



ICEYE

ICEYE AND THE SENTINELS:

COMPLEMENTARY CONSTELLATIONS

www.ICEYE.com

EUROPEAN NEW SPACE LEADER

- World's 1st small SAR Satellite launched **In 2018**
- Over **150 People** with 25+ nationalities
- **4 offices**, Finland, Poland, UK, US
- **World Leader In SAR** Miniaturization Technology
- Existing portfolio of international customers



- 2015 COMPANY FOUNDED
- 2016 INITIAL CUSTOMERS
- 2017 \$13M SEIRES A
- 2018 ICEYE-X1 LAUNCH
- 2018 \$34M SERIES B
- 2018 100 PEOPLE
- 2018 ICEYE-X2 LAUNCH
- 2019 2 MORE SATELLITE LAUNCHES

PROVEN RESULTS
WITH A

NEW SPACE APPROACH

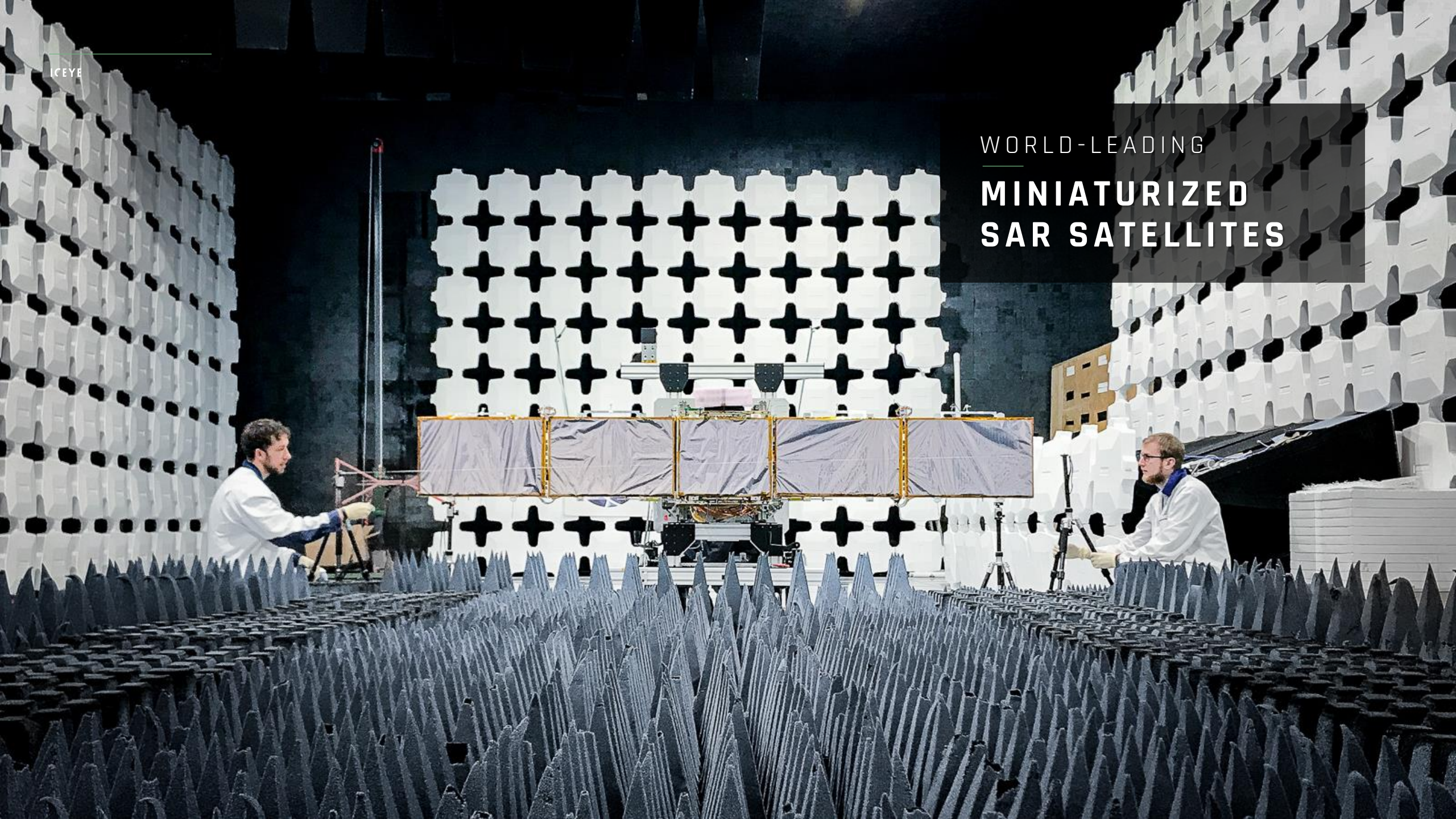


ICEYE



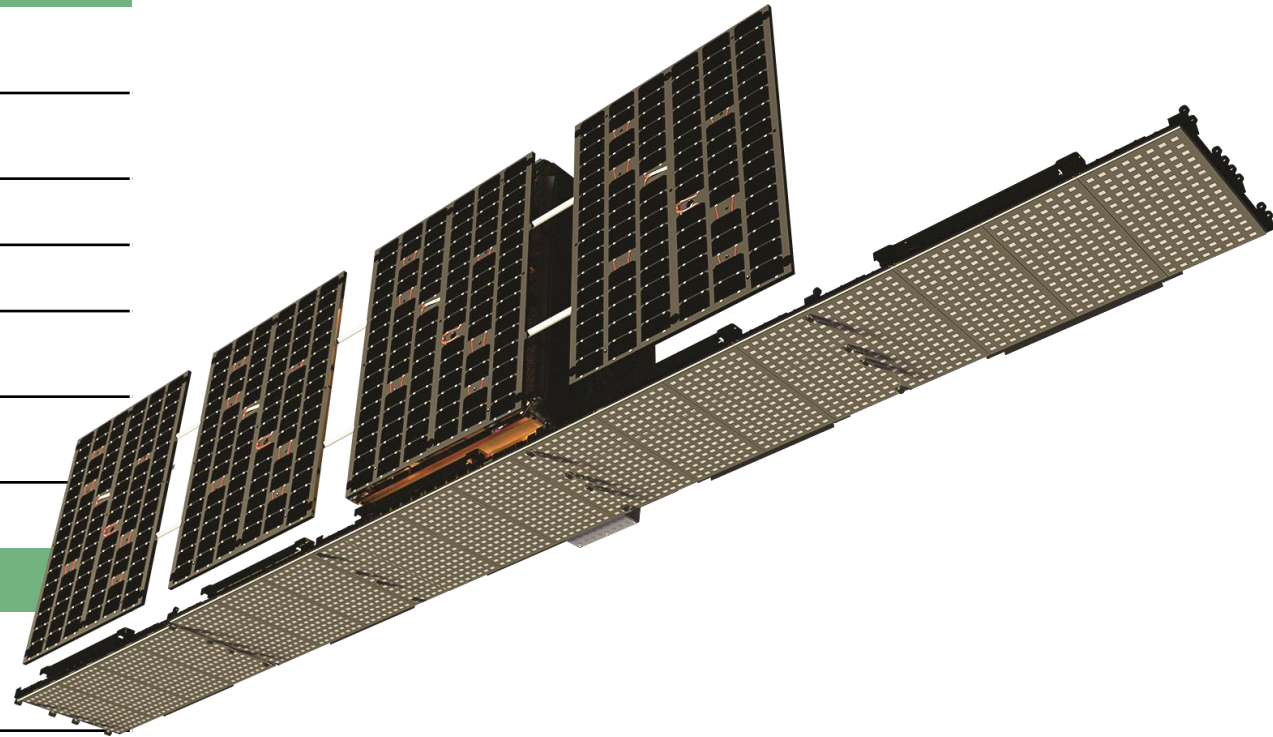
ICEYE

WORLD-LEADING
**MINIATURIZED
SAR SATELLITES**



SATELLITE SPECIFICATIONS

Parameter	Specifications
System Parameters	
Carrier frequency	9.65 GHz (X-band)
Look direction	both LEFT and RIGHT
Antenna size	3.2 meters x 0.4 meters
Polarization	VV
Incidence angle range	10-30 (stripmap mode)
Resolution	3x3 meters, 1x1 meter
Mass	85 kg
Orbital and Attitude Parameters	
Nominal orbit height at the equator	570 km
Orbits per day	15
Orbit repeat cycle (ground track revisit time)	17 days



ICEYE - CONSTELLATION BUILD-UP

3

SATELLITES
IN ORBIT

FULLY
OPERATIONAL

2019

5

SATELLITES
IN ORBIT

FULLY
OPERATIONAL

10+

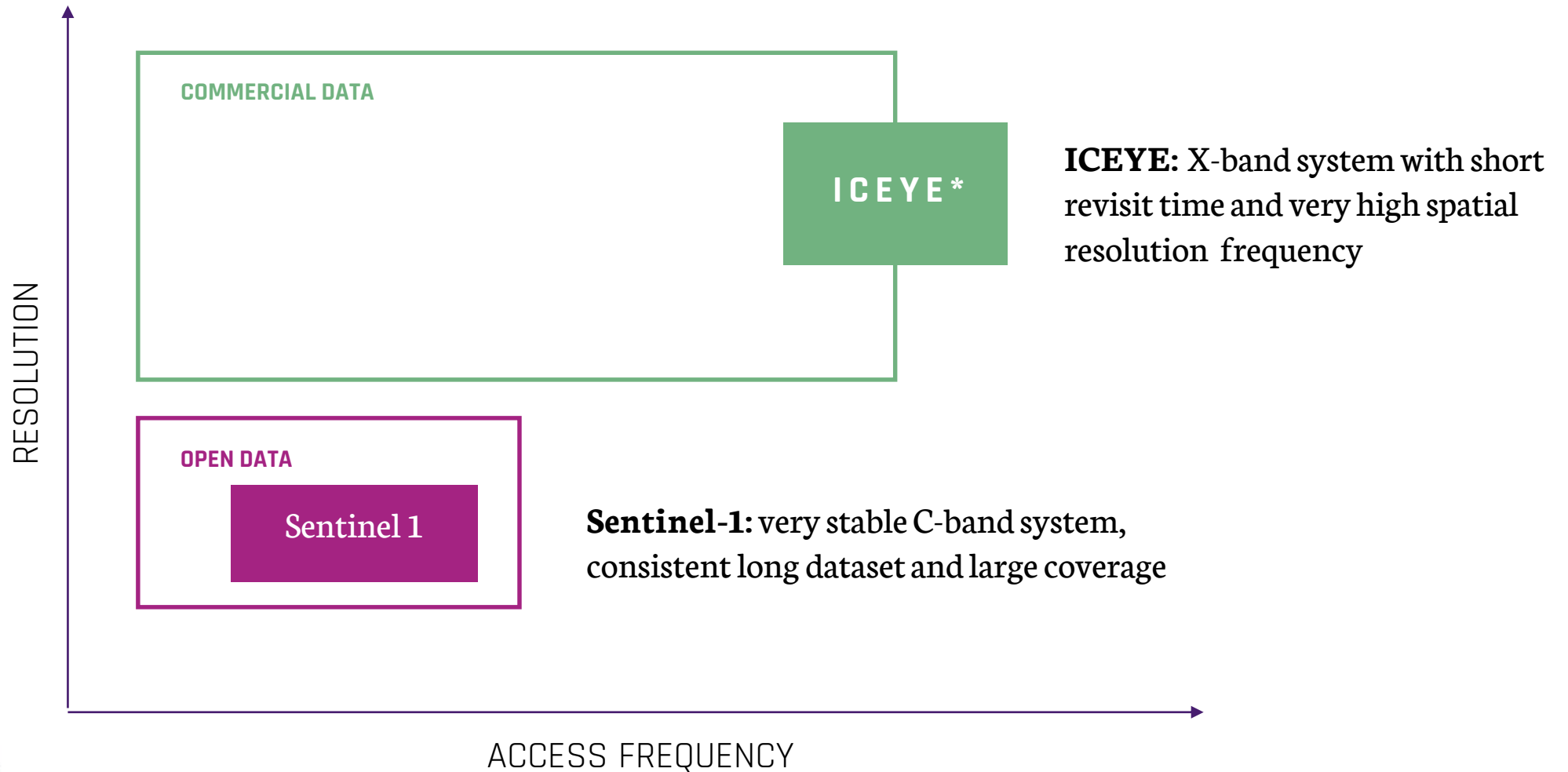
SATELLITES
IN ORBIT

THE WORLD'S LARGEST
SAR SATELLITE
CONSTELLATION

2020-

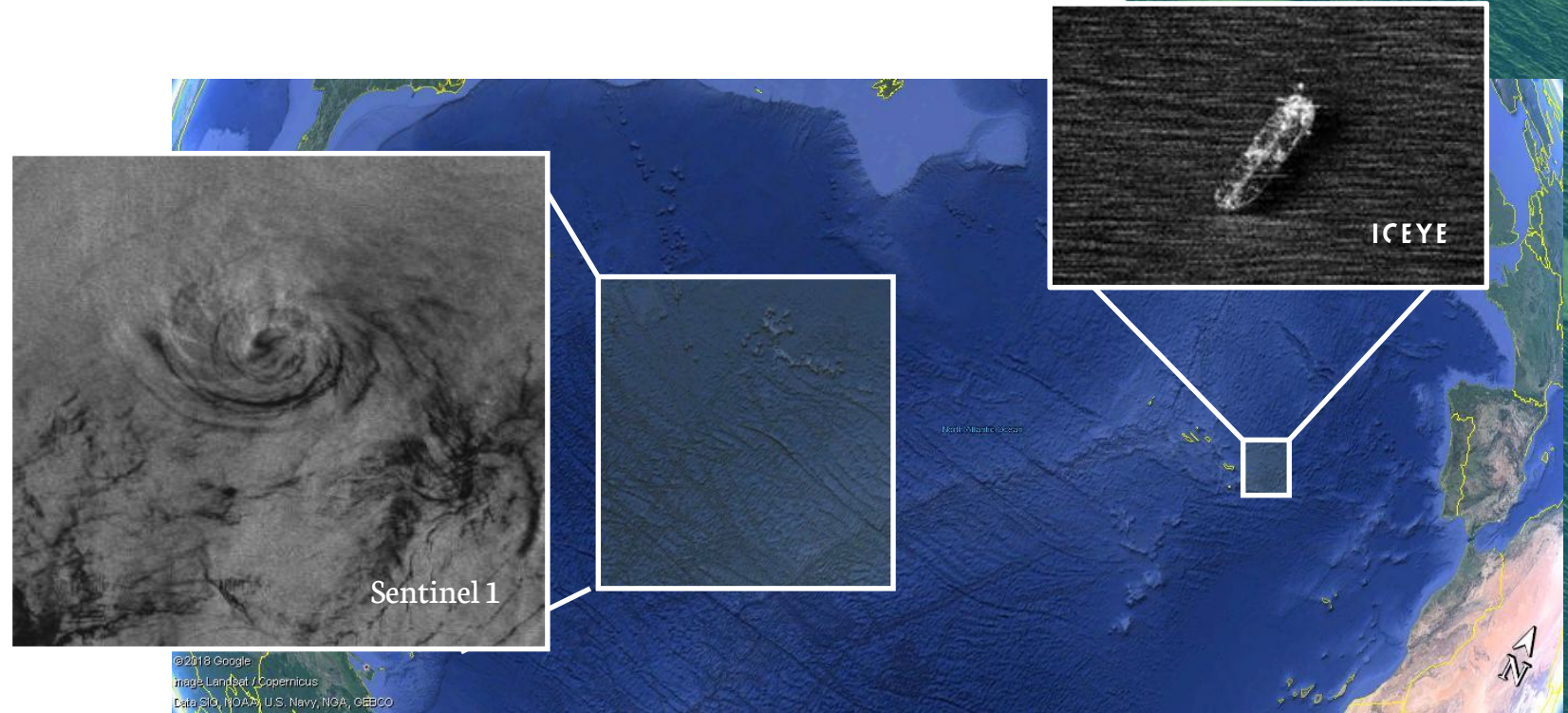


RADAR EARTH OBSERVATION DATA



COMPLEMENTARITY BETWEEN ICEYE AND SENTINELS: **COVERAGE**

- ▶ The large coverage of Sentinel-1 is well complemented by ICEYE data when very high resolution data for local area are needed. Macro-phenomena need imaging over big areas, while small targets or dedicated applications need very high resolution



VERY HIGH SPATIAL RES

ICEYE

KUWAIT INTL AIRPORT

9/10/2019 11:51:41 PM (UTC)

Imaging mode: Spotlight

Sensor Mode: RIGHT_29.94

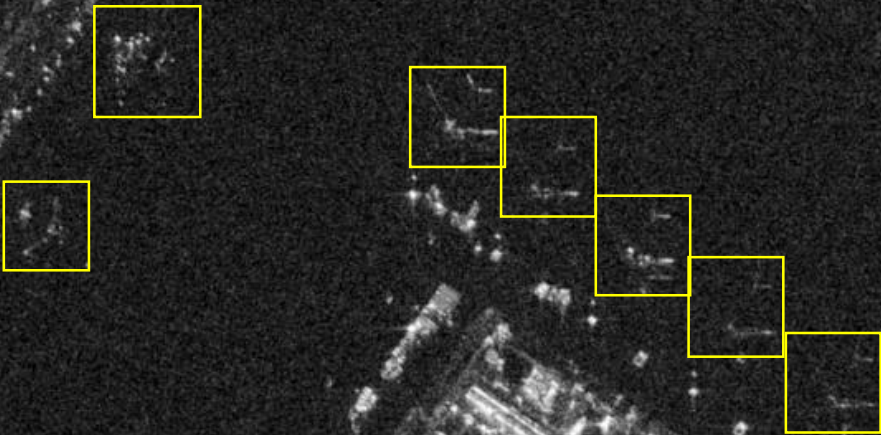
Orbit Direction: DESCENDING

Look Angle: -29.44

Center coordinates (LAT, LON): 29.2312, 47.9788

ICEYE

VERY HIGH SPATIAL RES
**AIRCRAFT DETECTION AND
CLASSIFICATION**



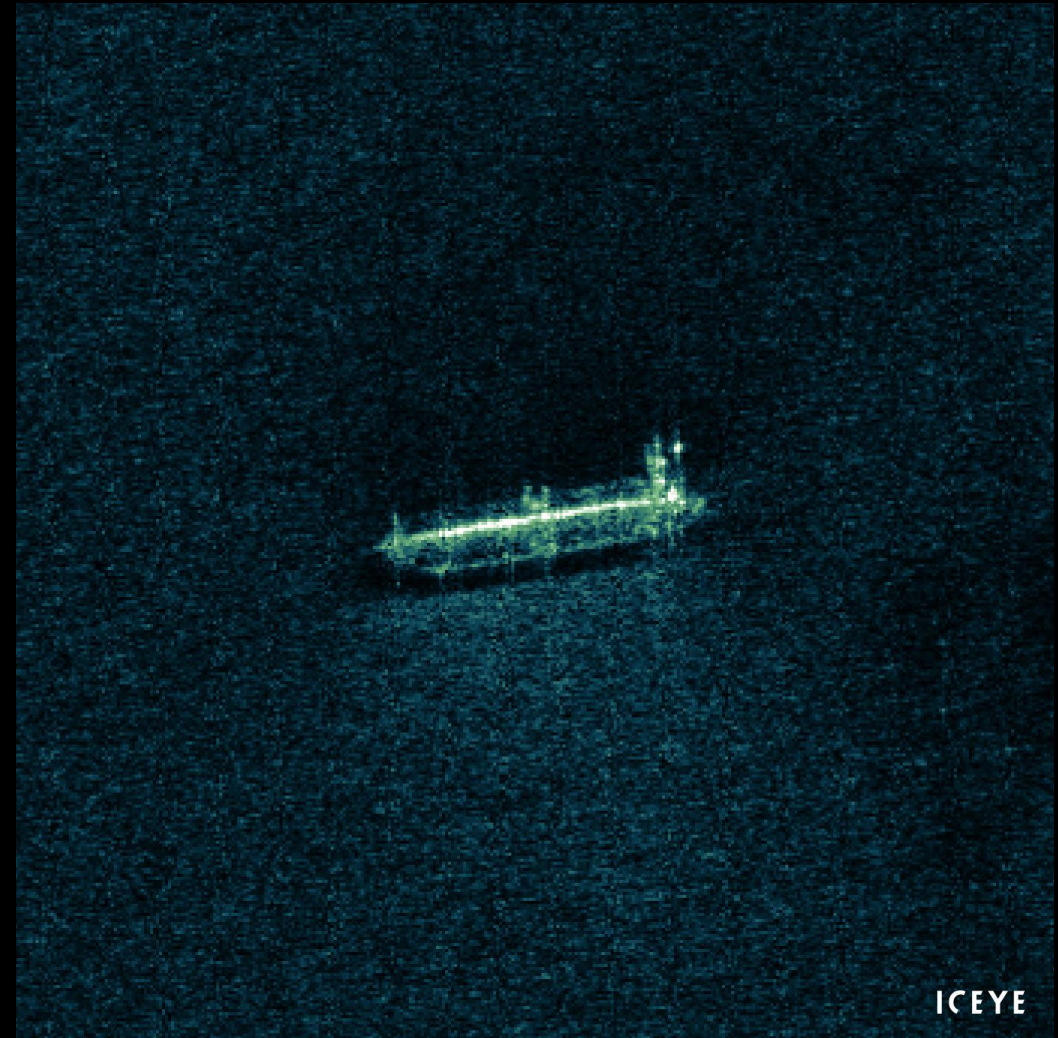
ICEYE SAR IMAGERY
**SPOTLIGHT, 1x1 METER
KUWAIT INTL AIRPORT**

ICEYE

HIGH SPATIAL RES
VESSEL DETECTION AND
CLASSIFICATION

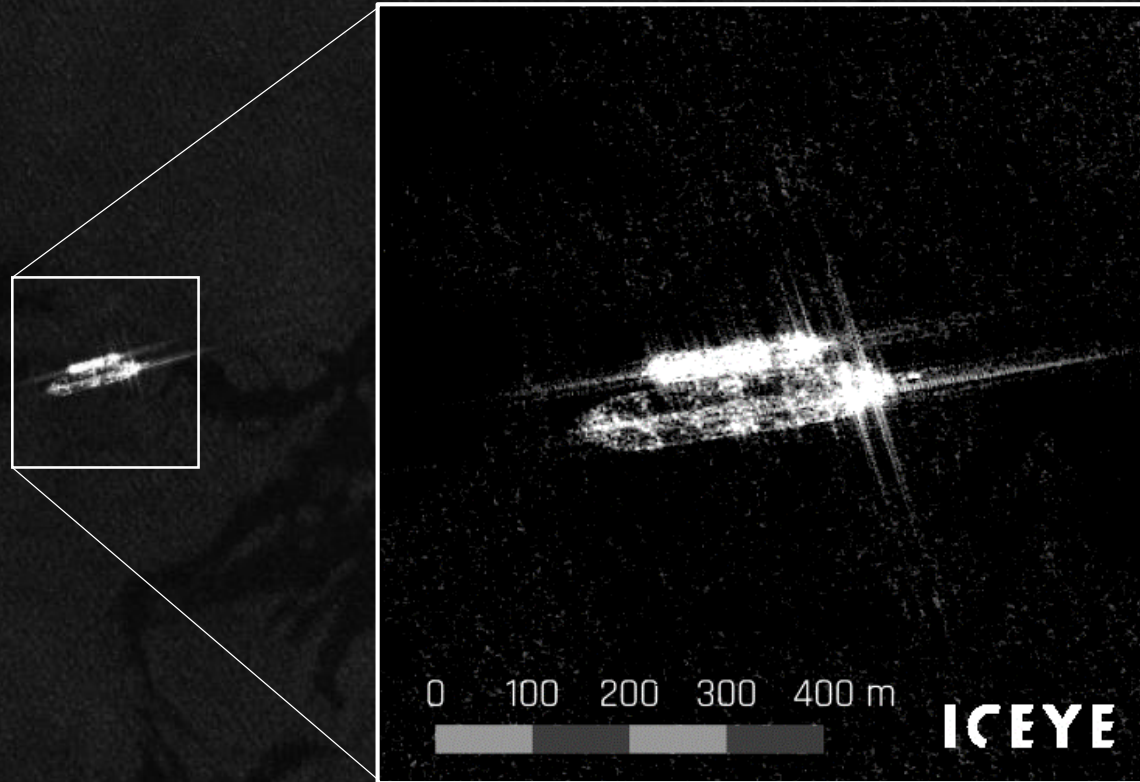
GRACE 1
3 Jan 2019
Asaloyeh, Iran

1

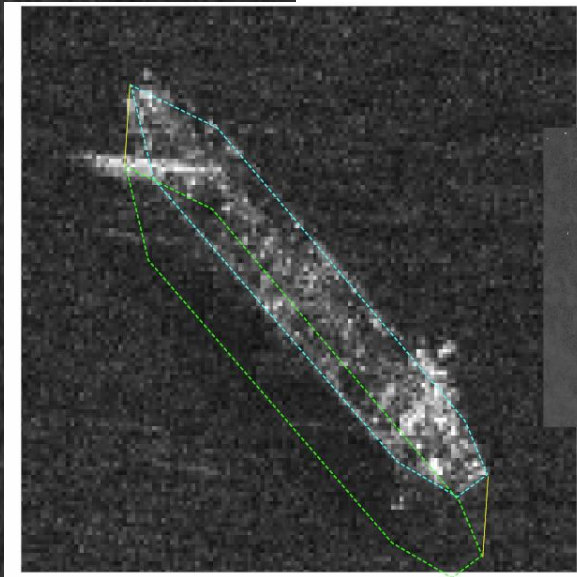


ICEYE

HIGH SPATIAL RES
**VESSEL DETECTION AND
CLASSIFICATION**

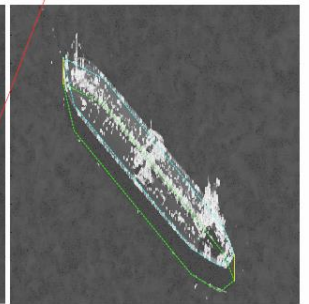
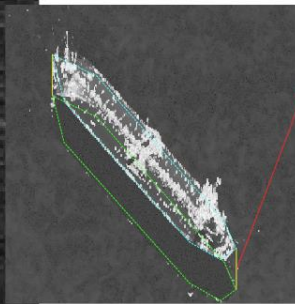


VERY HIGH SPATIAL RES
VESSEL IDENTIFICATION AND
CHARACTERIZATION



Simulated data

Deck to shadow distance



Empty

Full

Requires to have high enough sea clutter
(low incidence) that shadow is visible



HIGH SPATIAL AND
TEMPORAL RES
**TRANSPARENT SUPPLY &
DEMAND TRACKING**

ICEYE



An aerial, high-angle photograph of a city at night. The image is dominated by a dense network of glowing white lines representing roads and highways, which crisscross the dark landscape. The lights from buildings and streetlights create a complex, textured pattern of light and shadow. The overall tone is dark and grainy, emphasizing the intricate geometry of the urban environment.

HIGH SPATIAL AND
TEMPORAL RES
**TRANSPARENT SUPPLY &
DEMAND TRACKING**

ICEYE

VERY HIGH TEMPORAL RES
VESSEL TRACKING

ICEYE



VERY HIGH TEMPORAL RES
REAL TIME DISASTER
RESPONSE

ICEYE



VERY HIGH TEMPORAL RES
**REAL TIME DISASTER
RESPONSE**

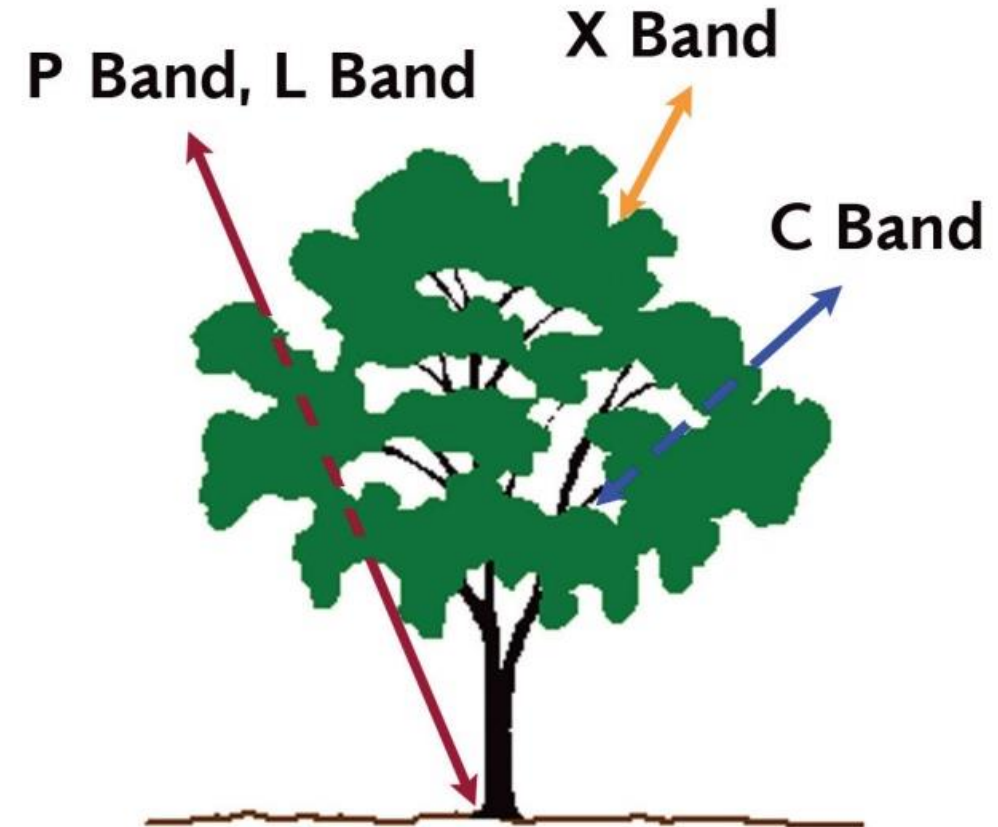
ICEYE



COMPLEMENTARITY BETWEEN ICEYE AND SENTINELS: **BAND**

- ▶ C and X bands have different mechanisms of interaction with the material due to the different wavelength.

Interaction wave-material: d/λ



COMPLEMENTARITY BETWEEN ICEYE AND SENTINELS



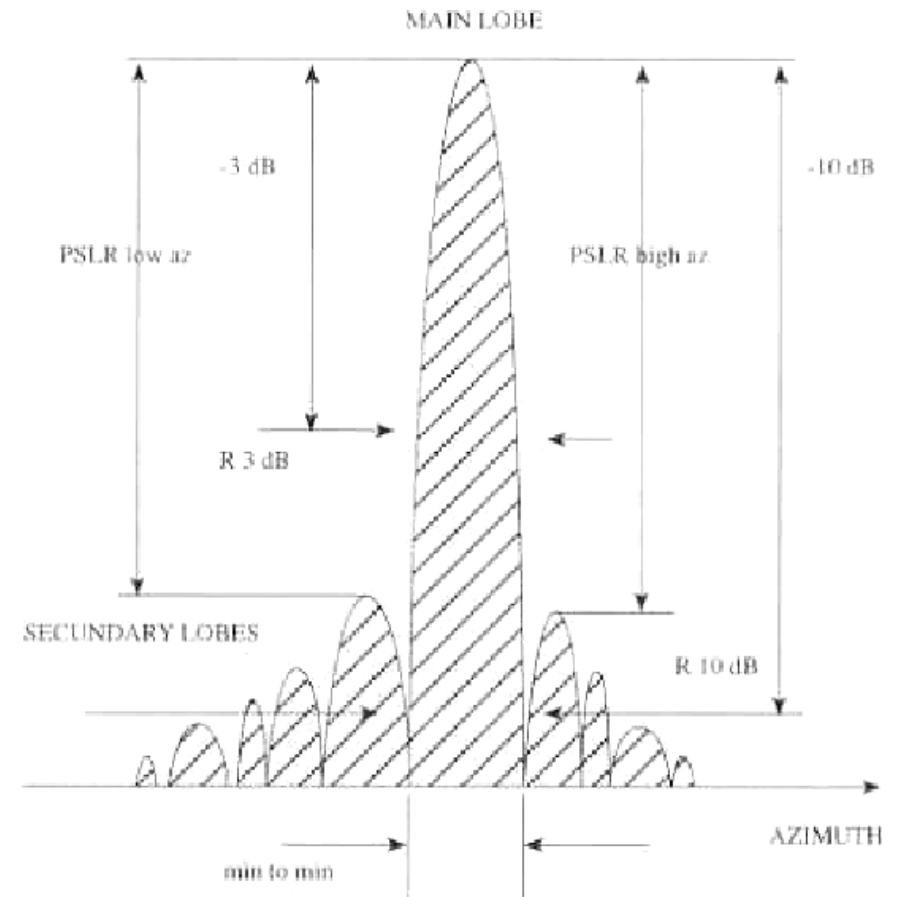
Combination of Sentinel 1 IW image
and ICEYE spotlight image

ICEYE SAR PERFORMANCE

IRF QUALITY PARAMETERS

The IRF quality parameters are the following:

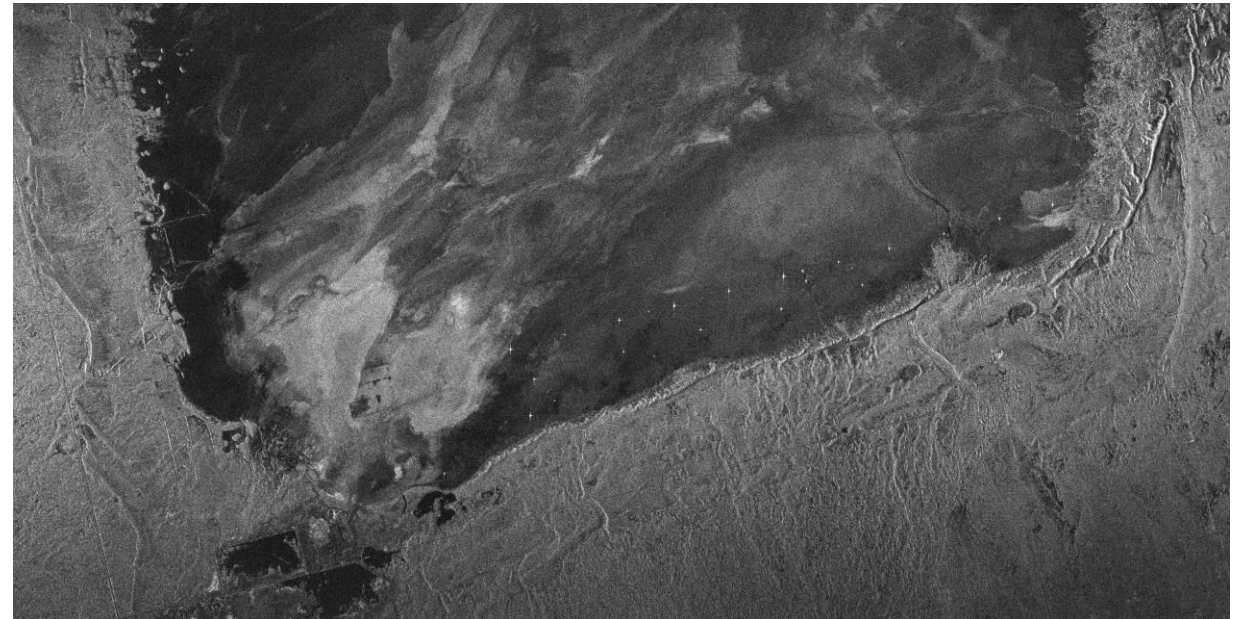
1. Spatial resolution
2. PSLR (Peak Side Lobe Ratio): ratio of the largest level of sidelobes to the peak level of mainlobe
3. ISLR (Integrated Side Lobe Ratio): ratio of the power (energy) in the main lobe to the total power in all the side lobes
4. Peak position for geolocation accuracy



ICEYE SAR PERFORMANCE

IRF QUALITY PARAMETERS

- ▶ The IRF quality parameters analysis has been performed in the Rosamond Corner Reflector Array (RCRA) area in California. Here, in the dry Rosamond lake bed there are 37 Corner Reflectors with different size (0.7 m, 2.4 m and 4.8 m), used by the JPL for SAR calibration



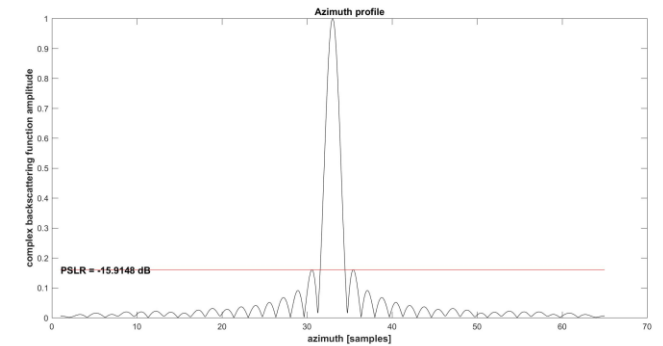
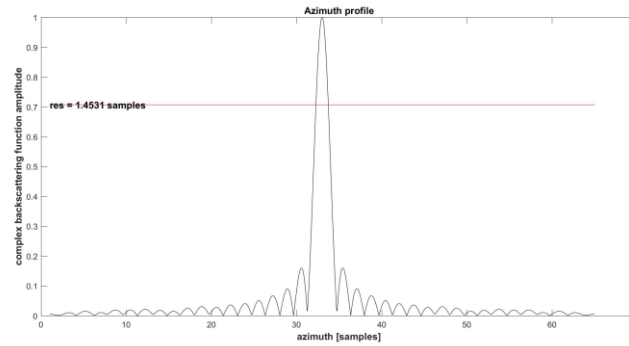
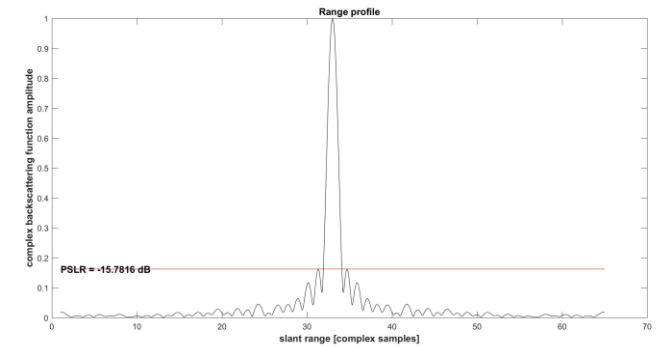
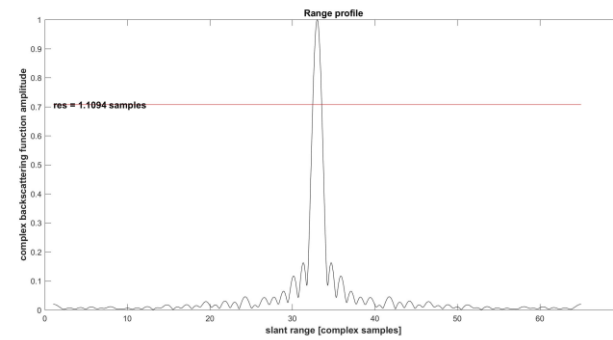
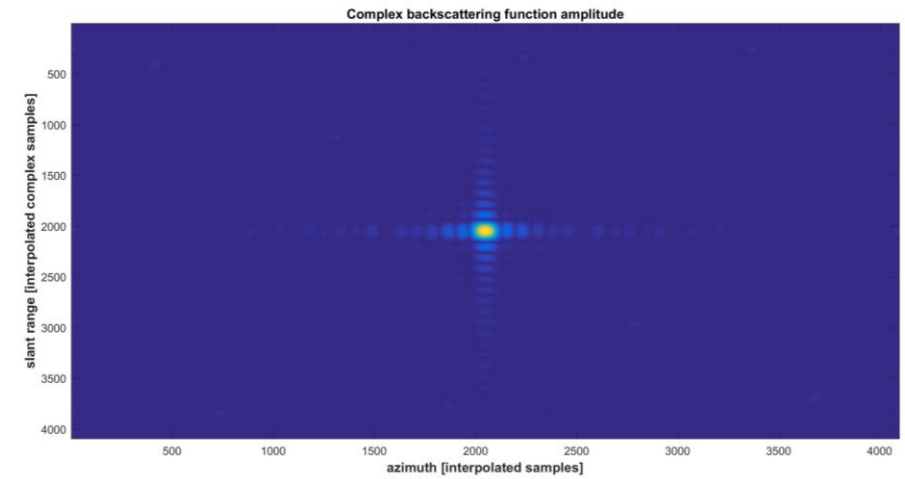
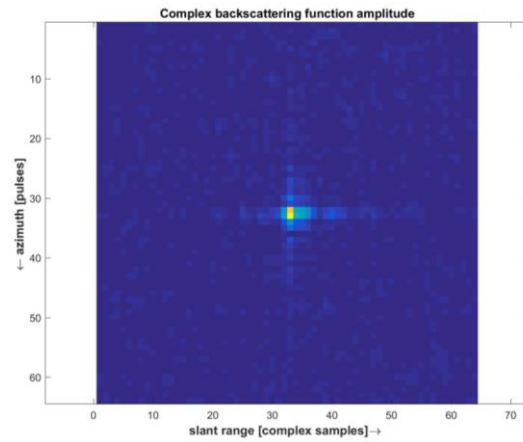
ICEYE SAR PERFORMANCE

IRF QUALITY PARAMETERS

Sinc interpolation for IRF
quality parameters
calculation

Range profile analysis

Azimuth profile analysis



ICEYE SAR PERFORMANCE

IRF QUALITY PARAMETERS

Preliminary results of X4 satellite (Calibration and Validation activities are on-going)

Image+Sat	Azimuth resolution [m]	Range resolution [m]	Azimuth PSLR [dB]	Range PSLR [dB]	Azimuth ISLR [dB]	Range ISLR [dB]	ALE [m]
X4 Strip Map	1.9±0.16	0.54±0.009 (at 260 MHz)	-15.81±0.82	-15.01±0.38	-4.26±0.44	-4.89±0.15	6.99±0.63
X4 SpotLight	0.64±0.05	0.46±0.02 (at 299 MHz)	-14.87±2.69	-15.89±0.67	-4.71±0.49	-4.99±0.2	5.15±1.8

ICEYE SAR PERFORMANCE

IRF QUALITY PARAMETERS AND RADIOMETRIC ACCURACY

Preliminary results of X4 satellite (Calibration and Validation activities are on-going)

Acquisition mode	Azimuth resolution [m]	Range resolution [m]	Azimuth PSLR [dB]	Range PSLR [dB]	Azimuth ISLR [dB]	Range ISLR [dB]	ALE [m]	NESZ [dB]
X4 Strip Map	1.9±0.16	0.54±0.009 (at 260 MHz)	-15.81±0.82	-15.01±0.38	-4.26±0.44	-4.89±0.15	6.99±0.63	16.9±0.9 (calibration on going)
X4 Spot Light	0.64±0.05	0.46±0.02 (at 299 MHz)	-14.87±2.69	-15.89±0.67	-4.71±0.49	-4.99±0.2	5.15±1.8	-

ICEYE SAR DATA RADIOMETRIC CALIBRATION

The radiometric calibration in SAR is the processing needed to associate univocally the received signal with the **Backscattering Coefficient**.



The calibration should compensate effects due to:

1. The atmosphere (delay and oscillations of the signal during tropospheric and ionospheric propagation)
2. The antenna (distribution of radiated energy in range and in azimuth)
3. The electronic (variation of transmitted power and receiver gain)
4. The processor (contribution due to the implemented algorithm)

ICEYE SAR DATA RADIOMETRIC CALIBRATION

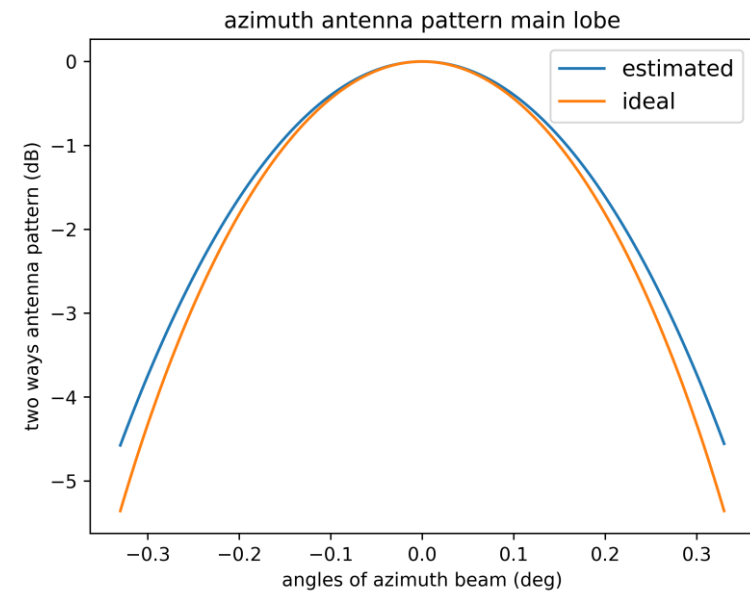
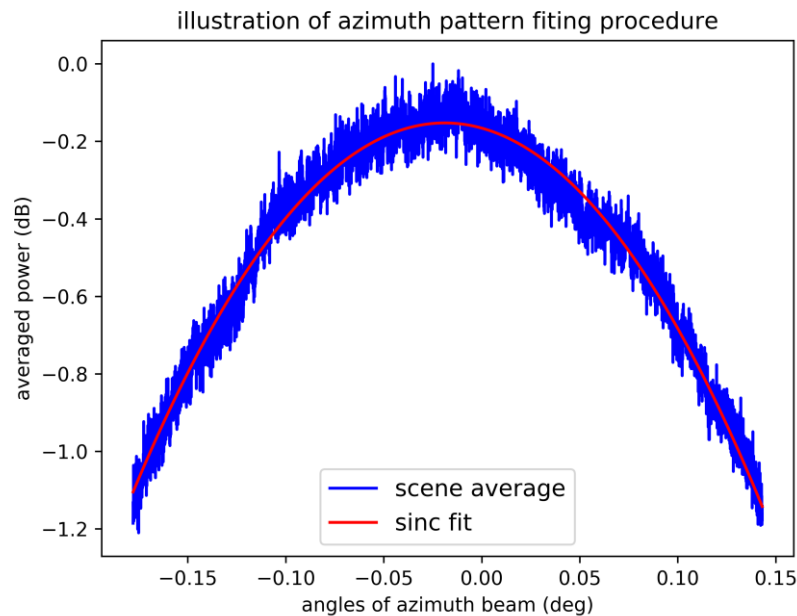
The ICEYE SAR processor compensates the following effects:

1. Range spread loss;
2. Elevation antenna pattern;
3. Azimuth antenna pattern in ScanSAR and spotlight modes;
4. Effects of different azimuth and range bandwidths;
5. Sensor settings variations (receiver gain, transmit power, duty cycle).

SIMULTANEOUS AZIMUTH ANTENNA PATTERN

- Homogeneous target (Amazon forest) spotlight imaging is utilized for estimation of azimuth antenna pattern main lobe.
- Azimuth profiles from multiple scenes are averaged and transformed to azimuth beam angle coordinates.
- Sinc function is fitted to averaged profile.

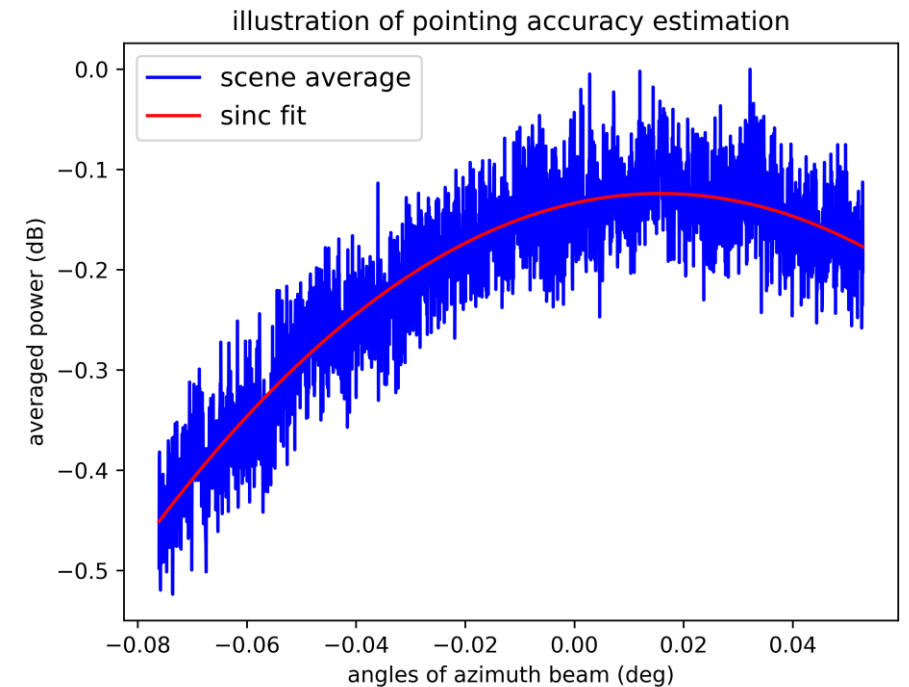
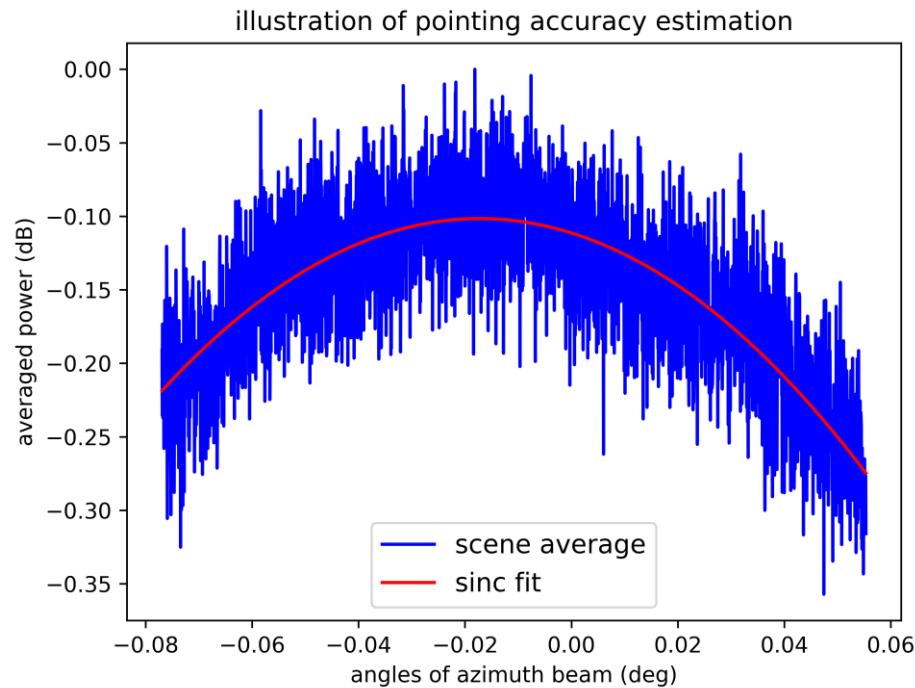
Pre-launch azimuth pattern 3dB beamwidth	Estimated azimuth pattern 3dB beamwidth
0.5	0.55



POINTING ACCURACY ESTIMATION

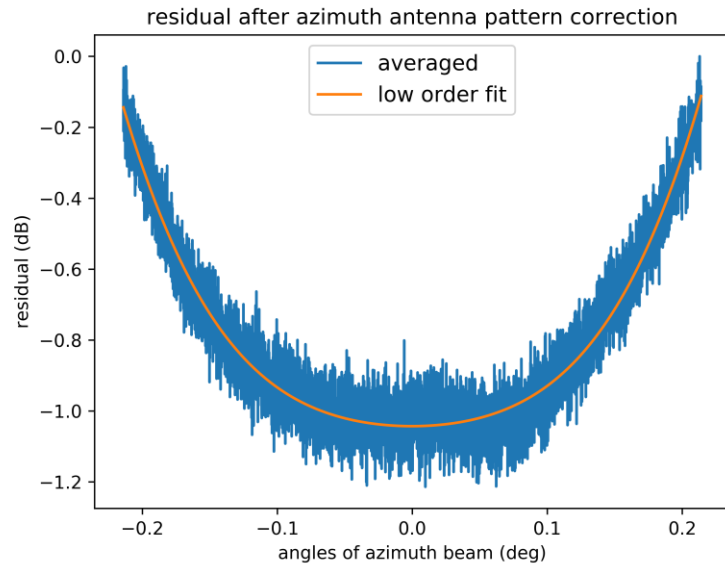
- Averaged profiles having a good agreement with estimated pattern chosen for azimuth pointing accuracy estimation
- Sinc function is fitted to profile and angle correspondent to Sinc maximum is measured.
- 0 degree of azimuth beam corresponds to commanded tracking target

Pointing bias μ	Pointing bias σ
0.006	0.015

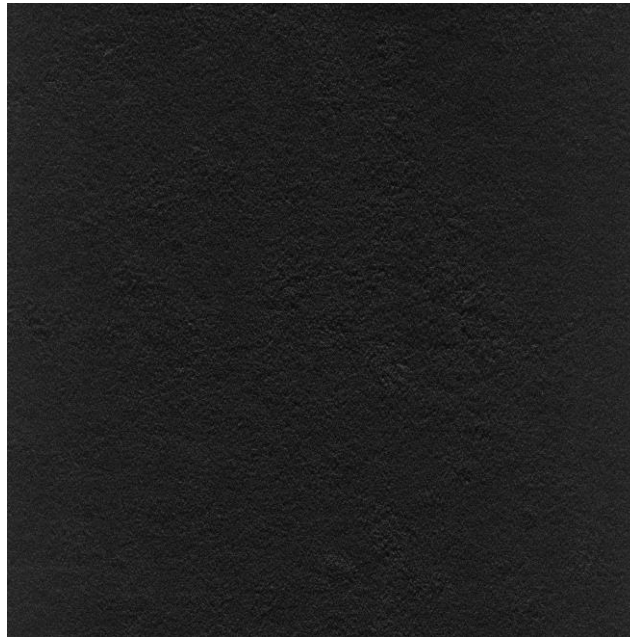
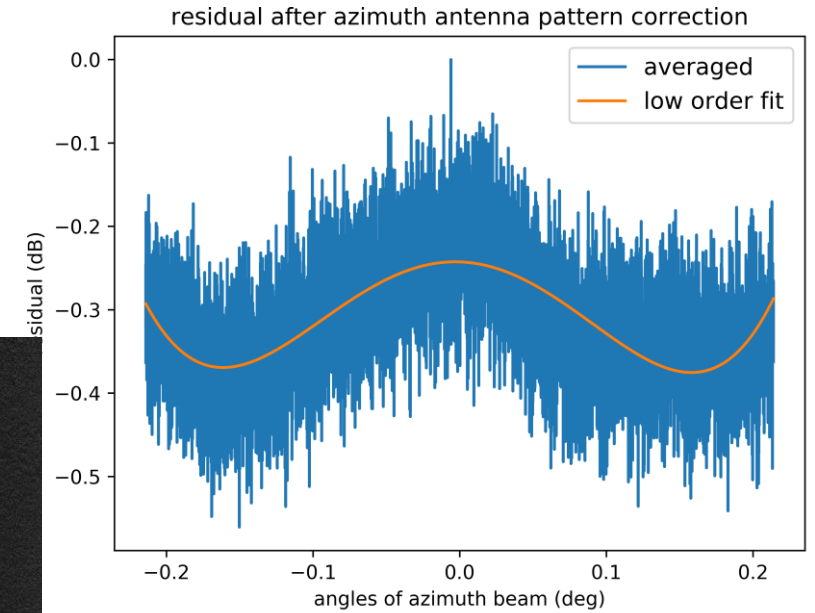


ICEYE SAR DATA RADIOMETRIC CALIBRATION

Pre-launch antenna azimuth pattern correction for the test scene



Estimated antenna azimuth pattern correction for the test scene



COMPLEMENTARITY BETWEEN ICEYE AND SENTINELS: **FUTURE ACTIVITIES FOR DATA VALIDATION**

- ▶ Sentinel-1 inherits the long experience of ERS and ENVISAT, becoming one of the more solid reference in the SAR field.
- ▶ ICEYE data validation will use external data from x band SAR systems, as CosmoSKY-med and TerraSAR-X
- ▶ ICEYE will search for dedicated targets to perform validation over small areas using Sentinel data
- ▶ ICEYE SAR data ingestion is already implemented on ESA SNAP software, making easier the validation activities
- ▶ **Calibration phase is still on-going. The validation will be performed after calibration**

ICEYE

REPUTATION OF DELIVERING RESULTS
CUSTOMERS INCLUDE:



