Machine-Learning for Safety Critical Airborne Applications
Part 2 – Case Study

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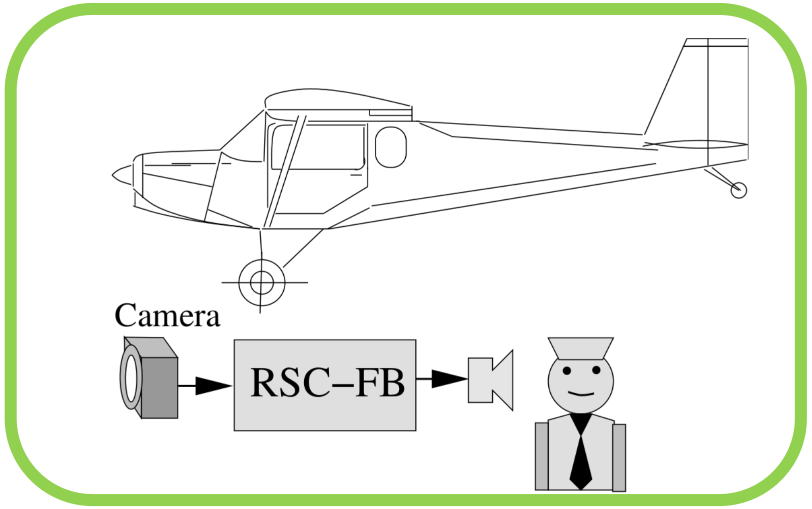
Case Study: Runway Sign Classifier (RSC) System

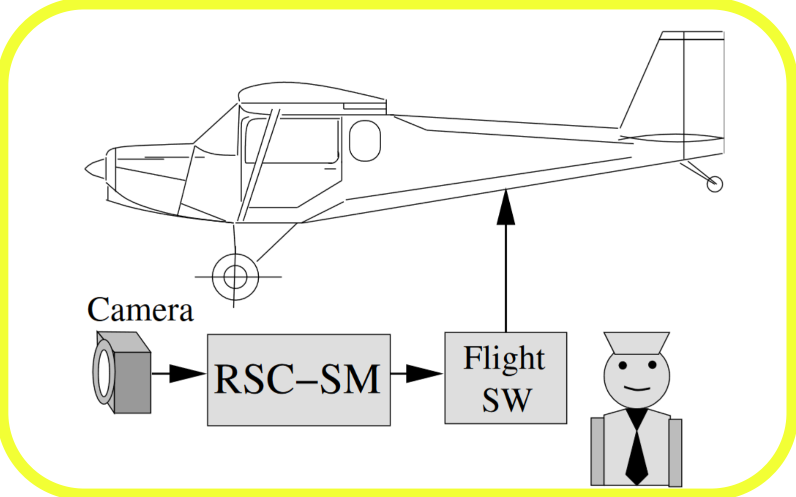
Runways and Taxiways at airports are marked by signs to guide pilots during taxi, takeoff, and landing

- Can the pilot be supported?
- What if there is no pilot?

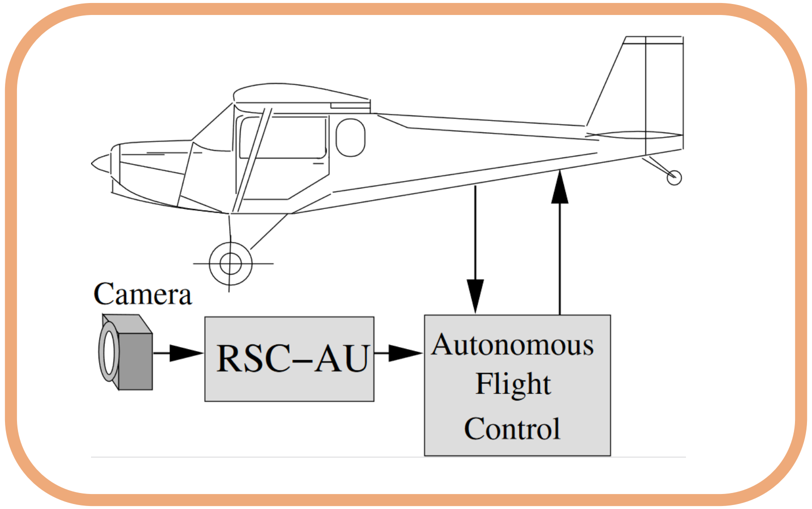
Case Study: Runway Sign Classifier (RSC) System



RSC-FB: Pilot Assistance – DAL D



RSC-SM: Safety Monitor – DAL C



RSC-AU: Autonomous – DAL A/B

Failure Category	Level
Catastrophic	A
Hazardous	B
Major	C
Minor	D
No Safety Effect	E

- RSC-FB: signs are annunciated. Pilot is full in charge
- RSC-SM: annunciation and emergency stops for „do-not-enter“. Pilot can override
- RSC-AU: support system for full autonomous ground operations of UAS

Vision-based Deep Neural Network (DNN) architecture as common component

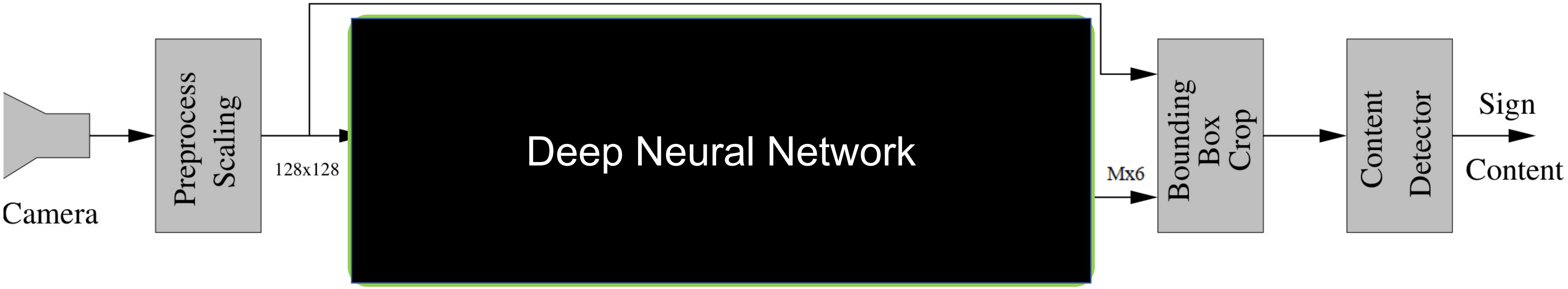
System Requirements

RSC-1	The RSC shall detect type and content of the mandatory instruction (red background) airport signs and information (yellow background) airport signs according to FAA AC 150/5340-18G Standards for Airport Signs Systems.
RSC-2	The RSC shall operate under normal lighting conditions and with clear visibility.
...	...
RSC-6	The RSC shall limit the detection latency to 500ms.
RSC-7	The RSC shall have a precision of sign detection and content identification of at least 95%.
RSC-8	The RSC shall use a forward-facing camera with a frame rate of at least 10Hz.

Detailed DNN Requirements

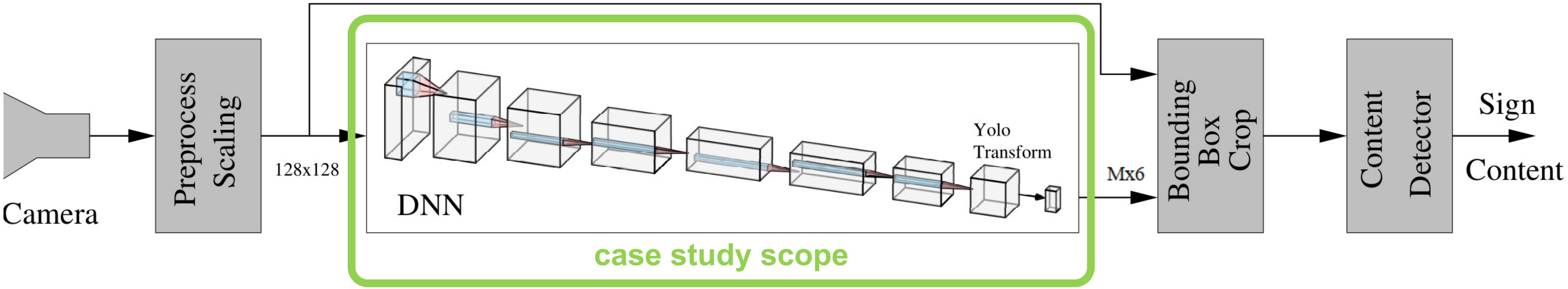
RSC-DNN-1a	The RSC DNN shall process the input 128×128 RGB image to detect the presence of the mandatory and information instruction signs
RSC-DNN-1b	The RSC DNN shall return the class (mandatory or information) of each detected sign and its bounding box position and size in pixels.
RSC-DNN-2	The RSC DNN shall operate under normal lighting conditions and with clear visibility
...	...
RSC-DNN-6	The RSC DNN shall have an average sign detection precision above 95%. The model average precision on a dataset is calculated ...

Prototypical Architecture



- Straight-forward architecture to implement the requirements
- Pre-trained Deep Neural network for sign detection and classification („AI“ component)
- Separate traditional component for content detection
- Scope of this case study: the Deep Neural Network
  - Popular architecture for vision tasks: Yolo (You only look once)
  - On-board: linear algebra, matrix-vector operations
  - Training before deployment

Prototypical Architecture



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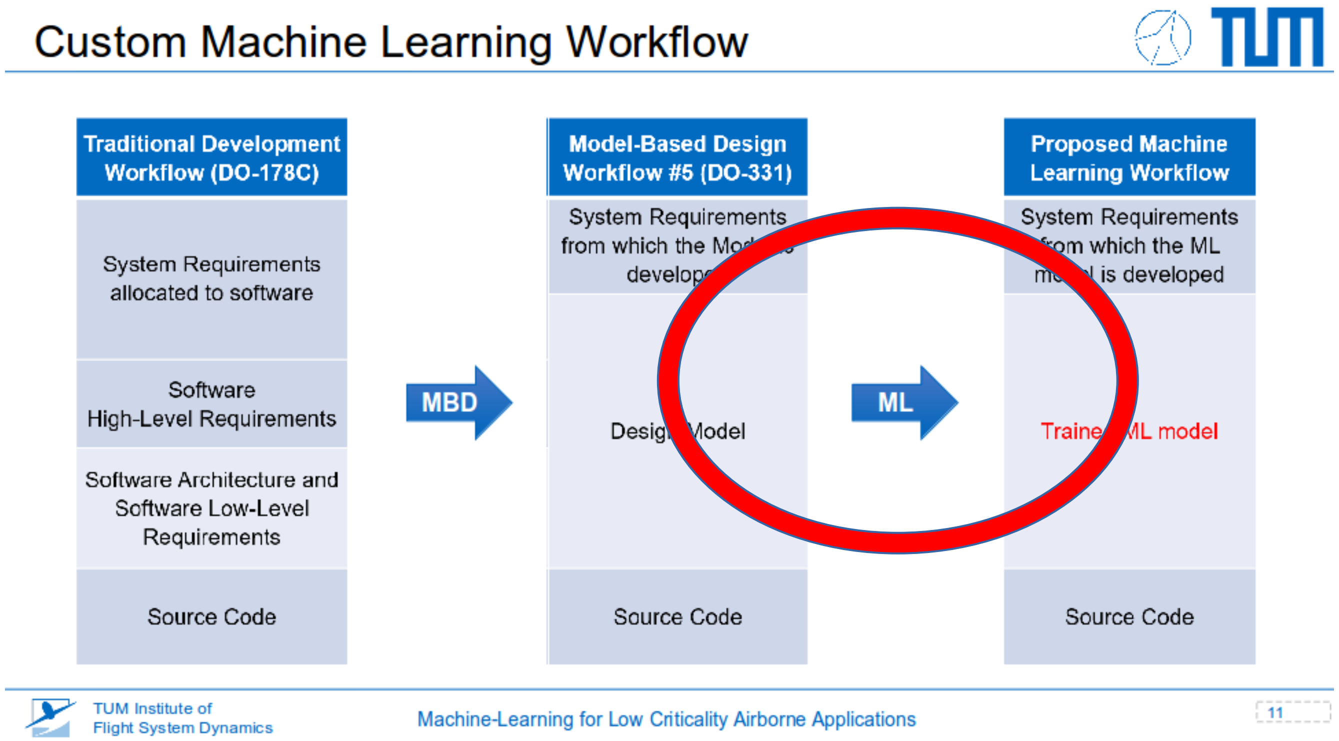
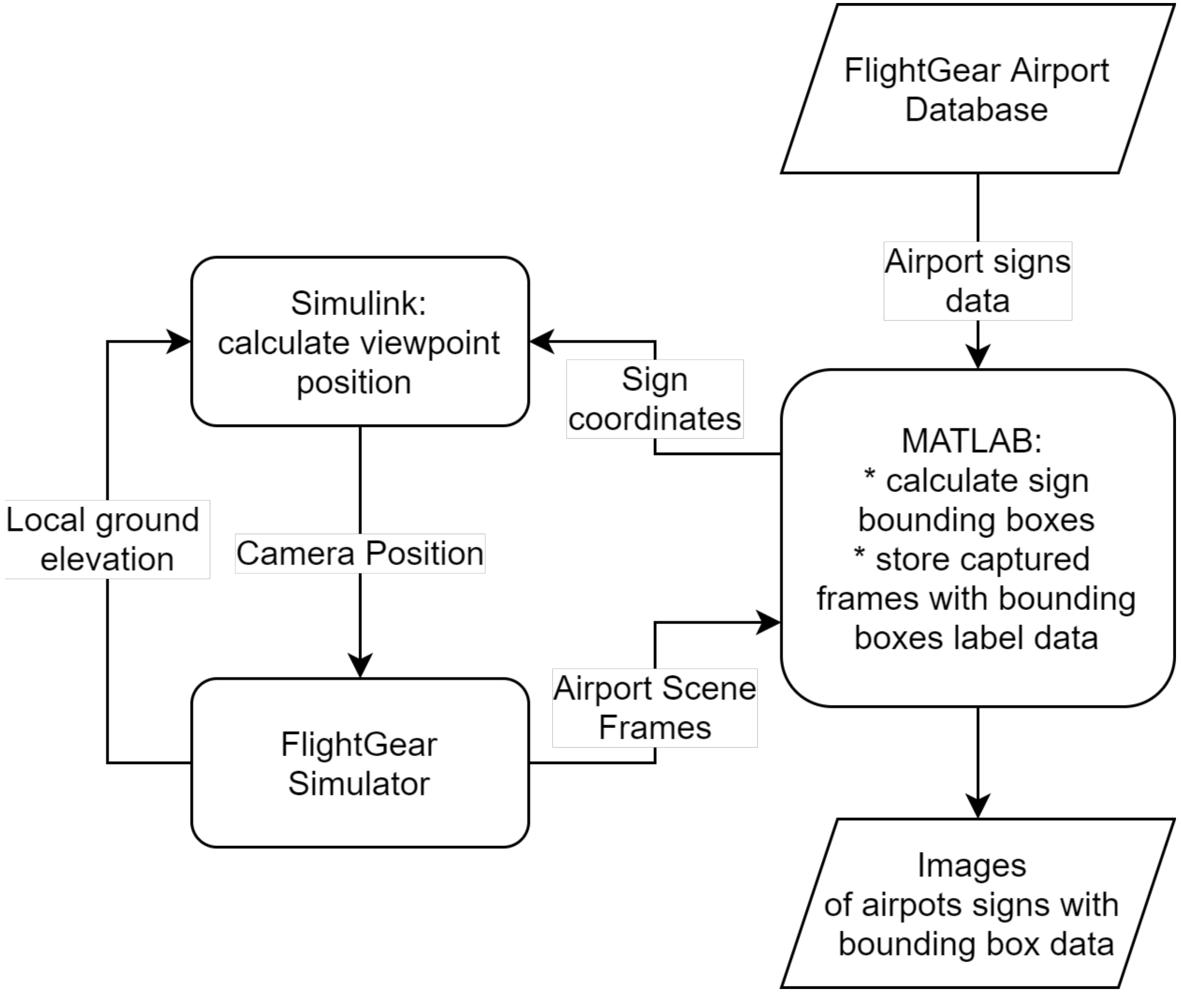
Data Collection, Training and Testing

- Data Collection, Training & Testing are extremely important tasks in the workflow
- We will discuss
  - Synthetic training data generation
  - Real-world data labeling



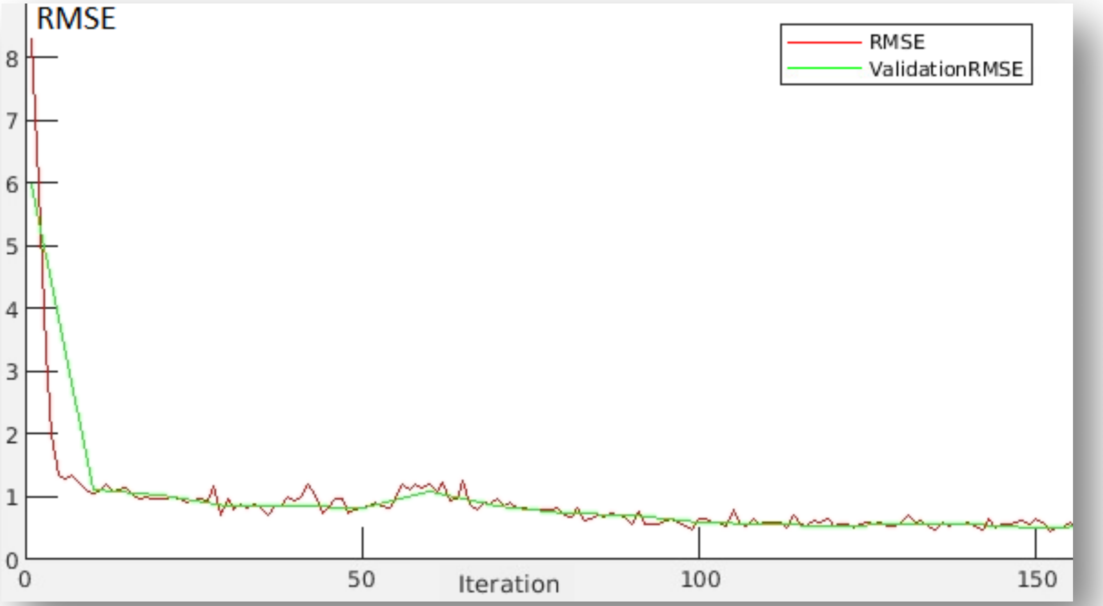
Data Collection, Training and Testing

- Synthetic data generation
  - FlightGear + MATLAB & Simulink
  - Different airports, landscape, time, weather
- Real-world data labeling
  - MATLAB Computer Vision Toolbox
  - 20% of the test dataset.



Data Collection, Training and Testing

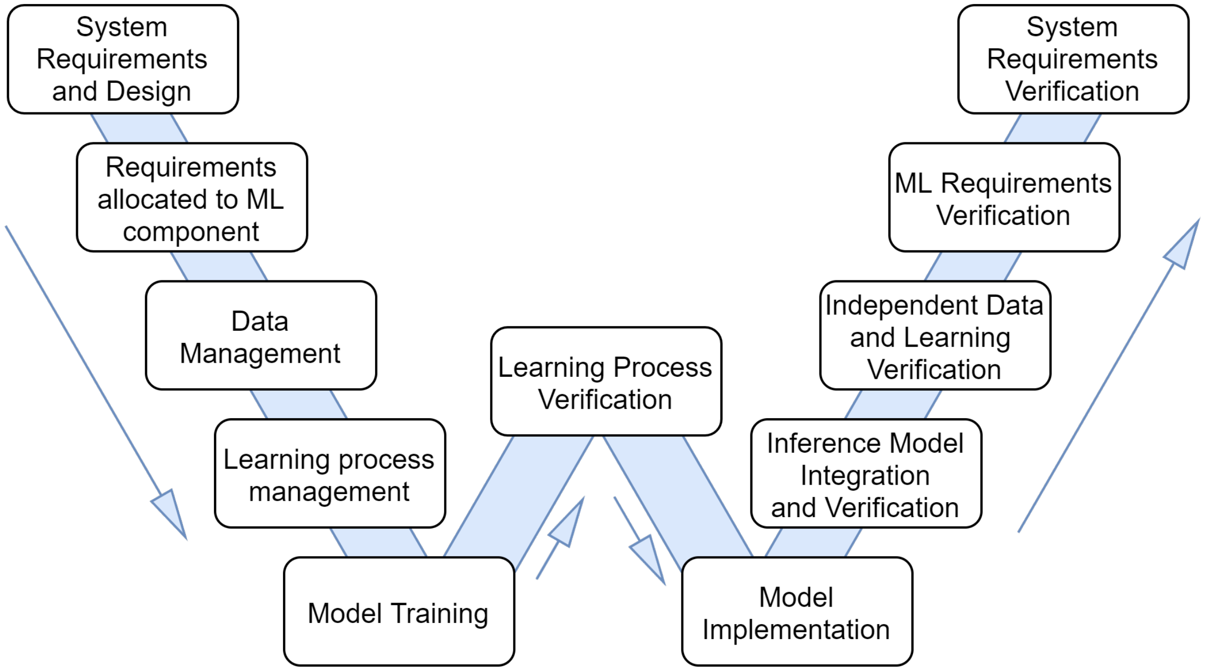
- Training, tuning and testing
  - MATLAB Deep Learning Toolbox
  - DNN precision on independent test dataset - 99%



Compliance with DO-178C

- Design Assurance Level D
  - All objectives are satisfied or justified

- Design Assurance Levels A, B and C
  - Identified methods to address gaps
  - DAL reduction through Architectural mitigation
  - Neural Network coverage metrics
  - Markov chain Monte Carlo simulation



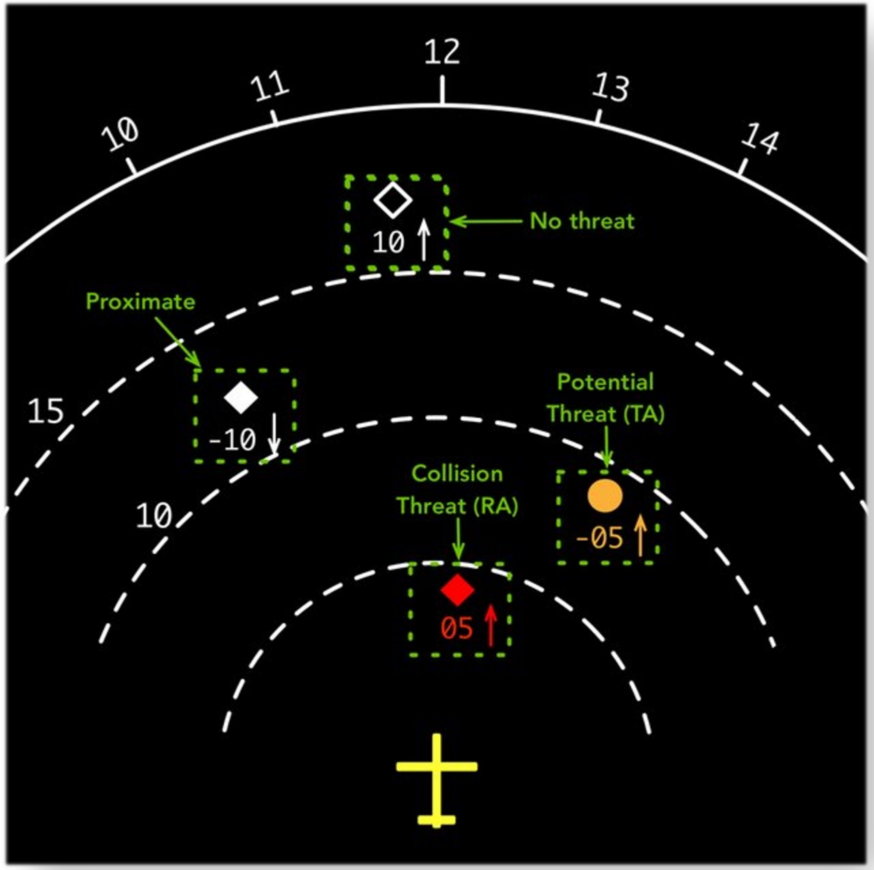
Summary and Future Work

- Major gaps between current certification standards and ML technology
  - Prevents ML deployment in aviation

- ML custom workflow enables complies with DO-178C

- Runway Sign Classifier Case Study
  - Demonstrated DAL D compliance for DNN-based computer vision system

- Future work
  - Upgrade the custom ML workflow to achieve DAL C / B compliance



M. Schäfer, X. Olive, M. Strohmeier, M. Smith, I. Martinovic and V. Lenders, "OpenSky Report 2019: Analysing TCAS in the Real World using Big Data," 2019 IEEE/AIAA 38th Digital Avionics Systems Conference (DASC), 2019, pp. 1-9, DOI: 10.1109/DASC43569.2019.9081686.

References

Toward Certification of Machine-Learning Systems for Low Criticality Airborne Applications

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***Abstract*—The exceptional progress in the field of machine learning (ML) in recent years has attracted a lot of interest in using this technology in aviation. Possible airborne applications of ML include safety-critical functions, which must be developed in compliance with rigorous certification standards of the aviation industry. Current certification standards for the aviation industry**

of machine learning technology in low criticality airborne systems based on the existing regulatory framework without a need for new regulations.

The rest of the paper is structured as follows: in Section II we provide an overview of ML technology and discuss related

- Custom workflow for low-criticality (DAL D) applications
  - Satisfy all DAL D objectives of DO-178C/331/254 and ARP-4754
  - Best of the session paper at the DASC 2021 conference

Toward Design Assurance of Machine-Learning Airborne Systems

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- Case study project for DAL D ML workflow
  - ML-based computer vision system
  - 2022 SciTech Forum
  - Path for DAL C compliance

Thank you!