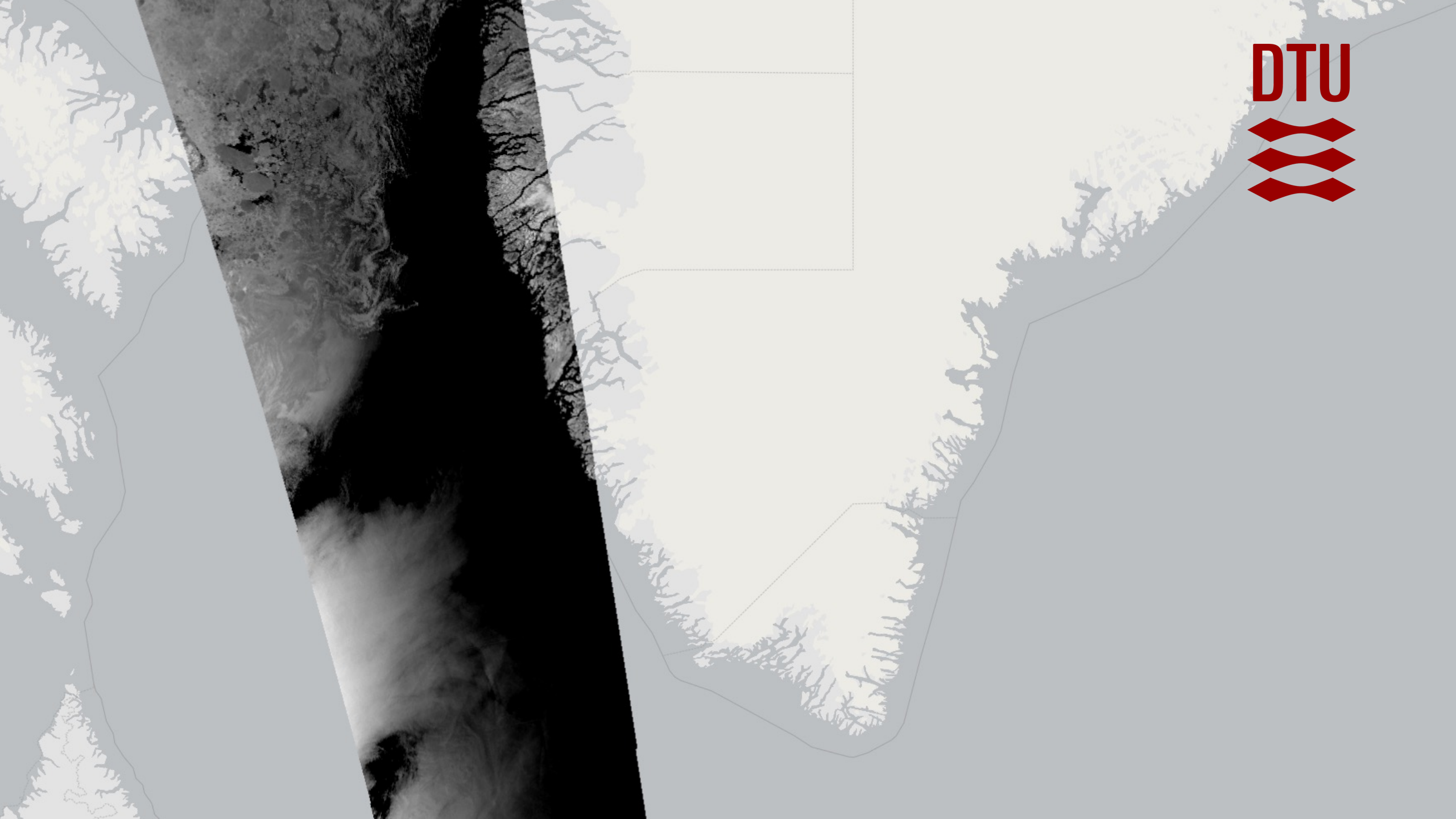
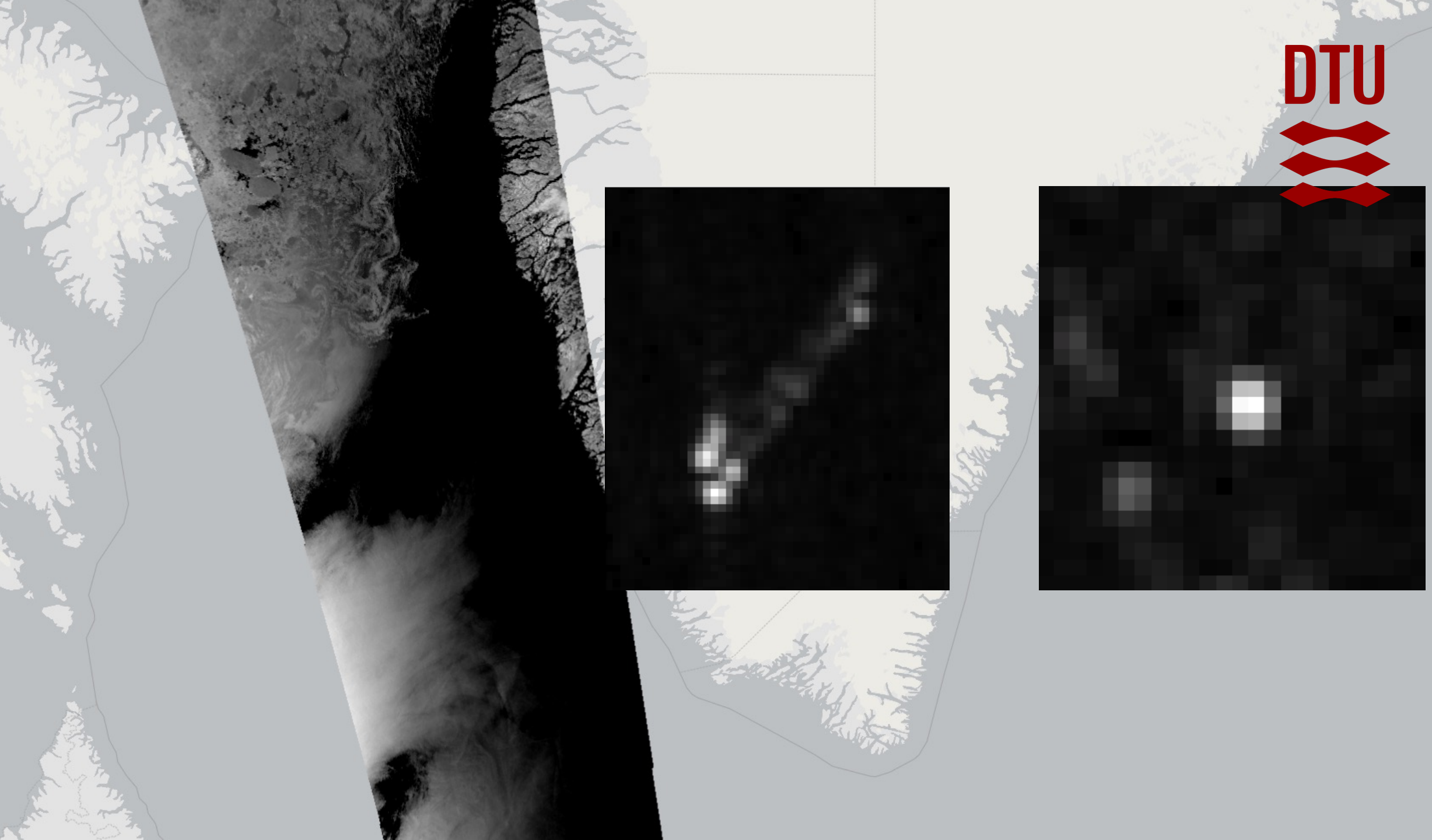
Light-weight ship detection

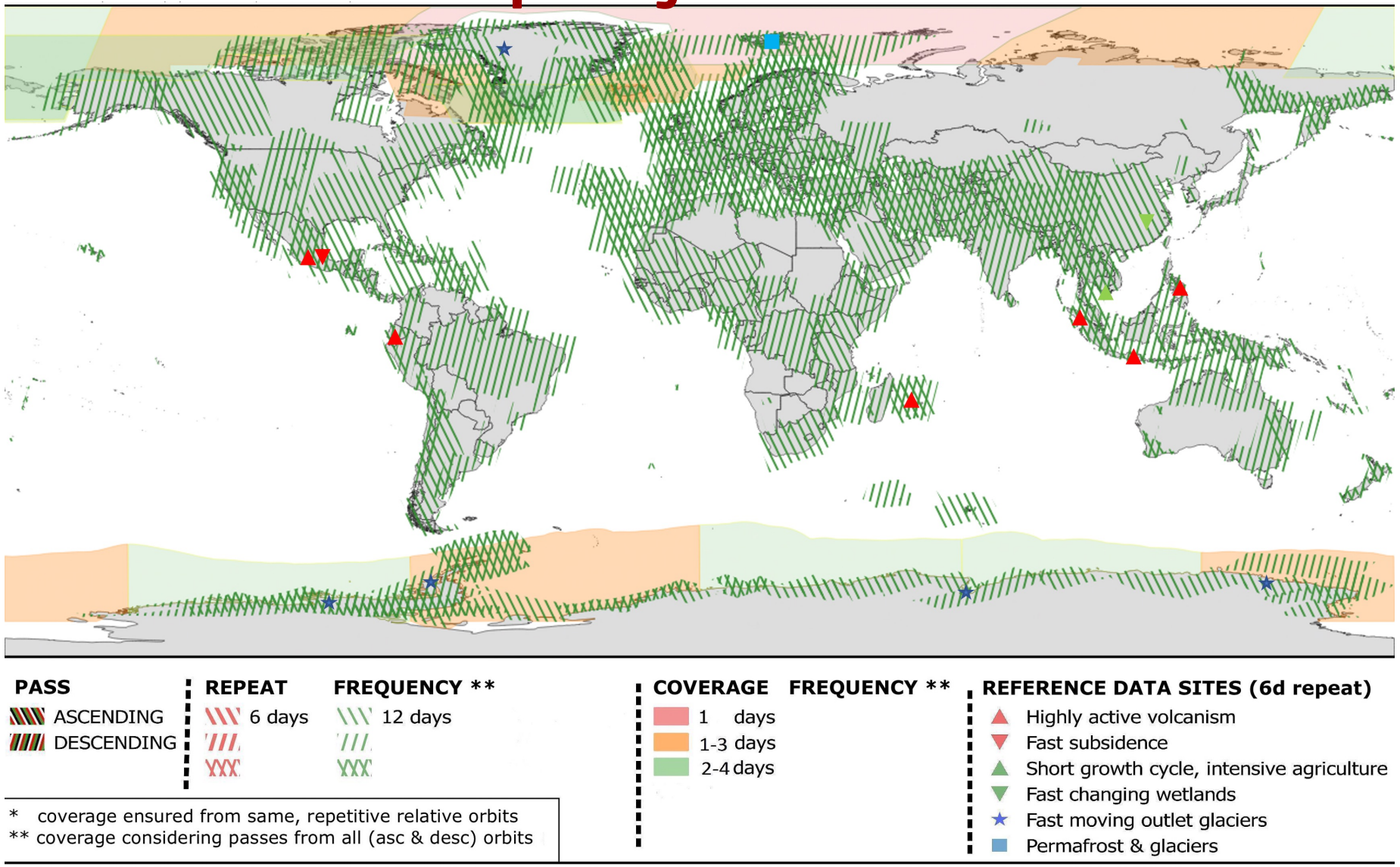
For onboard AI

Kristian Aalling Sørensen, Peder Heiselberg, Henning Heiselberg
National Space Institute of Denmark,
Center for Security



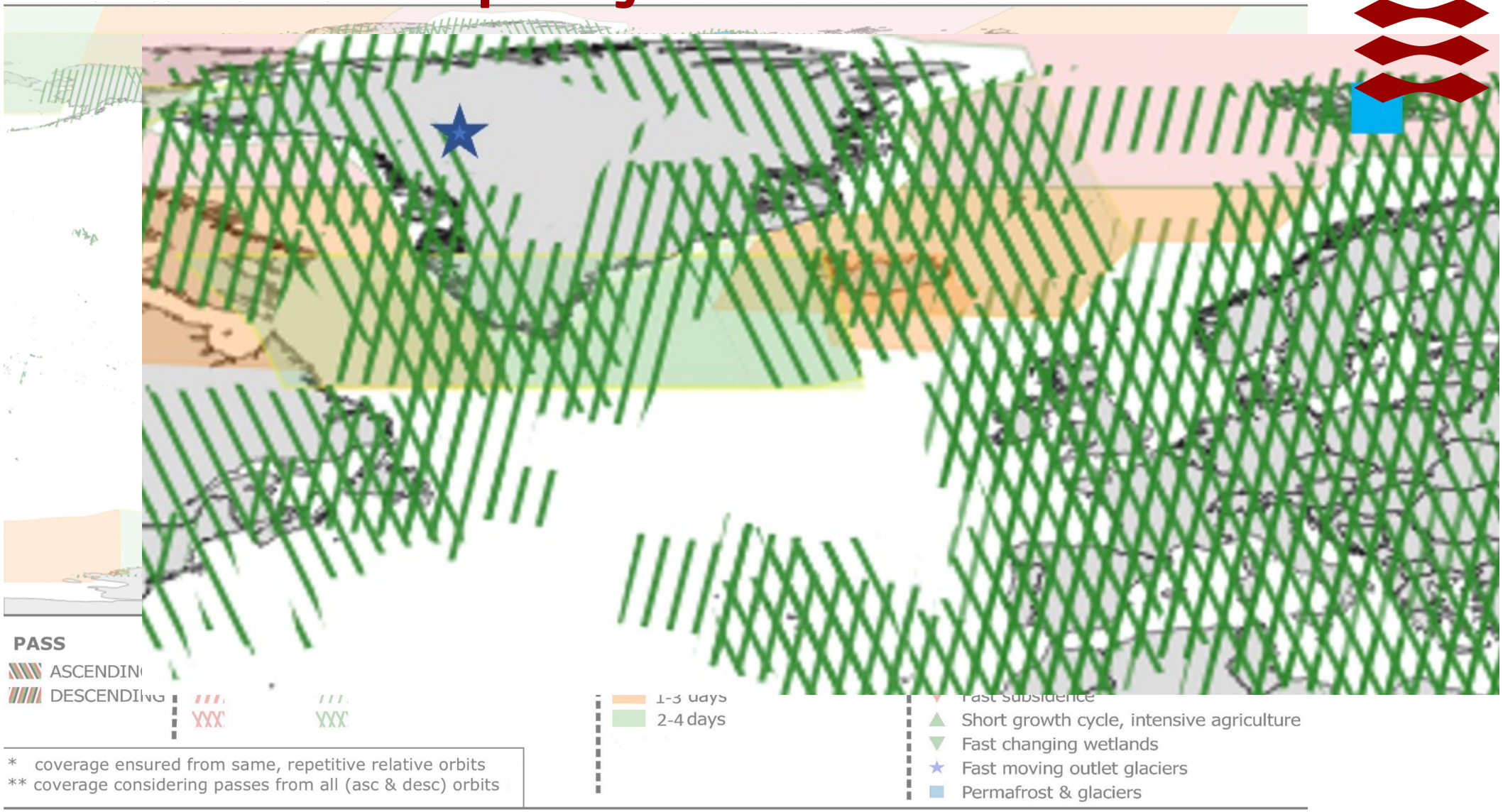


Sentinel-1 Revisit Frequency



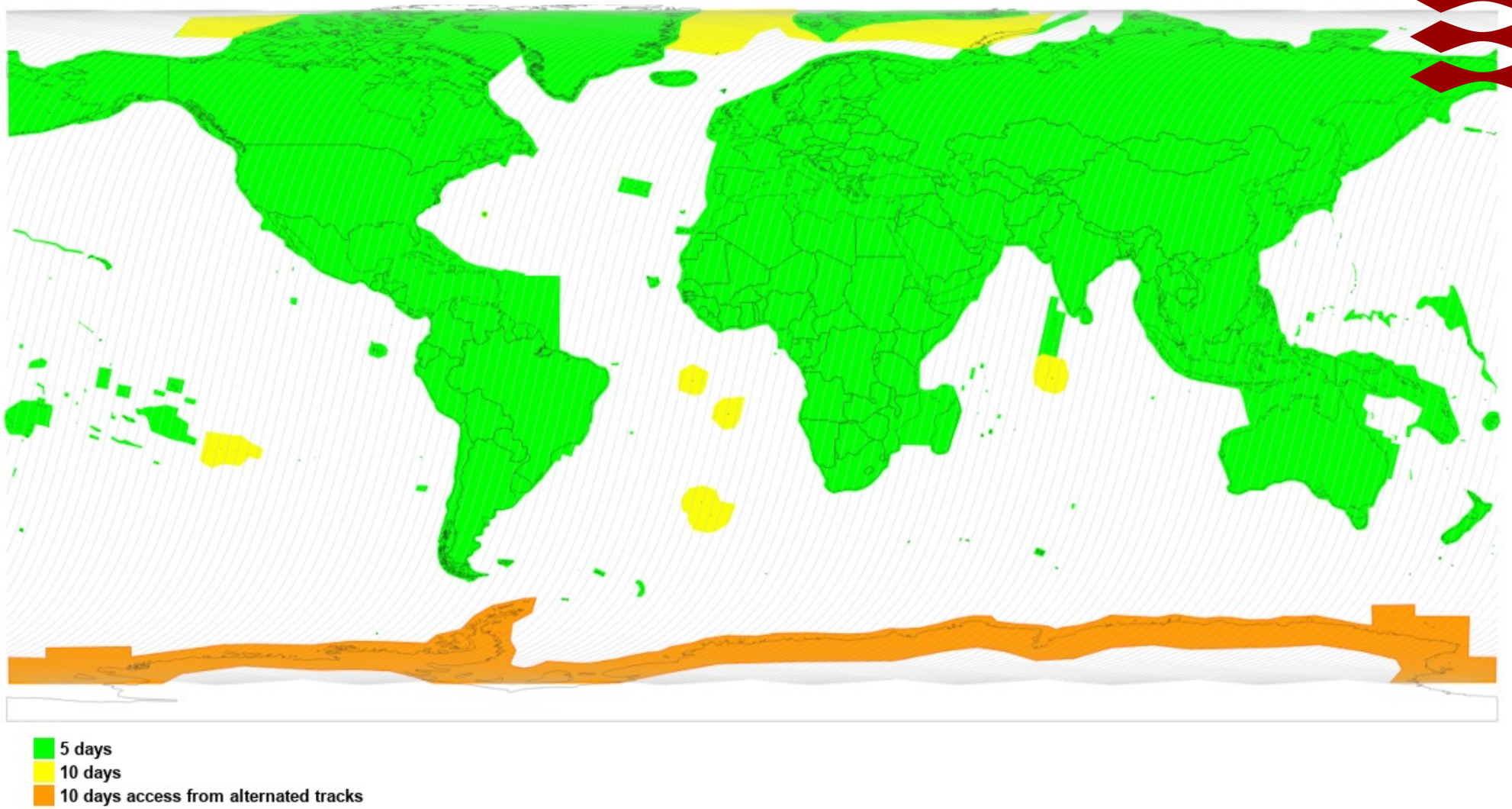
https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario

Sentinel-1 Revisit Frequency



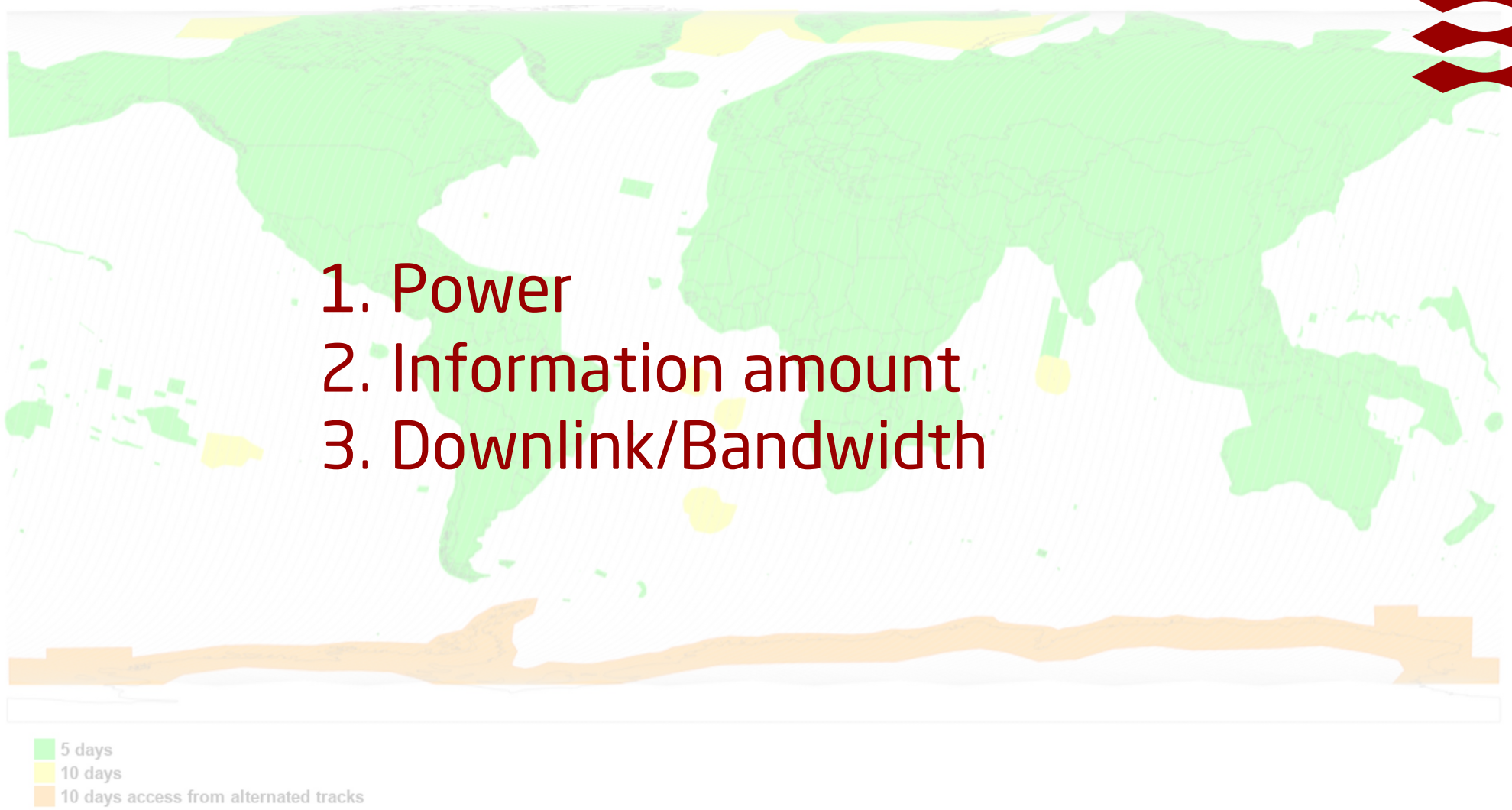
https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario

Sentinel-2 Revisit Frequency



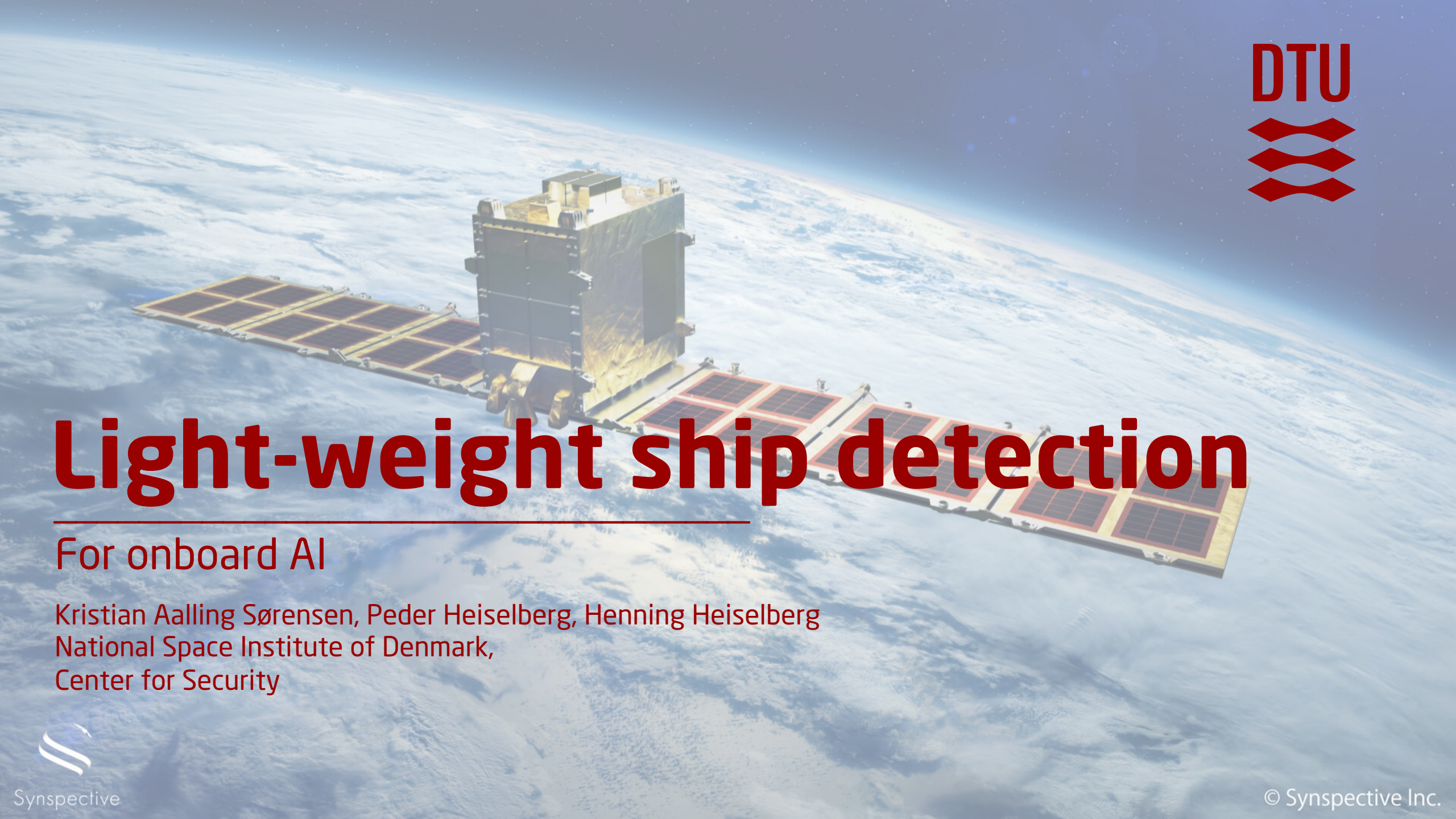
https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi/revisit-coverage

Sentinel-2 Revisit Frequency



1. Power
2. Information amount
3. Downlink/Bandwidth

https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi/revisit-coverage



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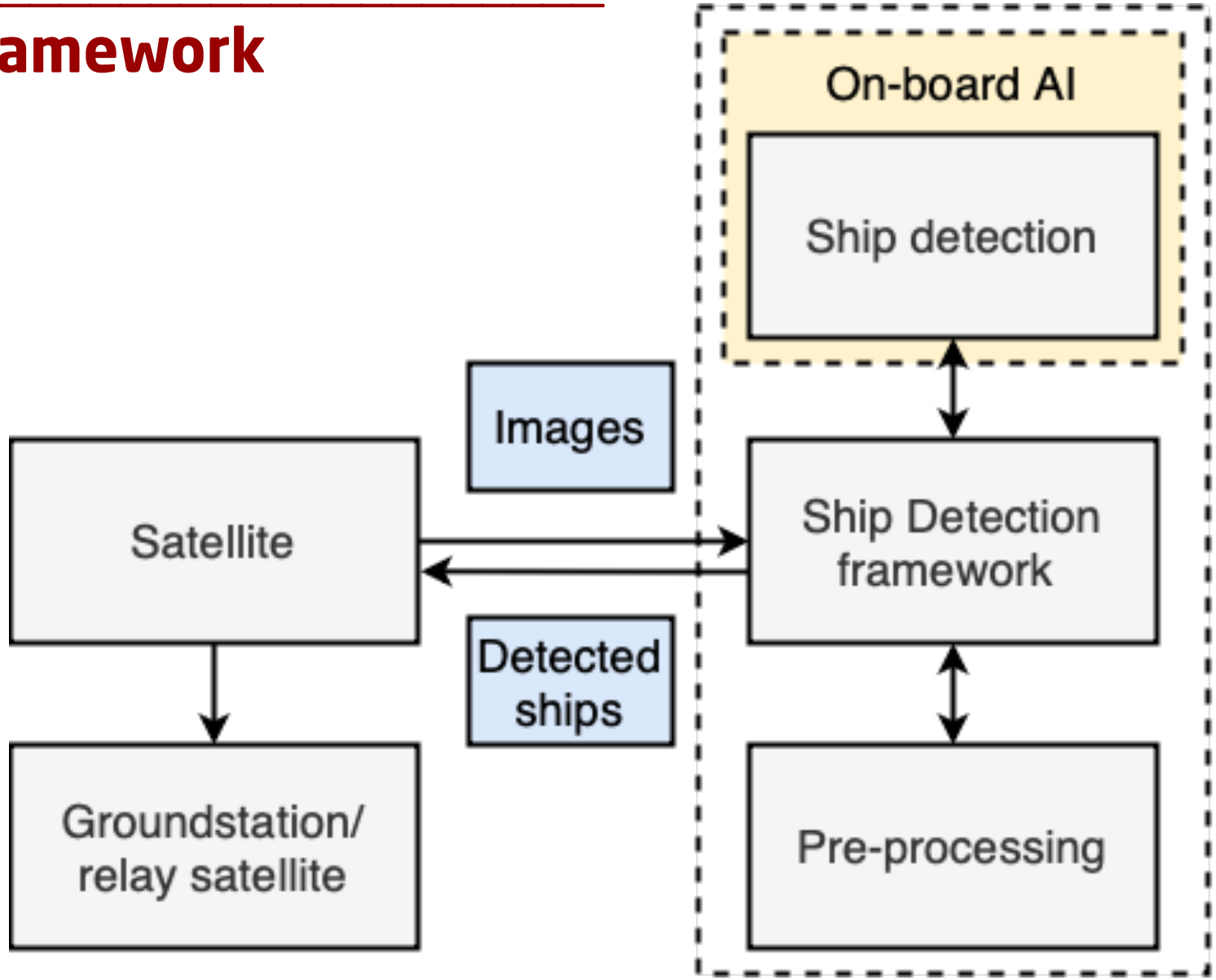
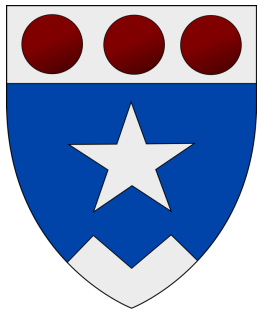
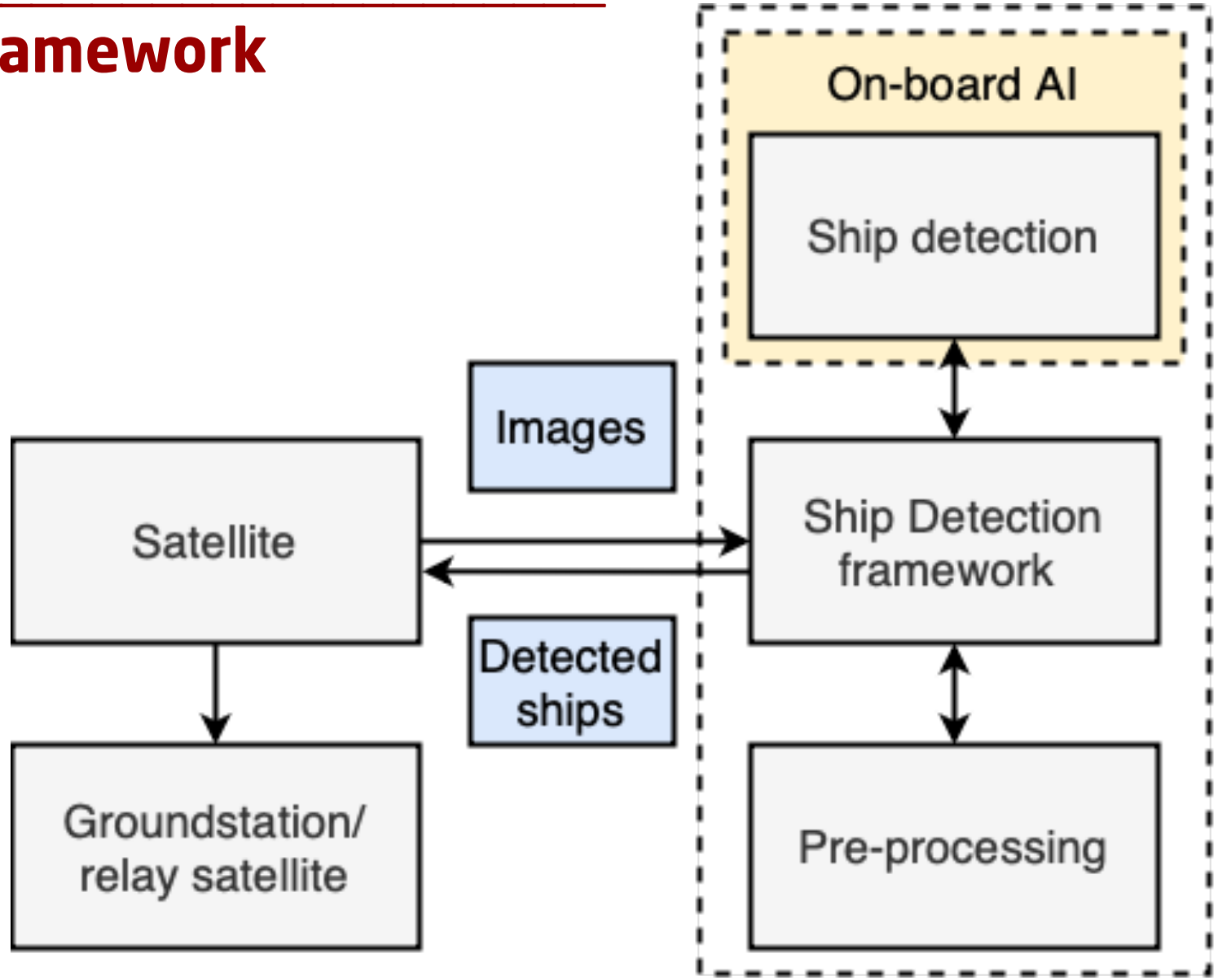
Synspective

Onboard AI framework

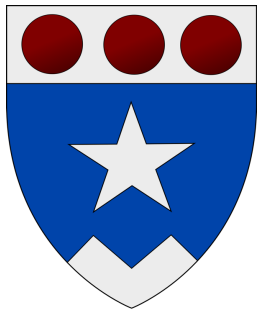


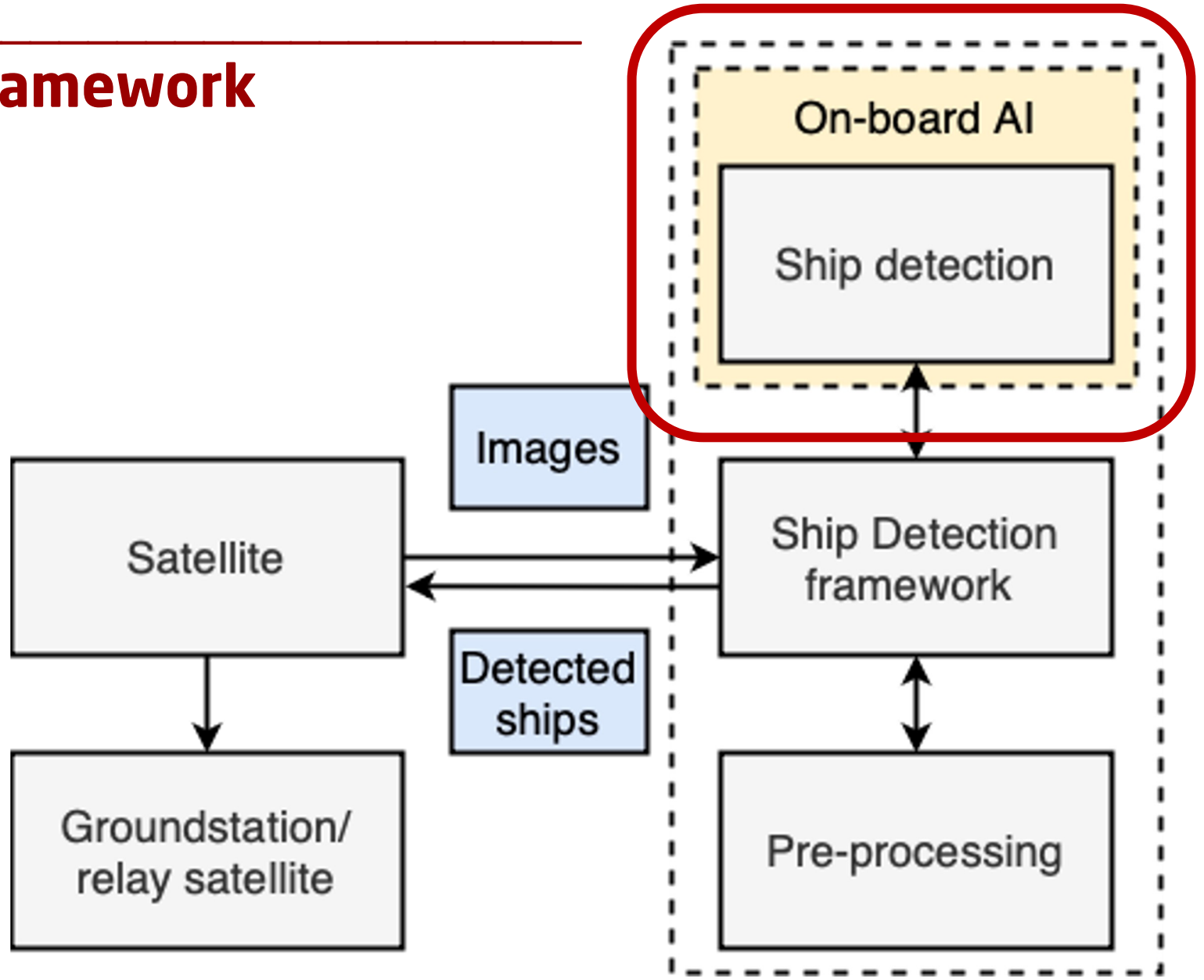
Onboard AI framework





Onboard AI framework

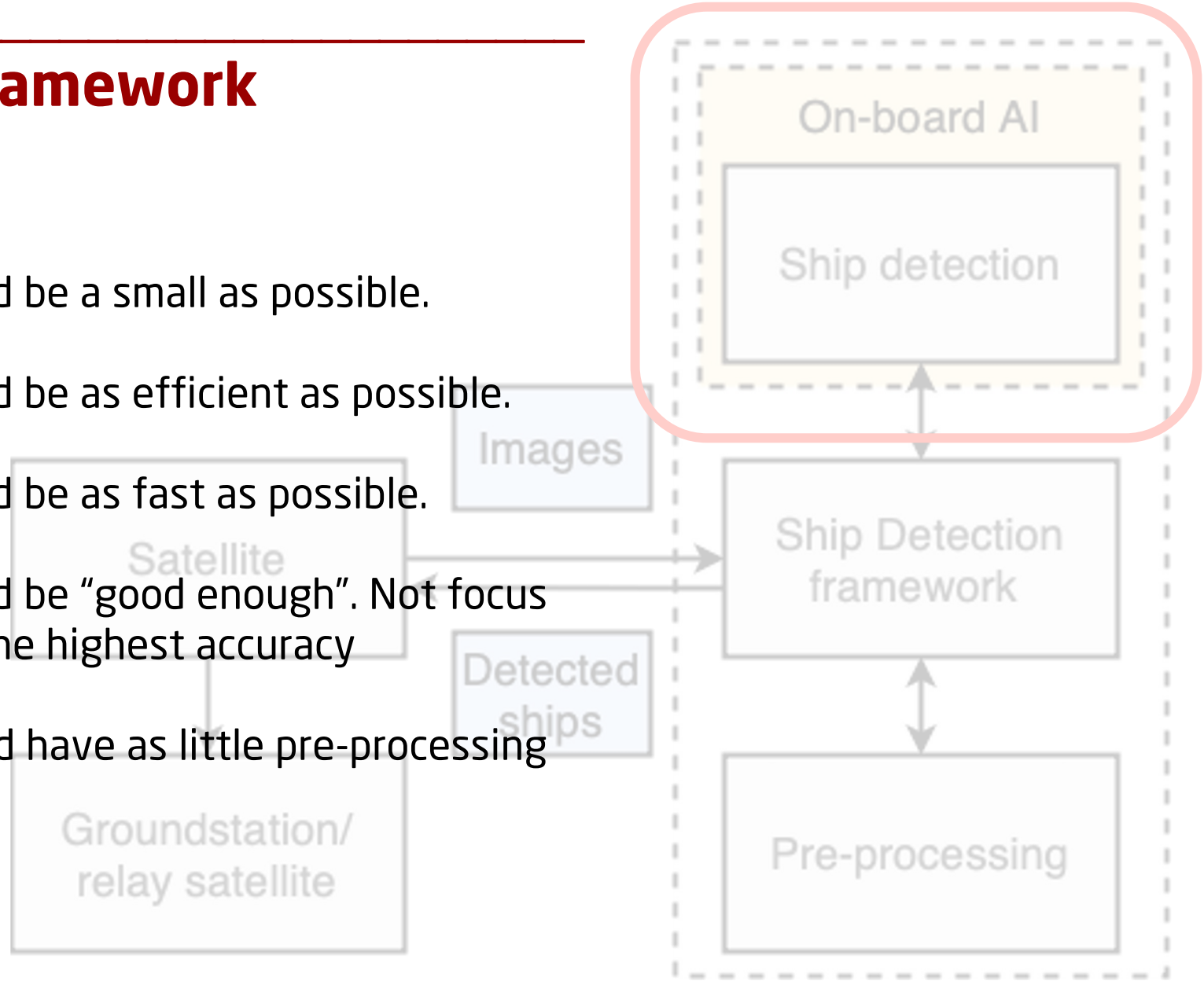




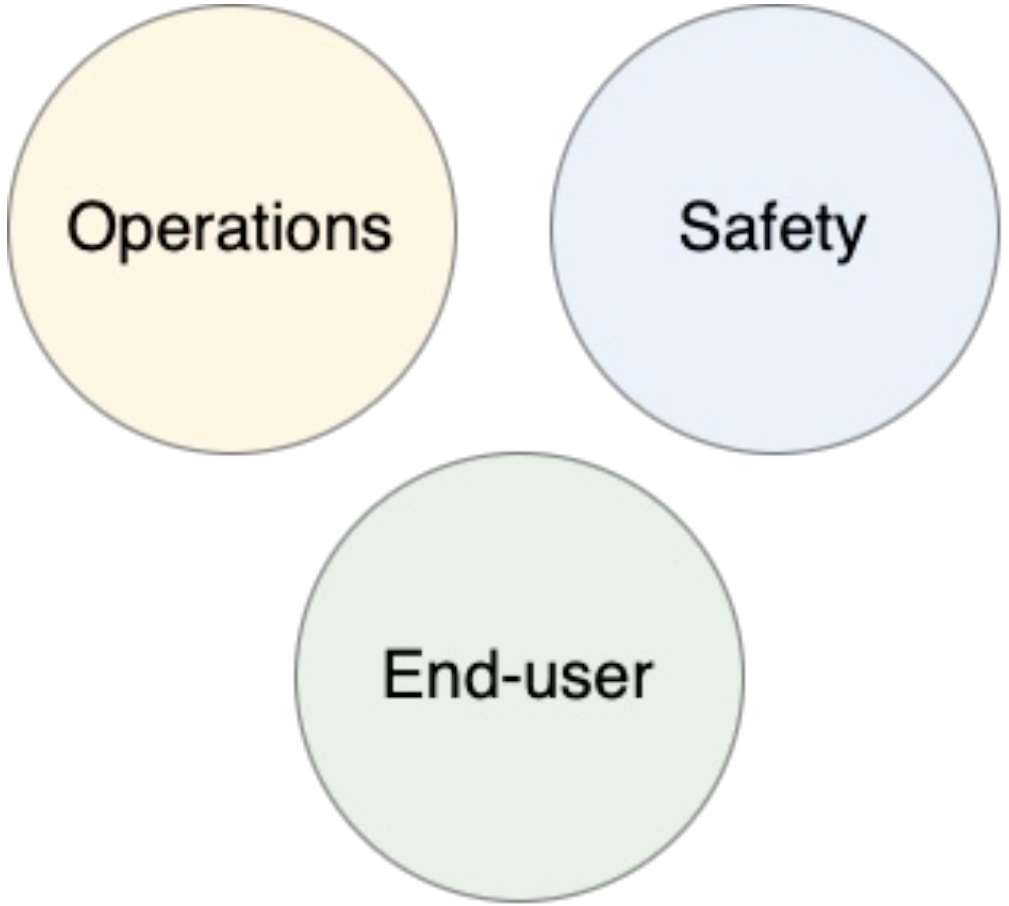
Onboard AI framework

Considerations

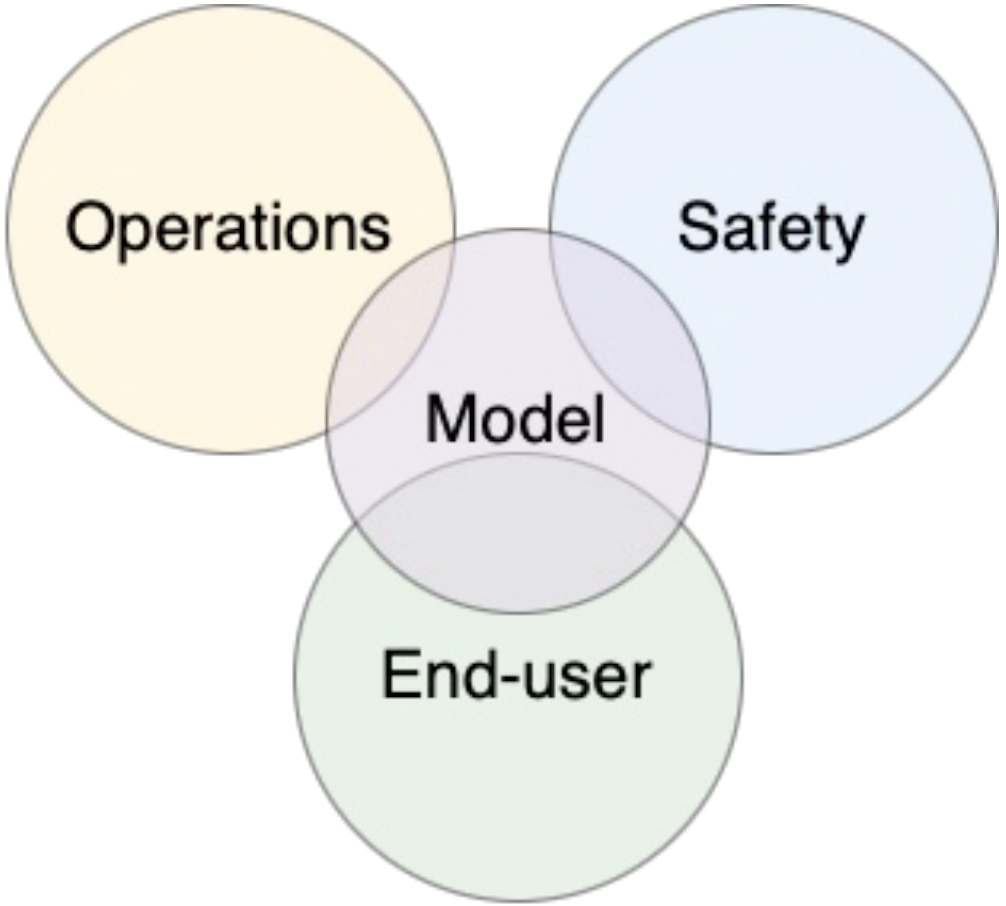
1. Model should be a small as possible.
2. Model should be as efficient as possible.
3. Model should be as fast as possible.
4. Model should be “good enough”. Not focus on getting the highest accuracy
5. Image should have as little pre-processing as possible



AI requirements

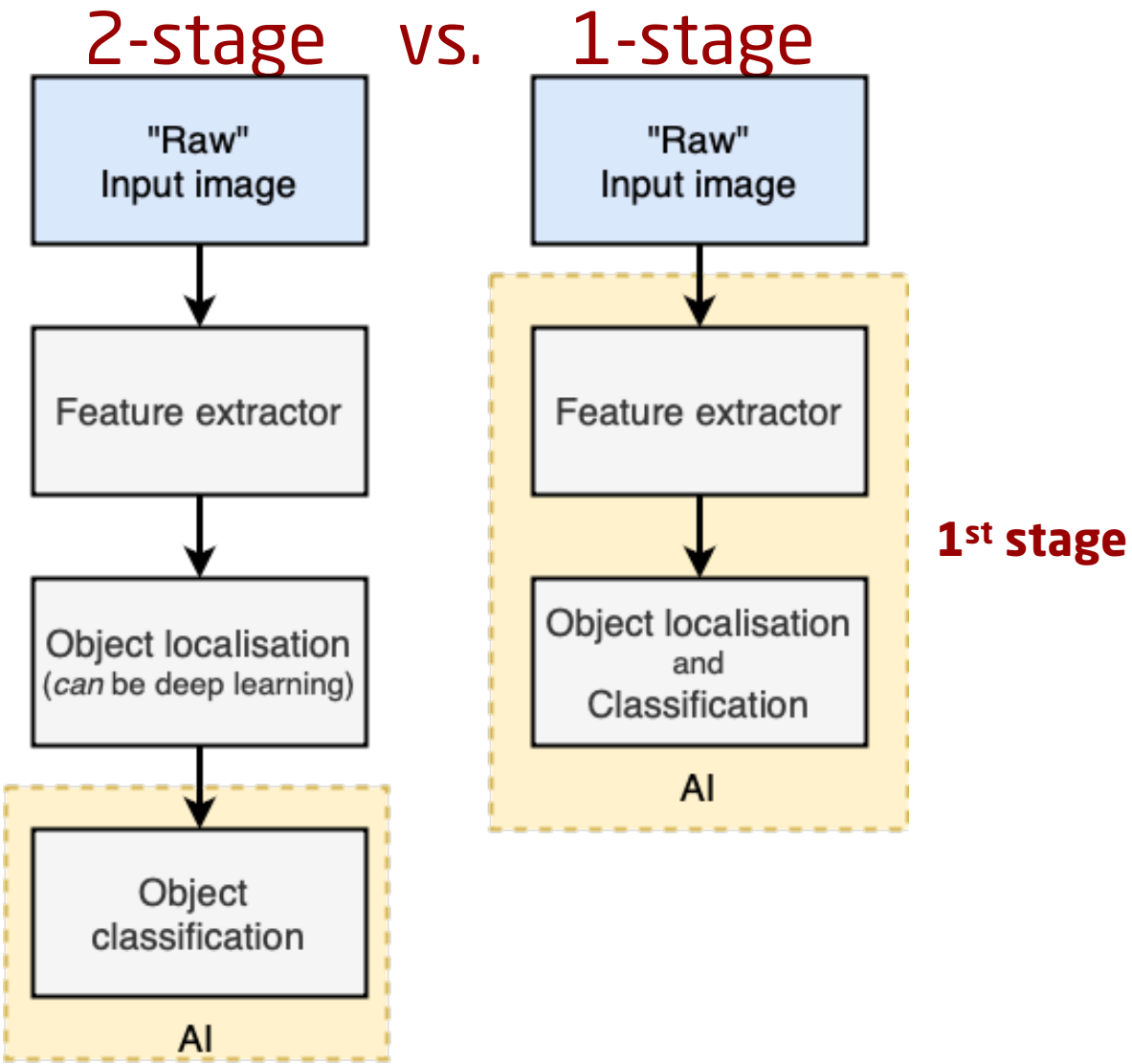


AI requirements

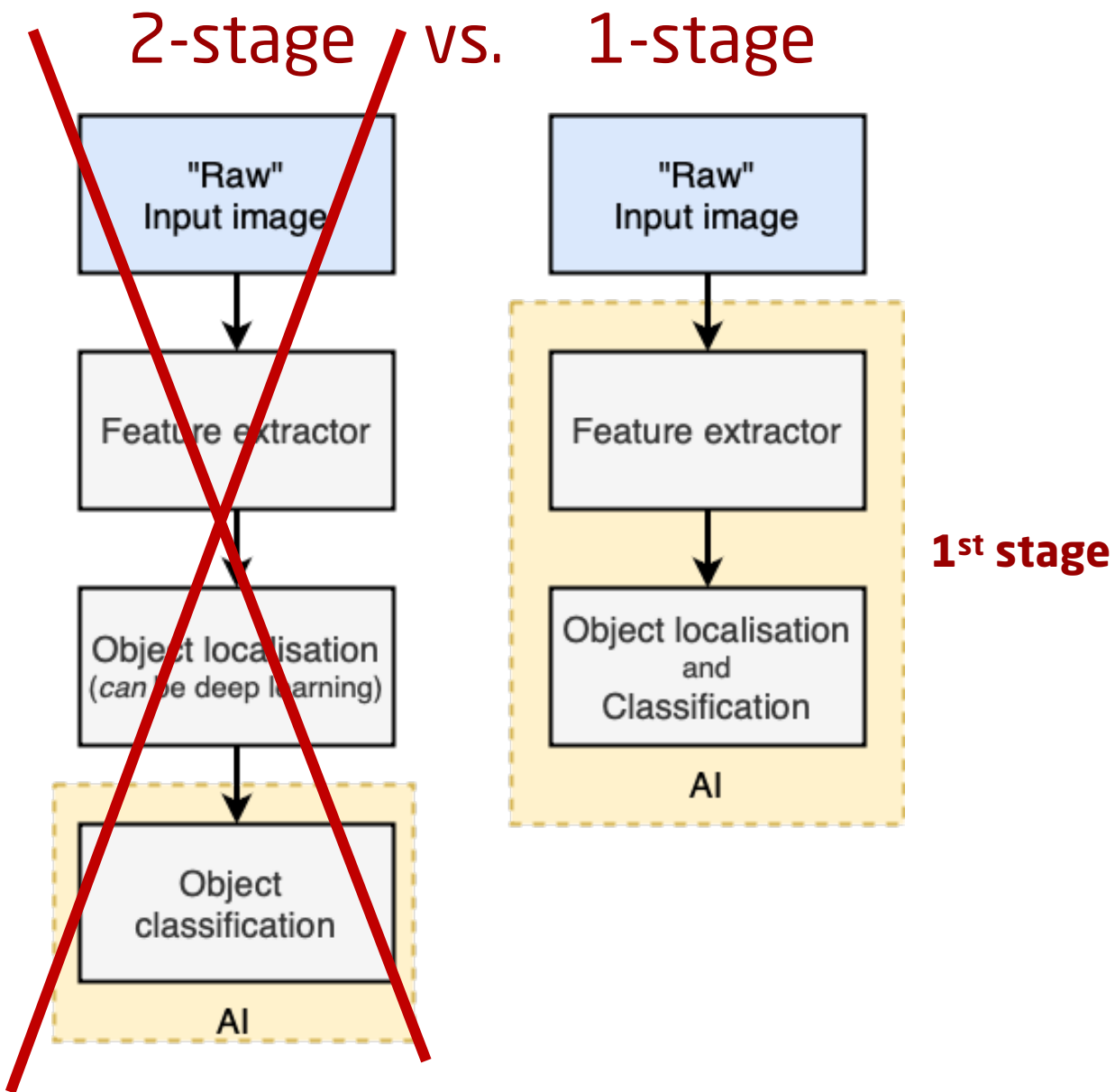


Object detection models

Fast model:



Fast model:

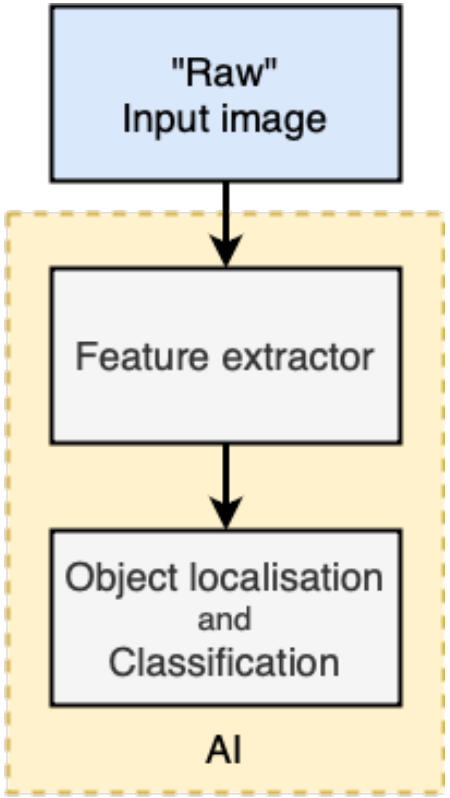


1st stage

2nd stage

1st stage

Fast model:
1-stage



- Make as small as possible (less parameters)
- Introduce more efficient deep learning layers
- Make it better for small objects
- ....

Results

Table 1: State of the art FOSS models

Model name	$AP_{0.5}(\%)$	$AP_{0.5:0.9}(\%)$	R(%)	P(%)	Parms(M)
YOLOv3tiny	57.9	32.6	42.2	90.0	12.13
YOLOv3sppu	85.5	52.9	77.8	**93.4**	104.7
YOLOv5mu	85.8	50.2	78.7	89.6	25.07
YOLOv8n	74.7	37.4	71.3	88.8	**3.01**
YOLOv8x	**88.5**	**55.1**	**82.9**	93.3	68.2

Table 1: Improved models

Augmentation	Depth-wise separable	Dilation rate	parameters	$AP_{0.5}$ (%)	R (%)
✗	✗	✗	1.94	96.58	93.13
✓	✗	✗	1.94	96.67	93.56
✓	✗	✗	0.529	96.10	92.54
✓	✓	✓	0.330	95.63	92.25

Results - small

Table 1: State of the art FOSS models

Model name	$AP_{0.5}$(%)	$AP_{0.5:0.9}$(%)	R(%)	P(%)	Parms(M)
YOLOv3tiny	57.9	32.6	42.2	90.0	12.13
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✓	✓	✓	0.330	95.63	92.25

Results – "good enough"

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Model name	$AP_{0.5}$(%)	$AP_{0.5:0.9}$(%)	R(%)	P(%)	Parms(M)
YOLOv3tiny	57.9	32.6	42.2	90.0	12.13
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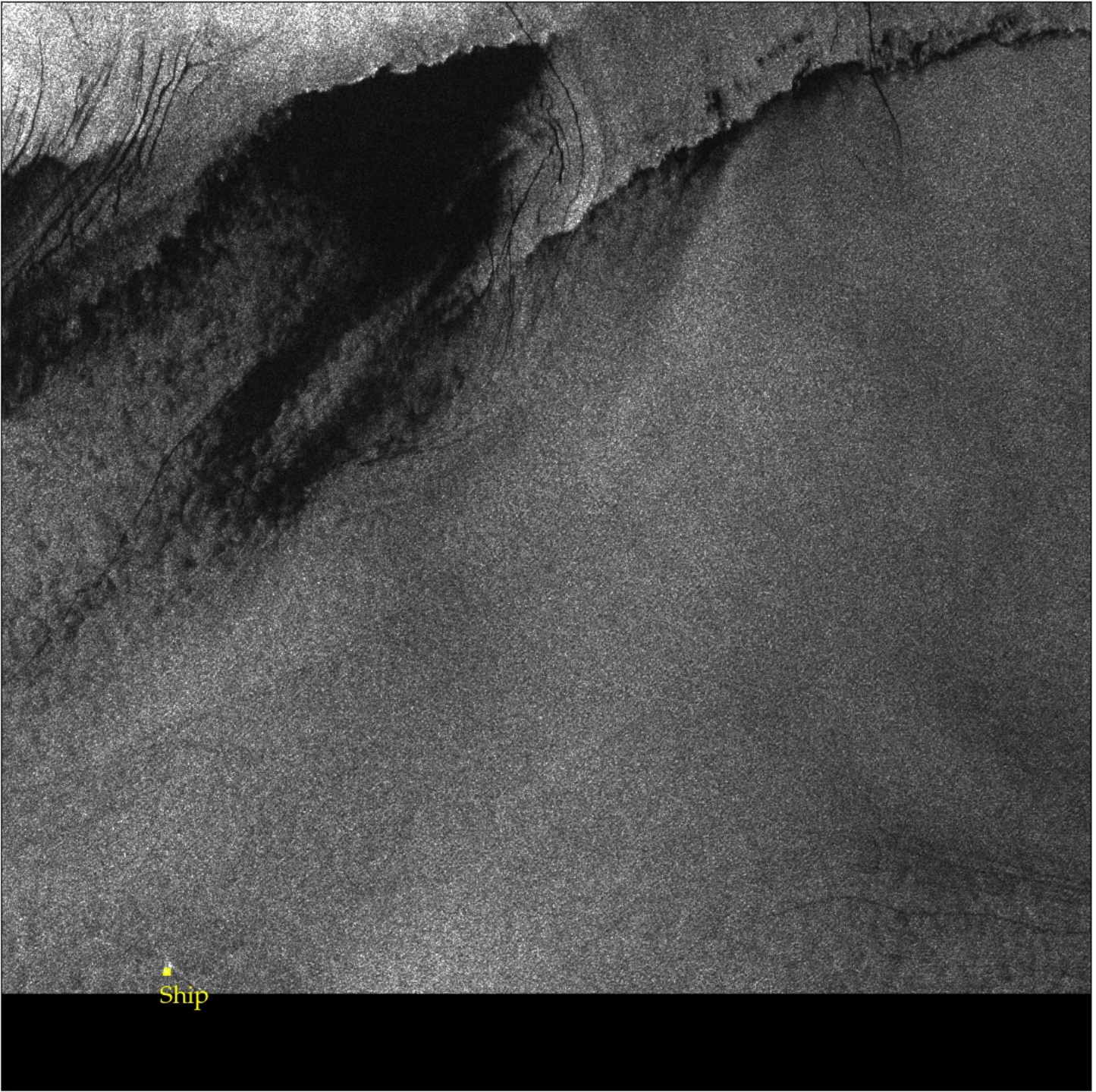
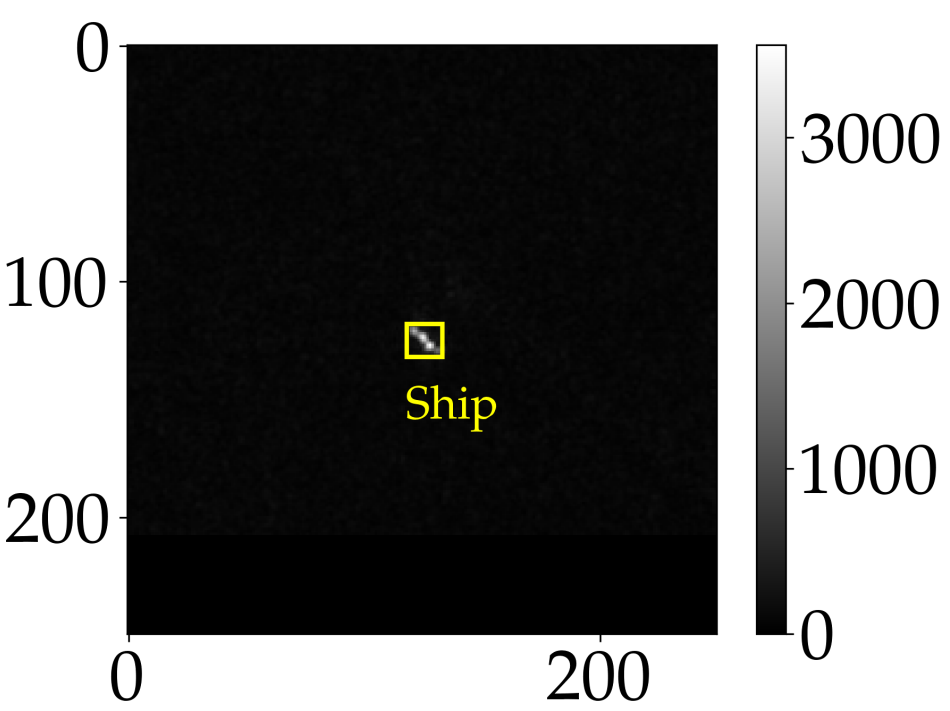
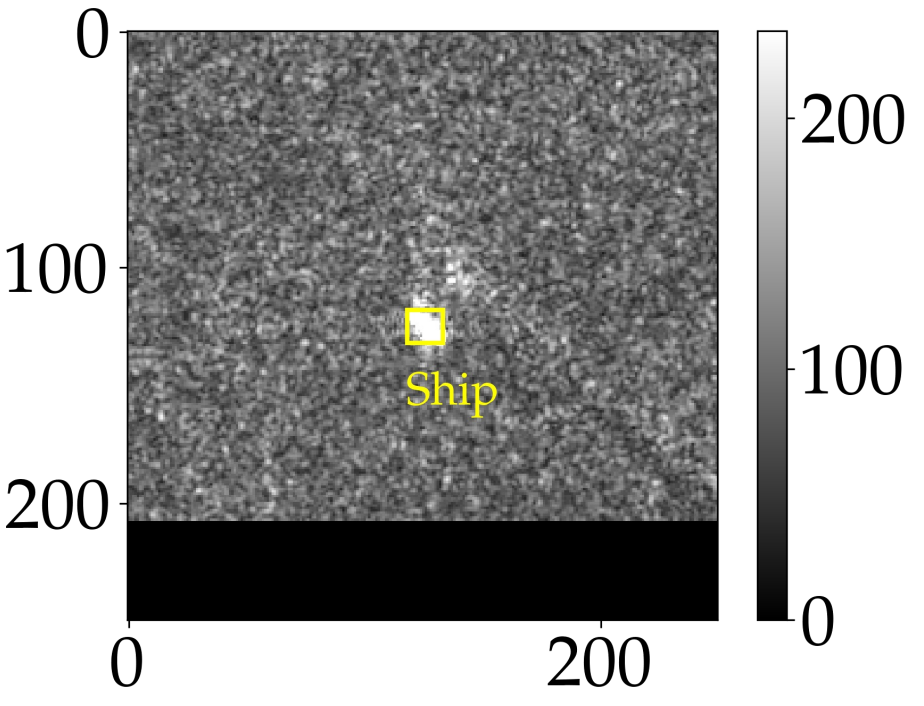
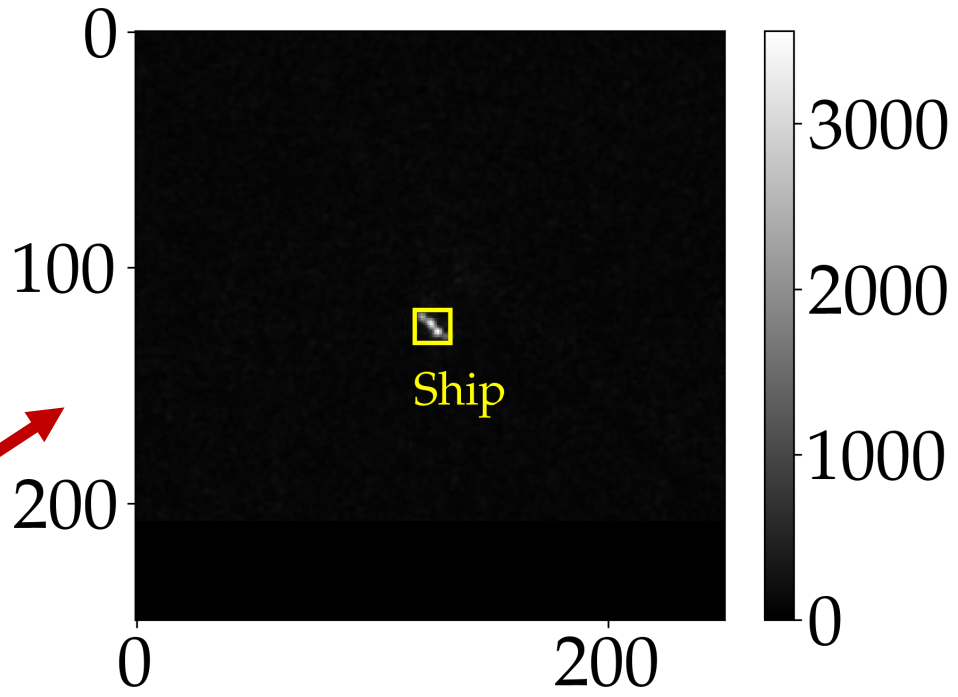
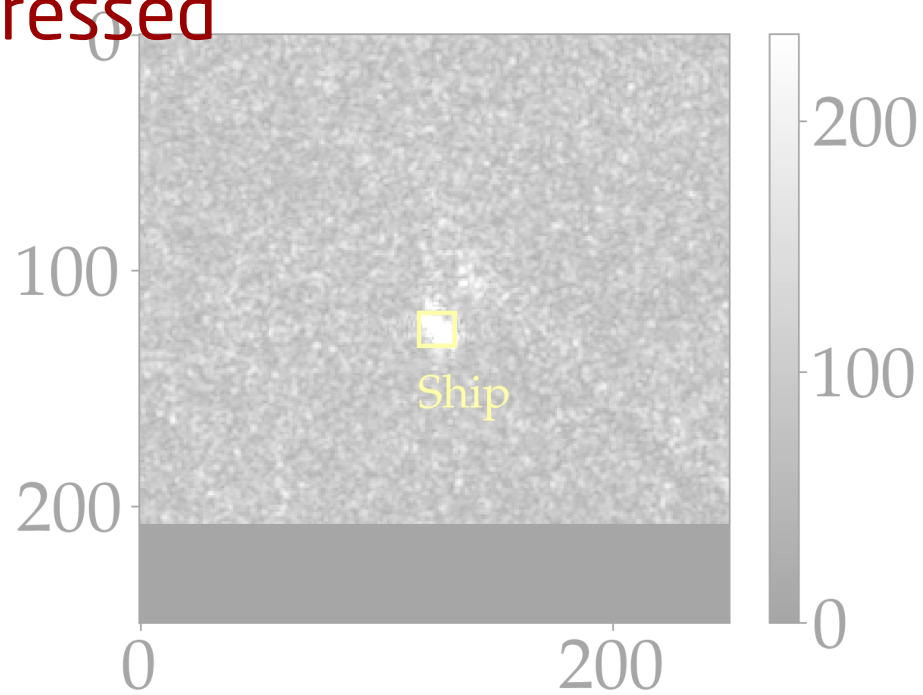

Ship

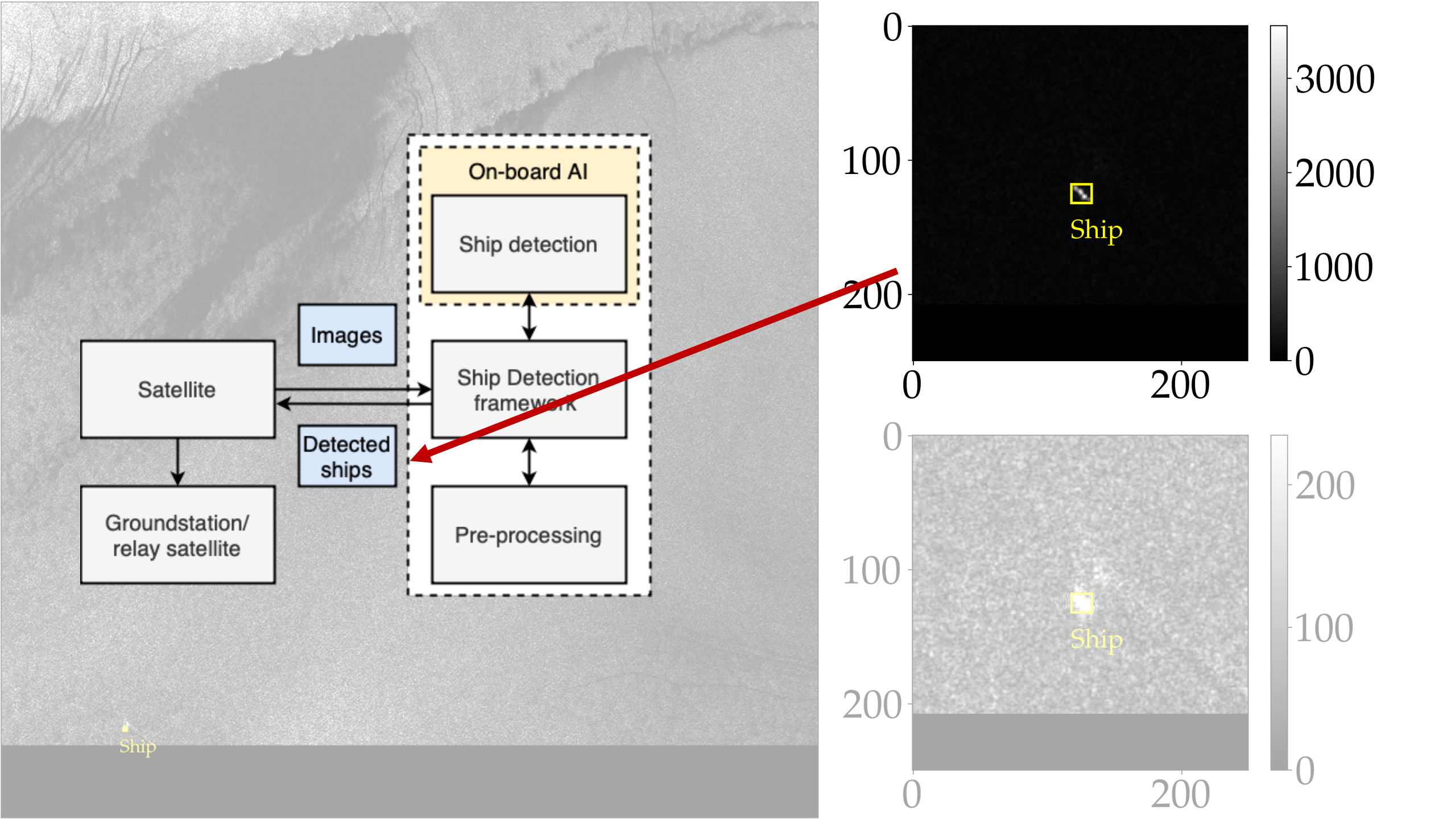

0
100
200
0
200
Ship
3000
2000
1000
0

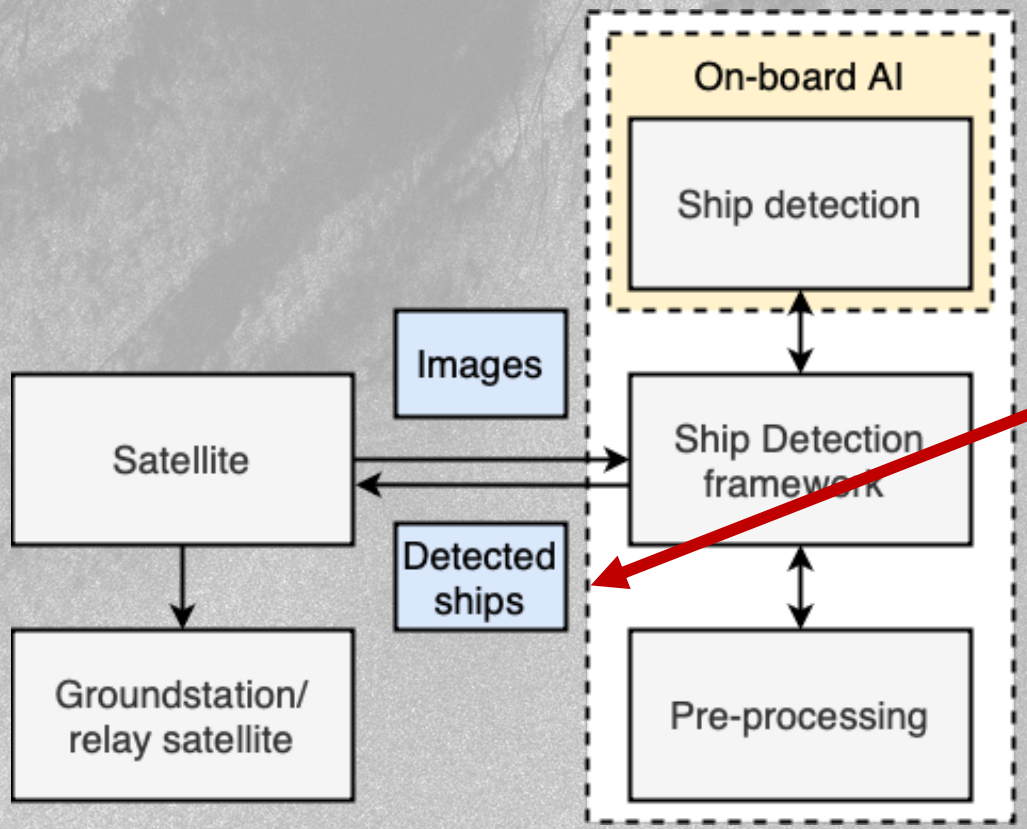

0
100
200
0
200
Ship
200
100
0

This will be downlinked/ compressed lossless

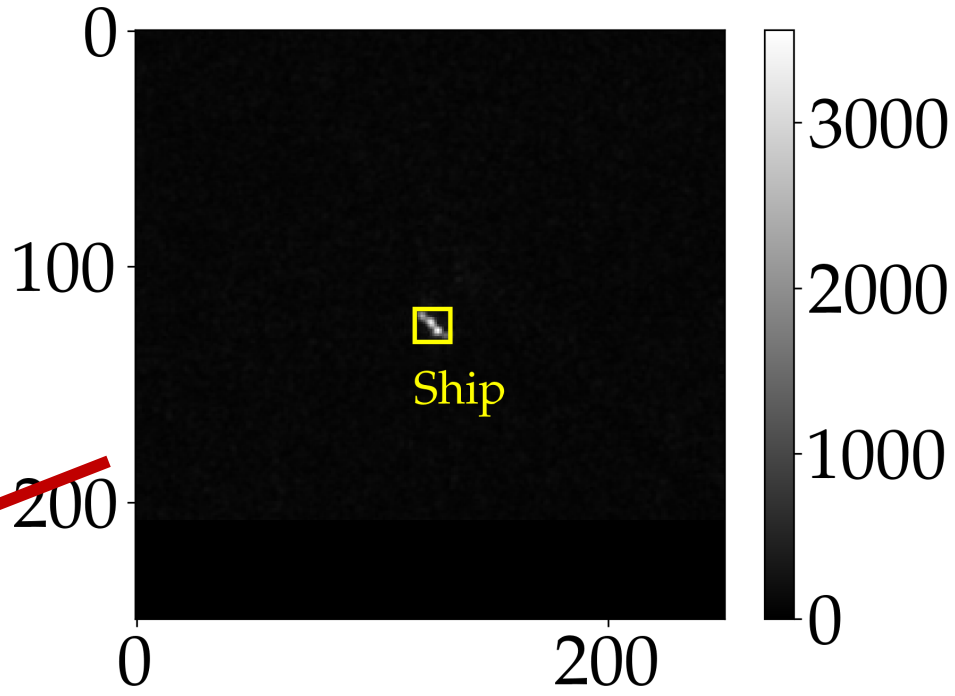


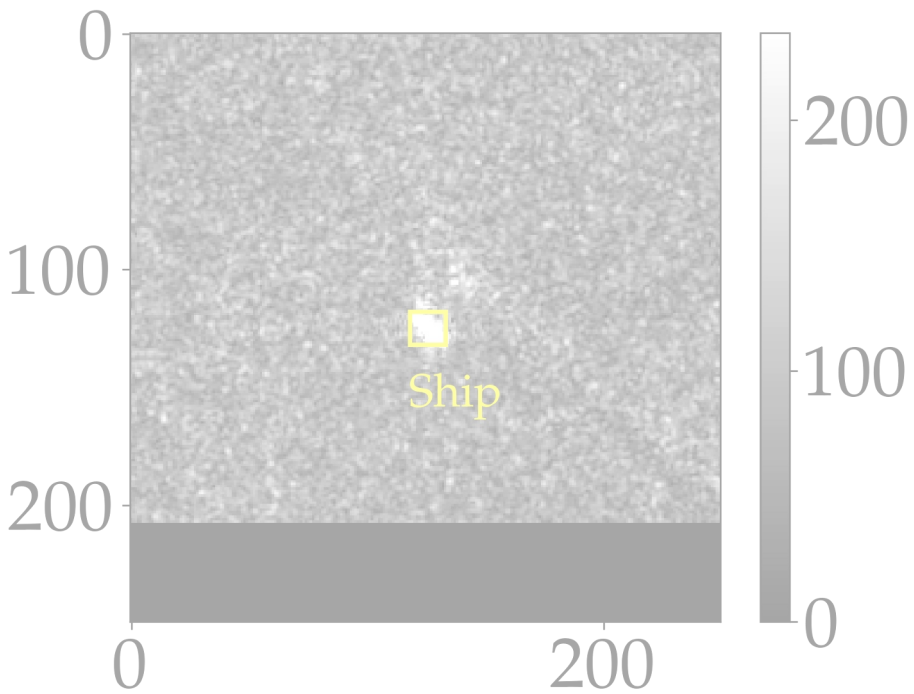



On-board AI
Ship detection
Images
Satellite
Ship Detection framework
Detected ships
Groundstation/ relay satellite
Pre-processing
Ship
0
100
200
Ship
0
200
3000
2000
1000
0
0
100
200
Ship
0
200
200
100
0



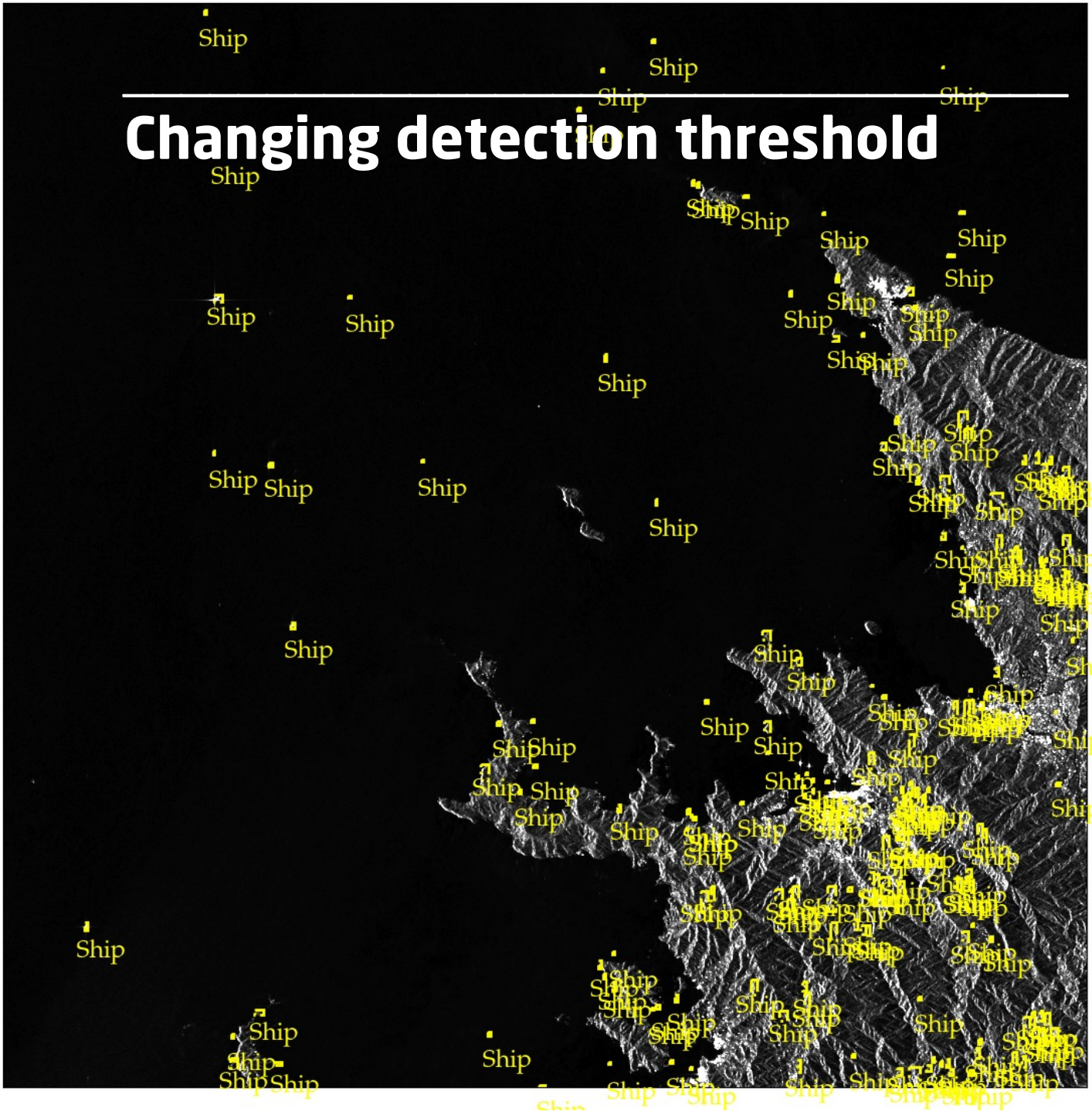
Downlink:
- Ship size, type, ID, speed, orientation ....
- Satellite metadata



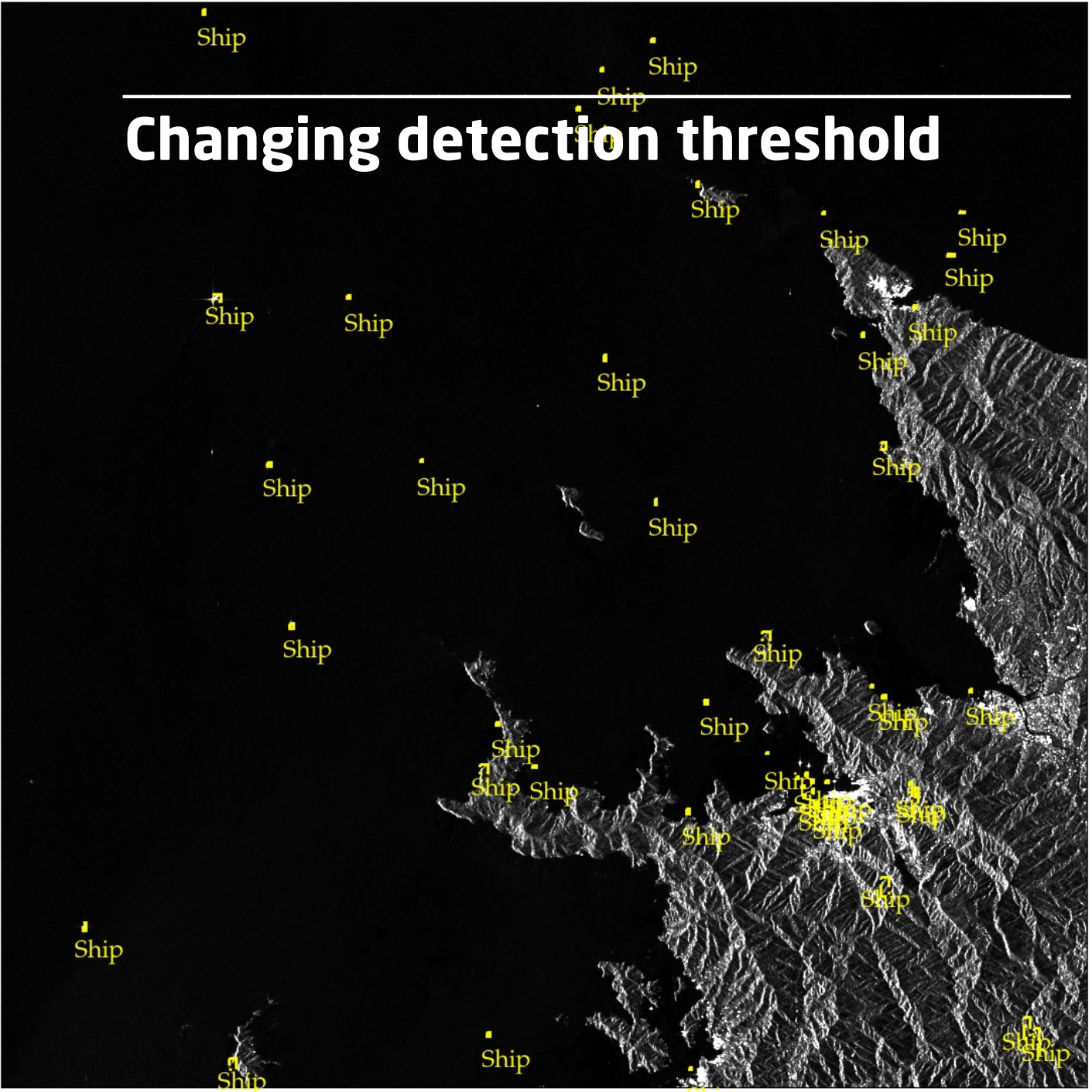


Ship

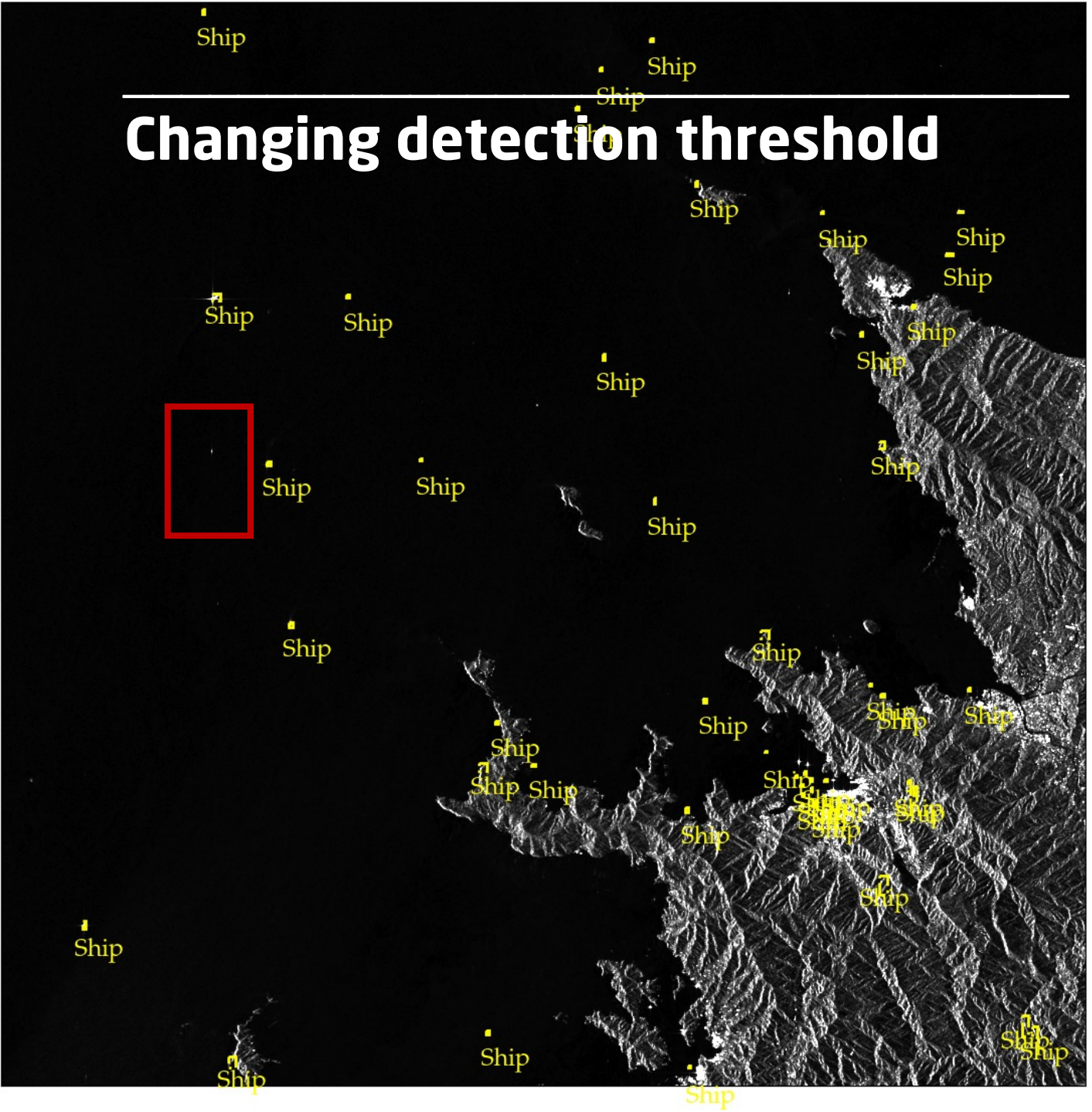
Changing detection threshold

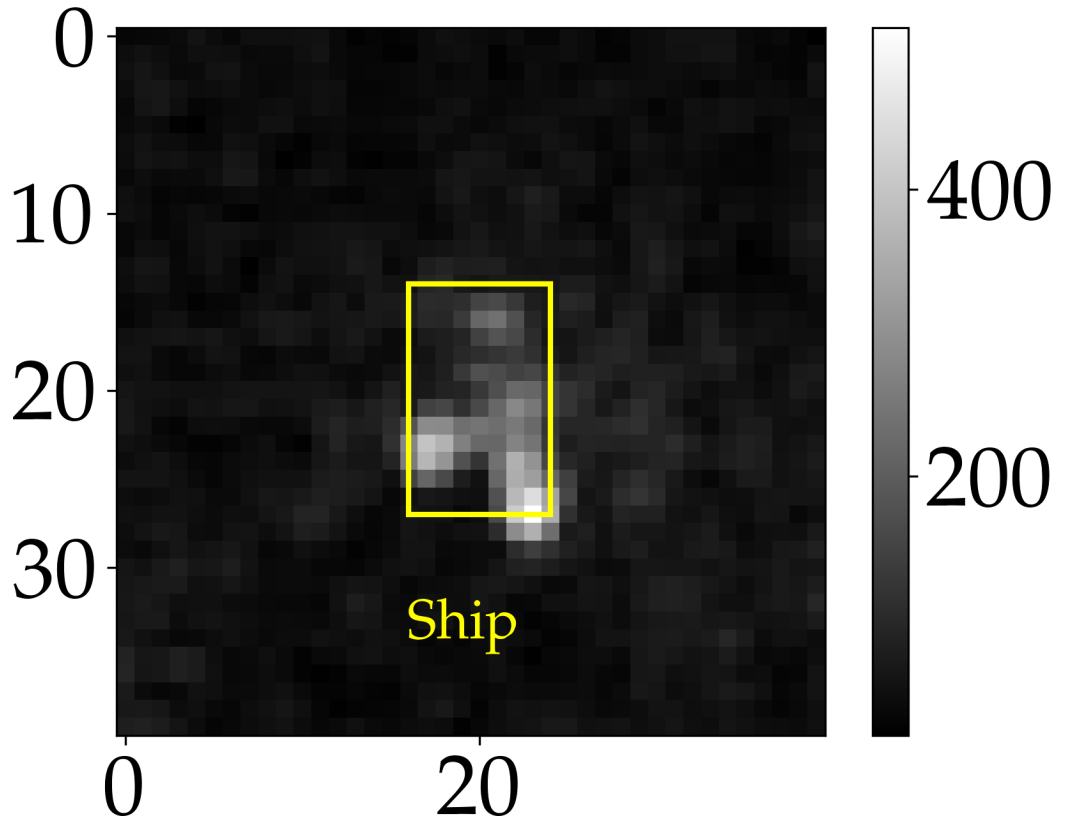


Changing detection threshold



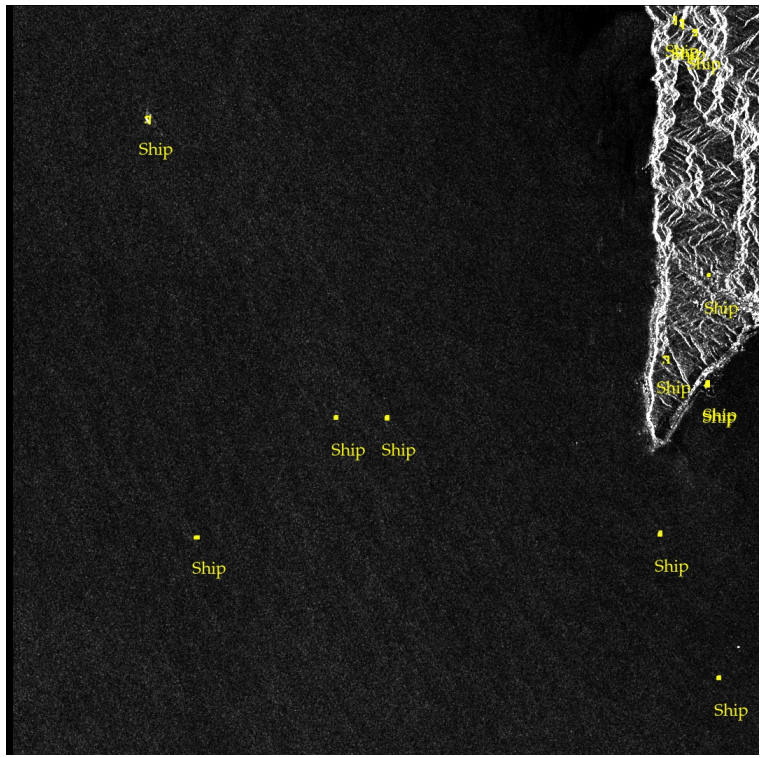
Changing detection threshold





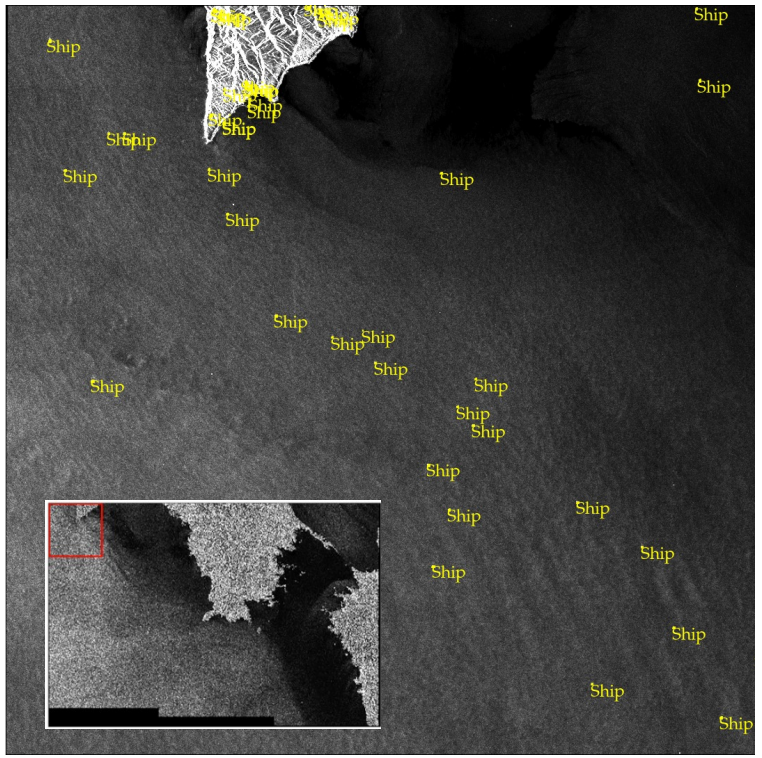
Model can detect ships in arbitrary sizes

2500x2500 pixels



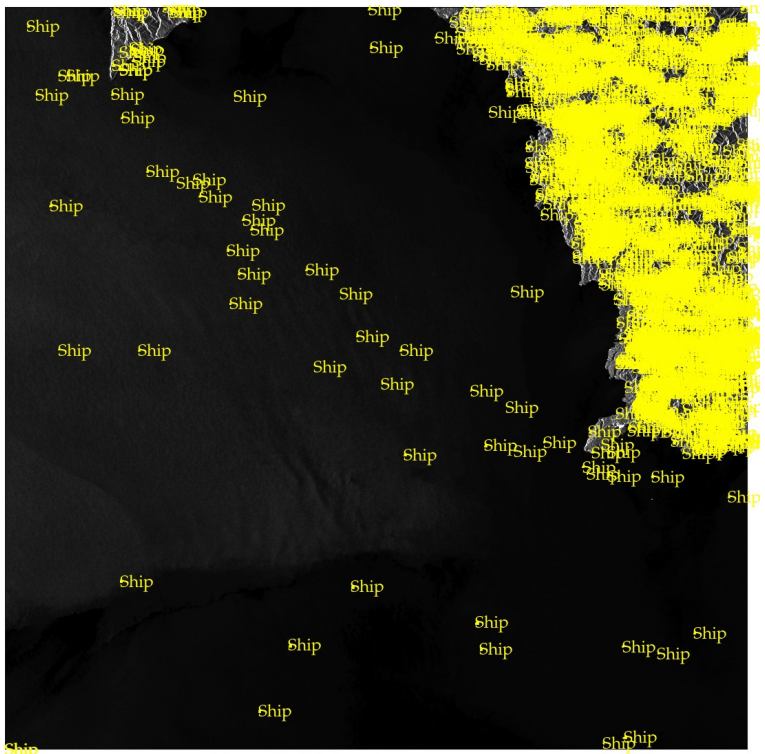
32 sec for entire image

8000x8000 pixels



27 sec for entire image

15000x15000 pixels

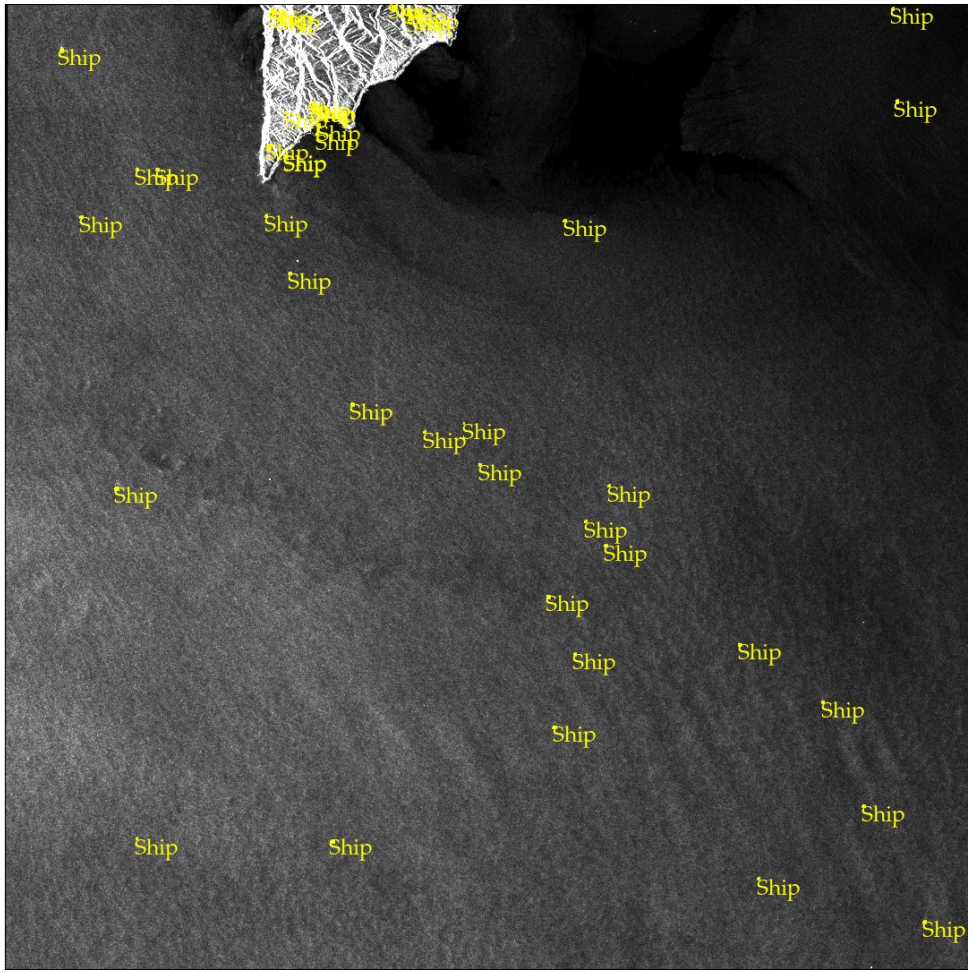


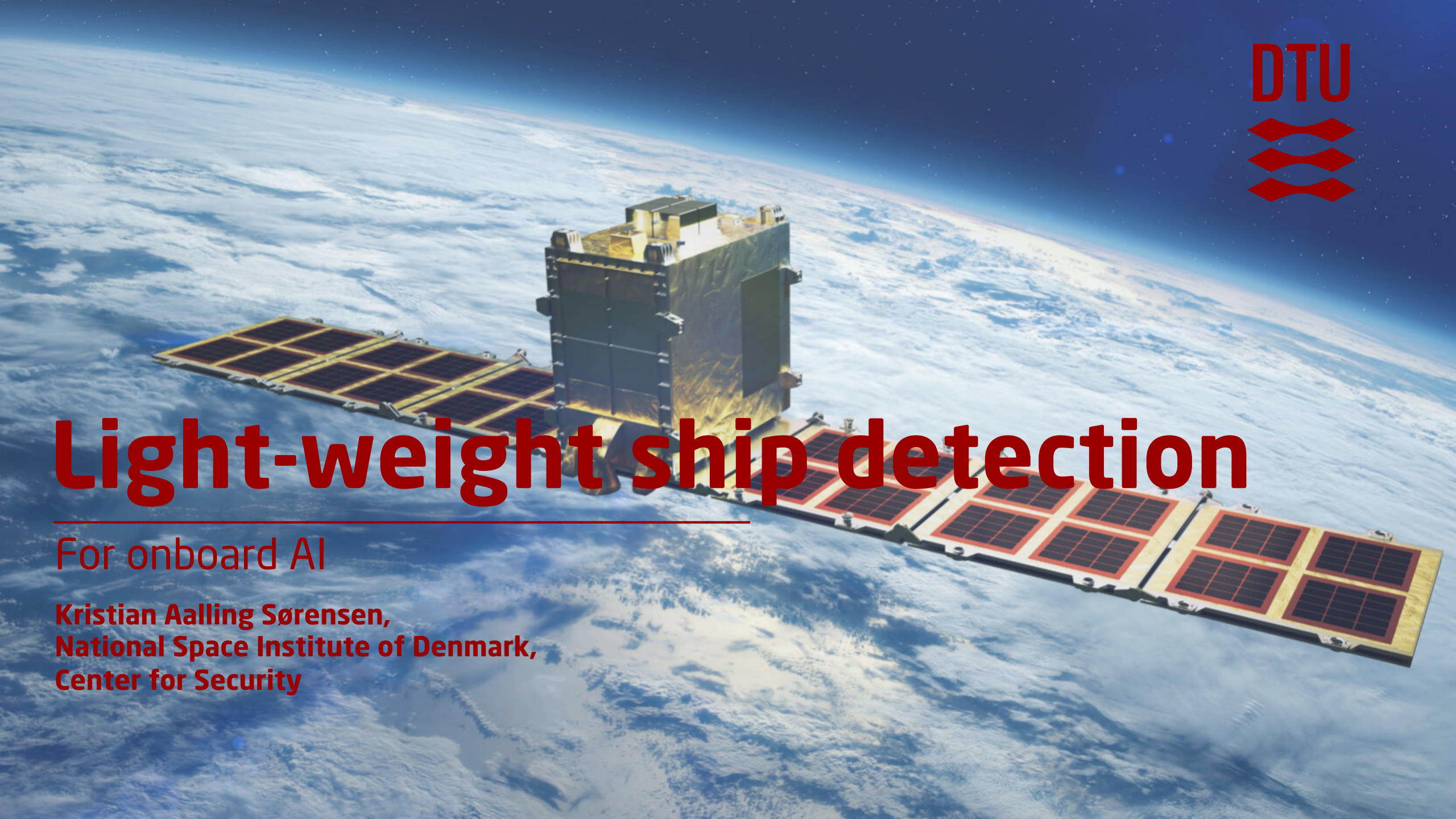
28 sec for entire image

Onboard AI framework

Considerations

1. Model should be a small as possible.
   330.000 Parameters ~800 KB
2. Model should be as efficient as possible.
3. Model should be as fast as possible.
   30 sec on my laptop
4. Model should be “good enough”. Not focus on getting the highest accuracy
   92.5 % of all ships are found
5. Image should have as little pre-processing as possible
   Detect ships in un-calibrated images





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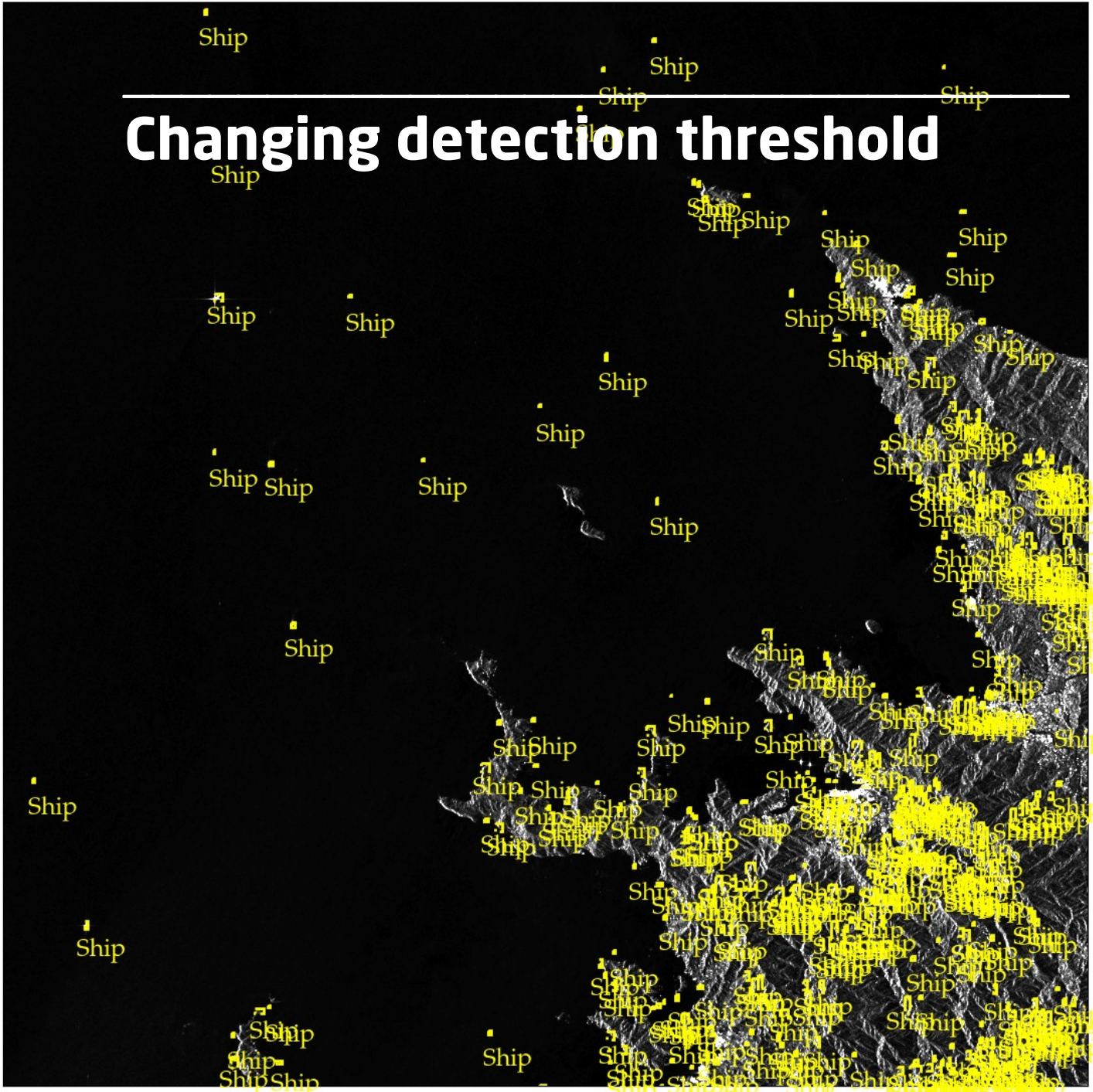
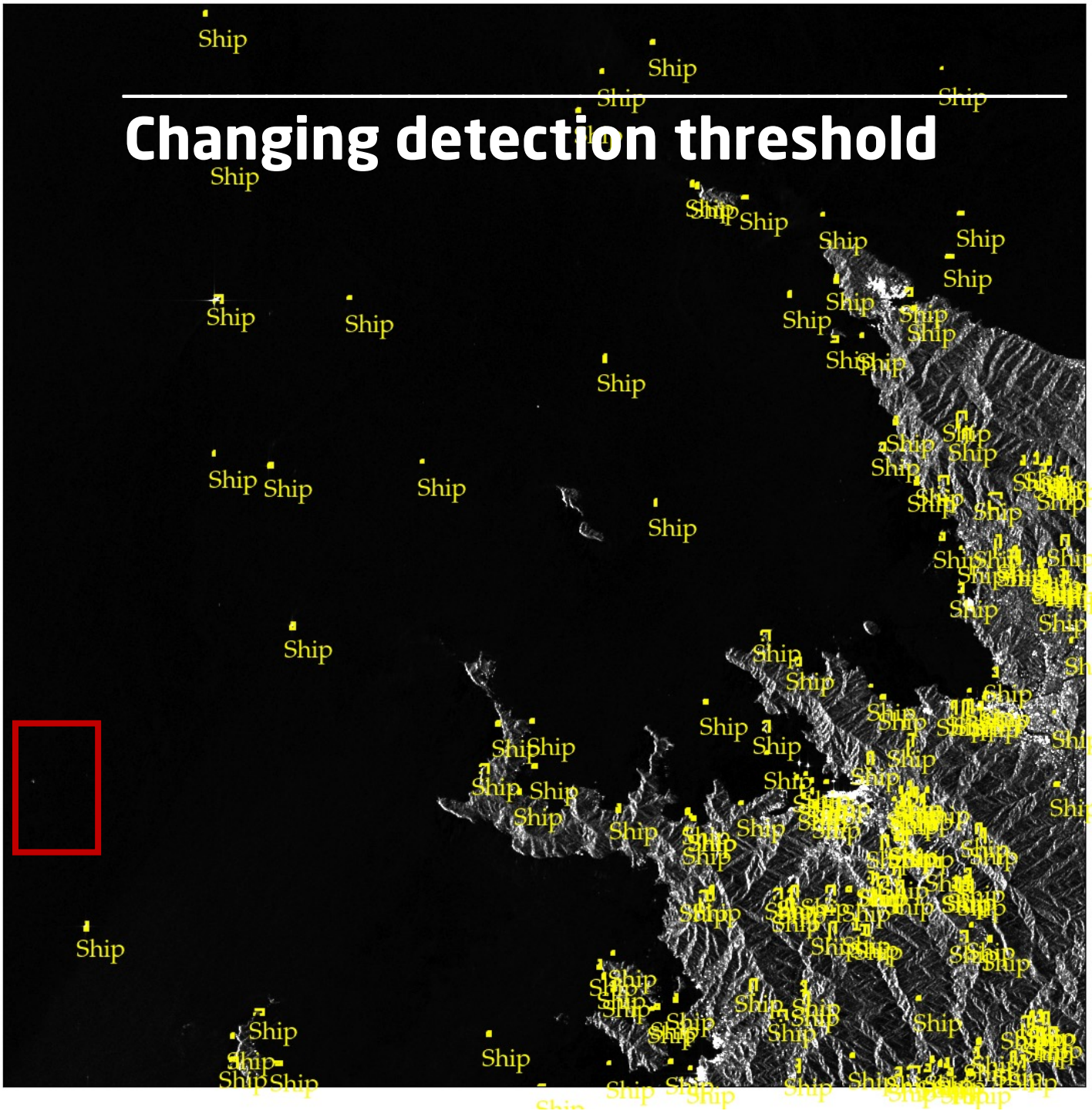
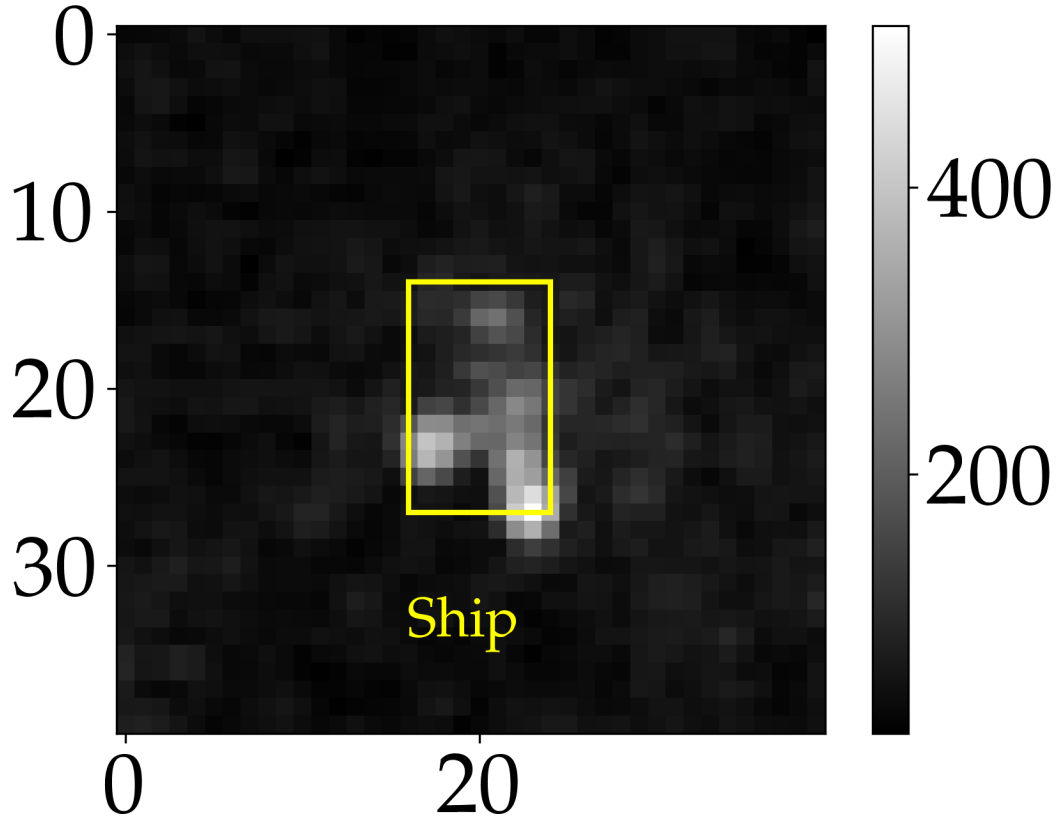
Changing detection threshold



Changing detection threshold





Changing detection threshold