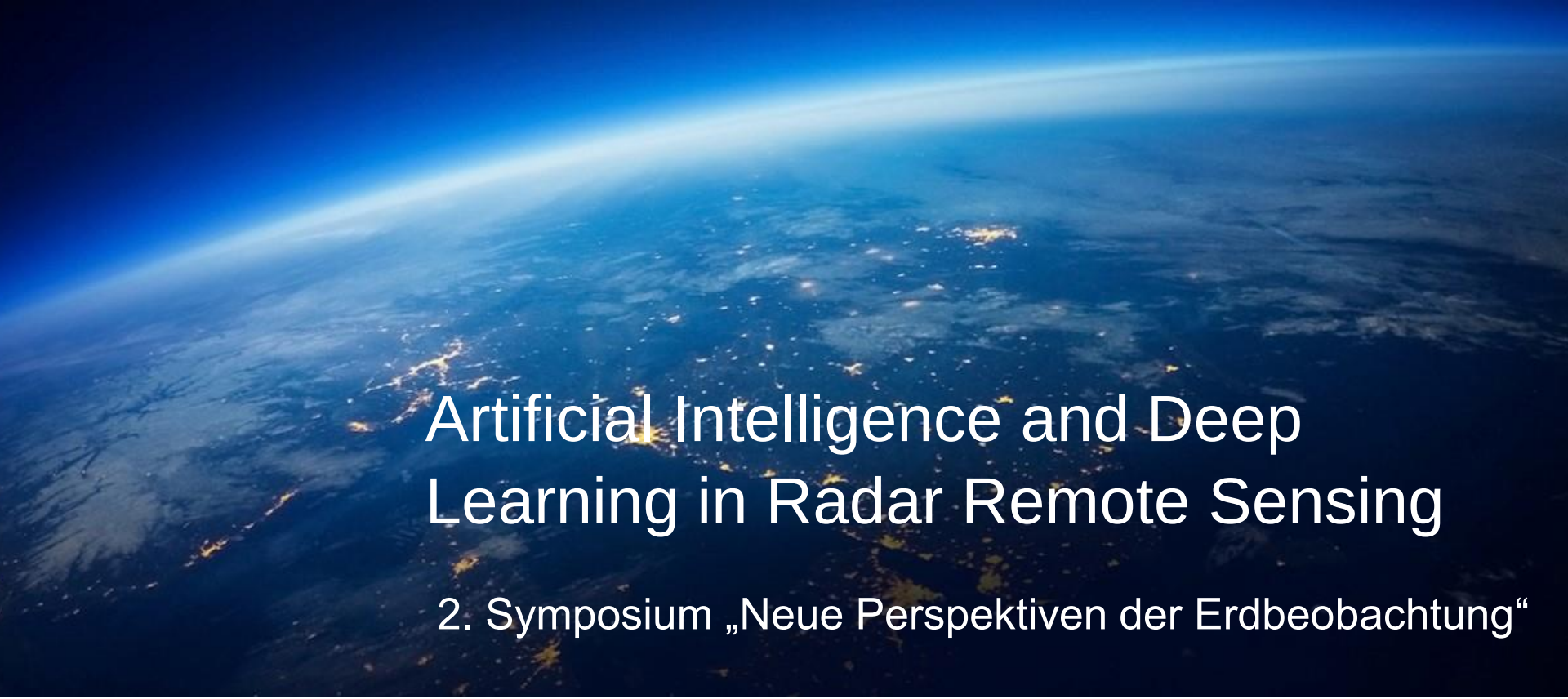

Artificial Intelligence and Deep Learning in Radar Remote Sensing

2. Symposium „Neue Perspektiven der Erdbeobachtung“

DEFENCE AND SPACE

Tatjana Bürgmann, Jürgen Janoth, Christoph Stahl,
Daniel Kalfass, Akhil Singh Rana

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Outline

1. Introduction
2. SAR to Optic Image Matching
3. SAR Image Segmentation
4. SAR Ship Detection

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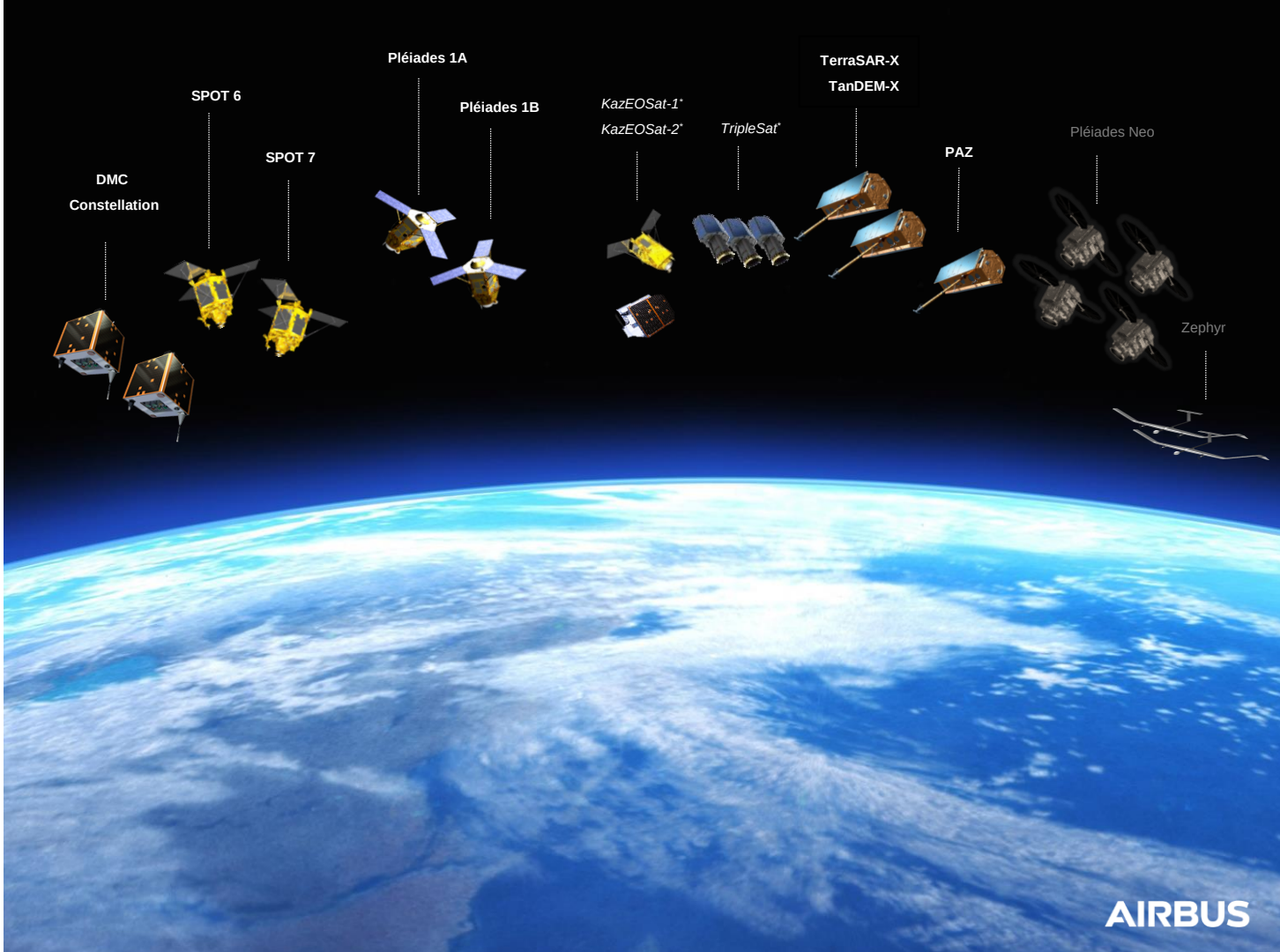
Outline

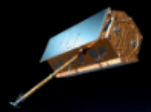
Big Data in Earth Observation



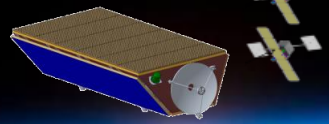
WorldSAR – Current and Future Missions

TerraSAR-X (2007)
TanDEM-X (2010)

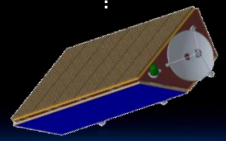
PAZ (2018)



HRWS (2025)
incl. 3 companions



Export partner



Small Sat Const. partner*

WorldSAR Constellation Operation with Hisdesat (ES)

WorldSAR Next Generation
- HRWS (1200 MHz, < 25 cm, mono- and multi-static mission incl. 3 passive companions)
- Export partner
- Small Satellite SAR Constellation

** Small Satellite SAR constellation concepts for massive revisit*

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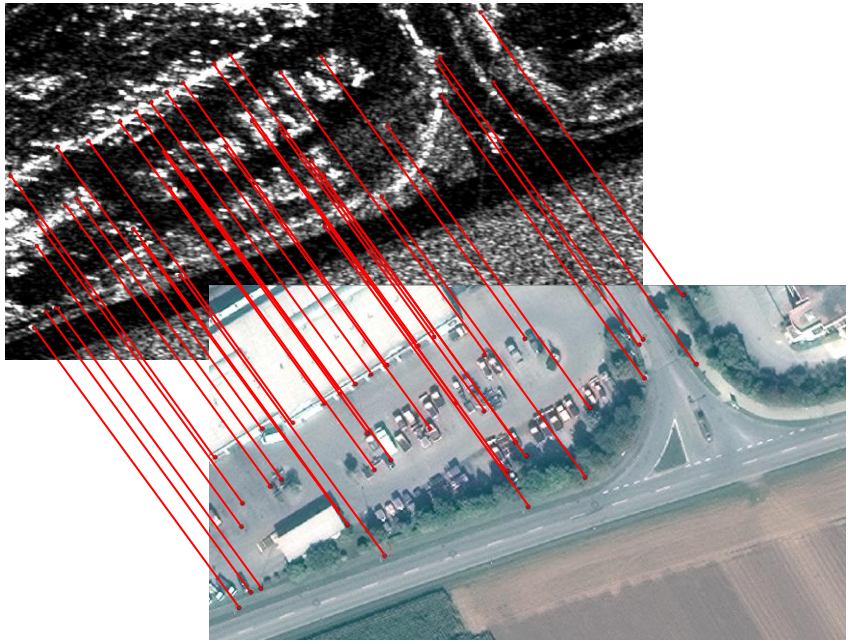
Idea

- Ground Control Points (GCPs) can be extracted from TerraSAR-X imagery with an absolute horizontal accuracy < 0.3 m

- Other sensors e.g. optical typically have a lower geolocation accuracy (e.g. Pléiades Neo < 5 m CE90 at Nadir expected[1])

- **Objective**: Identify the matching points of the GCPs in the optical image and use them to improve the geolocation accuracy of satellite images from other sensors



[1] https://www.intelligence-airbusds.com/files/pmedia/public/r51130_9_leaflet-pleiadesneov2.pdf

Data

TerraSAR-X (Radiometrically Enhanced)

Pléiades 1A/B

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Data

TerraSAR-X (Spatially Enhanced)

Pléiades 1A/B

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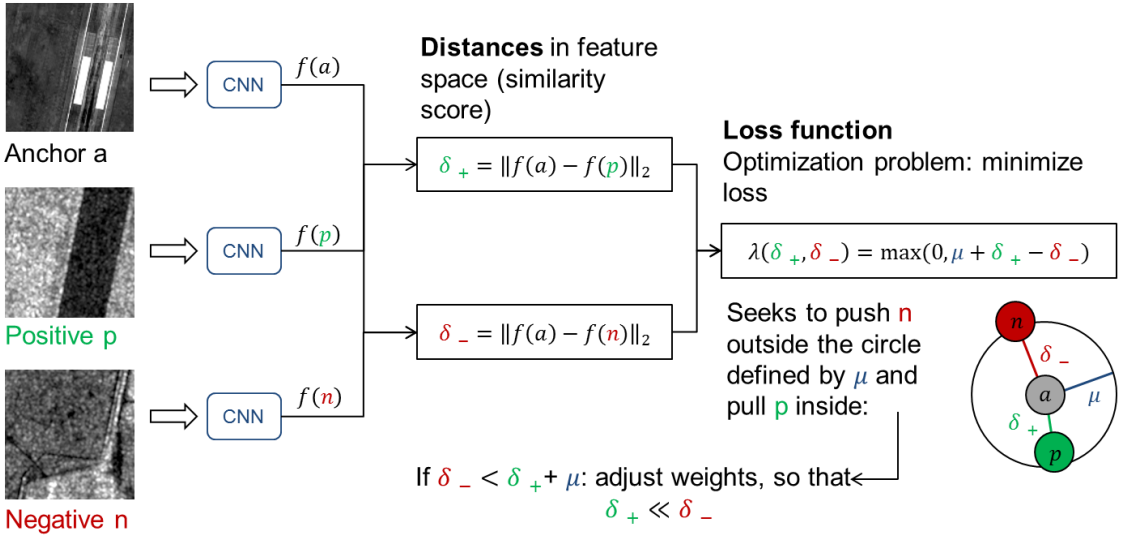
Methodology

During **training**, the network learns to discriminate between matching and non-matching patch pairs by calculating the Euclidean distance betweeen the two descriptors (similarity score)



- Distance small → matching
- Distance large → non matching

* The CNN was pre-trained on the SEN1-2 dataset (Schmitt, Hughes and Zhu, 2018)

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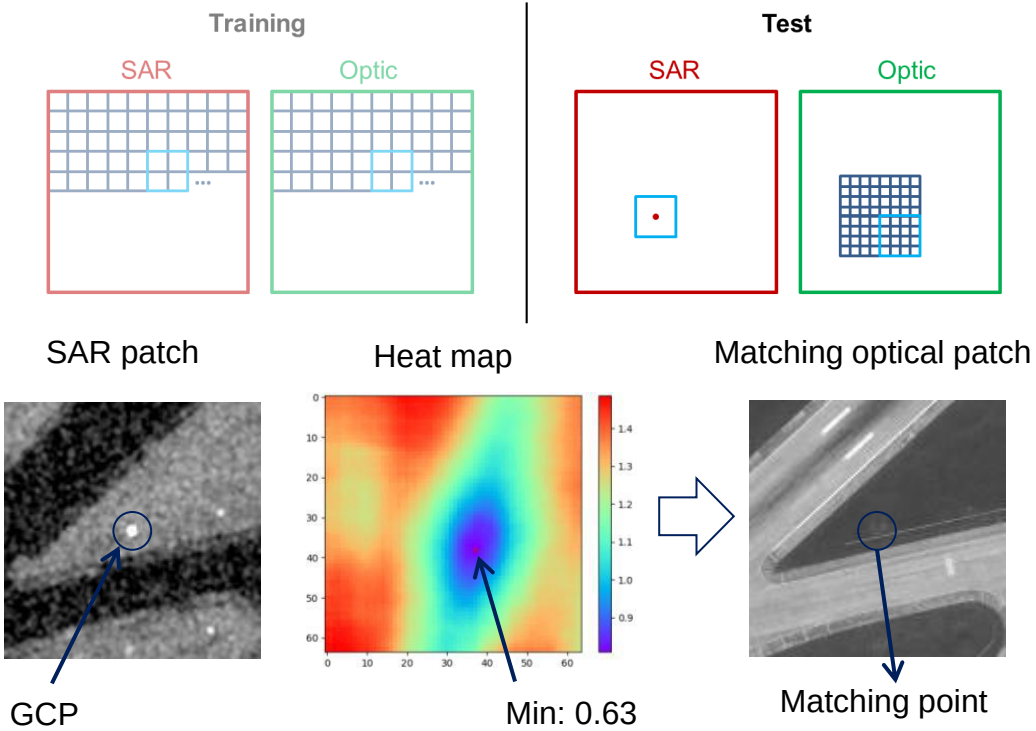
Methodology

- For **application / test**, one image patch is cropped around GCP in the SAR image and several patches within a search window in the optical image
- Descriptor distance between SAR and respective optical patch is used as similarity measure to identify the matching point in the optical image → **heat map**



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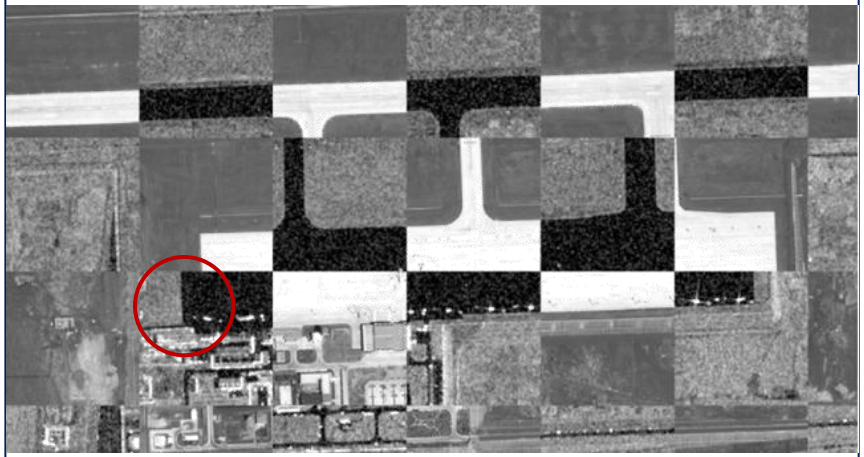
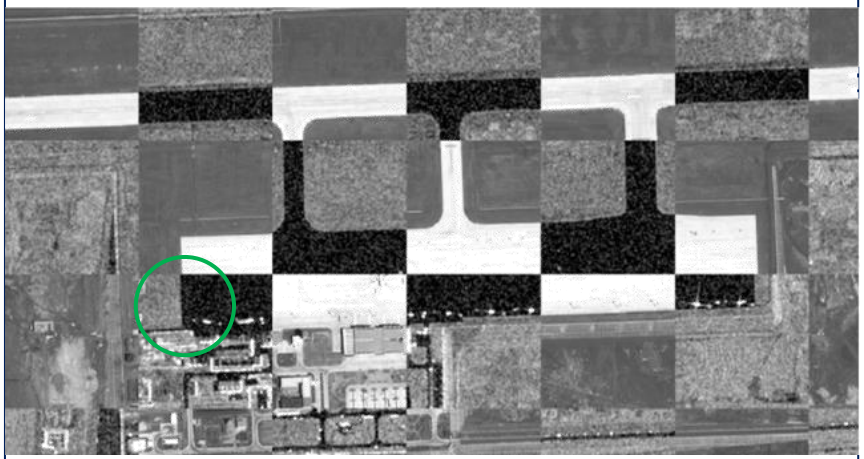
Results

Before co-registration



After co-registration



Bürgmann, T., Koppe, W., & Schmitt, M. (2019). **Matching of TerraSAR-X derived ground control points to optical image patches using deep learning**. *ISPRS Journal of Photogrammetry and Remote Sensing*, *158*, 241-248.

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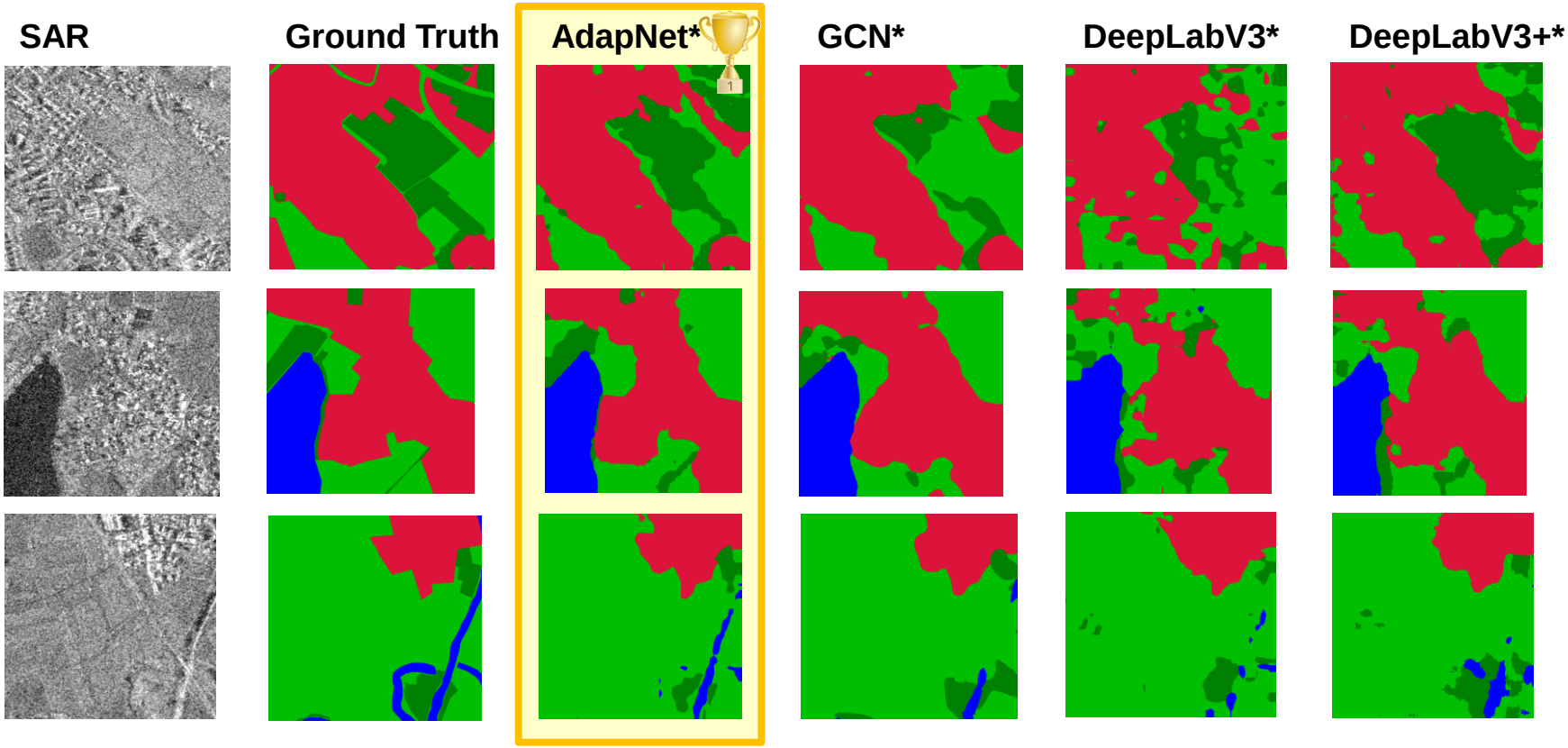
Validation results of different architectures



* source: https://github.com/GeorgeSeif/Semantic-Segmentation-Suite

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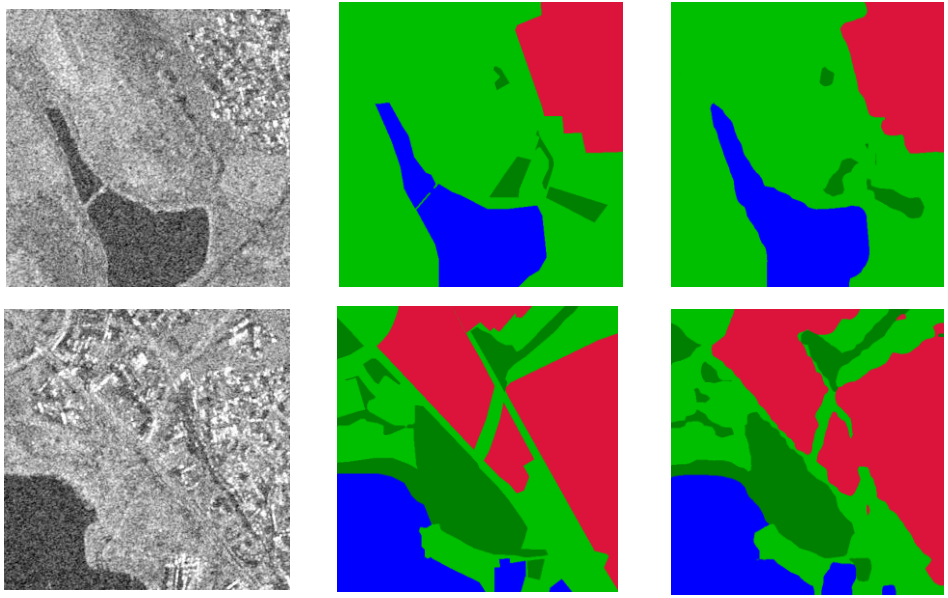
Test results of AdapNet

Results of testing the network on another SAR image of the lake of Constance area:

Average Test Accuracy	97.71 %
Average Precision	97.90 %
Average Recall	97.71 %
Average F1 score	97.74 %
Average mean IoU	88.76 %

SAR **Ground Truth** **Prediction**



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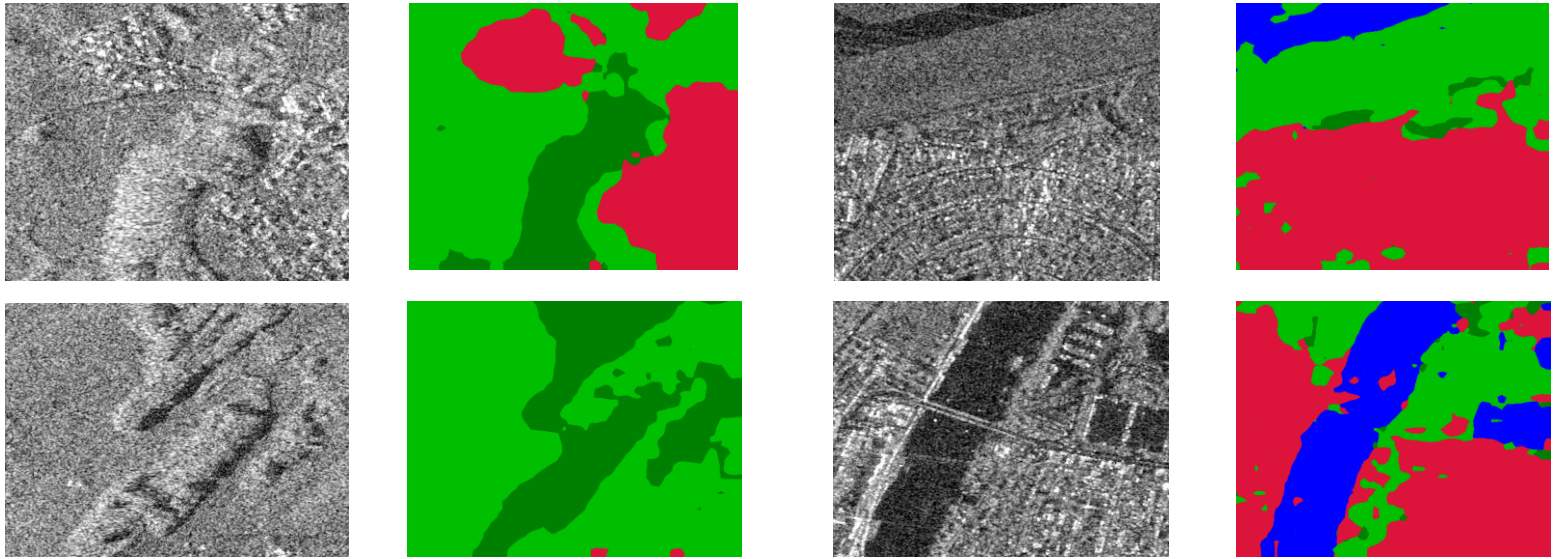
Test results of AdapNet

Results of testing the network on two separate regions (left: Wangen/Allgäu, right: Paris)

SAR **Prediction** **SAR** **Prediction**



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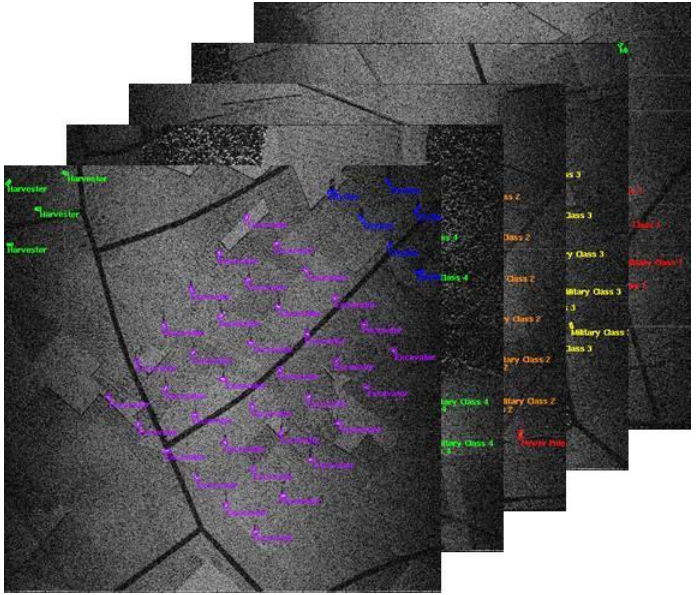
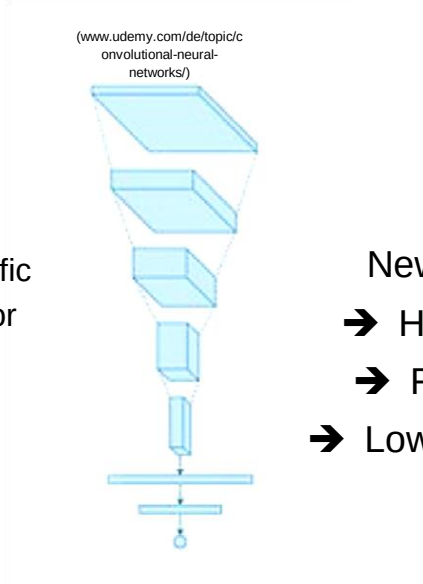
Adaptation of CeMore Deep for SAR → CeMore Deep SAR

SAR Training Images



Training of SAR specific CNN feature extractor



New CNN Architecture

- ➔ High spatial resolution
- ➔ Fast processing time
- ➔ Low memory consumption

"Deep Learning Features"

+

"High Speed Support Vector Machine"

CeMore Deep SAR

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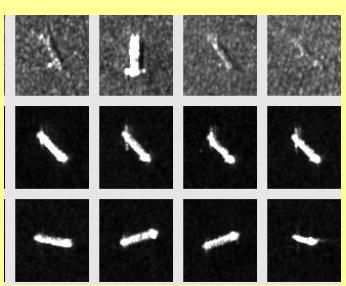
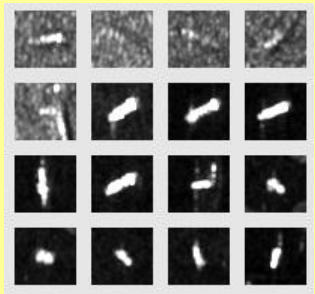
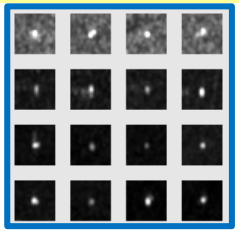
Relevant Object Classes for Maritime ATR

- Merchant ships (Cargo / Tanker / Bulk carrier / LNG / ...): large, small
- Passenger vessels (Cruiser, Ocean Liner, Ferries,...)
- Boats (pleasure crafts, fishing vessels, sail boats,…)
- Buoys
- Ambiguities
- Wakes
- Flares
- Icebergs
- Wind parks
- Off-shore and floating platforms (oil rigs, digging/dredging vessels,…)







Up to now no objects available in existing images

Hints for ships → not relevant in case of excellent ship classifier

Ground truth required, discrimination doubtful for low resolution

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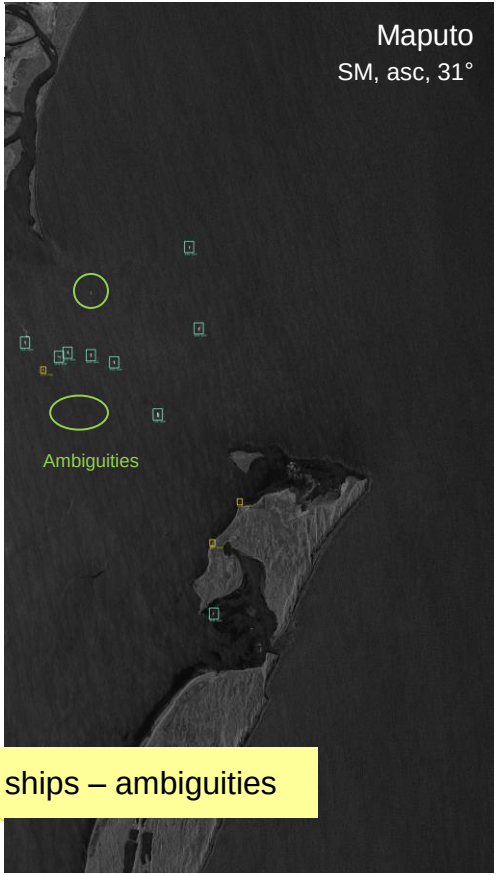
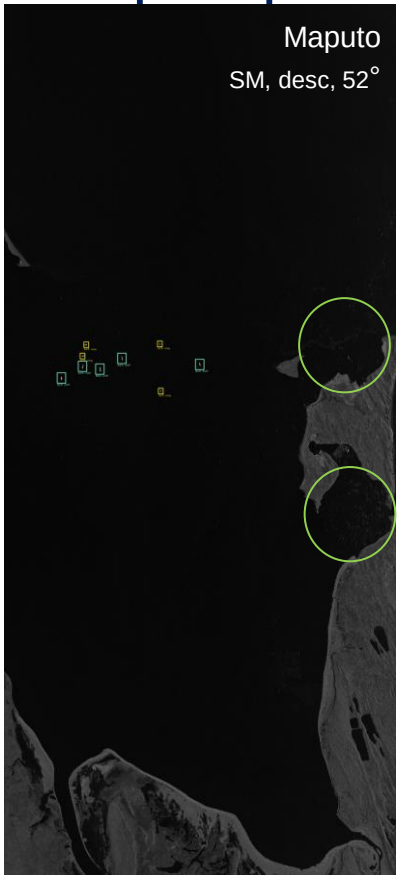
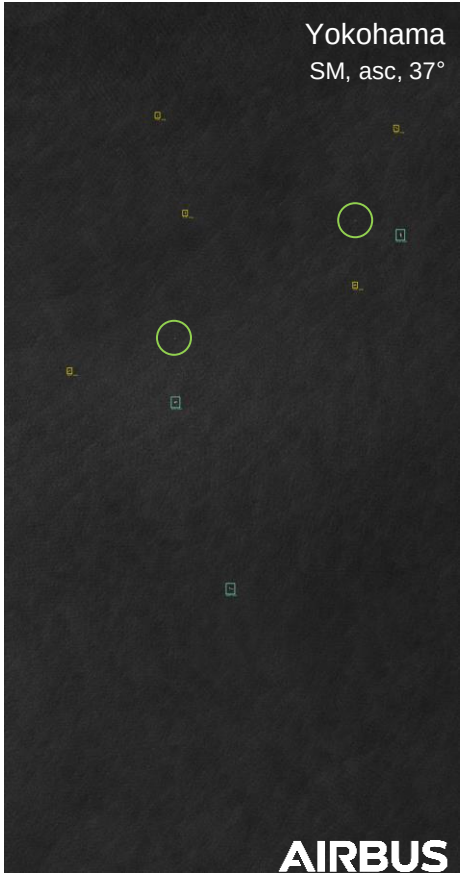
ATR Performance Results for Stripmap Mode

Class 29: Merchant Vessel large
Class 210: Merchant Vessel small

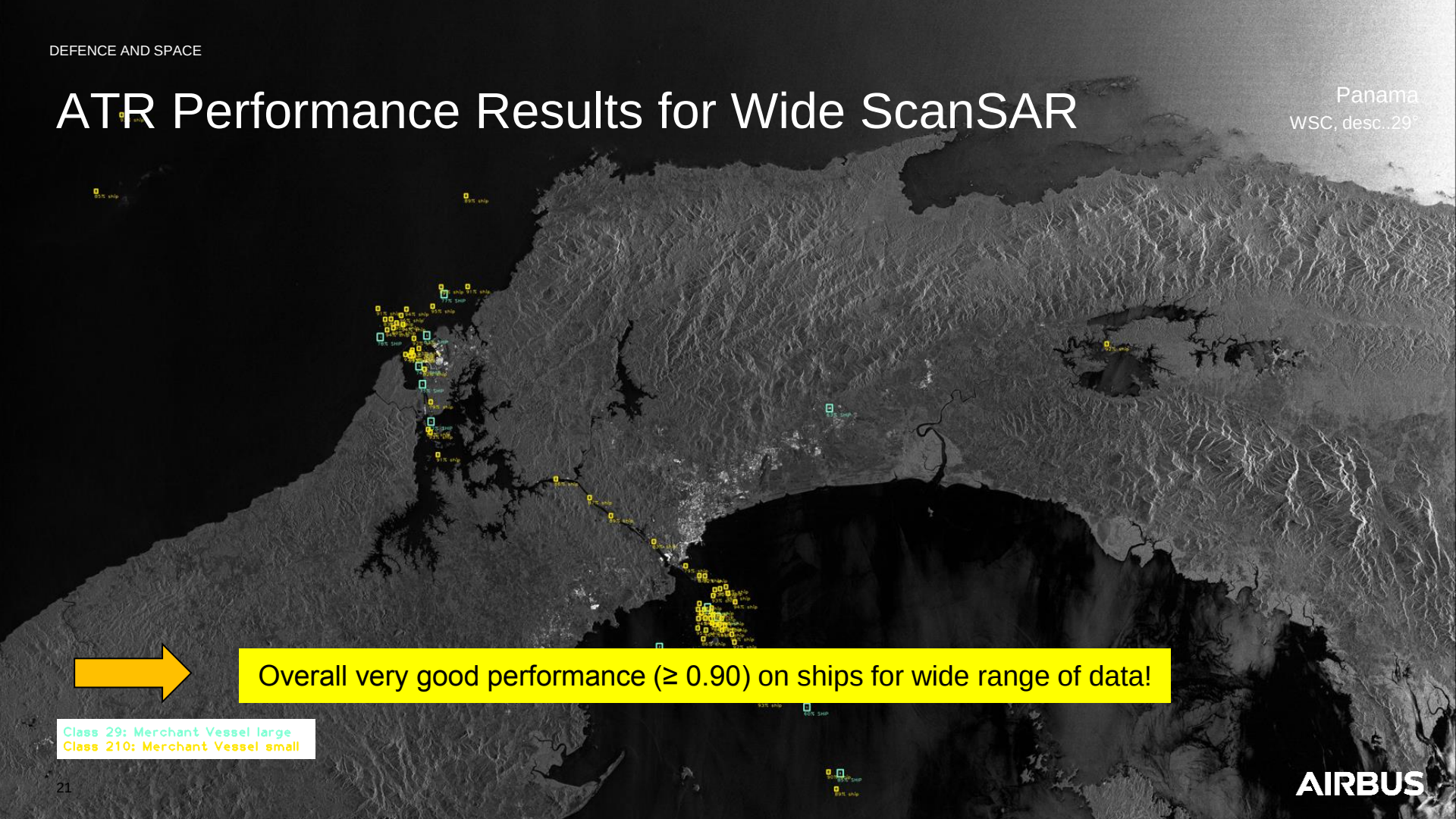






Separation ships – ambiguities

ATR Performance Results for Wide ScanSAR



Overall very good performance (≥ 0.90) on ships for wide range of data!

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Thank you

Point of Contact

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