R-SYS
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FMCW Radar Data Processing

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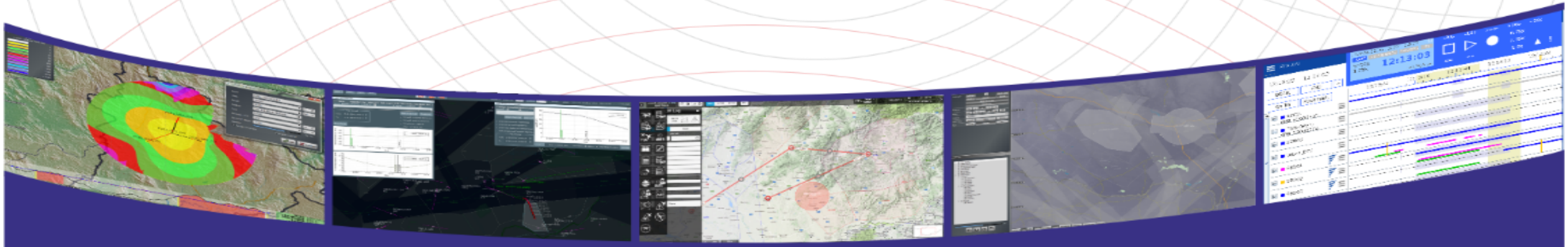
TCC 2023



Heritage of proven innovation

Contents

- FMCW radar intro
- Motivations
- RDP improvements utilizing Machine Learning algorithms
- Challenges and the next steps

Company Profile

1997

R-SYS, s.r.o. (Ltd.) was founded by a group of experts involved in Command & Control

2007

In September 2007 the General Assembly of the Company took a decision to change the company branding, corporate structure and business strategy to follow new trends and flexibly respond to market requirements by deliveries of competitive software & hardware solutions, and system integration services.

2016

R-SYS, s.r.o. was acquired by ERA a.s., Czech Republic, making ERA a majority owner of R-SYS. By entering the strategic alliance with ERA, R-SYS refocused its business primarily on the development of SW solutions as a support of ERA product portfolio, and other in-house innovations for the customers worldwide.

Today

Today, R-SYS represents a middle-sized project-oriented IT company employing 50 highly skilled IT engineers and ATC/ATM specialists. The company is organized as a distributed team spreading across multiple locations in Slovak Republic.

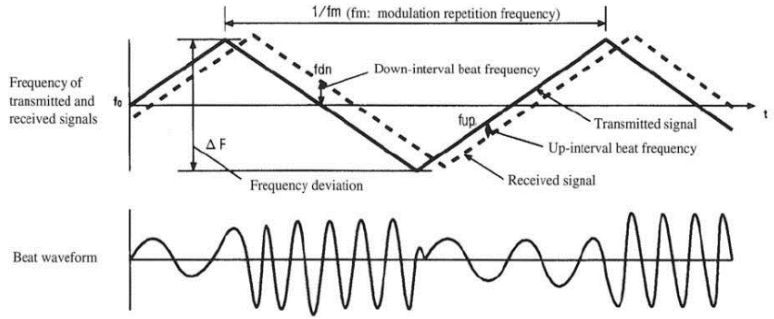
- Private company (wholly owned by ERA)
- Registered office Trenčín (distributed team within Slovakia)
- Middle-sized (50+ employees)
- Annual turnover around 3M EUR
- Certified - Quality Management System of EN ISO 9001 and Environmental Management System of EN ISO 14001 (since 2013), and Information Security Management System of EN ISO 27001 (sir

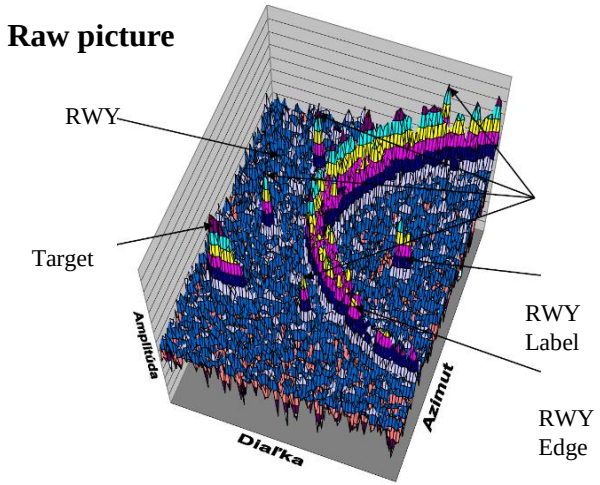
50+ **4** **SVK**

FMCW Radar Application

FMCW EHF radar operational band 76-77,5 GHz

- Application: Cost effective solution for non-cooperative targets detection
  - Main or supplementary source of ground surveillance data
- Radar parameters:
  - Resolution: 15-50cm
  - 4096 sweeps, next gen 5600 sweeps
  - Scalable range, up to 3 km
  - Update rate of 1 sec





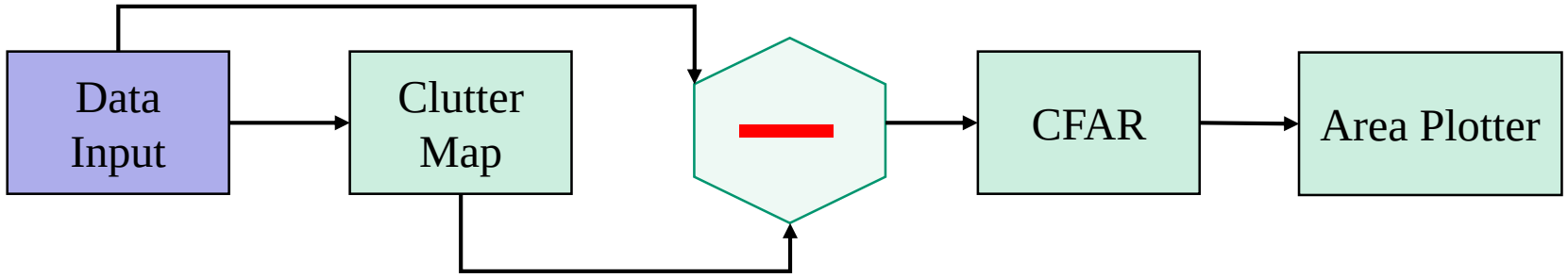
- The output of FFT for each individual sweep represents input data to RDP processing chain

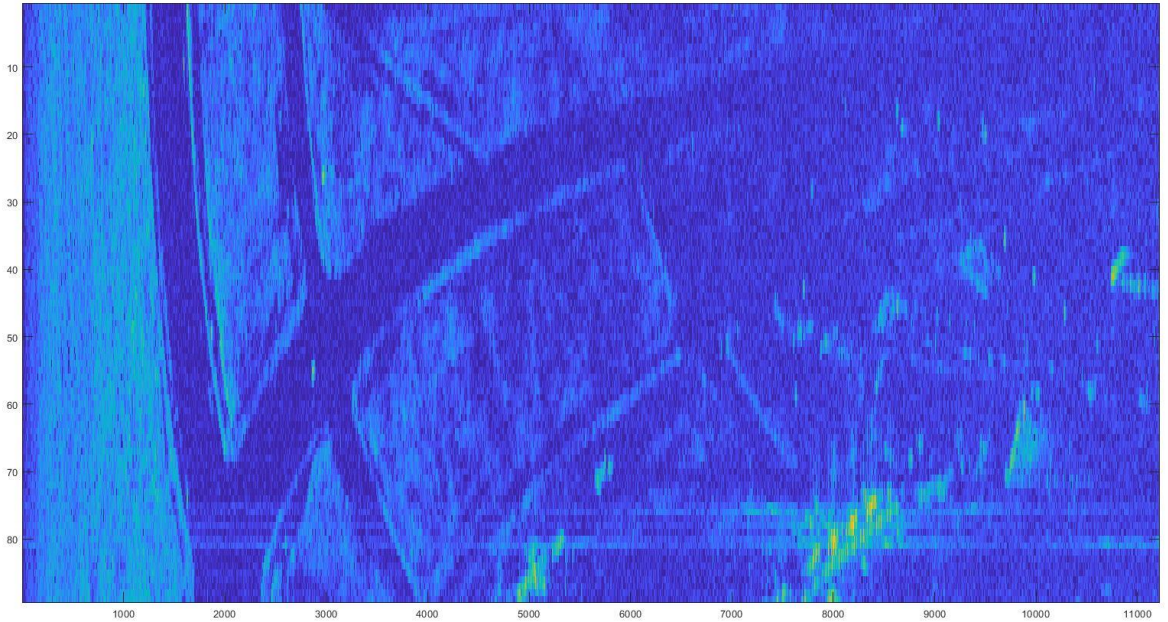
Motivations

Main motivations:

- Improve computation time of existing algorithms (based on sliding windows)
  - System shall process approx. 12500 x 5600 cells per second
- Improve the precission of object centroid calculation
- Improve the resolution capability in case of mutually proximate objects

Original Processing Chain





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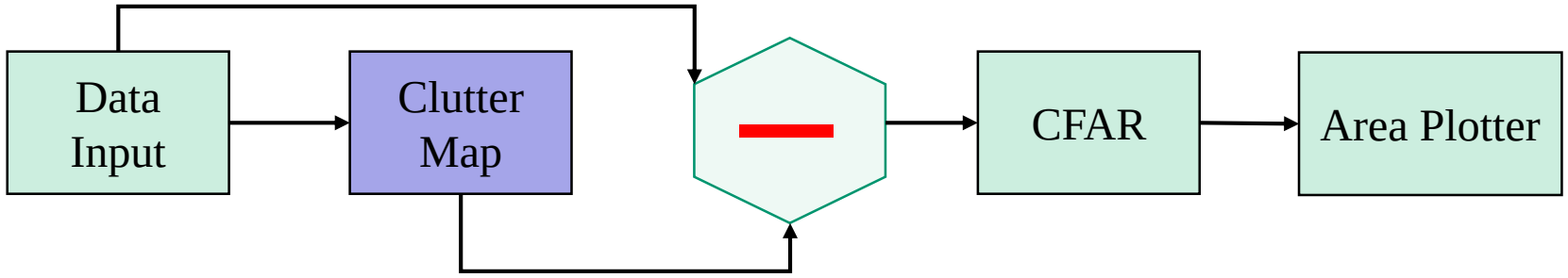

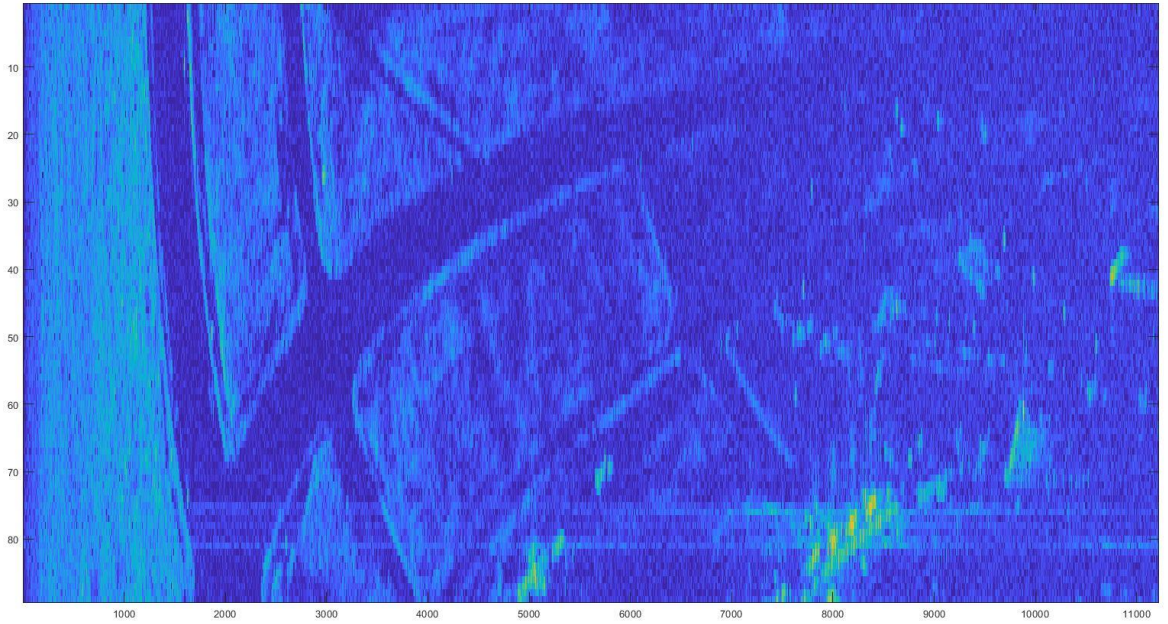

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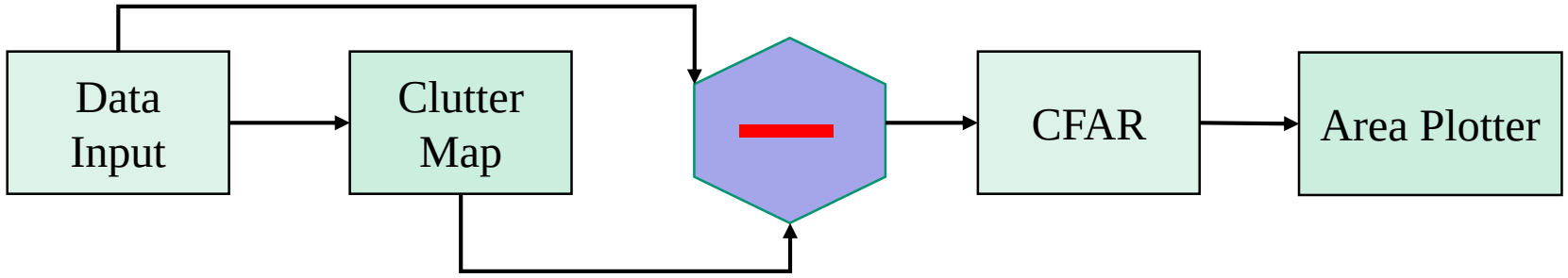

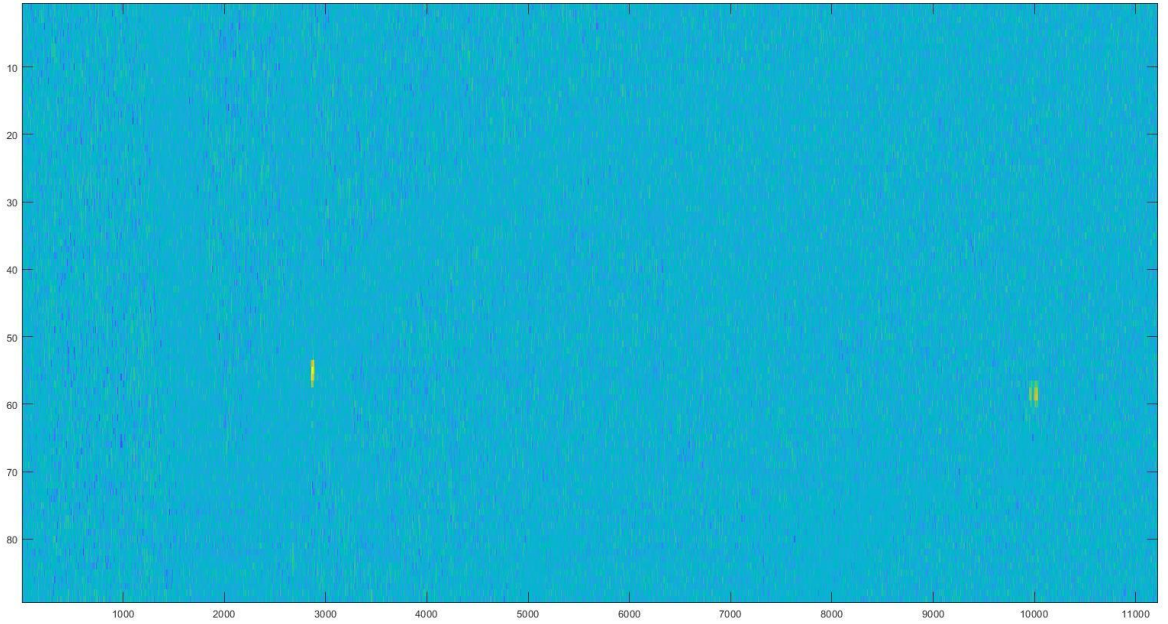

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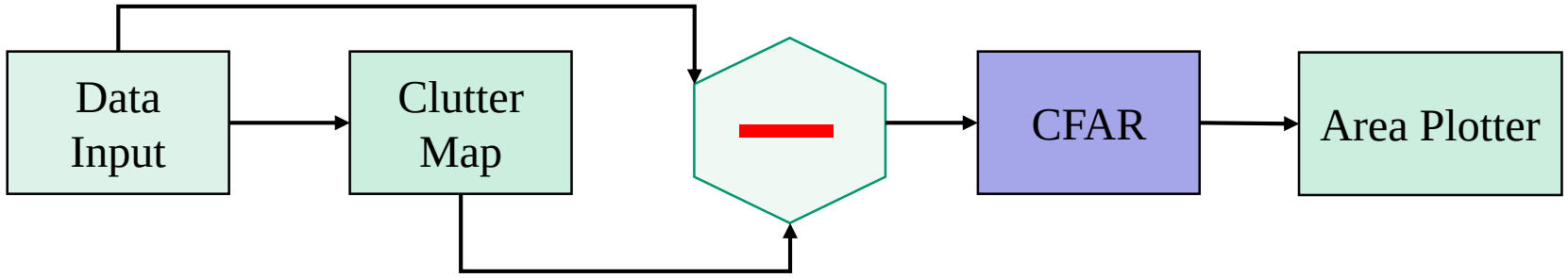

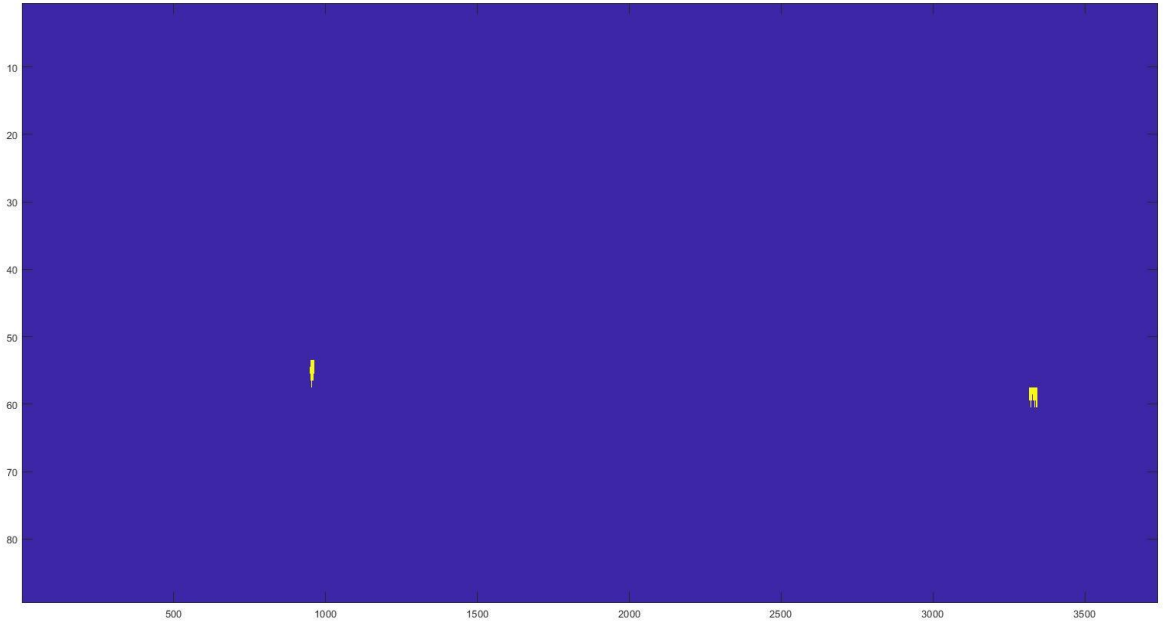

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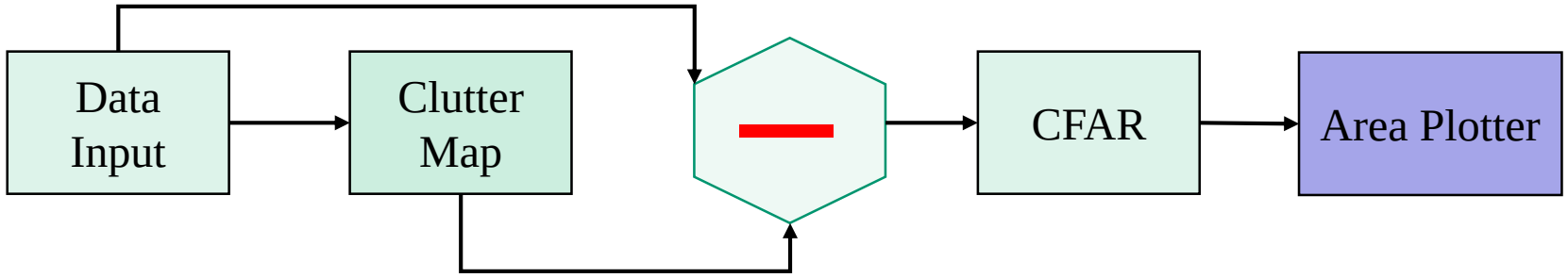
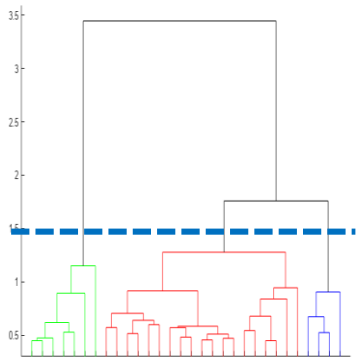
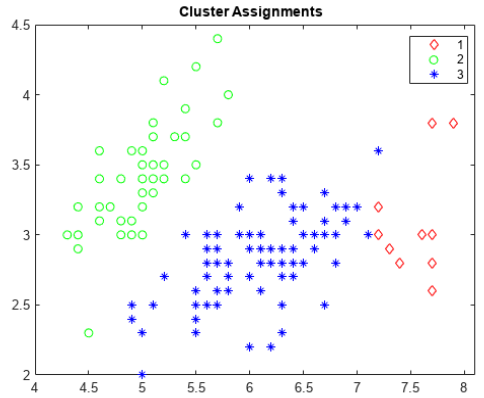


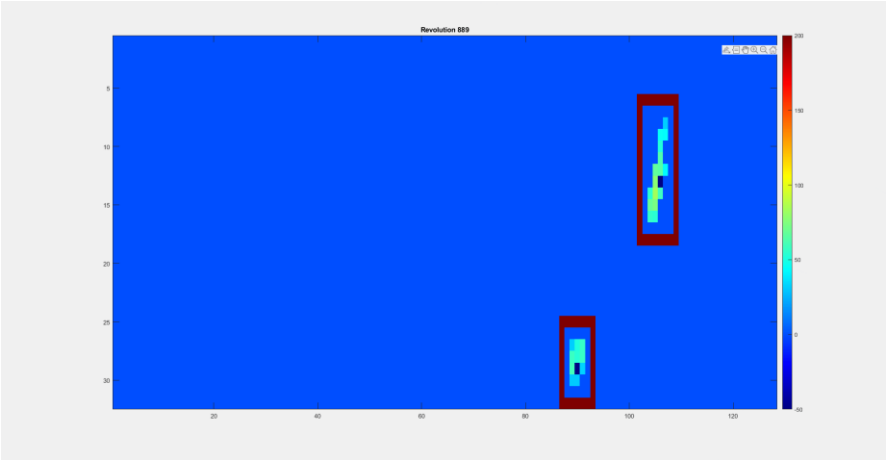
Area Plotter

Hierarchical Clustering

- Hierarchical clustering groups data over a variety of scales by creating a cluster tree
- Best used when the number of clusters is unknown
  - Pre-requirement for our application: polar to Cartesian coordinates transformation



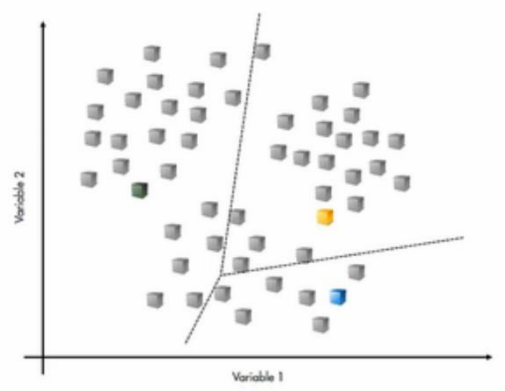


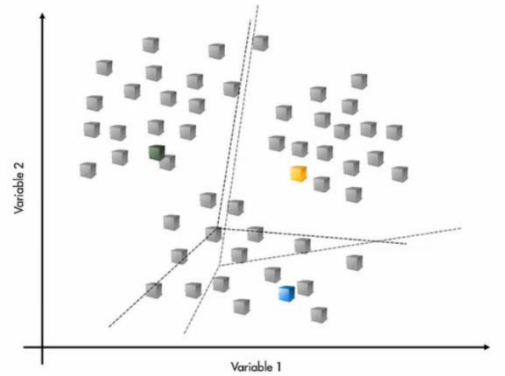


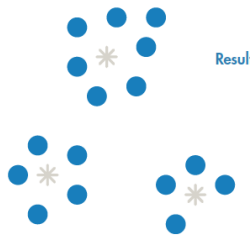
Adaptive Threshold Detector

Replacement of traditional CFAR detector

- Utilizing k-means clustering:
  - Partinioning data into k number of mutually exclusive clusters. How well a point fits into a cluster is determined by the distance to the cluster's center
  - Iterative approach - repeats until centers converge to fixed location
  - Best used for fast clustering of large data sets
- In our case, 2 clusters are determined by amplitudes of „target“ and noise
  - Processing each sweep individually (1D data)
  - Identification of „regions“ with potential targets (based on statistical properties of the signal)
  - Adaptive threshold incl. k-means clustering
  - Handling special cases







Clutter Map – Integration

only 1 fixed integrator

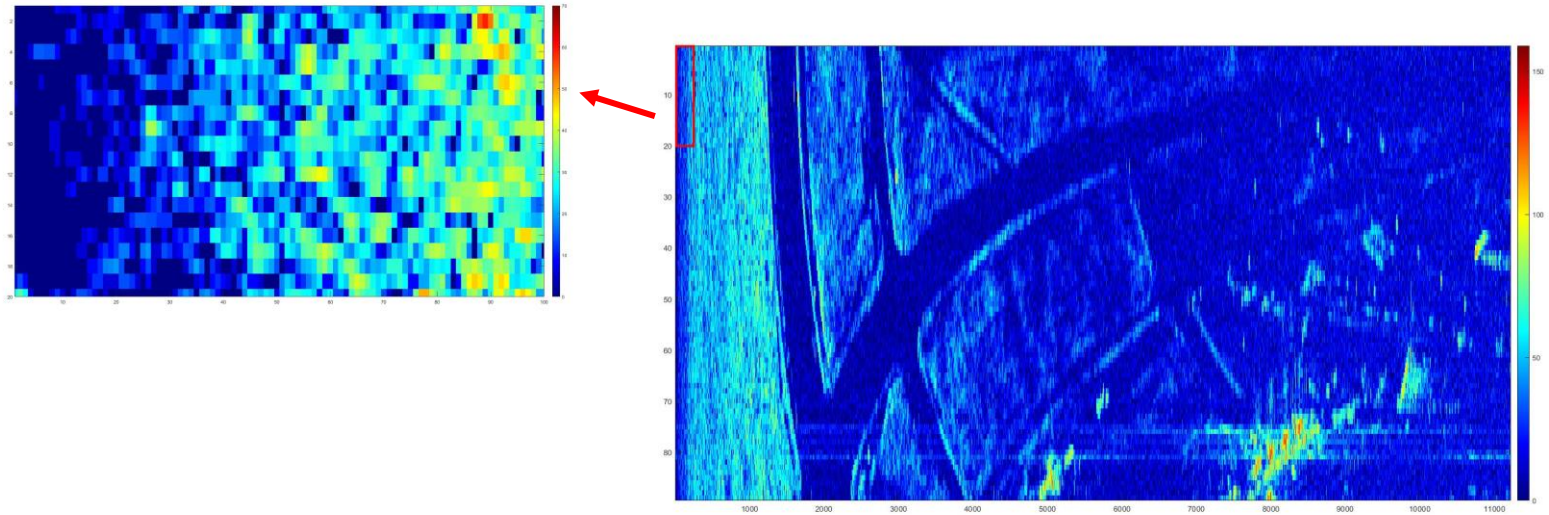
$$CluttermapStatic = CluttermapStatic \times \frac{integrateover - 1}{integrateover} + RawData \times \frac{1}{integrateover}$$

VS.

$$CluttermapLocal = CluttermapLocal. \times \frac{integrateoverfull - loc}{integrateover} + RawData. \times \frac{loc}{integrateover}$$

$$integrateoverfull = integrateover \times \begin{pmatrix} 1 & \cdots & 1 \\ \vdots & \ddots & \vdots \\ 1 & \cdots & 1 \end{pmatrix}$$

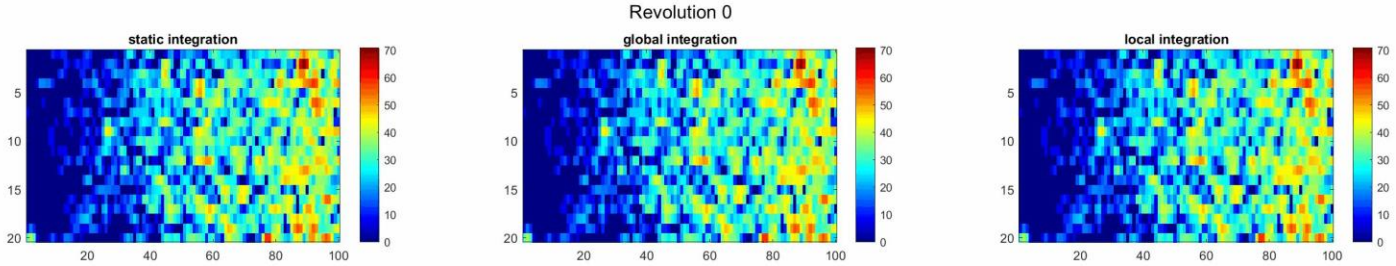
matrix of integrators (loc), elementwise multiplication



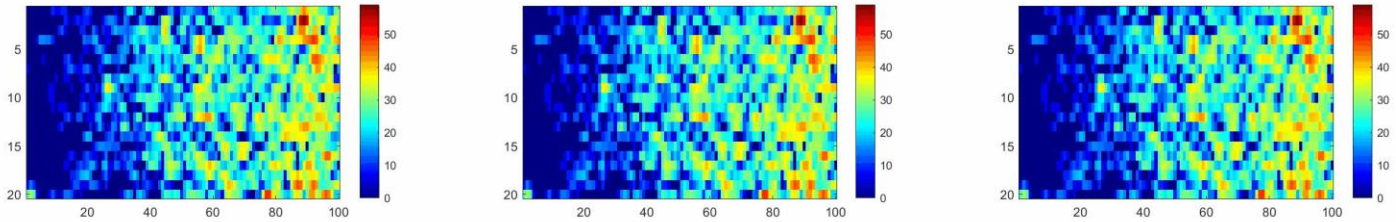
Clutter Map - Integration

Reaction of different integration techniques to a 20% amplitude increase

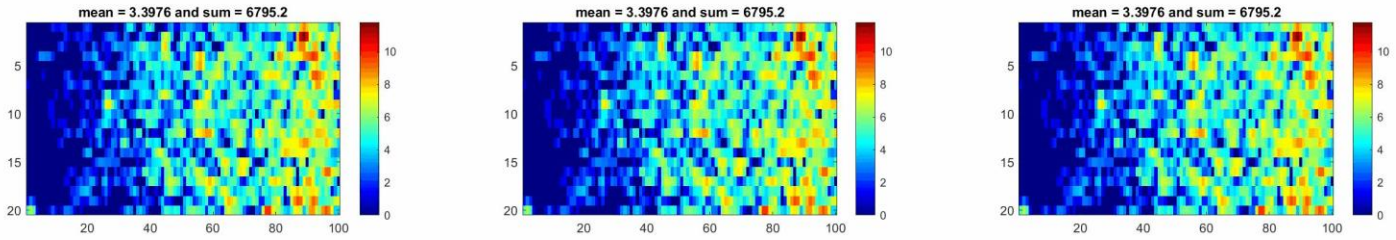
Raw data



Integrated clutter map

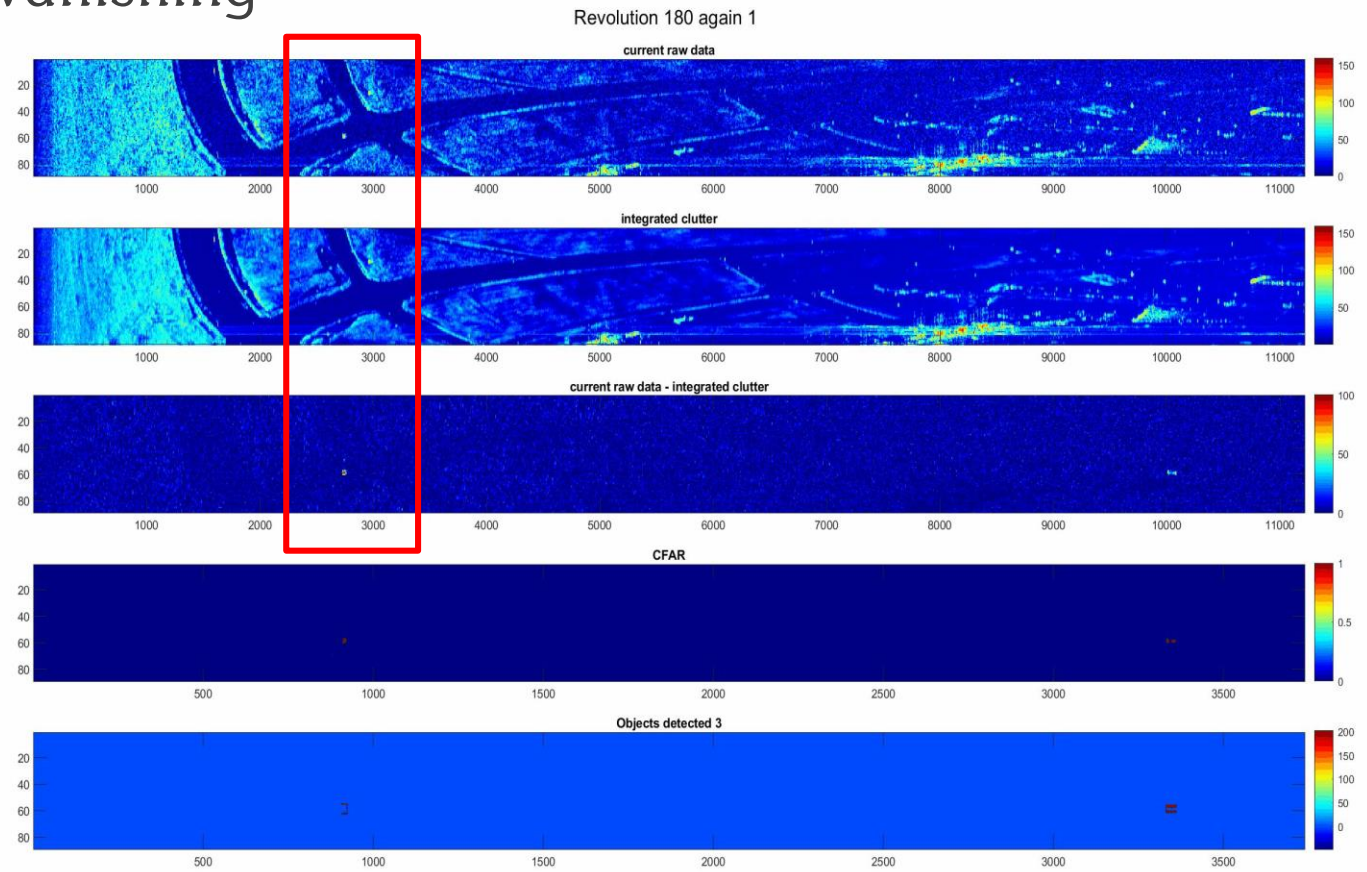


Raw data – Integrated clutter



Clutter Map – Object Presence Feedback

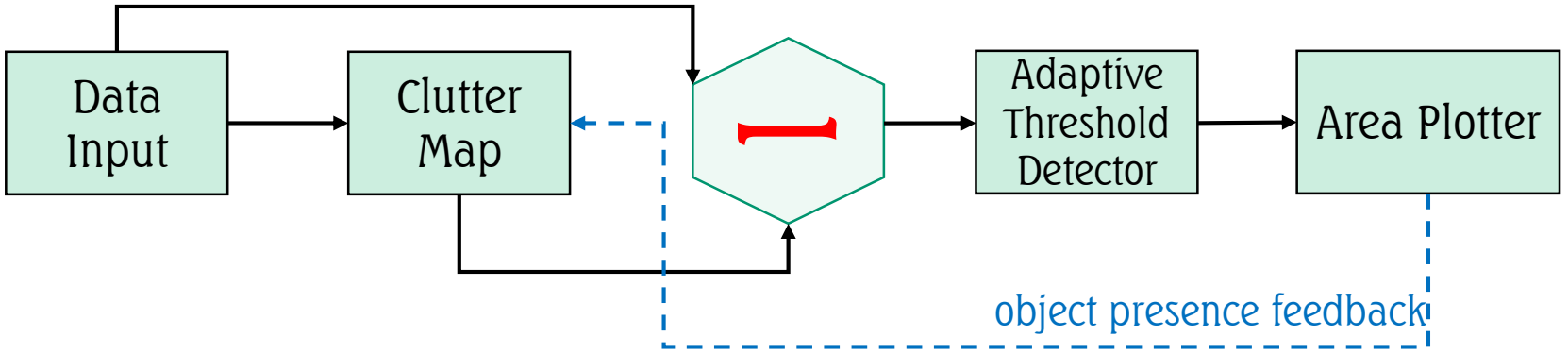
Static object „vanishing“



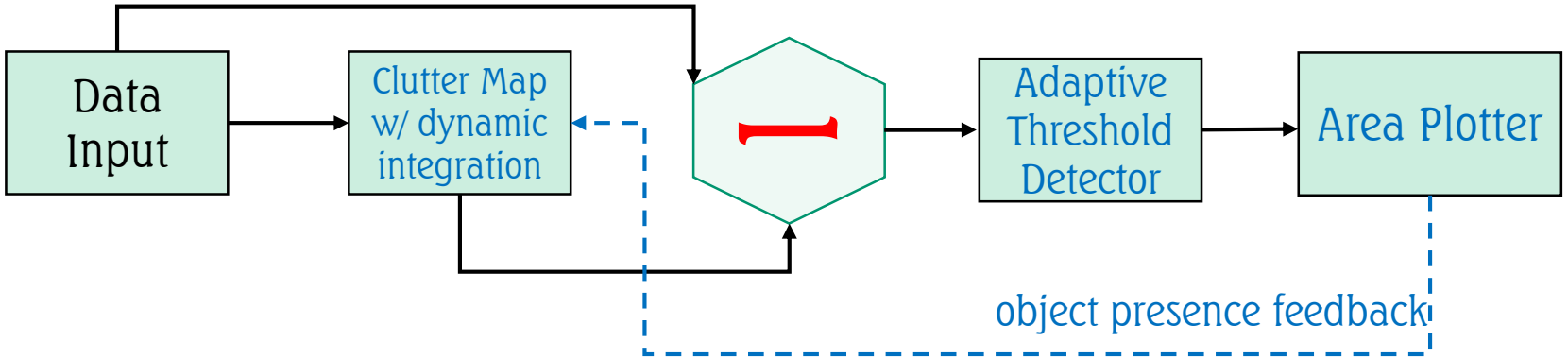
Clutter Map – Object Presence Feedback

Object presence feedback

- Propagates the information about detected object location to the Clutter map to avoid „object vanishing“ issue
- Clutter map update in the areas with present objects is handeled in a different way



New Processing Chain



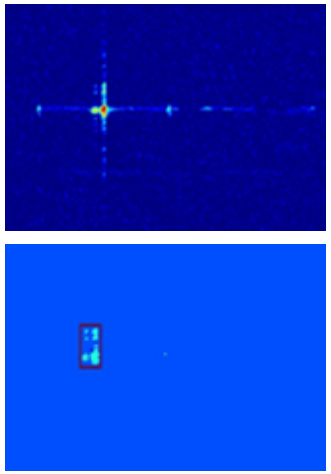
Performance improvements:

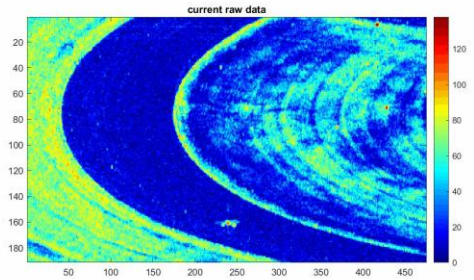
- Threshold detector is ~ 5x faster compared to CFAR
- Better detecion results (quantitative assesments ongoing)
- Clutter map able to react to the fast changes of weather conditions

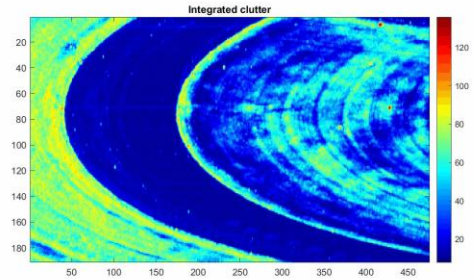
Challenges

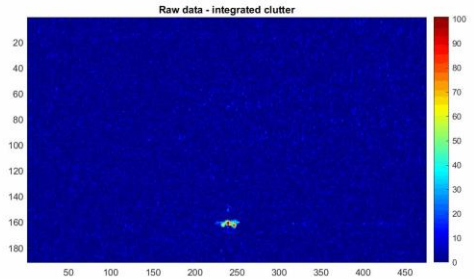
Effect of side reflections:

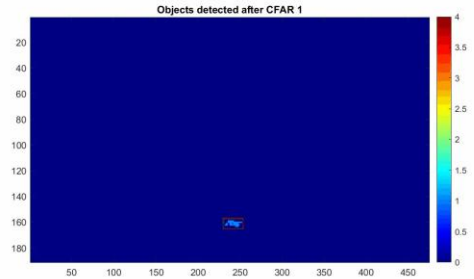
- Observed in case of the plane passing close by the radar
- Required introduction of additional logic for the suppression of unwanted detections







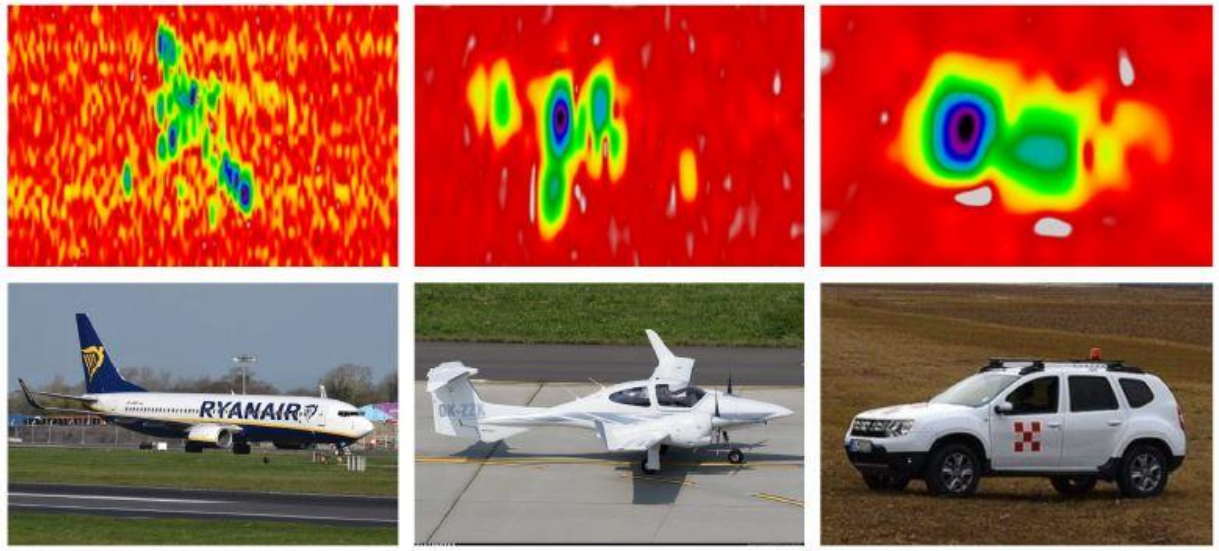




Next Steps

Further development possible in the areas:

- Object tracker algorithms
- Parameters auto-tuning (e.g. with changing weather conditions)
- Plot data as an input for object classification (utilizing deep learning and Artificial Neural Networks)



Summary

- All main components of radar data processing chain were redesigned
- Utilizing ML techniques improved the performance
- Ongoing validation at M. R. Stefanik - Airport Bratislava in accordance with EUROCAE ED-116 standard

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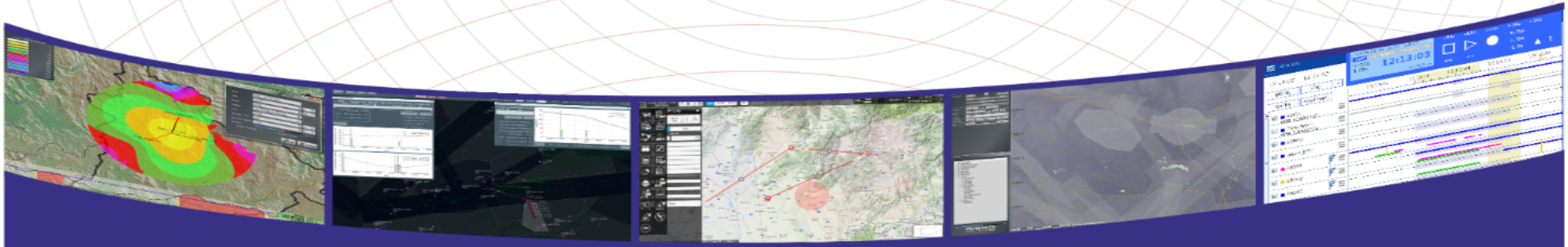
Thank you!



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