SMART2-Advanced integrated obstacle and track intrusion detection system for smart automation of rail transport

Transport Community Treaty

10th Technical Committee on Railway

Location: Belgrade – Hotel Mona Plaza (tbc) / MS Teams

Date: 05.10.2021

Prof. Milos Simonovic, Prof. Dusan Stamenkovic, Prof. Milan Banic

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SMART2 project ID card

Sift2Rail H2020 Open Call (OC) Project

- Area: IP5 – Technologies for sustainable and attractive European rail freight
- Project reference: 881784 — SMART2 — H2020-S2RJU-2019 / H2020-S2RJU-OC-2019
- Type of Action: Innovation Action (IA)
- Total budget: 1.708.737,5 €; Maximum S2R JU contribution 1.499.528,75€
- Project start: 1st December 2019; Duration: 36 months
- Consortium: 7 participants from 5 European countries
- Complementary project: X2Rail-4
- Follow up of SMART project

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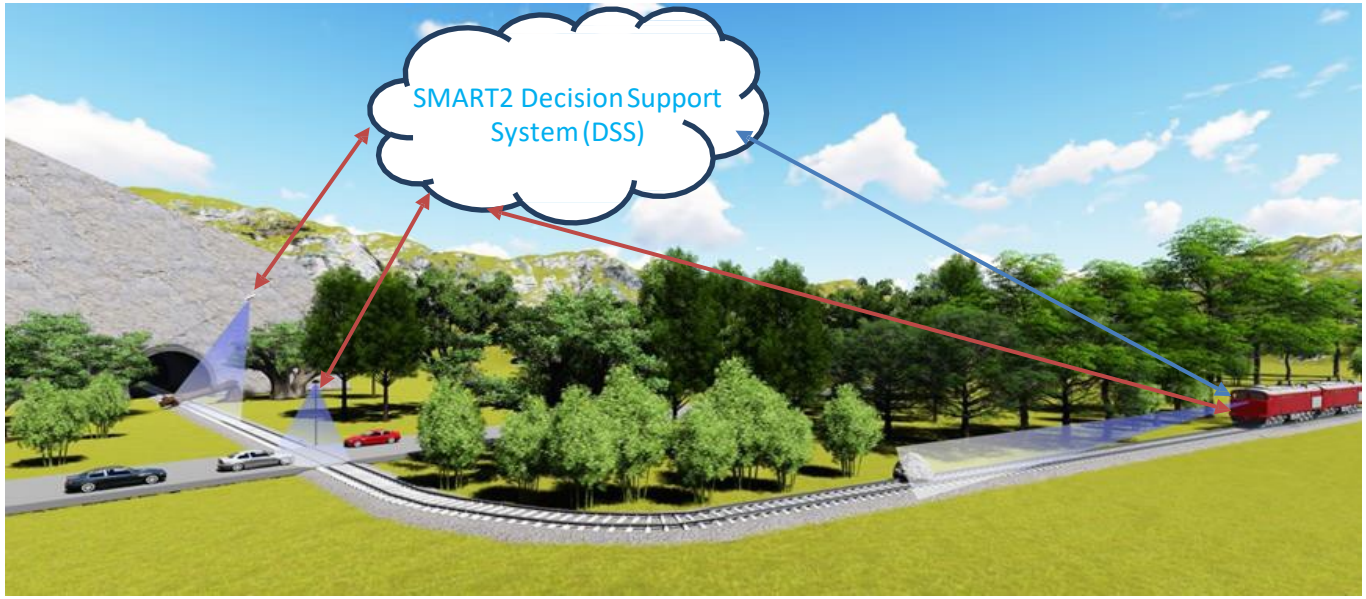
SMART2 project

- SMART2 objective is to develop, implement and evaluate a **holistic system for Obstacle Detection and Track Intrusion Detection (OD& TID) consisting of on-board, trackside and drone-based OD&TID systems, interfacing with central Decision Support System (DSS) unit**
- **Holistic approach to autonomous obstacle detection for railways** would enable increased detection area including areas behind a curve, slope, tunnels and other elements blocking the train's view on the rail tracks, in addition to a long-range straight rail-tracks OD.



SMART2 consortium

UB: Project coordinator; SW for on-board and drone-based OD&TID

Universität Bremen

UNI: DSS; Drone-based OD&TID; Evaluation

University of Niš

OHB-DS: Cloud-based DSS implementation; System integration

OHB

UNEW: RAMS; Analysis and definition of use-cases

Newcastle University

SOVA: LADAR on-board system for day&night vision and for challenging weather

HARDER digital SOVA

TUC: Airborne OD&TID system

UNIVERSITATEA TEHNICĂ DIN CLUJ-NAPOCA

FOKUS: Trackside OD&TID system

FOKUS TECH

Shift2Rail

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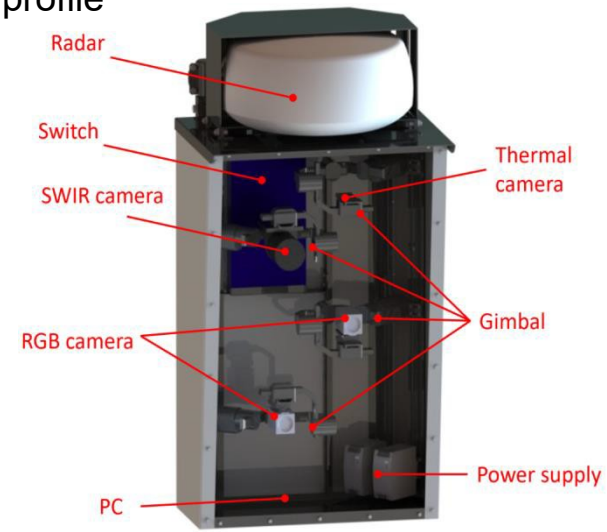
SMART2 demonstrator
On-board OD&TID system

Renderings of the SMART2 sensor housing: (above) sensor housing with front panel; (below) sensor housing without front profile



Requirement	RGB cameras	Thermal camera	SWIR camera	RADAR
SMART2 FR-T-01: Detect objects, potential obstacles, in the railway environment and path of trains that are not the part of the railway infrastructure	✓	✓	✓	✓
SMART2 FR-T-02: Mounting/dismounting of on-board OD&TID system	✓	✓	✓	✓
SMART2 FR-T-04: Detection functionality of the OD&TID system robust to environmental conditions		✓	✓	✓
SMART2 FR-T-05: The OD&TID system shall be able for long-range obstacle detection within 2 km ahead the train	✓	✓	✓	✓
SMART2 FR-T-08: OD&TID shall provide visualization of sensor data on HMI	✓	✓	✓	✓
SMART2 FR-T-018: OD&TID system shall be able to use zoom of specific mounted cameras	✓	✓	✓	
SMART2 FR-T-21: Radar detection of obstacles and track intrusions shall be with high level of reliability and accuracy				✓
SMART2 FR-T-22: Radar shall operate in the railway environment. All pieces of radar system should be able to operate with full nominal performance in relation to the environmental conditions: temperature, humidity, dust, smoke, sun exposure, rain, snow, fog				✓
SMART2 FR-T-23: The overall health and safety risk to staff, public, property and the environment, from the operation of the radar system (radio waves) shall be at an acceptable level				✓

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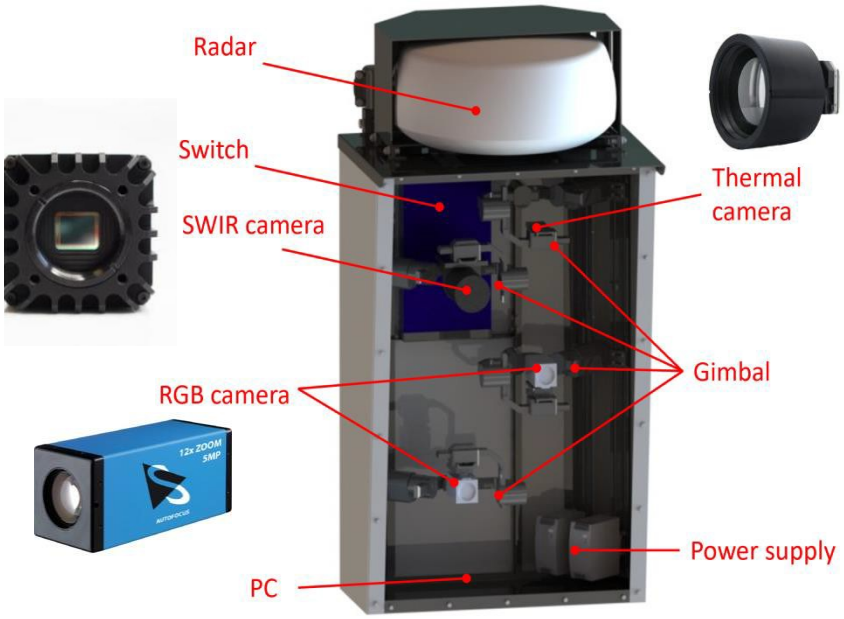
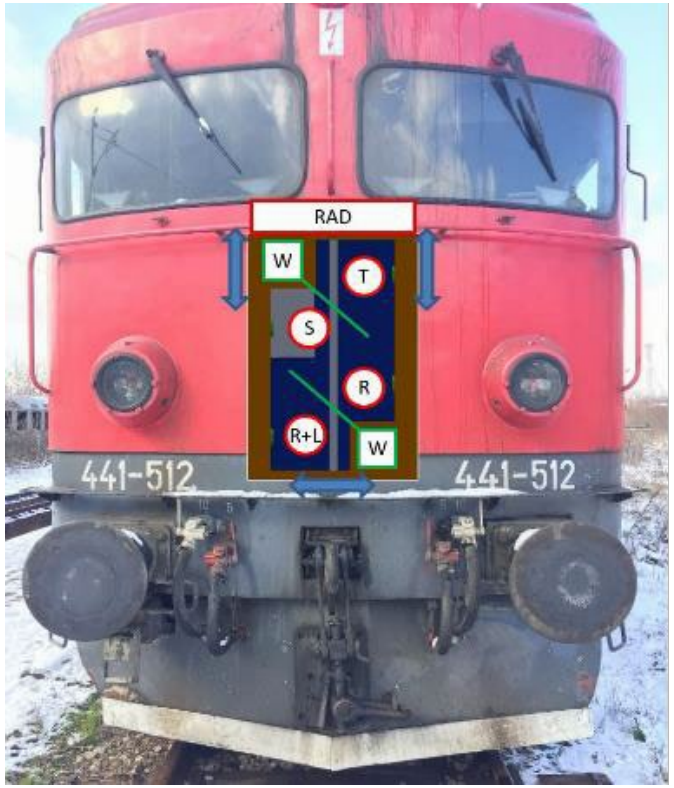
SMART2 demonstrator
On-board OD&TID system





Positioning of the integrated SMART2 on-board OD&TID system onto the frontal profile of the locomotive (SERBIAKARGO series 444)

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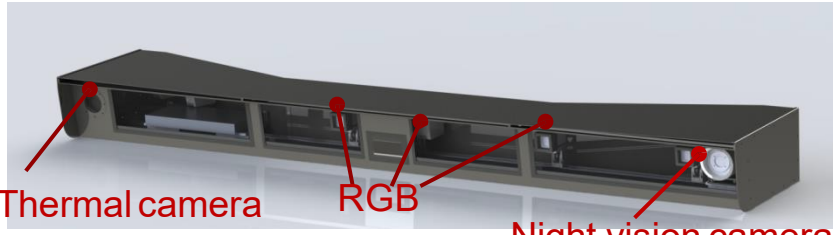
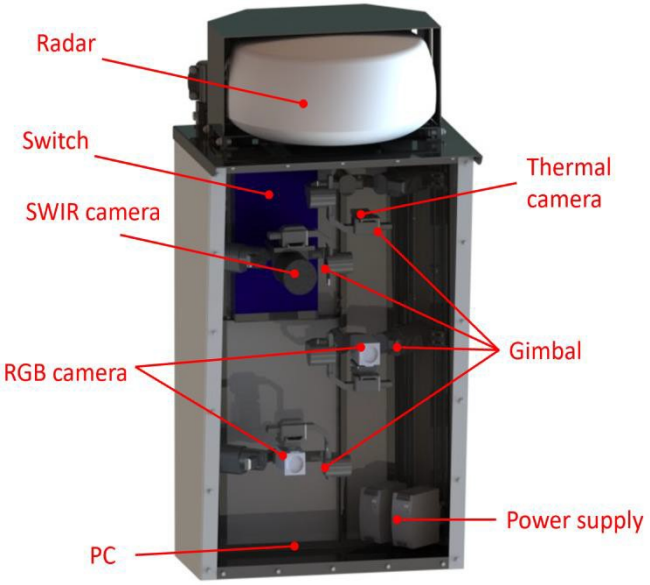
SMART2 demonstrator
On-board OD&TID system

- *From SMART to SMART2*

SMART Sensors housing with integrated sensors

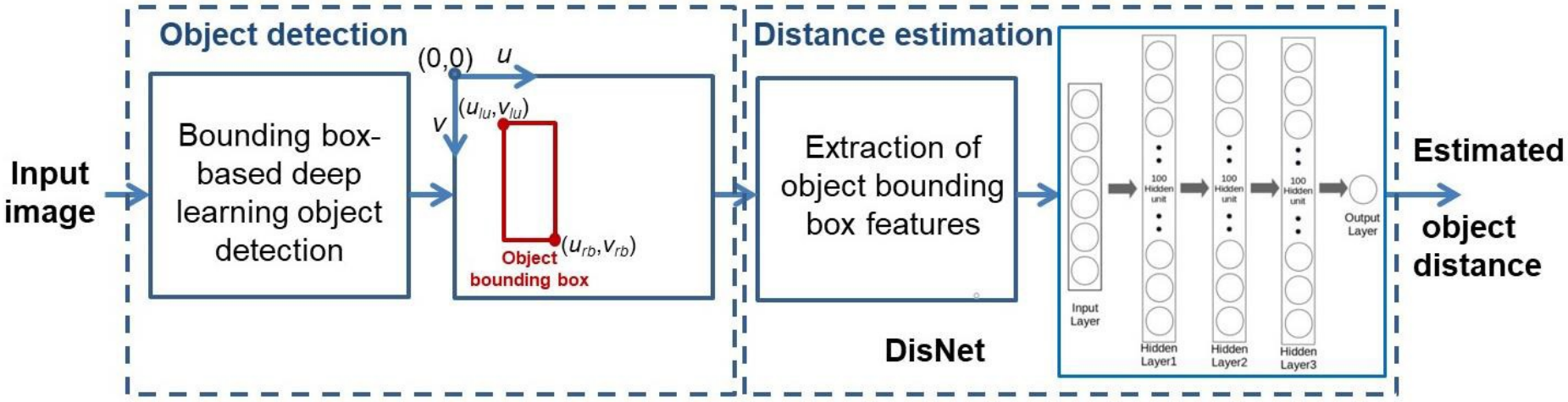




SMART2 Sensors housing with integrated sensors

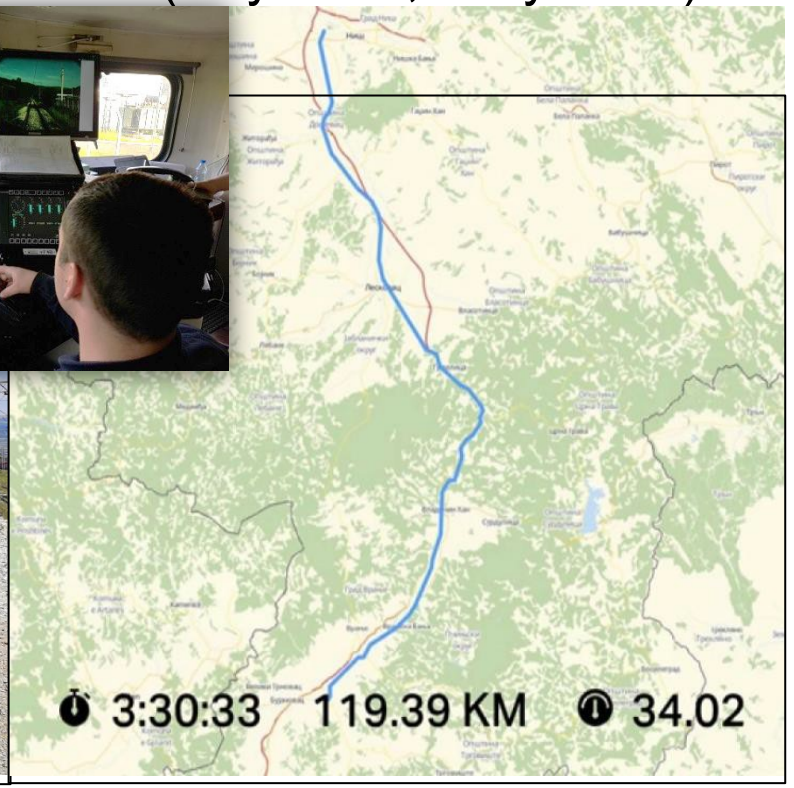
SMART2 WP2: On-board obstacle and track intrusion detection system

- ***Task 2.4: SW for vision-based obstacle and track intrusion detection, M2 to M32***
  - Starting point, SMART on-board OB software (image below):
    - –Re-training of SMART Machine Learning (ML) model for object detection with further images from SMART dataset with the goal to improve long-range detection performances
    - –Investigation and implementation of advanced (state-of-the-art) ML-based (in particular deep learning (DL)-based) object detection methods8
    - –SMART Dataset augmentation (**was not foreseen in DoA; imposed due to problems in new data recordings due to COVID-19 constraints*)



SMART2 demonstrator
On-board OD&TID system

- **SMART Dataset generation -** dynamic field tests (July 2018, May 2019)



- SERBIA CARGO Locomotive 444-018
- 21 wagons
- Total mass 1194 t
- Total length 458 m

- Serbian part of Corridor X to Thessaloniki
- Length 120km
- Max speed 80 km/h

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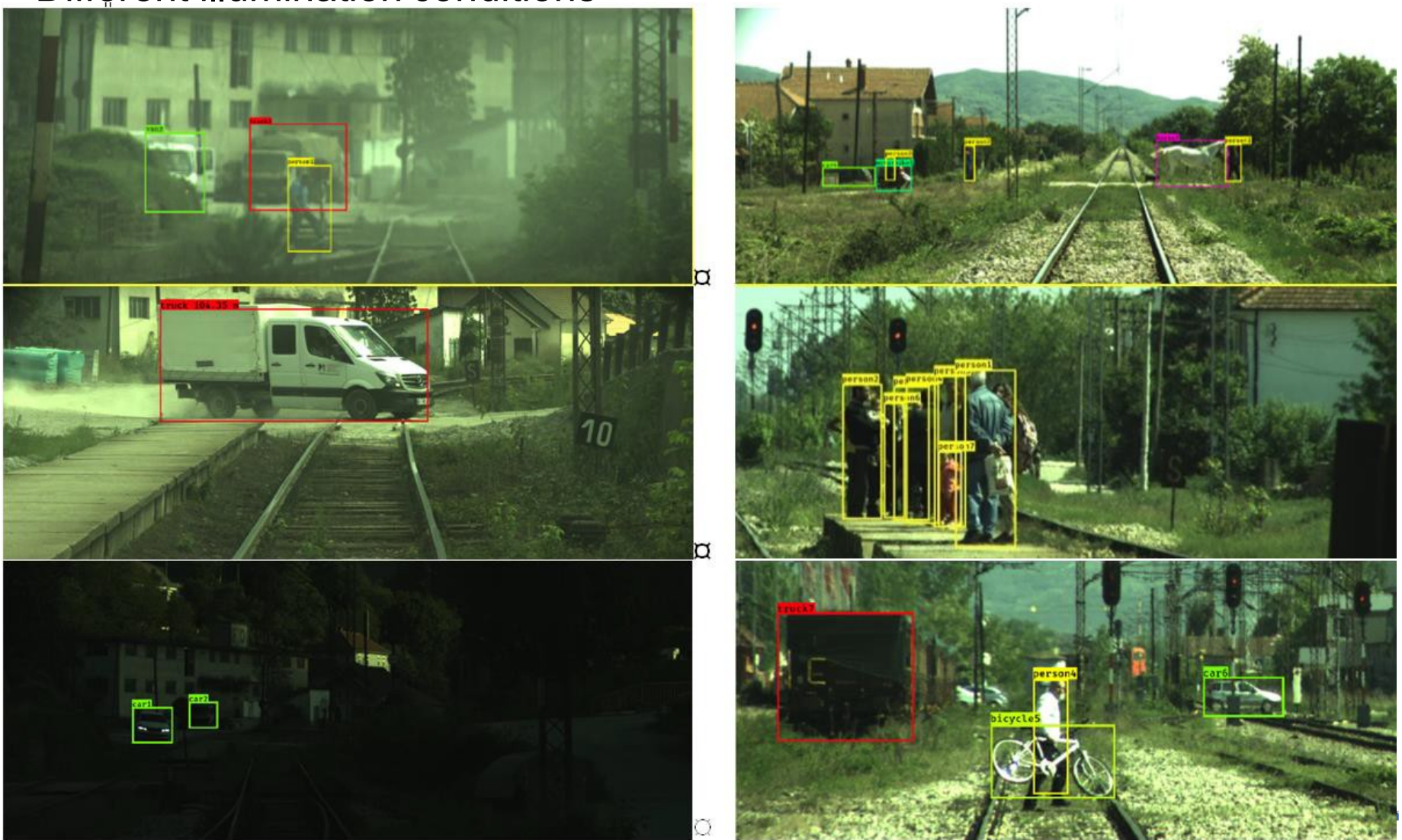
SMART2 demonstrator
On-board OD&TID system

- **SMART Dataset -** Real-world scenarios; Different object classes; Different illumination conditions



SMART2 demonstrator OD&TID software

- Starting point: SMART on-board OD software for object detection and distance estimation from single camera
  - Re-training (transfer learning) of SMART Machine Learning (ML) model for object detection with further images from SMART dataset with the goal to improve long-range detection performances

Without Transfer Learning

After Transfer Learning

SMART2 demonstrator OD&TID software

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SMART2 demonstrator OD&TID software

- Starting point, SMART on-board OD software for object detection and distance estimation from single camera
  - SMART Dataset augmentation (creation of synthetic data including long-range objects) and re-training of distance estimation model with augmented data

Ground truth distance = 261.19m

SMART
Person 1 – 187.66m Car 2 – 220.92 m
RMSE = 21.78%

SMART 2
Person 1 – 300.63m Car 2 – 248.87m
RMSE = 9.9%

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SMART2 demonstrator OD&TID software

- Starting point, SMART on-board OD software for object detection and distance estimation from single camera
  - SMART Dataset augmentation (creation of synthetic data including long-range objects) and re-training of distance estimation model with augmented data

SMART
Person 1 – 520.76m Person 2 – 546.18 m
RMSE = 29.38%

SMART 2
Person 1 – 688.34m Person 2 – 722.09m
RMSE = 6.96%

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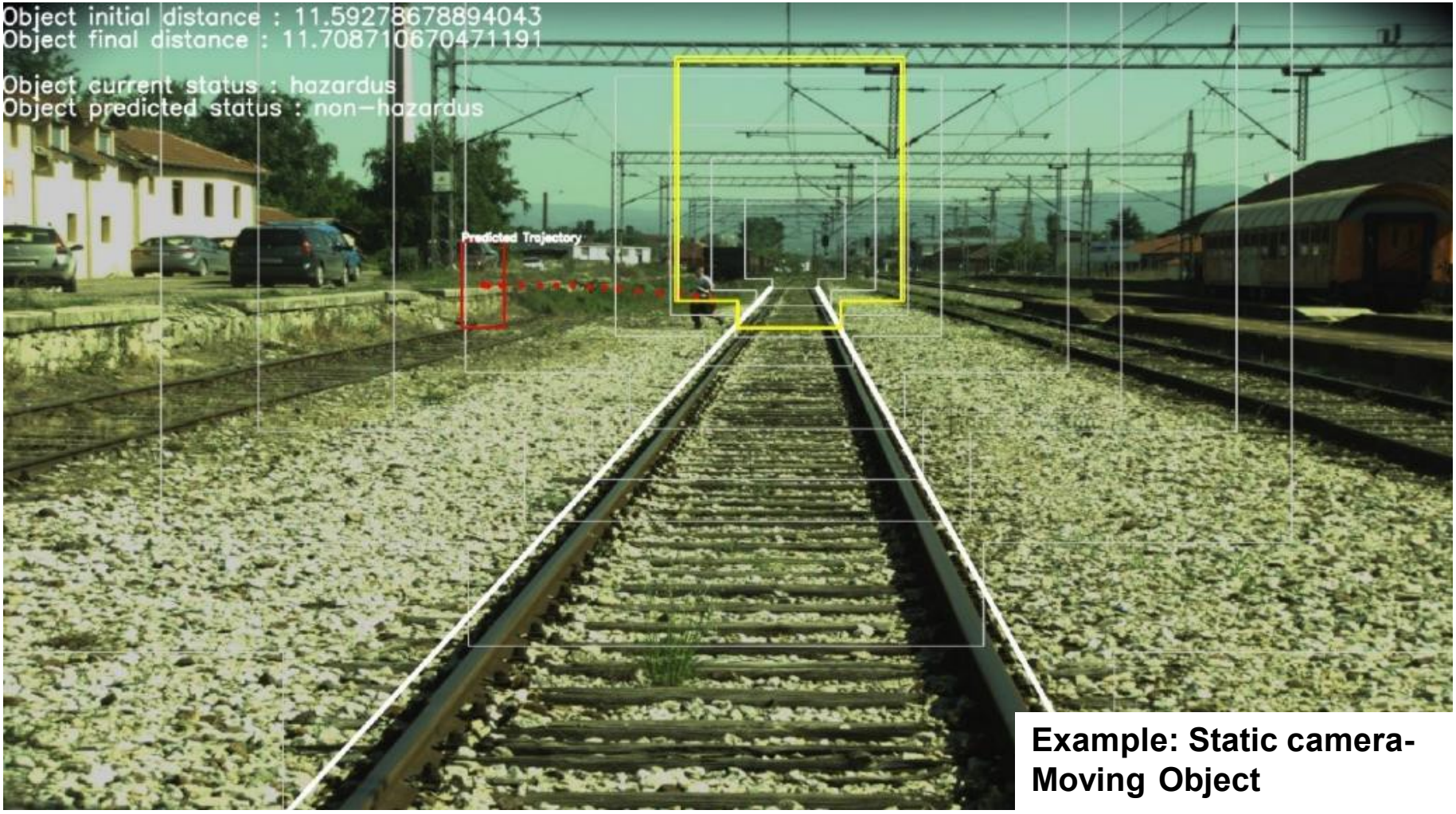
SMART2 demonstrator OD&TID software

- Novel SMART2 functionalities
  - Deep learning-based rail tracks detection and clearance region definition; *Object trajectory prediction and estimation of Hazardous level*



Example: Static camera-Moving Object

SMART2 demonstrator OD&TID software

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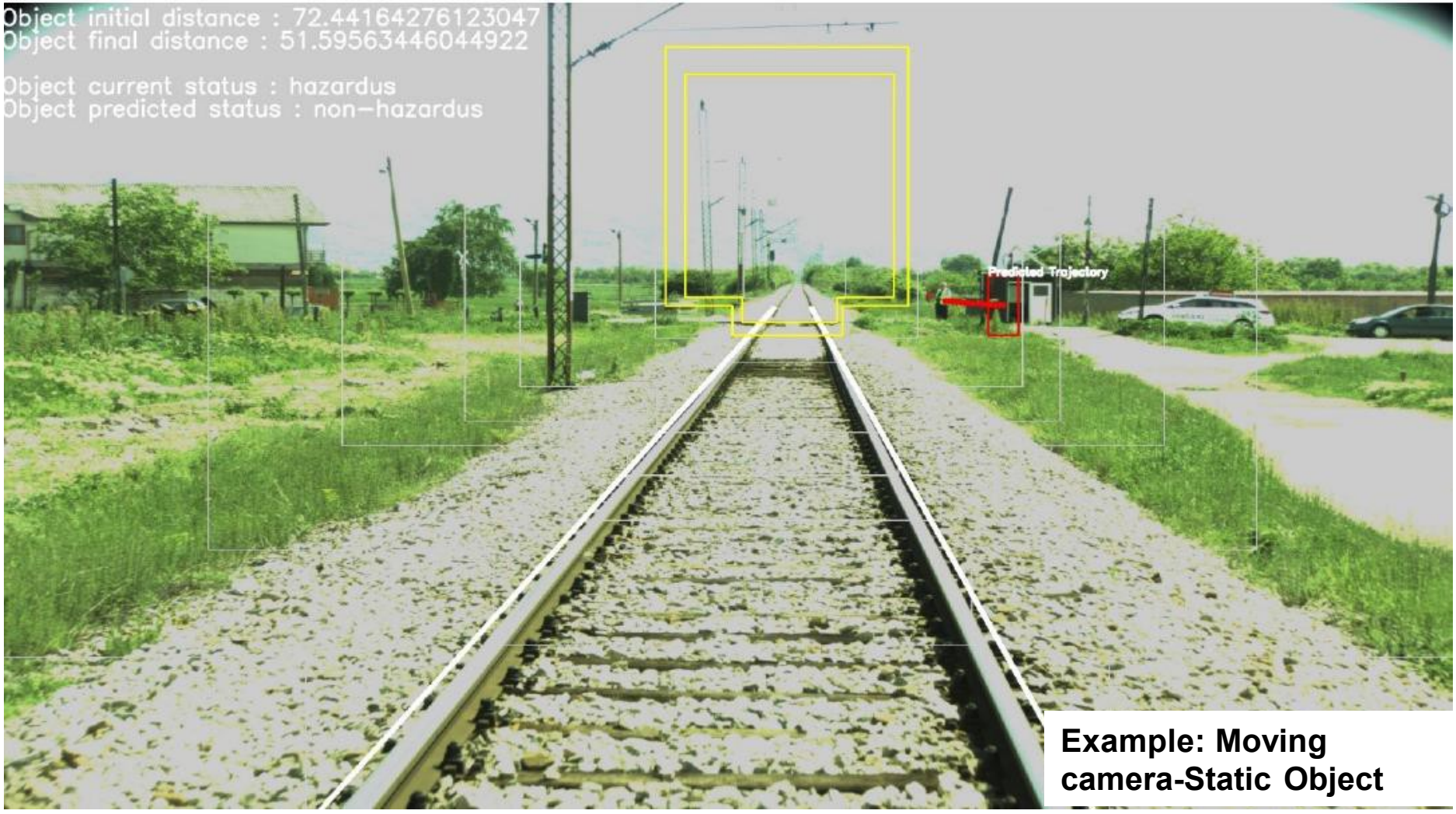

Example: Moving camera-Static Object

SMART2 demonstrator OD&TID software

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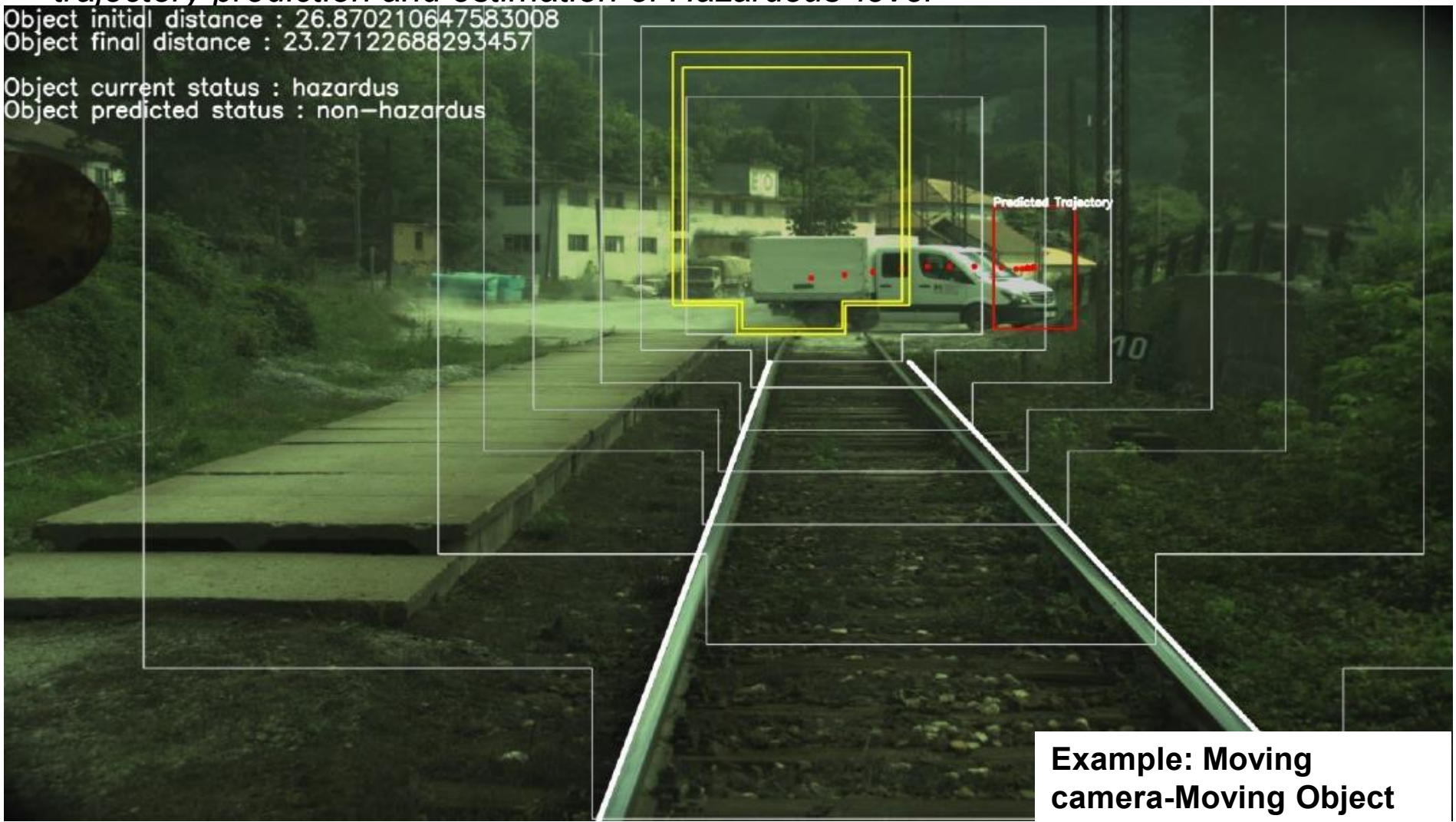
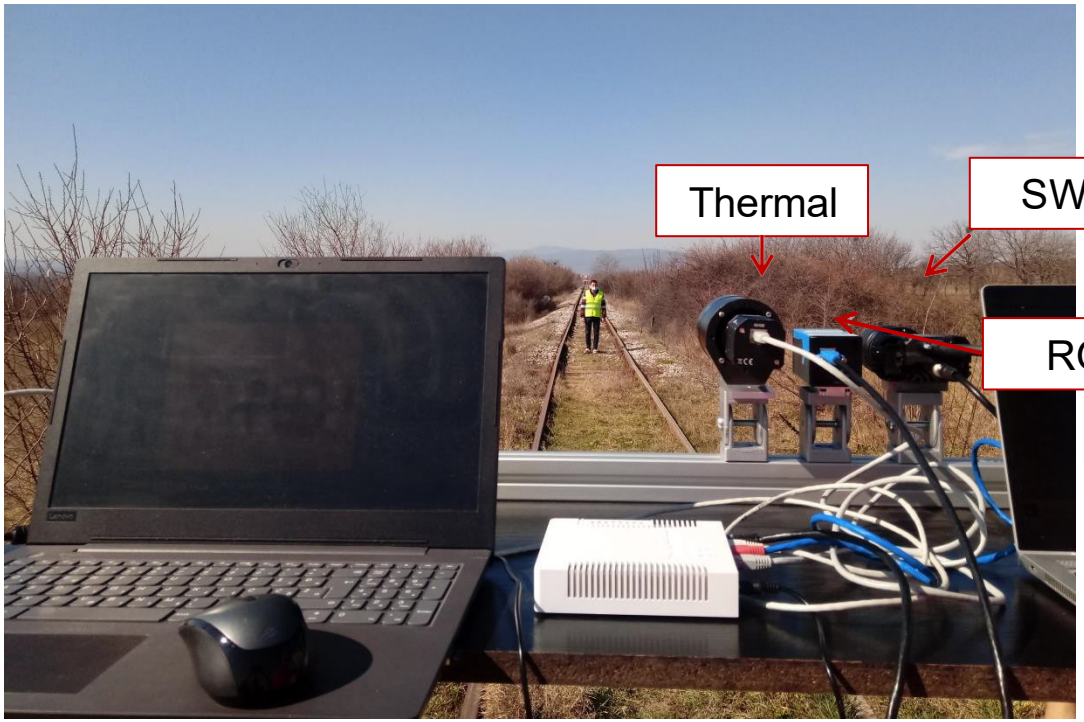


Example: Moving camera-Moving Object

SMART2 demonstrator On-board and Drone-based system

OD&TID

- Novel SMART2 data recording
  - Preliminary results: towards a **holistic approach to autonomous obstacle detection for railways**



SMART2 drone and on-board sensors „in action“ Field Test, 5th March 2021, Serbia

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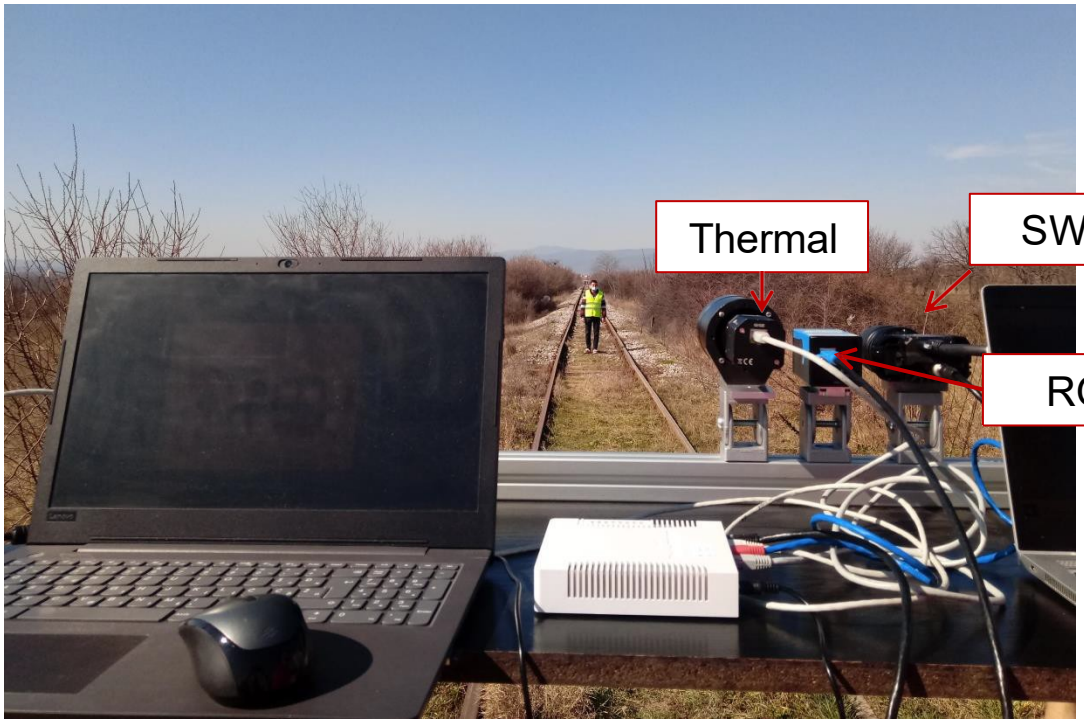
SMART2 demonstrator On-board and Drone-based OD&TID system

- ***Task 2.1: HW for multi-modal on-board sensory system for OD&TID, M4 to M12, Task Leader: SOVA***



SMART2 on-board sensors „in action“ Field Test, 5th March 2021, Serbia

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SMART2 demonstrator
On-board and Drone-based OD&TID system

Scenario 1: 417m streight camera‘s view+aprox. 500m drone field of view

Scenario 2: 470m streight camera‘s view+aprox. 500m drone field of view

Scenario 3: 417m streight camera‘s view+aprox. 500m drone field of view

5.3.2021 on-board cameras (C) + Drone (D) data recording

SMART2 demonstrator
On-board and Drone-based OD&TID system

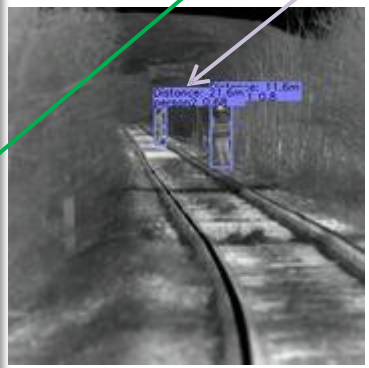
Scenario 1: 417m streight camera‘s view+aprox. 500m drone field of view

Person_300 (in front of the curve) visible by on-board cameras
Person_600 (beyond the curve) not visible by on-board cameras/visible by drone camera

SMART2 demonstrator
On-board and Drone-based OD&TID system

Scenario 1: 417m streight camera‘s view+aprox. 500m drone field of view

Drone camera image



Thermal camera image

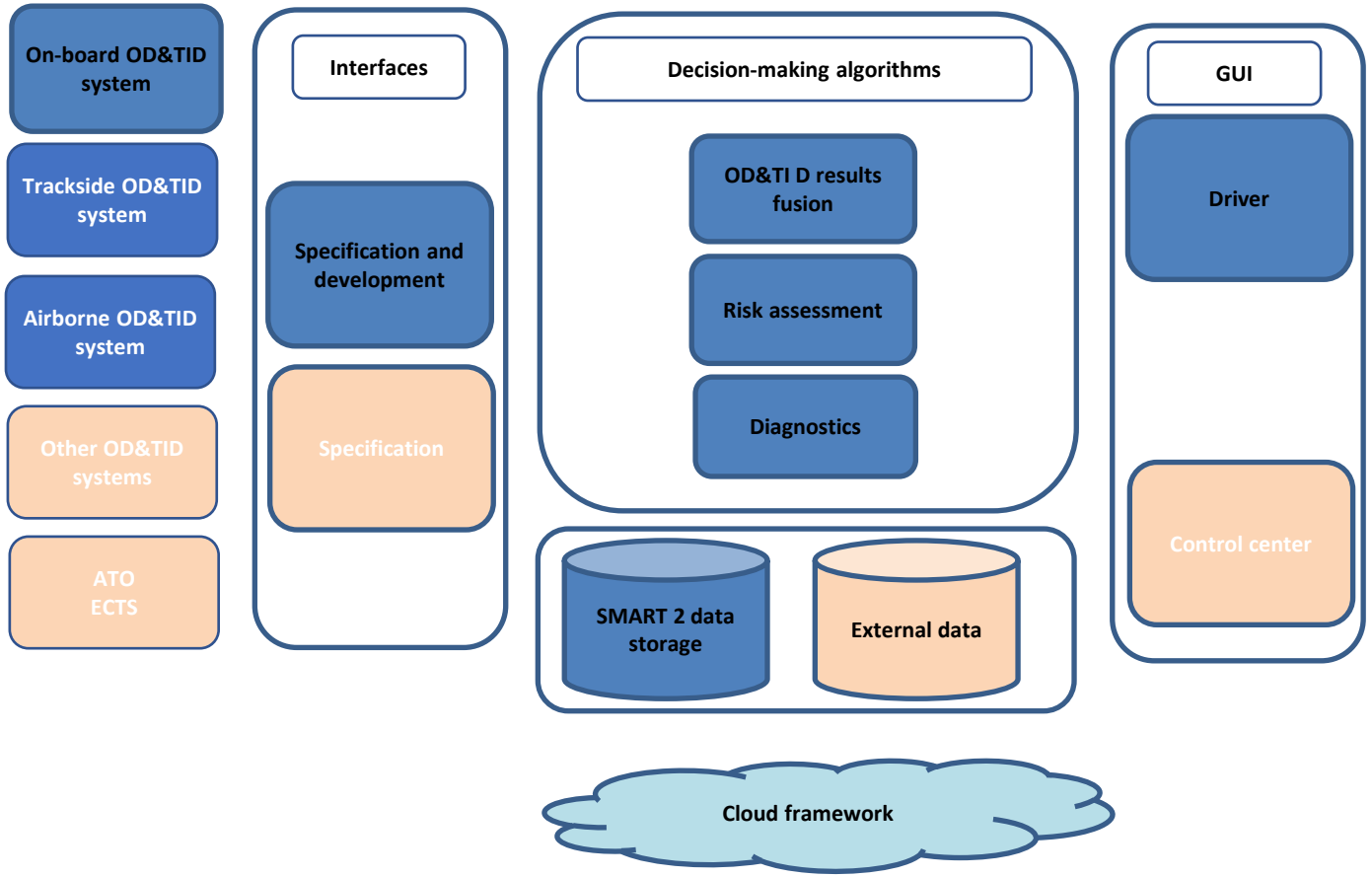
SWIR camera image

?

RGB (not zoomed) camera image

Person_300 (in front of the curve) detected in 2 out of 3 on-board cameras

CLOUD BASED DECISION SUPORT SYSTEM



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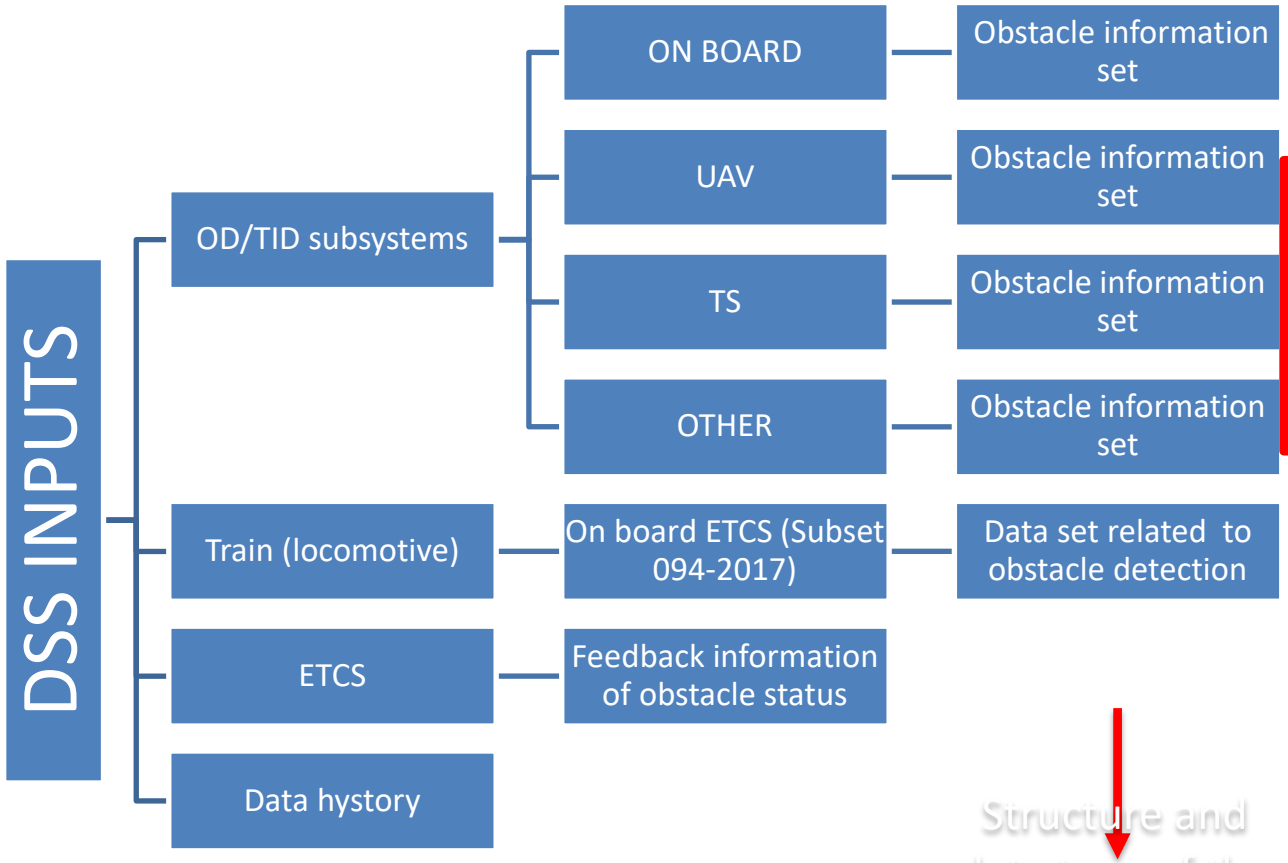
DSS DATA INPUT/OUTPUT MODEL



Class of detected object
Class reliability
Size of the detected object
Location of detected object
Distance
Subsystem status

Structure and data type of the OIS are not the same from different subsystems

Data input structure is adaptable to receive different outputs

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Future SMART2 activities

Static tests (all three OD subsystems – on board, trackside and airborne)

Dynamic tests (all three OD subsystems – on board, trackside and airborne)

- Section Nis – Ristovac (straight section to Leskovac, everything else in Grdelica gorge)
- Section Markovac – Belgrade, subsection Ralja – Avala (has all elements)
- Short development runs – Nis junction

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Thank you for your attention!

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