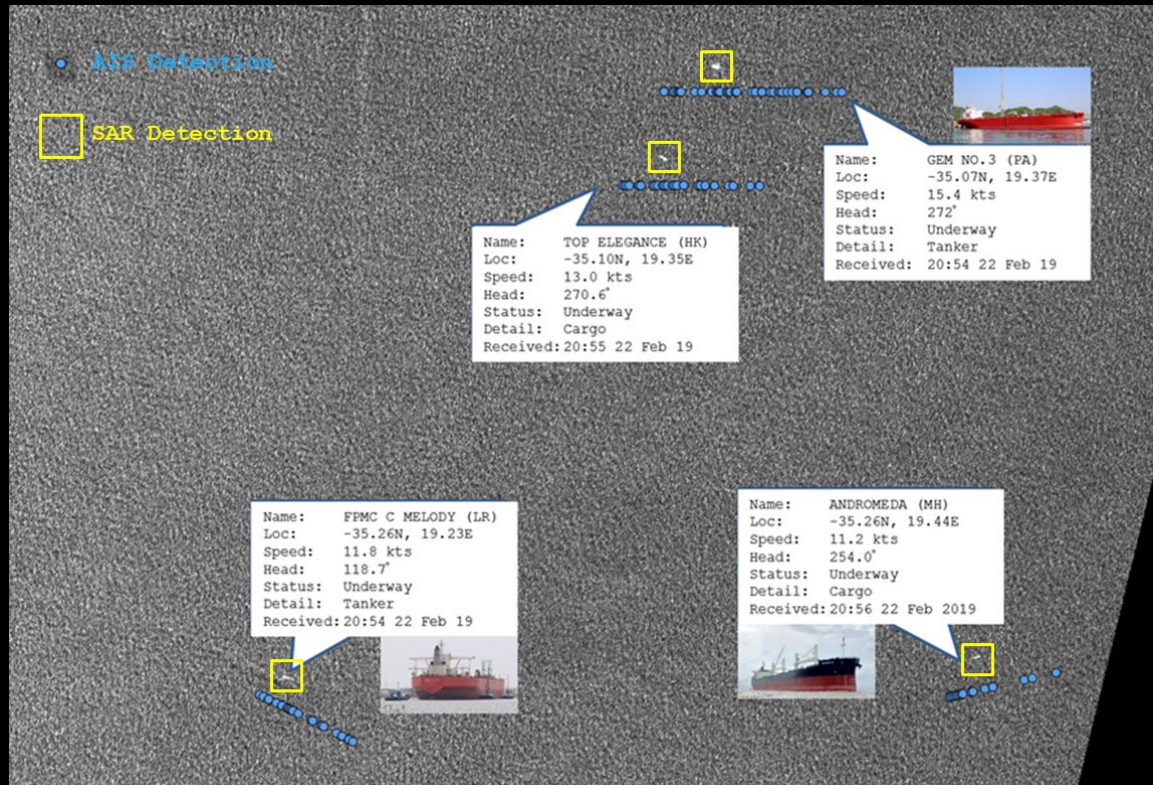
Coincident
SAR + AIS



AIS data



NovaSAR AIS Detections



NovaSAR 20m ScanSAR image showing coincident AIS message information

Suez Canal - 30m Alt-Pol ScanSAR

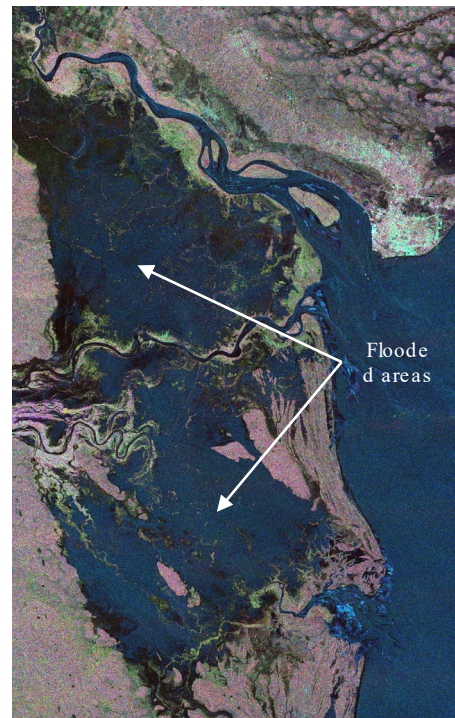
(HH: Green, VV: Blue, HV, Red)



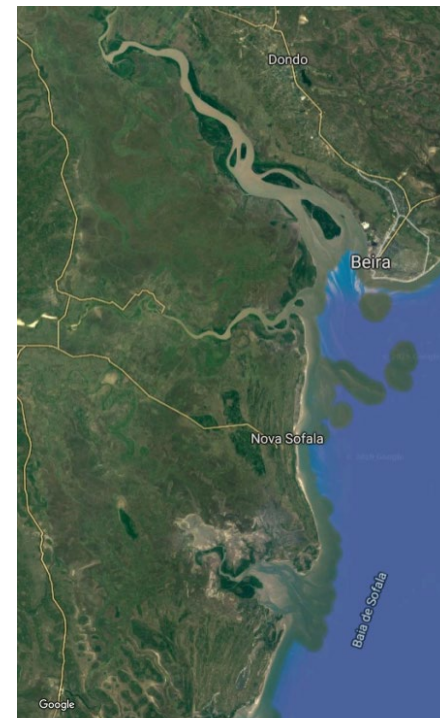
Disaster Response



- SAR imagery can support disaster response, management and mitigation for emergencies such as earthquakes, landslides and flooding. Potential tasks include:
- Locating and evaluating affected areas and determining access routes to guide response efforts especially in remote regions of the world.
- Providing information on flood extent to allow assessments of the areas at risk and aid decision-making on relief and clean-up operations.
- Mapping and assessing damage to infrastructure and buildings through change detection techniques.
- Providing ongoing information on disaster status to assist with humanitarian aid missions.



Multipolarimetric ScanSAR NovaSAR Image of Beira, Mozambique, showing flooding due to Cyclone Idai

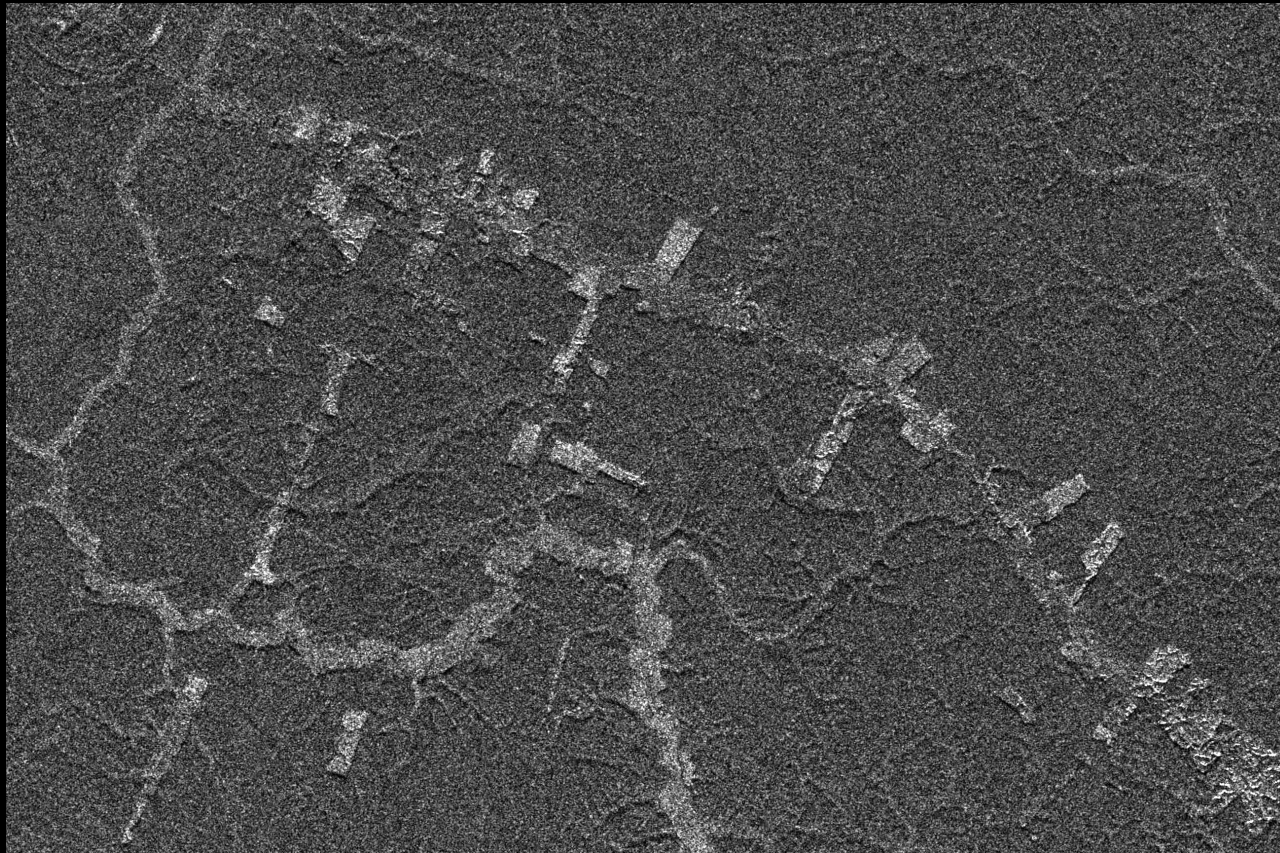


Google Maps image of Beira, Mozambique, before Cyclone Idai
Imagery ©2019 Landsat / Copernicus, Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Map data ©2019

Kansas, USA – 30 m Alt-Pol ScanSAR

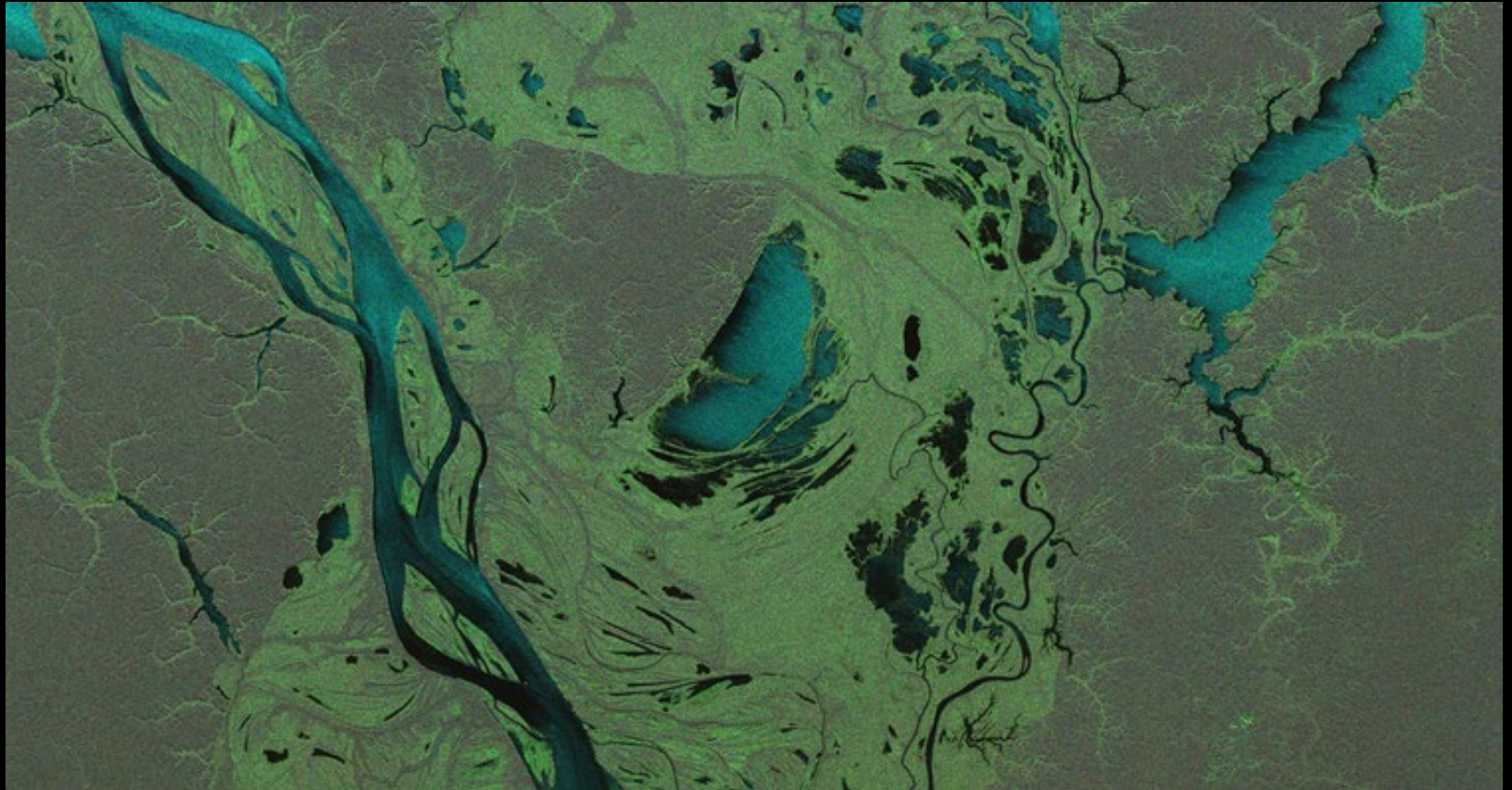
(HH: Green, VV: Blue, HV, Red)



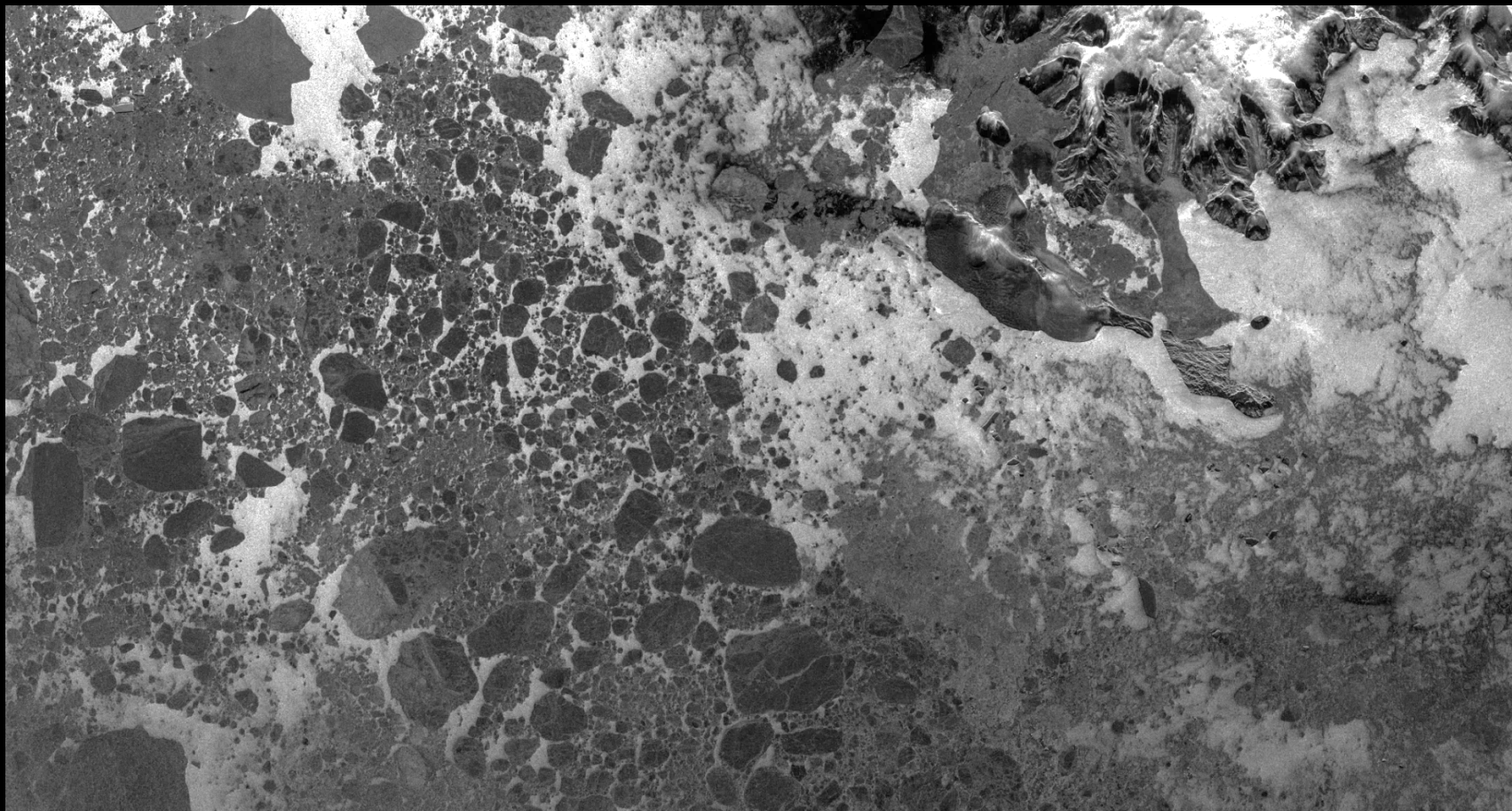


Amazon Lakes – 30 m Alt-Pol ScanSAR

(HH: Green, VV: Blue, HV, Red)

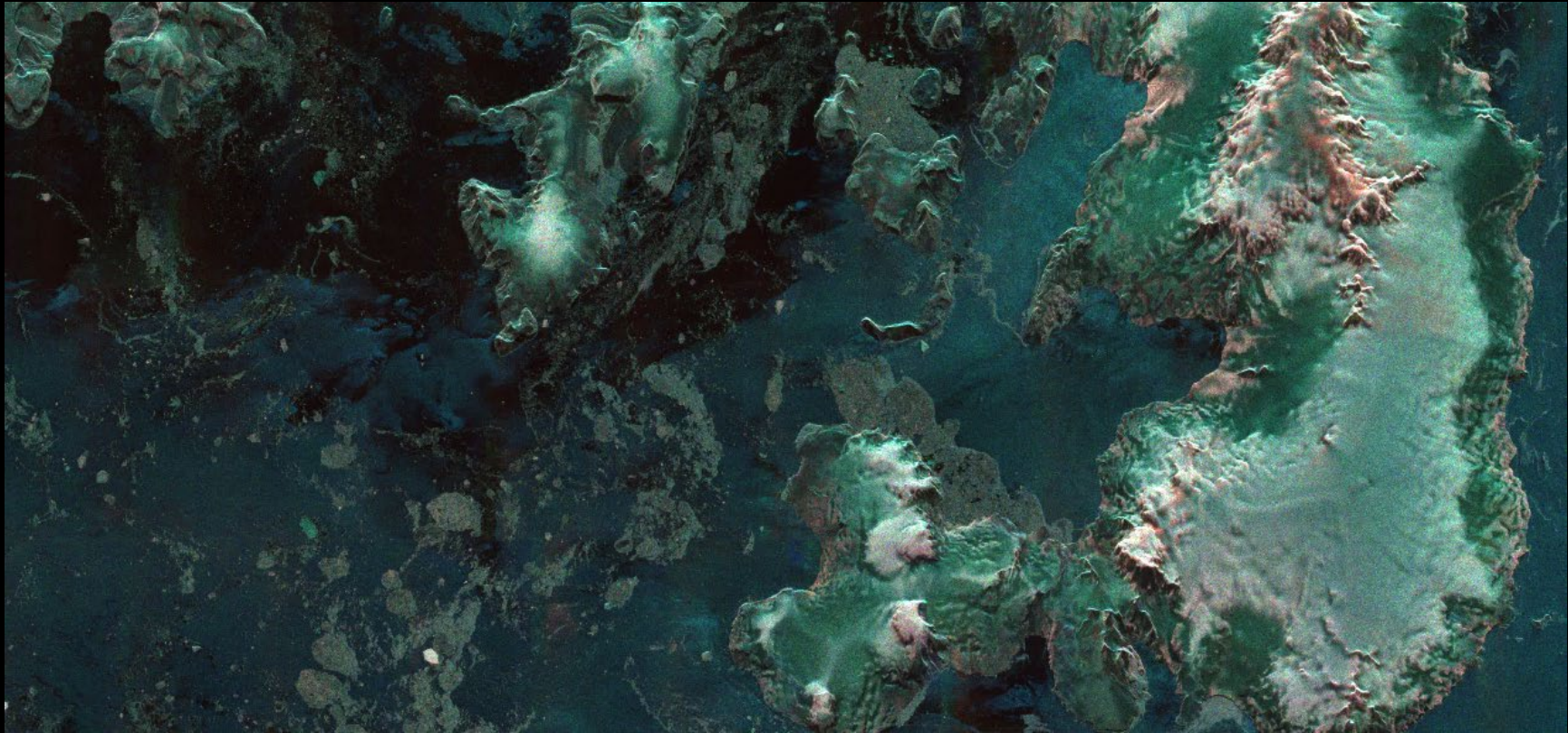


Antarctica – 30m ScanSAR HH, 150km swath



Antarctica - 30m Alt-Pol ScanSAR

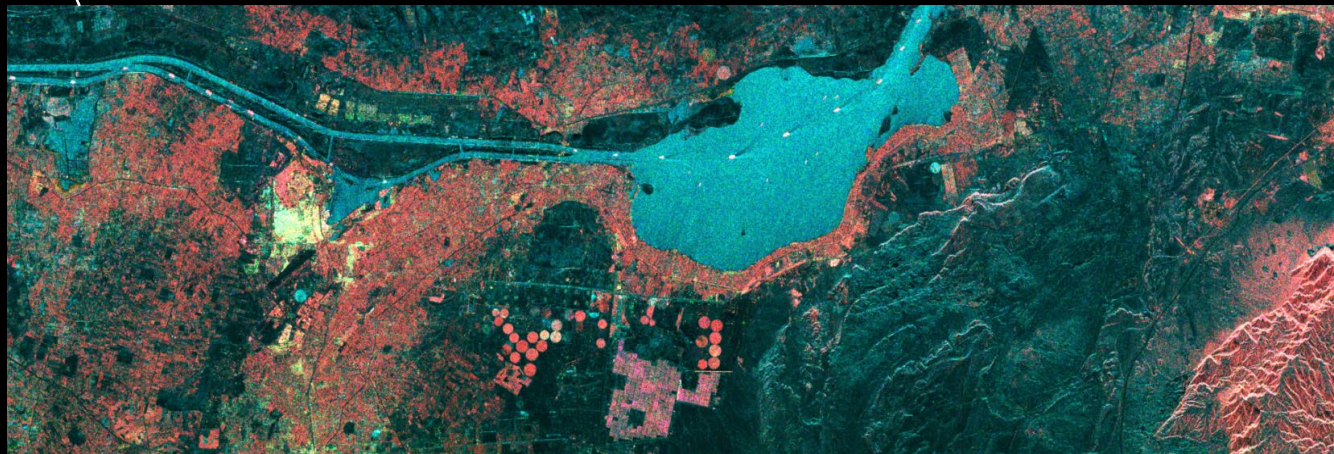
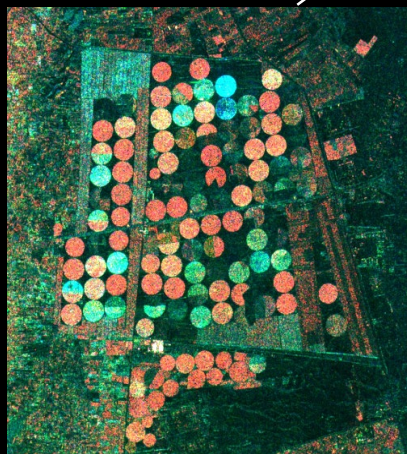
(HH: Green, VV: Blue, HV, Red)





Suez Canal - 30m Alt-Pol ScanSAR

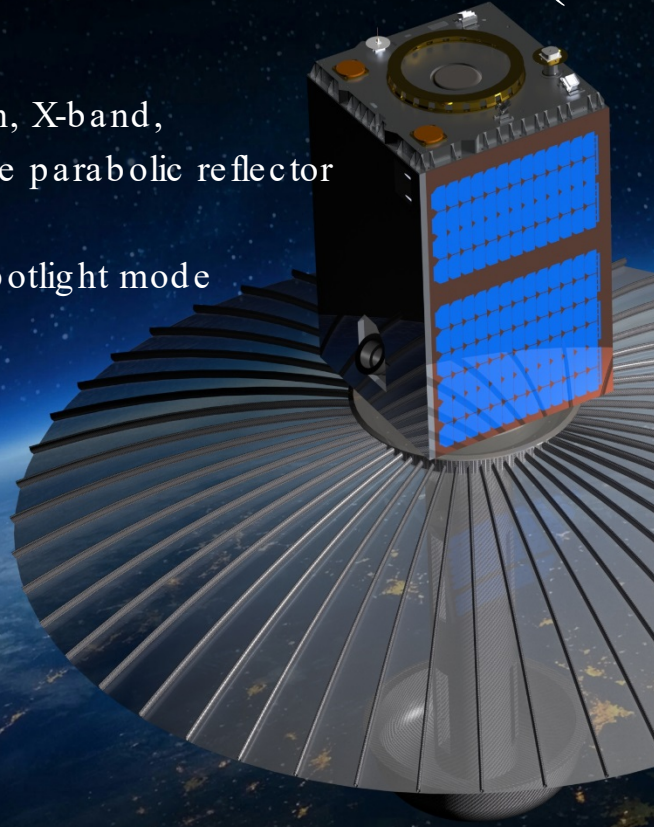
(HH: Green, VV: Blue, HV, Red)



Carb SAR (due 2021)

- Targets:

- $<<1\text{m}$ resolution, X-band,
- 3-5m deployable parabolic reflector
- 3% duty cycle,
- 5x5km swath spotlight mode



<https://vimeo.com/276328226>

<https://ukdefencejournal.org.uk/uk-to-develop-own-synthetic-aperture-radar-satellite-capability/>

<https://spacewatch.global/2019/04/sstl-and-oss-collaborate-on-disruptive-smallsat-sar-payload/>

<https://www.gov.uk/government/news/defence-secretary-outlines-ambitious-space-programme>

SmallSat SAR enables “Business under the clouds”

1. For SAR, **data return, sensitivity and utility** must be sacrificed for size
2. SAR missions will have to be cheaper, and address new markets and applications.
3. NovaSAR and CarbSAR are addressing commercial SAR applications

Surreysatellites

<https://www.youtube.com/user/SSTLTV>

https://www.linkedin.com/company/sstl?trk=cp_followed_name_sstl

SurreySat

A.Curiel@sstl.co.uk