ROSCon 2024
21st – 23rd October 2024
Odense, Denmark

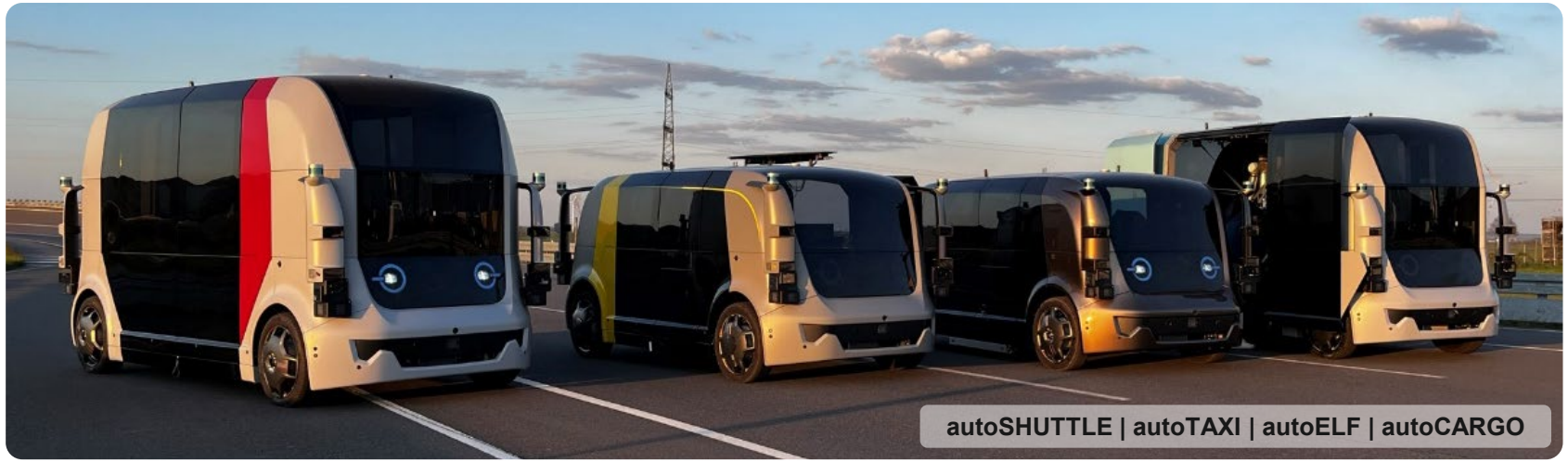
Integration of ETSI ITS messages for V2X communication in ROS

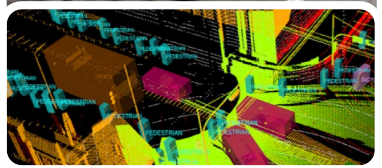
Odense, 22nd October 2024

Jean-Pierre Busch, M.Sc., Guido Küppers M.Sc., Lennart Reiher M.Sc.

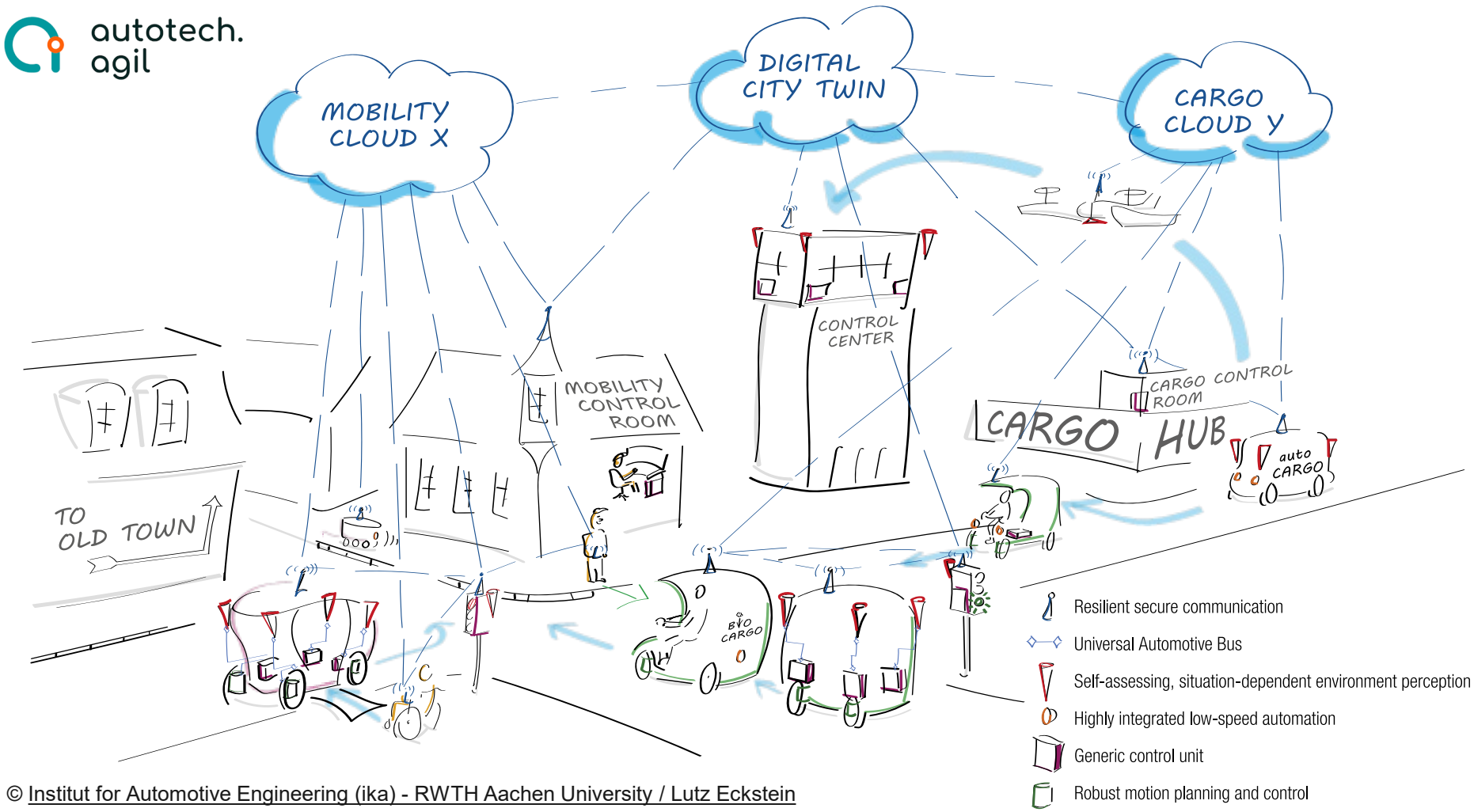
Institute for Automotive Engineering (ika), RWTH Aachen University

Institute for Automotive Engineering
Vehicle Intelligence & Automated Driving





Communication in C-ITS



→ The mobility system of the future is characterized by **communication** between a wide variety of entities

Fundamentals and State of the Art – V2X Communication

Technical Approaches

- *Dedicated Short Range Communication (DSRC)* based on *IEEE 802.11p* (peer-to-peer)
  - Europe: *ITS-G5*
- *C-V2X*
  - *Uu* (non-peer-to-peer)
  - *PC5* (peer-to-peer)

Message Definitions

- Multiple standardization activities
  - *European Telecommunications Standards Institute (ETSI)*
  - *Society of Automotive Engineers (SAE)*

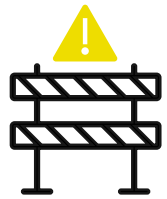
Implementation of vehicle manufacturers

- *Volkswagen Group* → ITS-G5 using *ETSI* application-layer message formats
- Other Manufacturers *(e.g. BMW, Mercedes)* → *C-V2X* (non-peer-to-peer) with unknown/proprietary message definitions

Fundamentals and State of the Art – ETSI ITS Messages

- *ETSI-ITS* – Standardization of external communication for intelligent transport systems (ITS)
  - **CAM:** *Cooperative Awareness Message*
    - Position and state information of road users

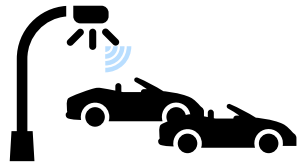
  - **DENM:** *Decentralized Environmental Notification Message*
    - Position and information about relevant events such as accidents, roadworks, traffic jams, vehicle breakdowns, etc.



  - **MAPEM:** *Map Extended Message*
    - Road and lane topology of an infrastructure area, e.g. an intersection

  - **SPATEM:** *Signal Phase And Timing Extended Message*
    - Signal state and forecast for traffic lights

  - **CPM:** *Collective Perception Message*
    - Information about perceived objects in the local environment



Introduction and motivation

- **WLAN 802.11p:** Standard for V2X-Communication
- Using dedicated hardware, messages can be received and for example provided via UDP for various applications
  - Payload in the form of **ASN.1 encoded bit strings**

- In research and development of intelligent transportation systems, **ROS** is often used

→ **Objectives:**
  - Make ETSI ITS messages available in **ROS**
  - **Automated generation** of ROS messages and corresponding conversion functions

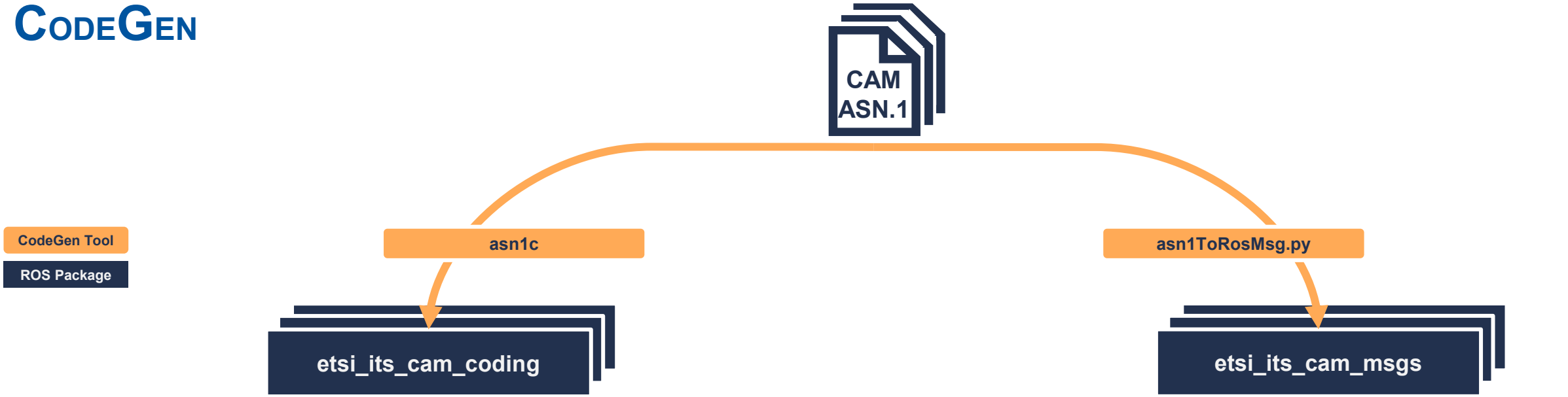
Concept – `etsi_its_messages`


```
CAM-PDU-Descriptions {
itu-t (0) identified-organization (4) etsi (0) itsDomain (5) wg1 (1) en (302637) cam (2) version (1) }

...

BEGIN IMPORTS
ItsPduHeader, CauseCode, ReferencePosition, ... FROM ITS-Container {...};

CAM ::= SEQUENCE {
        header ItsPduHeader,
        cam CoopAwareness
}
CoopAwareness ::= SEQUENCE {
        generationDeltaTime GenerationDeltaTime,
        camParameters CamParameters
}
...
```

Source: etsi.org

Concept – `etsi_its_messages`

CodeGen

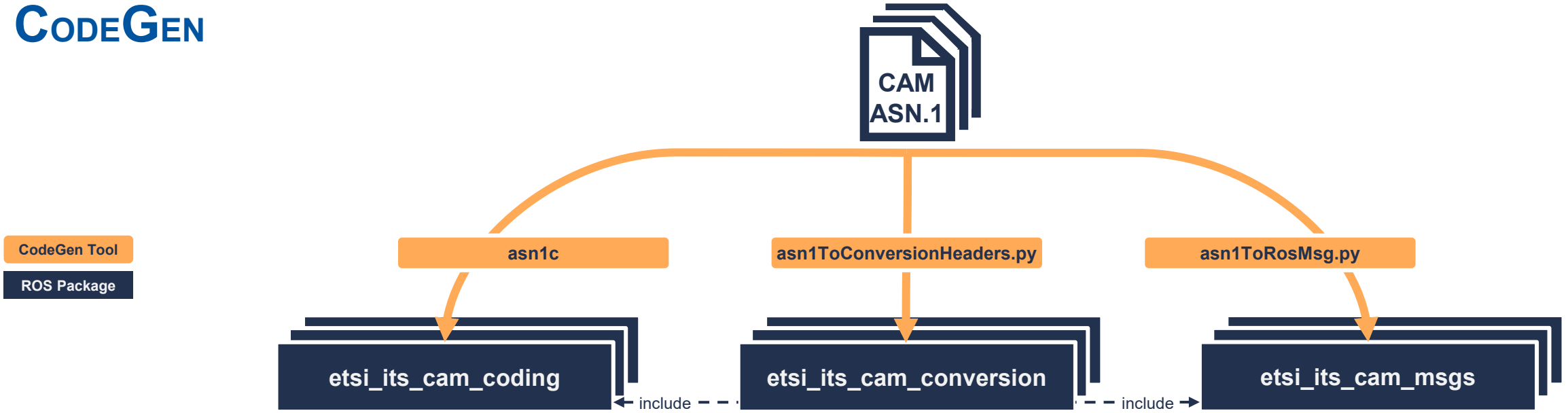



```c
#include "etsi_its_cam_coding/ItsPduHeader.h„
#include "etsi_its_cam_coding/CoopAwareness.h„
#include <etsi_its_cam_coding/constr_SEQUENCE.h>

/* CAM */
typedef struct CAM {
  ItsPduHeader_t header;
  CoopAwareness_t cam;

  /* Context for parsing across buffer boundaries */
  asn_struct_ctx_t _asn_ctx;
} CAM_t;
```

```
# cam.msg

ItsPduHeader header

CoopAwareness cam
```

Concept – `etsi_its_messages`

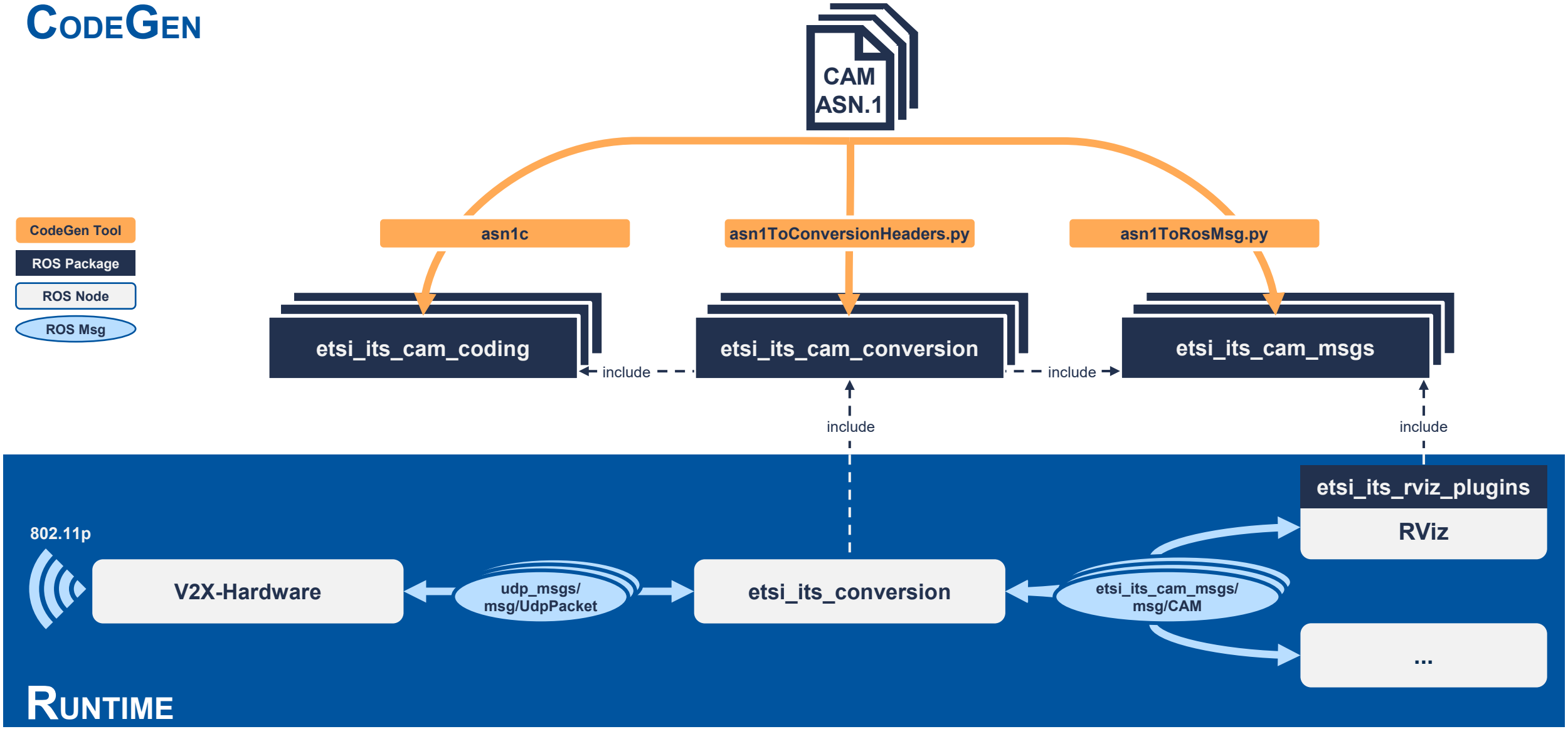
CodeGen




```
void toRos_CAM(const CAM_t& in, cam_msgs::CAM& out) {
  toRos_ItsPduHeader(in.header, out.header);
  toRos_CoopAwareness(in.cam, out.cam);
}

void toStruct_CAM(const cam_msgs::CAM& in, CAM_t& out) {
  toStruct_ItsPduHeader(in.header, out.header);
  toStruct_CoopAwareness(in.cam, out.cam);
}
```

Concept – etsi_its_messages

CodeGen

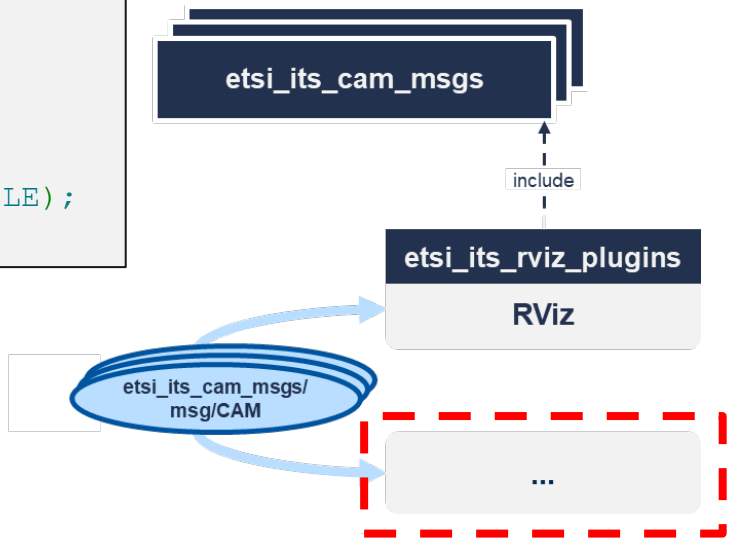


Usage in ROS-Applications

```
// ASN.1 Definition
// unit: 0,01 m/s
SpeedValue ::= INTEGER {
    standstill   (0),
    outOfRange   (16382),
    unavailable  (16383)
} (0..16383)
```

```cpp
#include <etsi_its_cam_msgs/msg/cam.hpp>

void callback(etsi_its_cam_msgs::msg::CAM& cam) {
  double speed =
    cam.cam.cam_parameters.high_frequency_container.basic_vehicle_container_high_frequency.speed.speed_value.value * 1e-2;
  cam.cam.cam_parameters.high_frequency_container.basic_vehicle_container_high_frequency.speed.speed_value.value = 16383;
}
```

```cpp
#include <etsi_its_cam_msgs/msg/cam.hpp>
#include <etsi_its_msgs/cam_access.hpp>

void callback(etsi_its_cam_msgs::msg::CAM& cam) {
  double speed = etsi_its_cam_msgs::access::getSpeed(cam);
  etsi_its_cam_msgs::access::setSpeed(cam, etsi_its_cam_msgs::msg::SpeedValue::UNAVAILABLE);
}
```



Access functions enable:

→ Easy access to nested ROS messages

→ Easy integration and conversion into other message formats

→ Ensure correct use of the standard

Publication – ROS Package Stack

- **`etsi_its_messages`**
  - ROS / ROS 2 packages installable via **apt**

```
sudo apt install ros-$ROS_DISTRO-etsi-its-messages
```

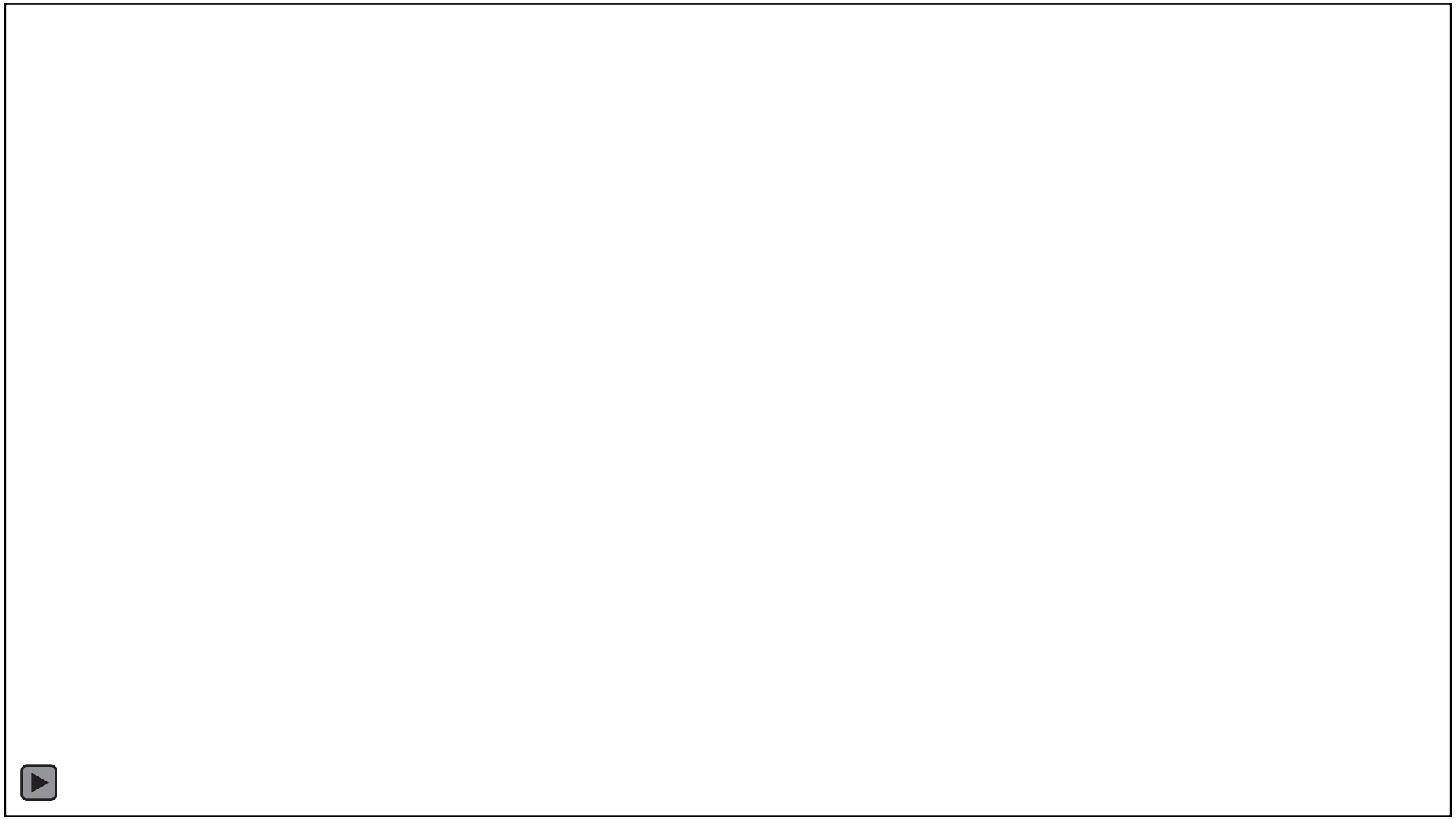
  - Additionally: available in containerized form (docker-ros)

```
docker pull ghcr.io/ika-rwth-aachen/etsi_its_messages
```

Status	ETSI ITS Messages	EN Version	TS Version
✓	CAM	1.4.1	2.1.1
✓	DENM	1.3.1	-
✓	CPM	-	2.1.1
✓	VAM	-	2.2.1
→ SOON	MAPEM	-	-
→ SOON	SPATEM	-	-

Open-source auf GitHub:
https://github.com/ika-rwth-aachen/etsi_its_messages

Visualization of CAMs transmitted by a standard VW ID.3



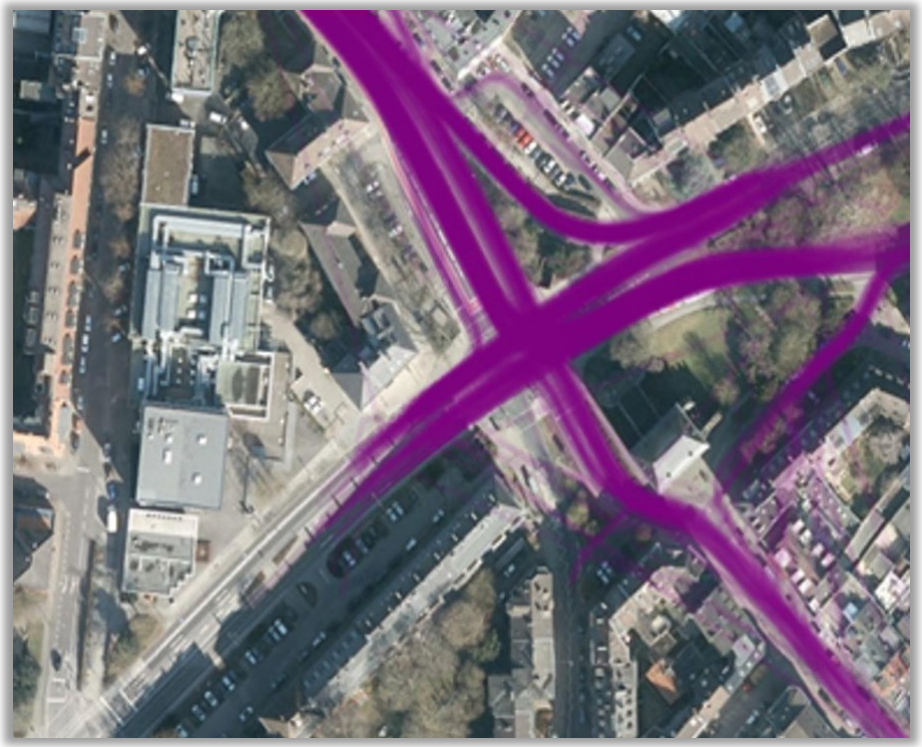
V2AIX – Dataset of ETSI ITS V2X messages

V2AIX Dataset

ITS Stations	CAMs	DENMs	MAPEMs	SPATEMs	V2X Duration	V2X Track Distance
2388	263 467	1338	2315	18 192	30 h	1988 km

A Multi-Modal Real-World Dataset of **ETSI ITS V2X Messages** in **Public Road Traffic**

- Dataset containing various vehicle-to-everything (V2X) messages, captured in public traffic via ETSI ITS-G5 and additional sensor information for context
- Collected in measurement drives and stationary infrastructure
  - more than 285 000 V2X messages from more than 2380 vehicles and roadside units
  - available at https://v2aix.ika.rwth-aachen.de/



V2AIX – Data Collection

Mobile Recordings

© Till Beemelmanns

Stationary Recordings

With Sensor Context

Urban
46 *Road Side Units*

Rural
11 *Road Side Units*

Highway
11 *Road Side Units*

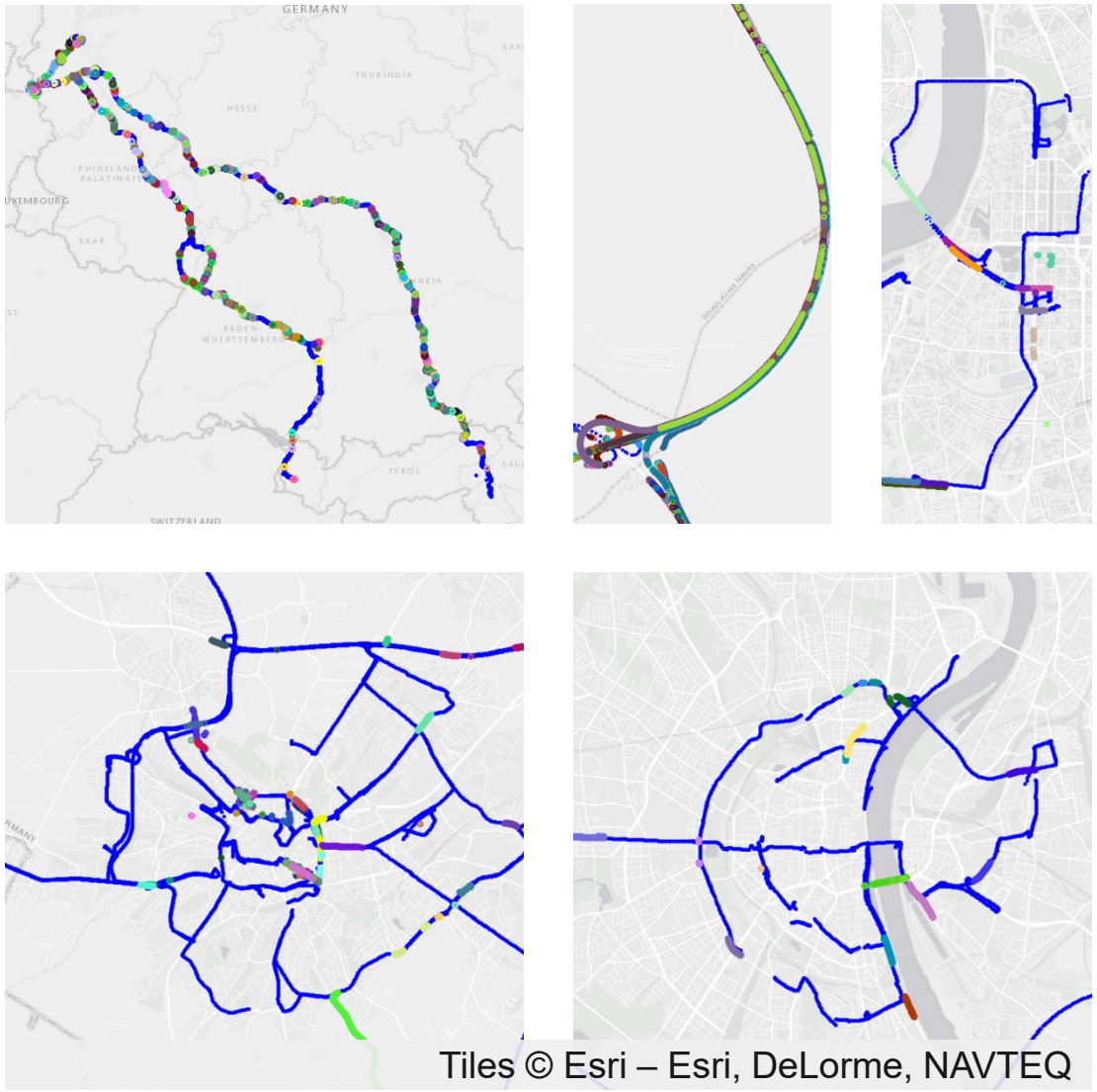
Without Sensor Context

→ **Vehicle drives with V2X OBU**

→ **Stationary recordings with V2X RSU**

V2AIX – Data Collection

Various Recording Locations



Dataset Format and Contents

ROS (2) Bag Files

- 1300 GB Filesize
- V2X Messages (encoded & decoded)
- GNSS Poses
- Sensor Context Data
  - Camera Images
  - Lidar Point Clouds

JSON

- 21 GB Filesize
- V2X Messages (encoded & decoded)
- GNSS Poses

→ Preview available on Website

Funding

`etsi_its_messages` is being developed and funded as part of the following projects:

Althena - https://www.aithena.eu/

- Funded by the *European Union's Horizon Europe Research and Innovation Program* under Grant Agreement No. 101076754

autotech.*agil* - http://www.ika.rwth-aachen.de/autotechagil

- Funded by *the Federal Ministry of Education and Research* (BMBF) under funding reference 01IS22088A

6GEM - https://www.6gem.de/

- Funded by *the Federal Ministry of Education and Research* (BMBF) under funding reference 16KISK036K

Funded by the European Union

SPONSORED BY THE
Federal Ministry of Education and Research

Questions & Discussion

CodeGen