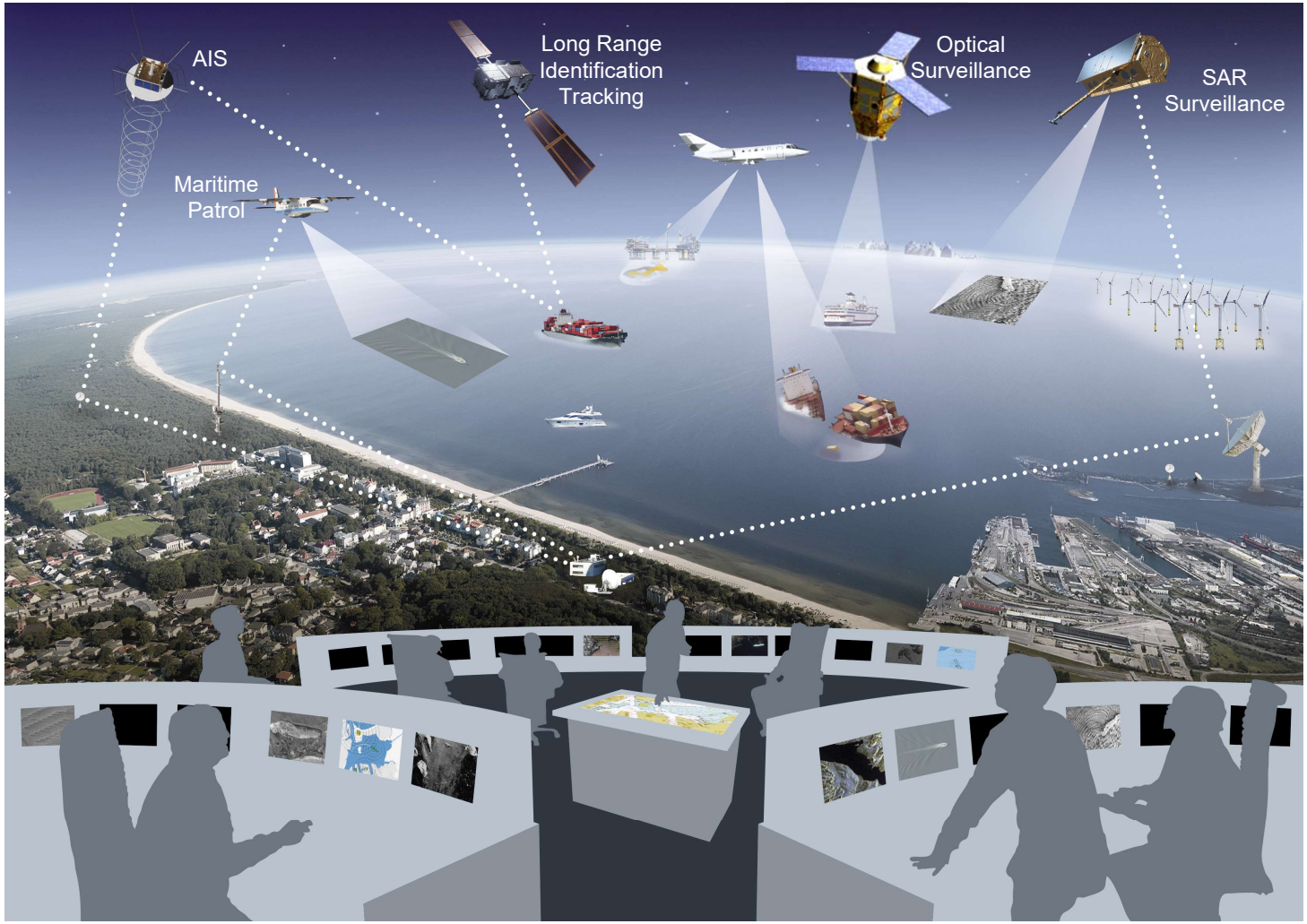
REMOTE SENSING-BASED OBJECT DETECTION FOR MARITIME SITUATIONAL AWARENESS

Tobias Kaminski, Egbert Schwarz, Dr. Sergey Voinov
Maritime Safety and Security Lab Neustrelitz
Earth Observation Center EOC

DLR

INTRODUCTION

Components of Maritime Surveillance Systems



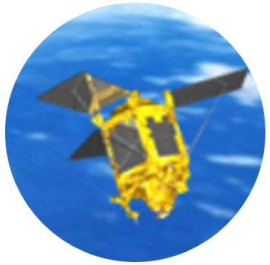
- Earth Observation
  - SAR Satellites
  - Optical Satellites
- Aircraft
- Remotely Piloted Aircraft
- Automatic Identification System AIS
- Long Range Identification & Tracking LRIT (EMSA)

Benefits and Constraints of remote sensing using Synthetic Aperture Radar (SAR)

- Compared to optical satellites that cannot observe in darkness or when there is cloud coverage, SAR enables persistent 24-hour monitoring.
  and automated feature extraction (e.g. wind and wave)
- Increasing number of satellite resources, partly launched as constellation
- Different types of sensors (wave length, S,C,X and L-Band) and sensor modes (coverage, resolution)
- SAR processing enables fast processing of large volumes of data and information delivery within 15 - 30 minutes of image acquisition

- Mainly dusk dawn orbits (Day Night Border) e.g. Sentinel-1, TerraSAR, CosmoSkyMed but changed in case of for mission constellations e.g. ICEYE
- Tasking nominal twice per day
- SAR instrument orbit duty cycle, revisit and coverage capabilities (single mission)
- Order (static planning cycle | user competition | dual use)
- Pricing e.g. emergency tasking

Benefits and Constraints of remote sensing using very high resolution optical data



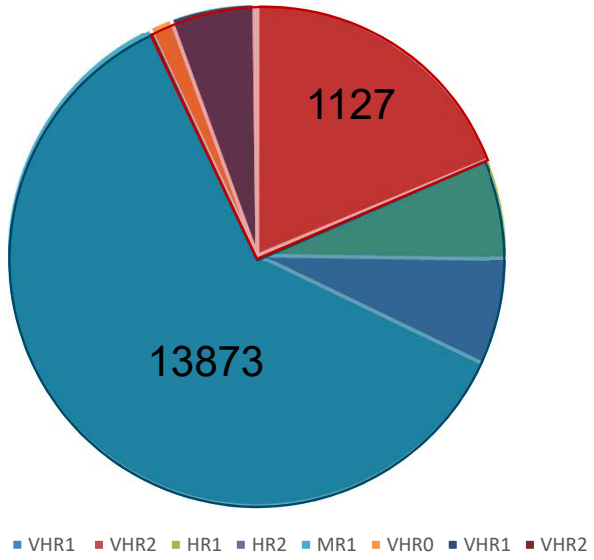
- Very High resolution up to 31 cm panchromatic, up to 1.24 m multispectral resolution or e.g. 3,7 m short-wave infrared resolution
- Higher number of spectral bands
- High agility and flexibility, e.g. acquisition of coastlines
- Increasing number of satellite resources and satellite constellations e.g. MAXAR, AIRBUS, Planet, SuperView
- Direct tasking before acquisition

- Monitoring dependents on weather situation (clouds)
- Order, e.g. user competition and dual use
- Processing requires more processing power and time compared to SAR
- Pricing, expensive

Maritime Satellite Services for the European Maritime Safety Agency EMSA (2020)

Sensor	EMSA Product Classes, resolution (m)	% of delivered Services	Number of images
Synthetic Aperture Radar SAR	VHR1 , Azimuth resolution: ≤1	0.02%	4
	VHR2, Azimuth resolution >1 and azimuth resolution: ≤ 4	18.72%	1995
	HR1, Azimuth resolution >4 and azimuth resolution: ≤10	6.49%	1038
	HR2, Azimuth resolution >10 and azimuth resolution: ≤30	6.91%	1106
	MR1, Azimuth resolution >30 and azimuth Resolution: ≤100	60.81%	**9730**
Optical	VHR0, Spatial resolution: ≤0.40	1.45%	232
	VHR1, Spatial resolution: >0.40 and spatial Resolution: ≤ 1	5.40%	**864**
	VHR2, Spatial resolution >1 and spatial resolution: <10	0.19%	31
Total		100%	16.000

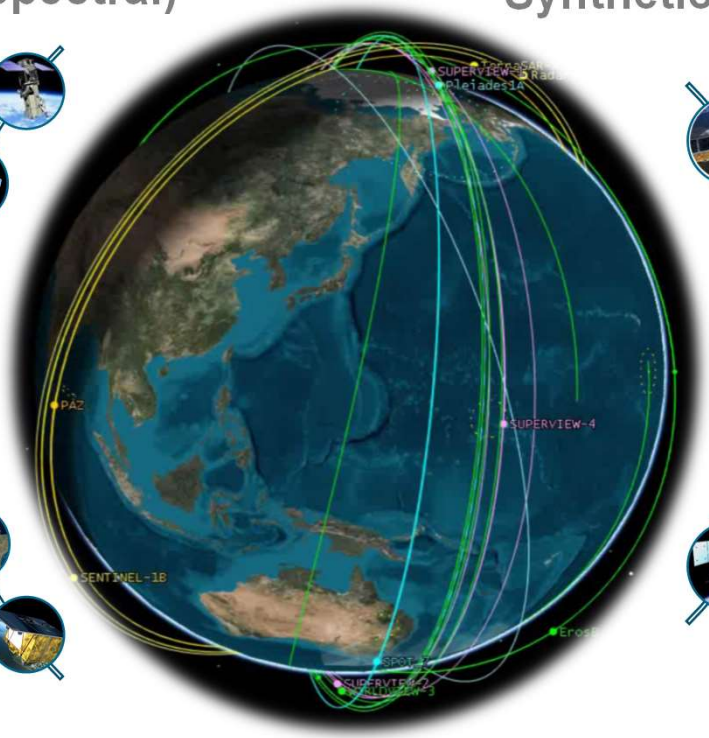
EMSA, EO delivered Services, aggregated by: Sensor (SAR and Optical) in 2020



DLR Multi-EO Sensor Approach

Optical (multi- and hyperspectral)

- Worldview-1-3
- GeoEye-1
- Deimos-2
- Plèiades-(NEO)
- Spot-6
- Landsat, Sentinel-2
- DESIS, EnMAP



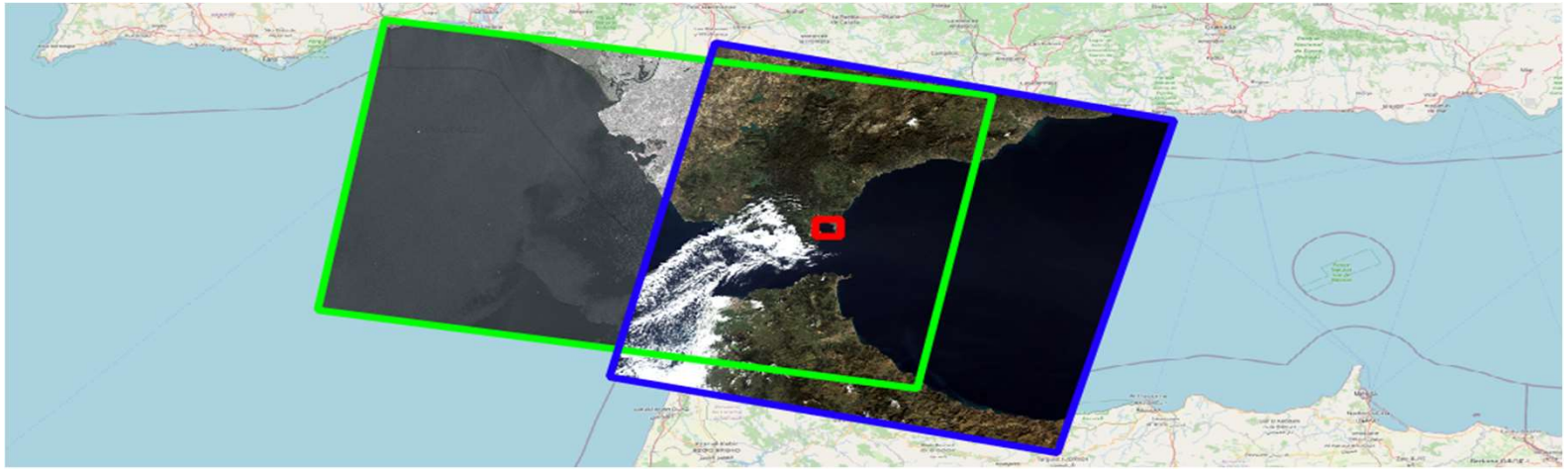
Synthetic Aperture Radar (SAR)

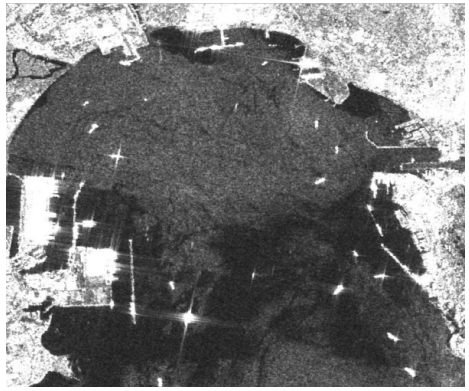
- Sentinel-1A
- ICEYE
- TerraSAR-X
- TanDEM-X
- Radarsat-2

Automatic Identification System

- Terrestrial AIS
- Satellite AIS

Remote Sensing for Maritime Surveillance



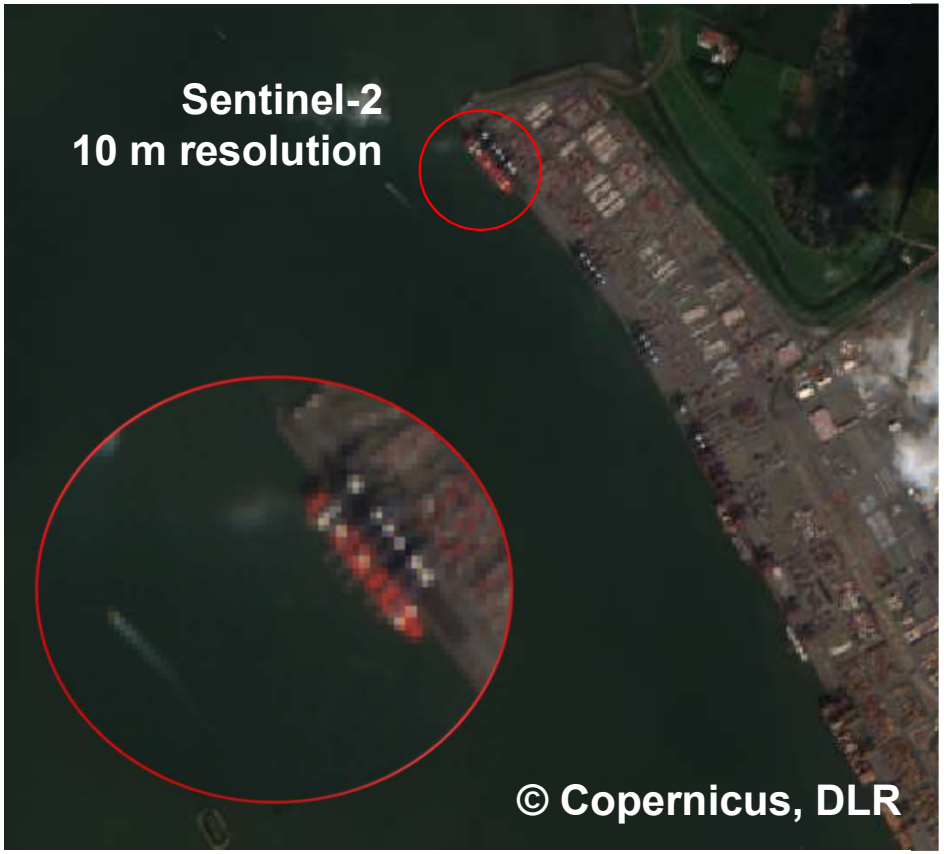


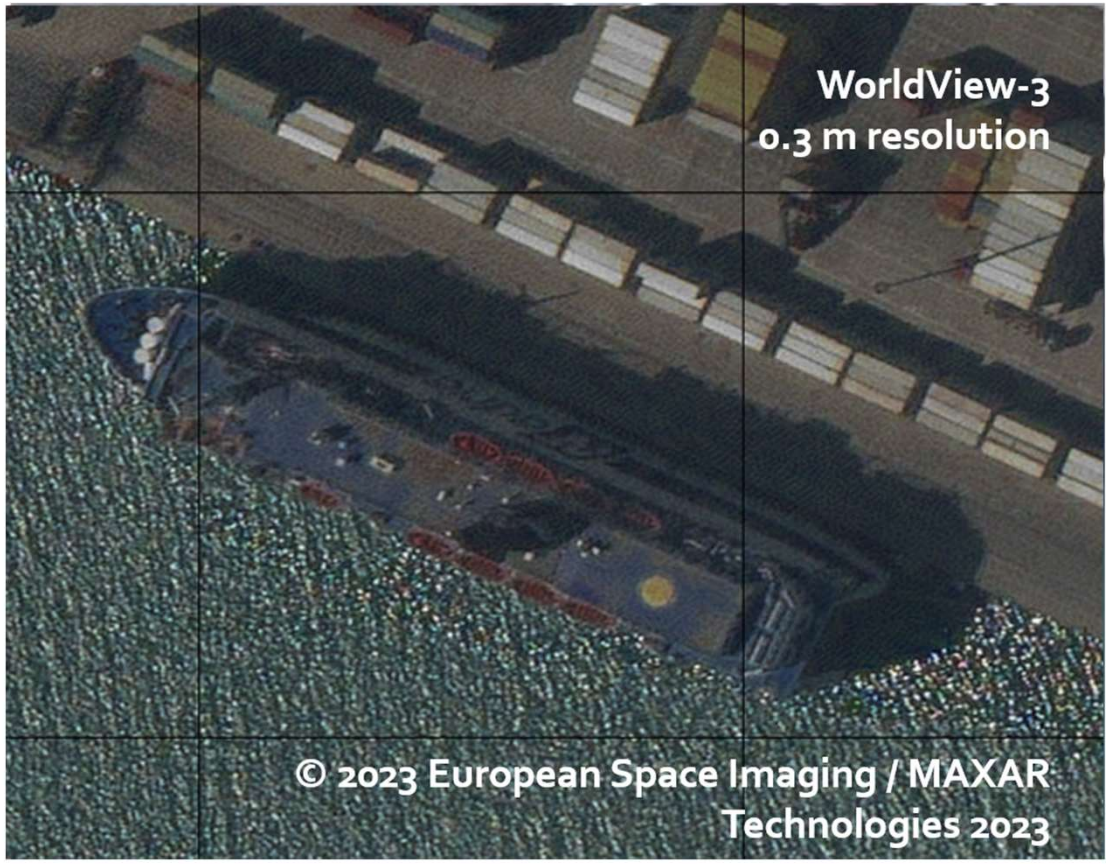
SAR: Sentinel-1B

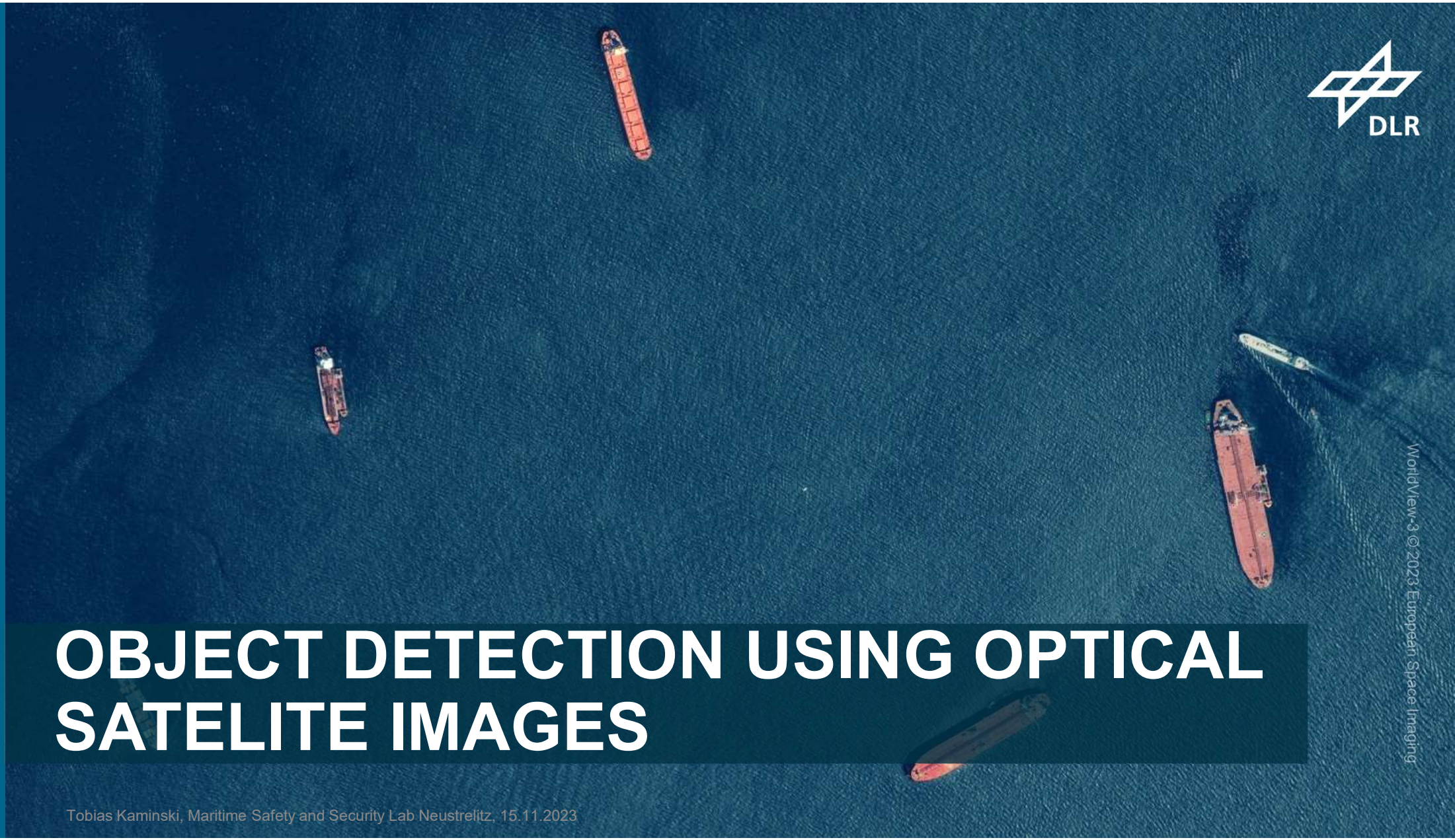
MR Optical: Landsat-8

VHR Optical: Worldview-3

Optical Imaging Modes, High and very high resolution



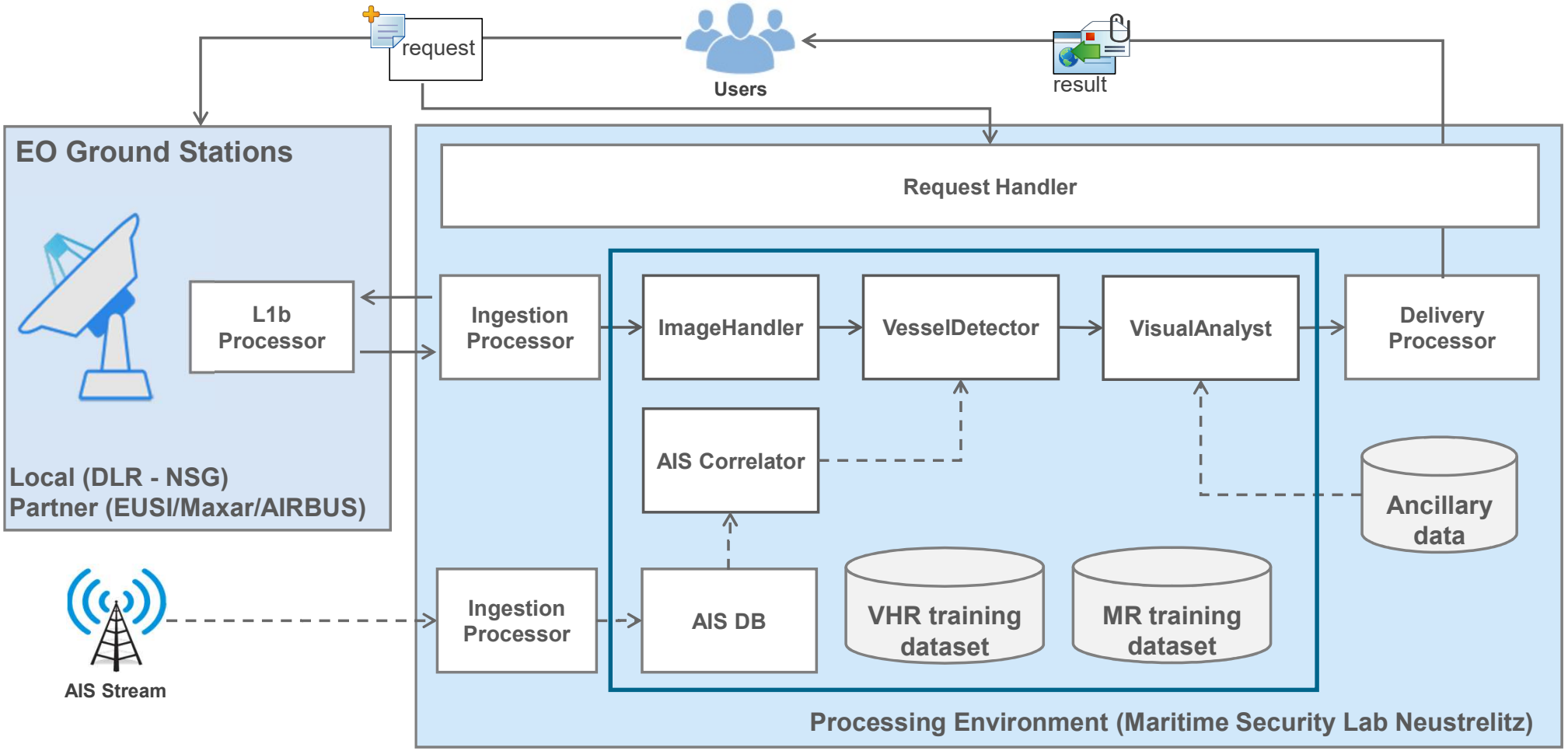




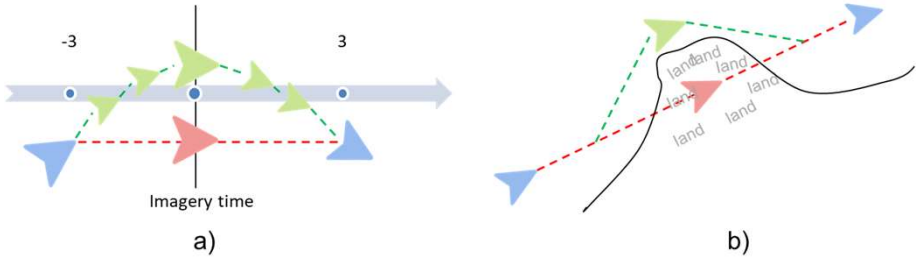
OBJECT DETECTION USING OPTICAL SATELITE IMAGES

Tobias Kaminski, Maritime Safety and Security Lab Neustrelitz, 15.11.2023

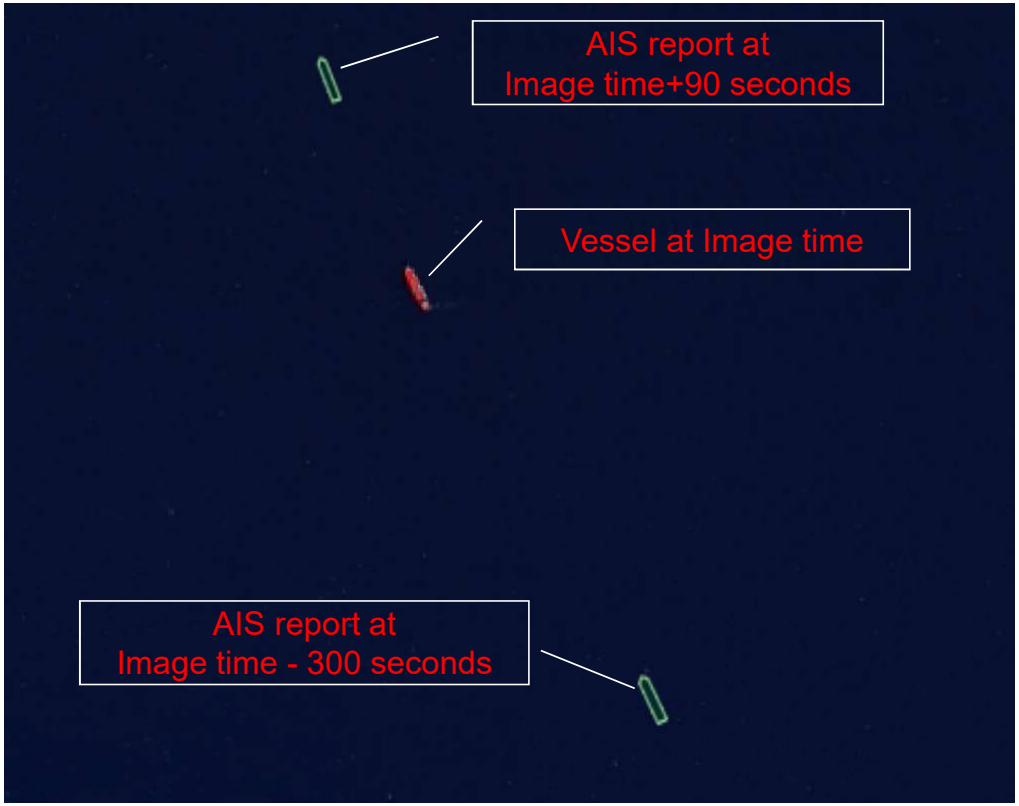
Workflow for object detection using optical satellite images



AIS Data Preprocessing



- Movement trajectory must be considered
  - changes in COG and SOG between known points
- Unique timestamps within the image
  - not very critical for VHR sensors
  - very critical for MR (and SAR) sensors

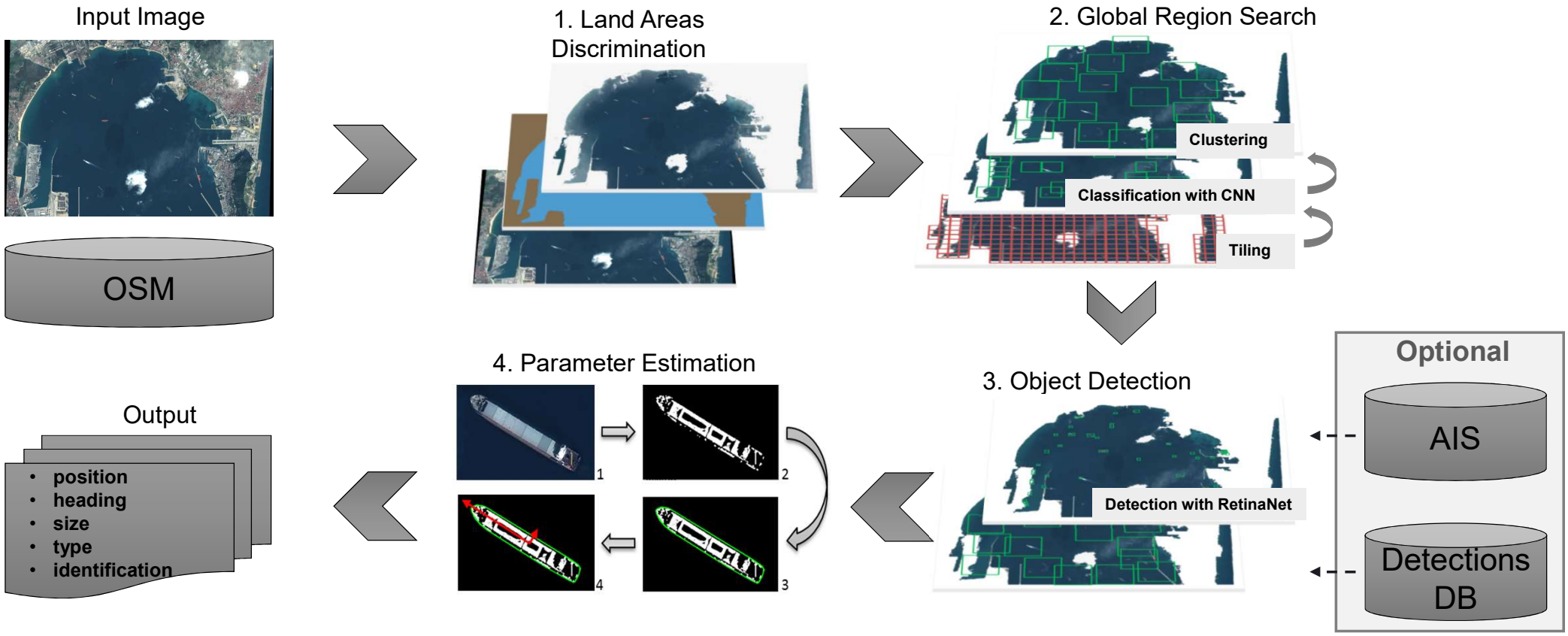


Landsat-8 © 2023 USGS

Image Preprocessing

WorldView-3 © 2023 European Space Imaging / Maxar

Artificial Intelligence Method
Deep Learning based Vessel Detection



Very High Resolution Training Dataset

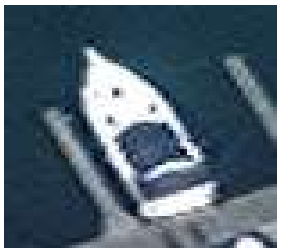
- 14 vessel classes
- Based on AIS classification schema
- 40 000 of unique annotated vessels
- 500-5000 of unique object samples per class
- 1500x1500px sample size

- Annotation includes:
  - Center coordinates
    - Pixel/Line
    - Geographical
  - Min/Max bounding boxes
  - Rotated bounding boxes
  - PNG masks
  - True heading
  - Object state (moving or stopped)
  - Type
  - EMSA type and subtype


Passenger ship/ Ferry


Yacht / Superyacht


Sailing boat

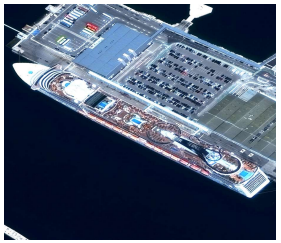

Leisure boat

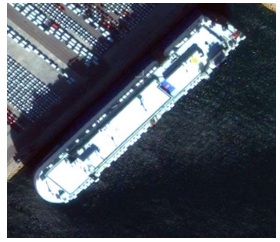

Service / tug boat


Fishing boat


Patrol vessel

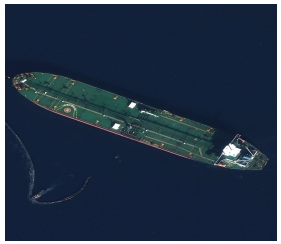

Warship

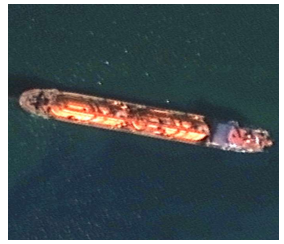

Cruise boat


Generic cargo


Bulk Carrier


Container carrier


Oil tanker

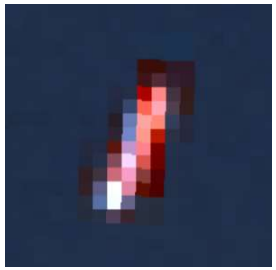

LNG / Chemical

MR Training Dataset

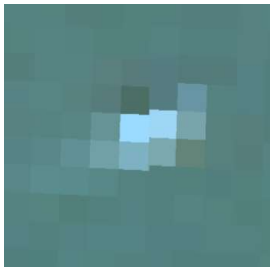
- 7 vessel classes
- 14 000 of unique annotated vessels
- 1000-3000 of unique object samples per class
- 300x300px sample size

- Annotation includes:
  - Center coordinates
    - Pixel/Line
    - Geographical
  - Min/Max bounding boxes
  - Rotated bounding boxes
  - PNG masks
  - True heading
  - Object state (moving or stopped)
  - Type
  - EMSA type and subtype


Generic cargo vessel

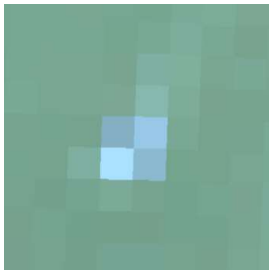

Tanker


Service/tug boat


Small passenger boat / yacht

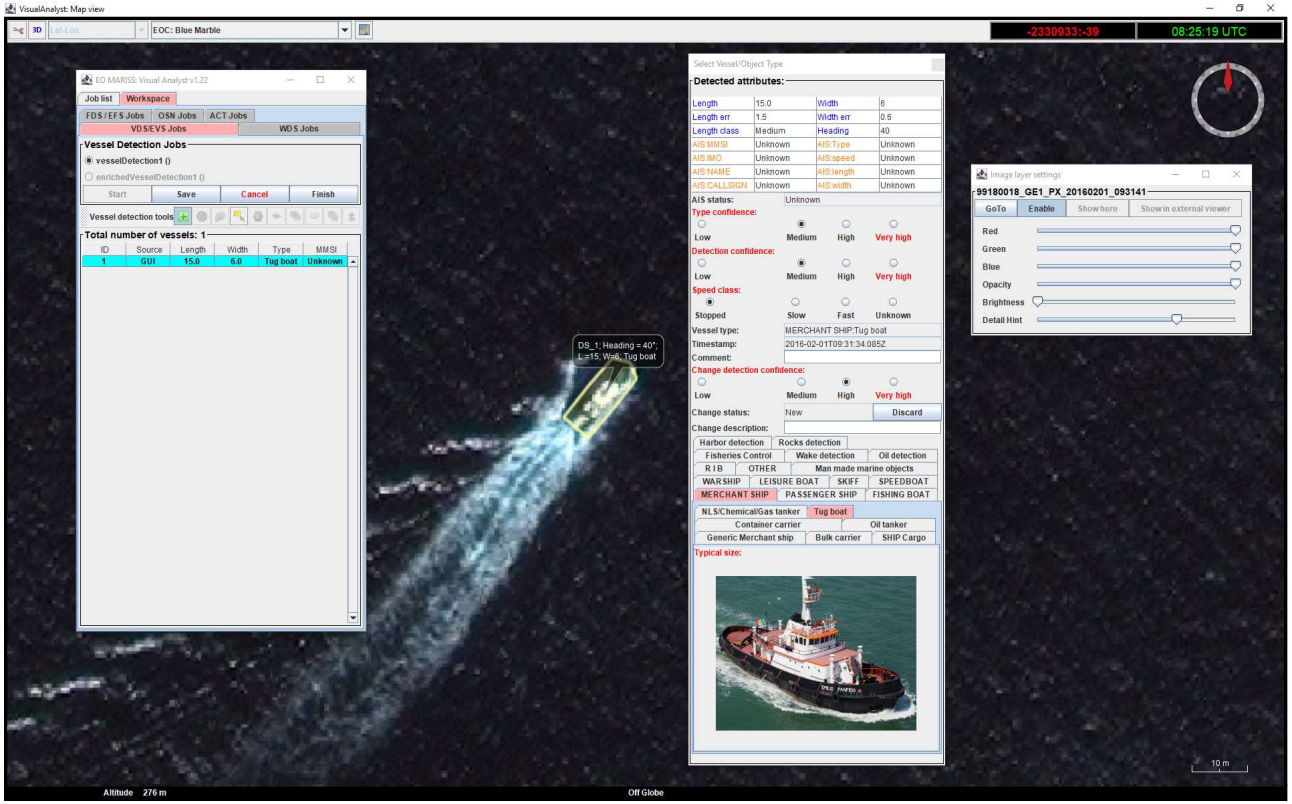

Passenger ship / Ferry


Container carrier


Fishing boat

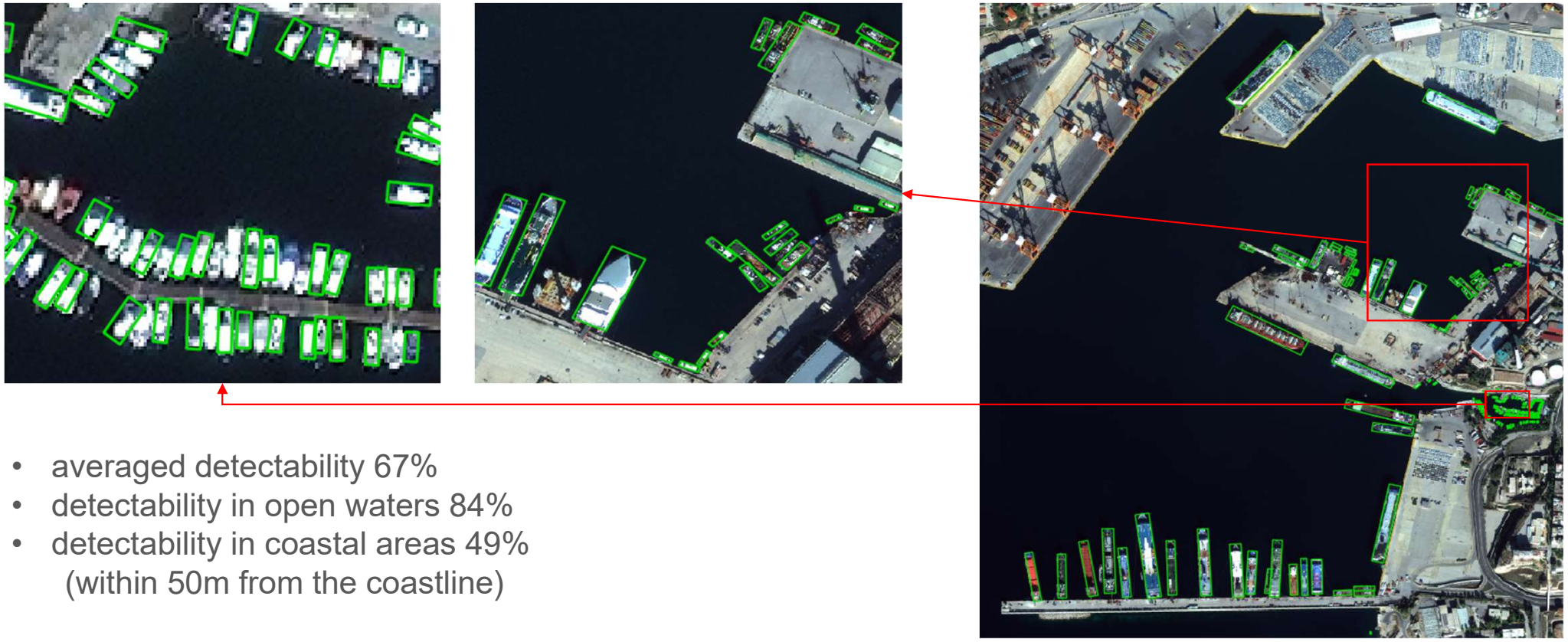
Analysis tool “Visual Analyst”

- Java application
- Works on thin-client basis
- Integration with DLR’s PSM
- Manual annotation/detection
- Validation/correction of automated detections



Performance examples on VHR images

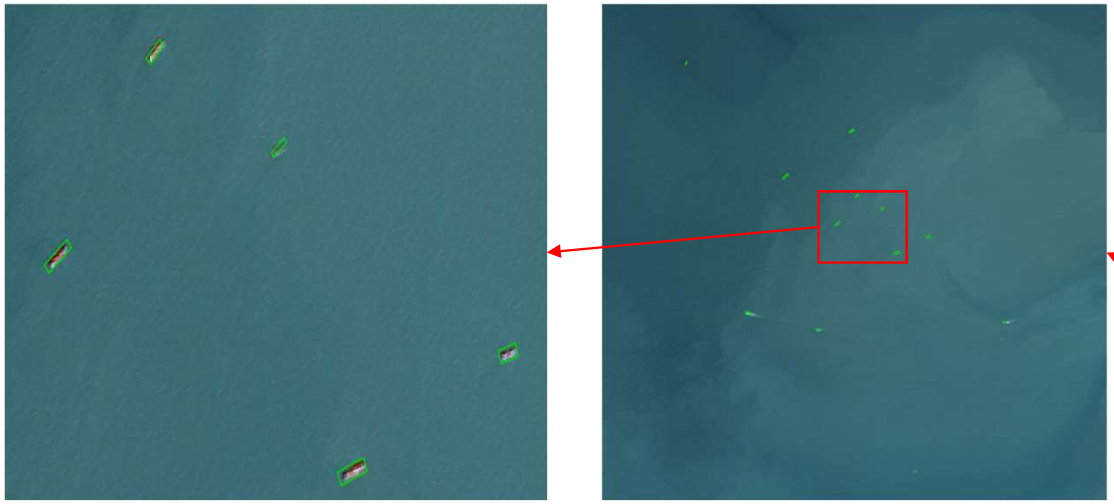
GeoEye-1 © 2019 European Space Imaging / Maxar

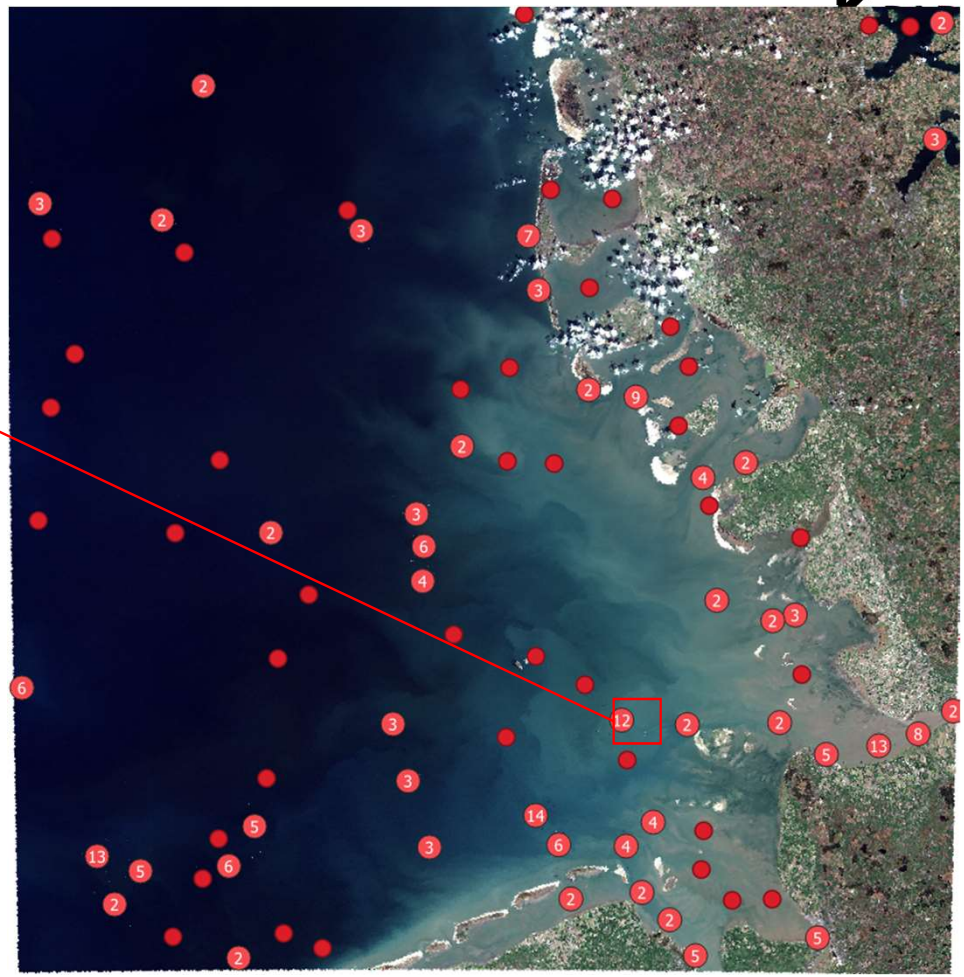


- averaged detectability 67%
- detectability in open waters 84%
- detectability in coastal areas 49%
  (within 50m from the coastline)


DS_125; Heading = 329°; L=113; W=26; Oil tanker
DS_134; Heading = 328°; L=250; W=49; Generic Merchant ship
DS_128; Heading = 146°; L=30; W=7; Tug boat
DS_124; Heading = 145°; L=59; W=10; Tug boat
DS_156; Heading = 329°; L=101; W=23; Oil tanker
DS_151; Heading = 146°; L=44; W=9; Tug boat
DS_165; Heading = 140°; L=59; W=10; Generic Merchant ship
DS_153; Heading = 323°; L=125; W=20; Oil tanker
DS_155; Heading = 115°; L=44; W=11; Tug boat
@Singapore, WorldView-2 © 2019 European Space Imaging / DigitalGlobe, a Maxar Company

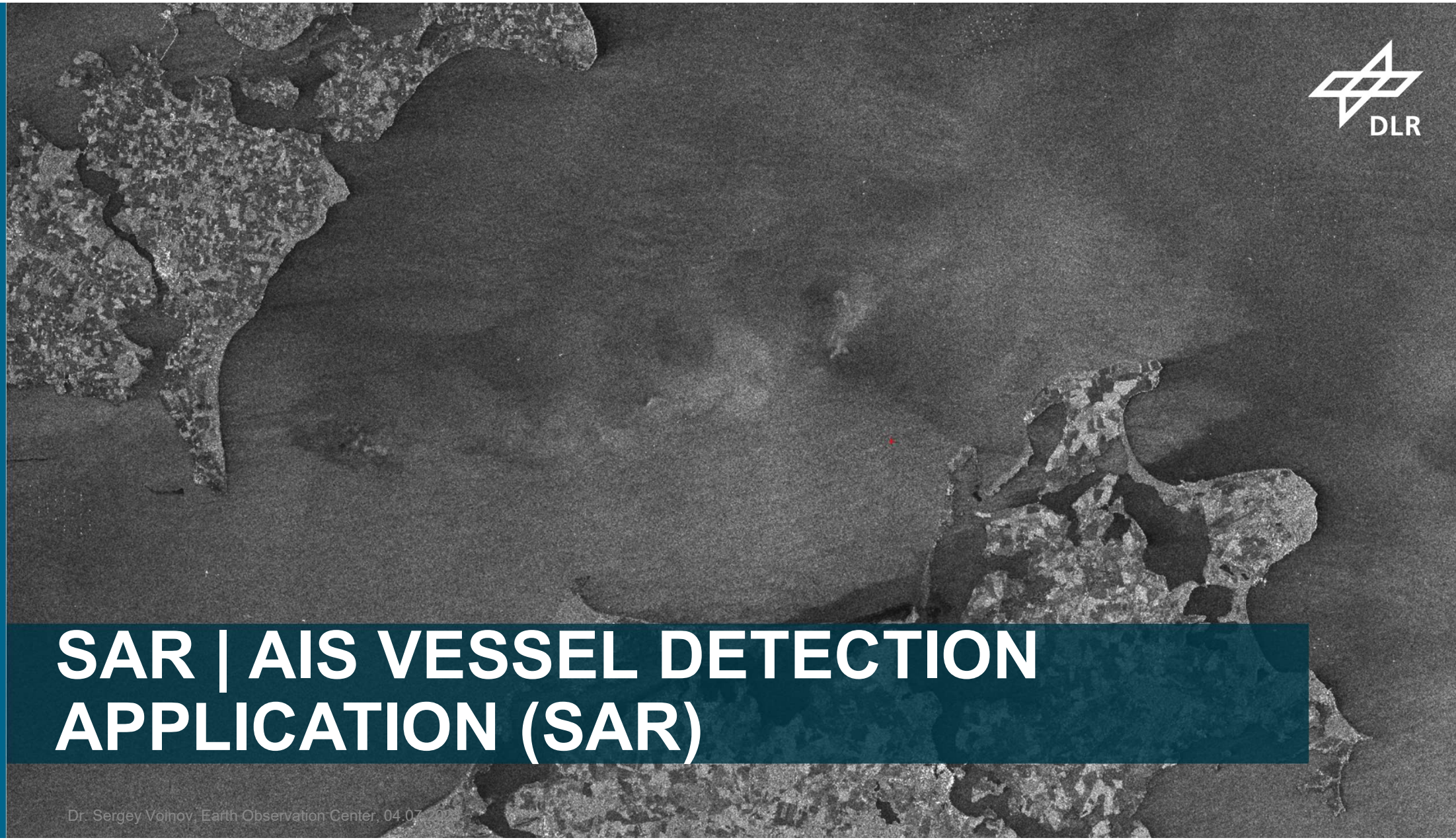
Performance examples on medium resolution EO images





- averaged detectability 62%
- coastal areas are excluded
- averaged image processing time: 35s
- averaged detection time: 31s

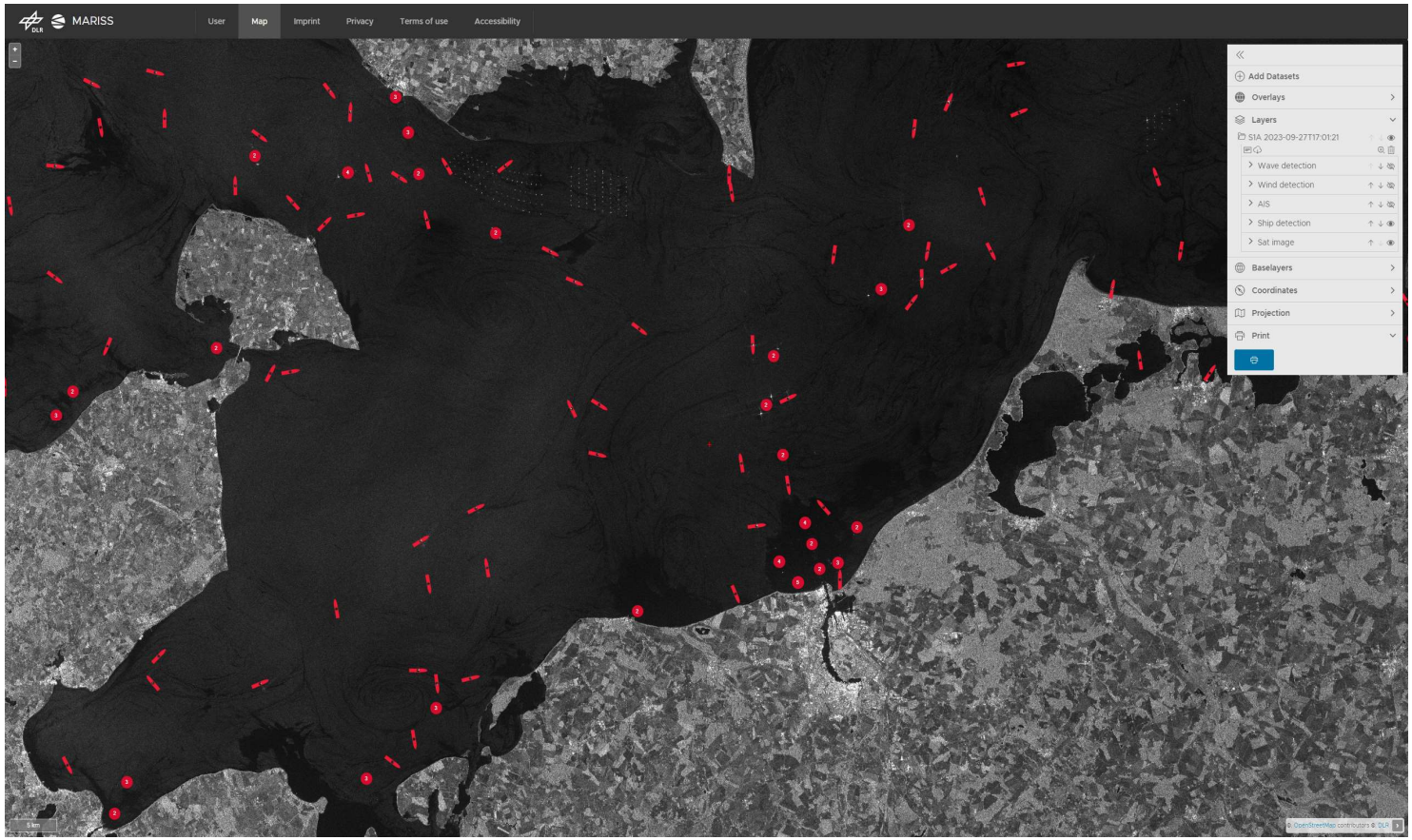
Landsat-8 © 2020 USGS



SAR | AIS VESSEL DETECTION APPLICATION (SAR)

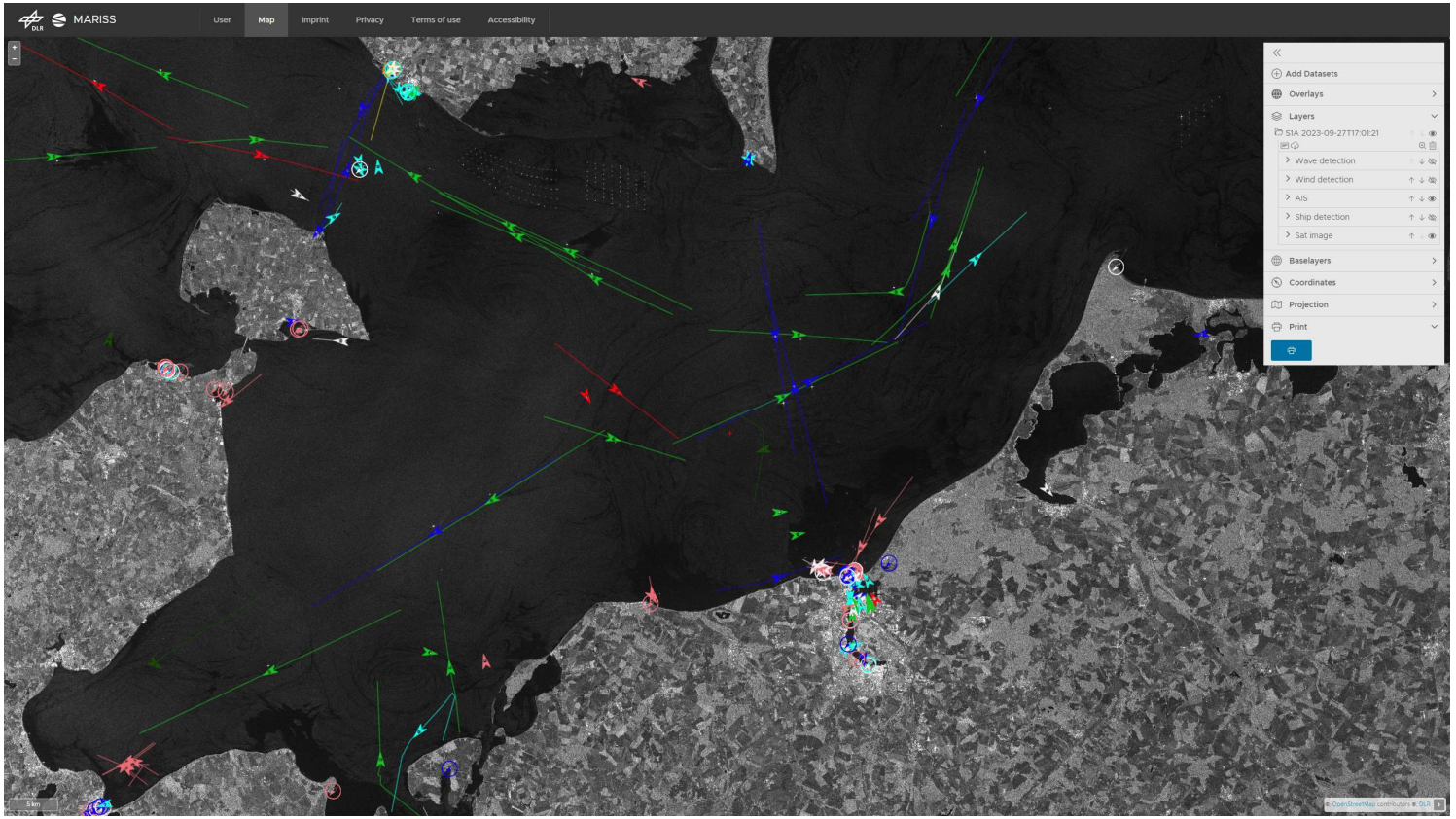
SAR | AIS Vessel Detection Application (SAR)

- Near real time ship detection application based on SAR images
- currently developed for: TerraSAR-X, TanDEM-X, Radarsat-2, Sentinel-1, Bremen, Björn Tings
- Application and SAR | AIS fusion, licenced to AIRBUS Ltd. Neustrelitz, Sergey Voinov



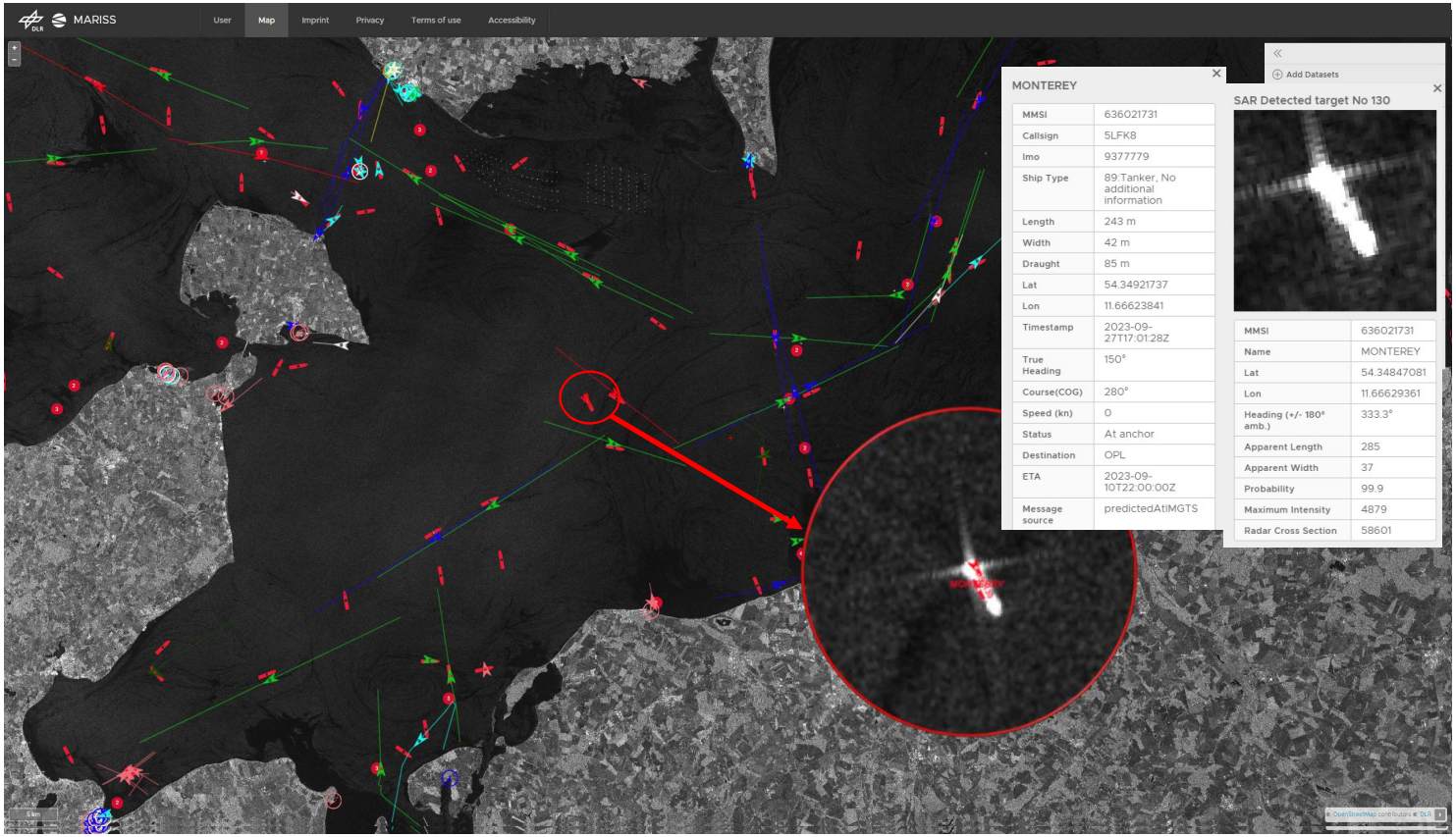
SAR | AIS Vessel Detection Application (SAR)

- Near real time ship detection application based on SAR images
- currently developed for: TerraSAR-X, TanDEM-X, Radarsat-2, Sentinel-1, Bremen, Björn Tings
- Application and SAR | AIS fusion, licenced to AIRBUS Ltd. Neustrelitz, Sergey Voinov



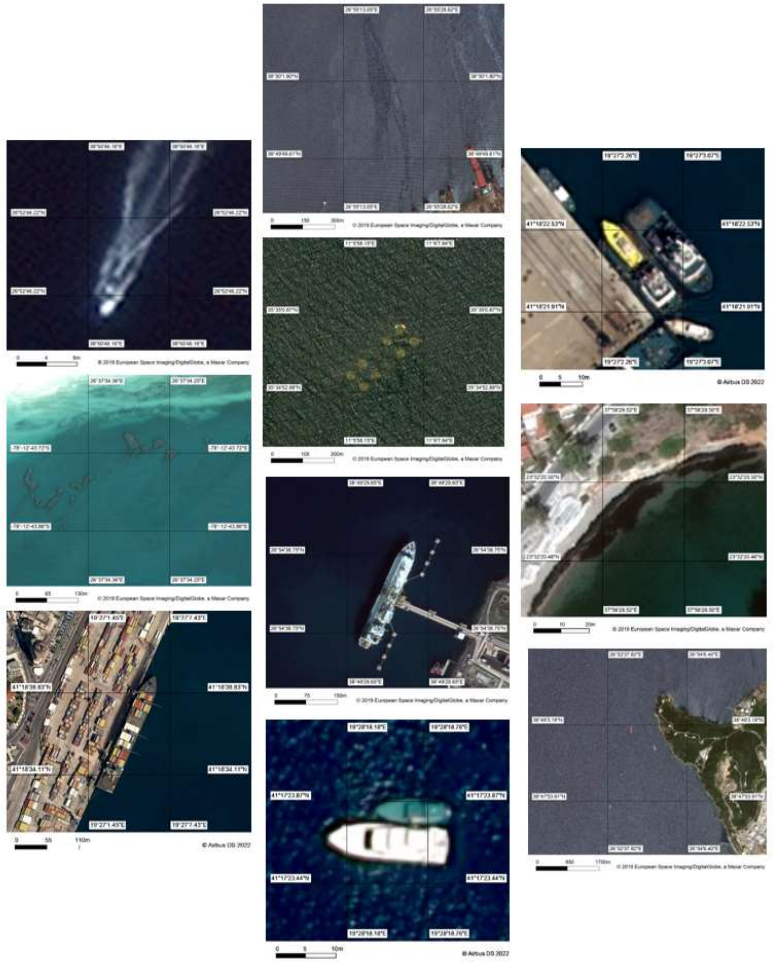
SAR | AIS Vessel Detection Application (SAR)

- Near real time ship detection application based on SAR images
- currently developed for: TerraSAR-X, TanDEM-X, Radarsat-2, Sentinel-1, Bremen, Björn Tings
- Application and SAR | AIS fusion, licenced to AIRBUS Ltd. Neustrelitz, Sergey Voinov



Conclusion

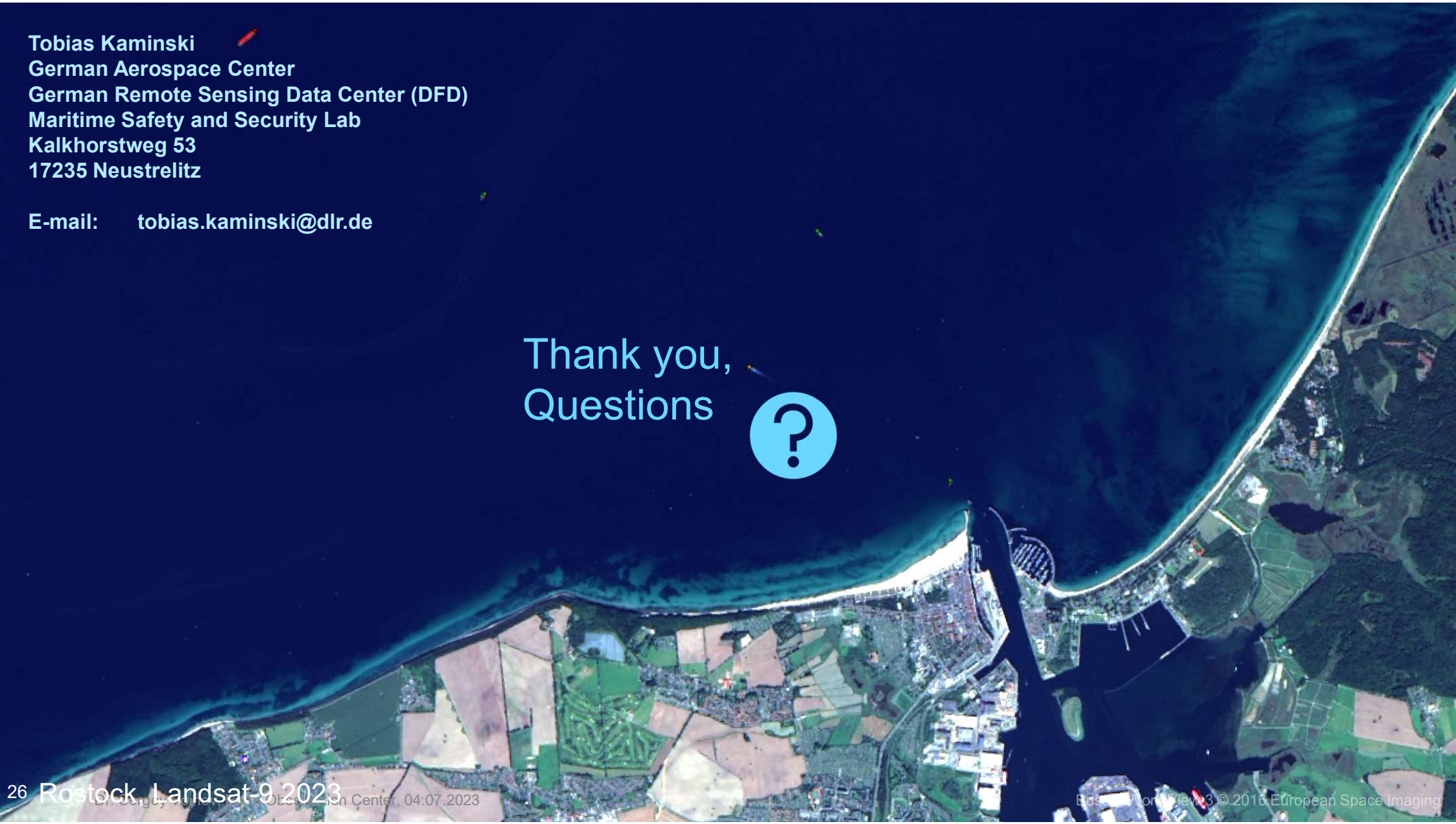
- Earth observation from Space is well established and used as a contributing source to derive information for marine situational awareness.
- In particular, the start and operation of constellations allows for shorter repetition rates with regard to a new image acquisition.
- Sensors with a ground resolution of better than 50 centimeters are available for both optical and SAR remote sensing.
- Because of the rapidly changing conditions, the focus of applications is on the provision of information in near real time.
- In the frame of AI based methods a large comprehensive training dataset is needed.
- Developed processors can not be used in a fully automated environment without control by an operator. (Question of reliability and completeness)



Tobias Kaminski
German Aerospace Center
German Remote Sensing Data Center (DFD)
Maritime Safety and Security Lab
Kalkhorstweg 53
17235 Neustrelitz

E-mail: **tobias.kaminski@dlr.de**

Thank you,
Questions



 Rostock, Landsat-9 2023