HEADSTART:
Positioning & Communication V2X

Andrea Steccanella [CRF],

Jacco van de Sluis [TNO]

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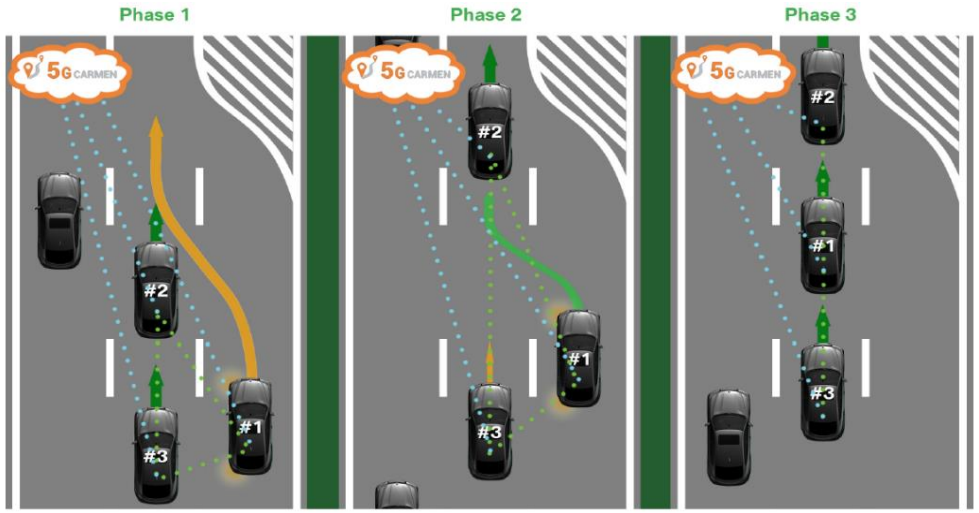
Impact of Positioning and V2X into CAD

Highway Pilot:

- **Cooperative Lane Merge**
  - ✓ Position with lane-level accuracy
  - ✓ V2X Comm. vehicle data sharing

5G CARMEN

1. Trigger of lane-merge request,
2. Open the gap,
3. Cooperative ACC.

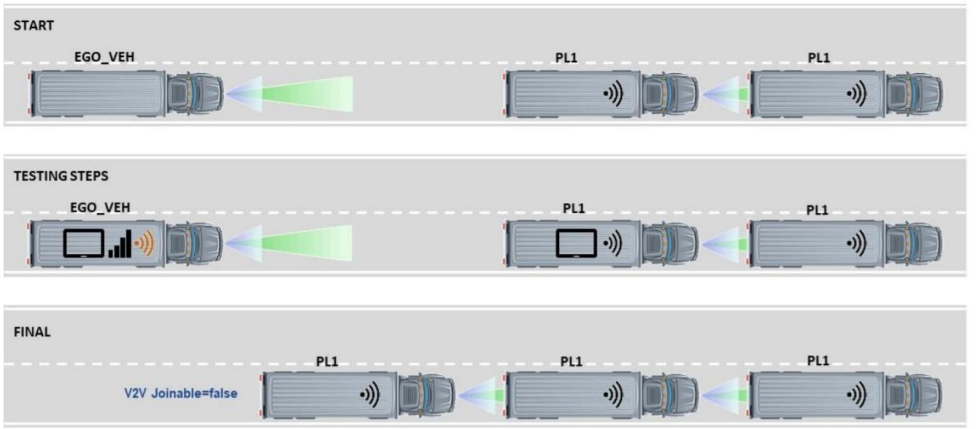


Truck Platooning:

- **Platoon formation**
  - ✓ Position of each truck in the lane
  - ✓ V2X Comm. vehicle data-sharing

ENSEMBLE

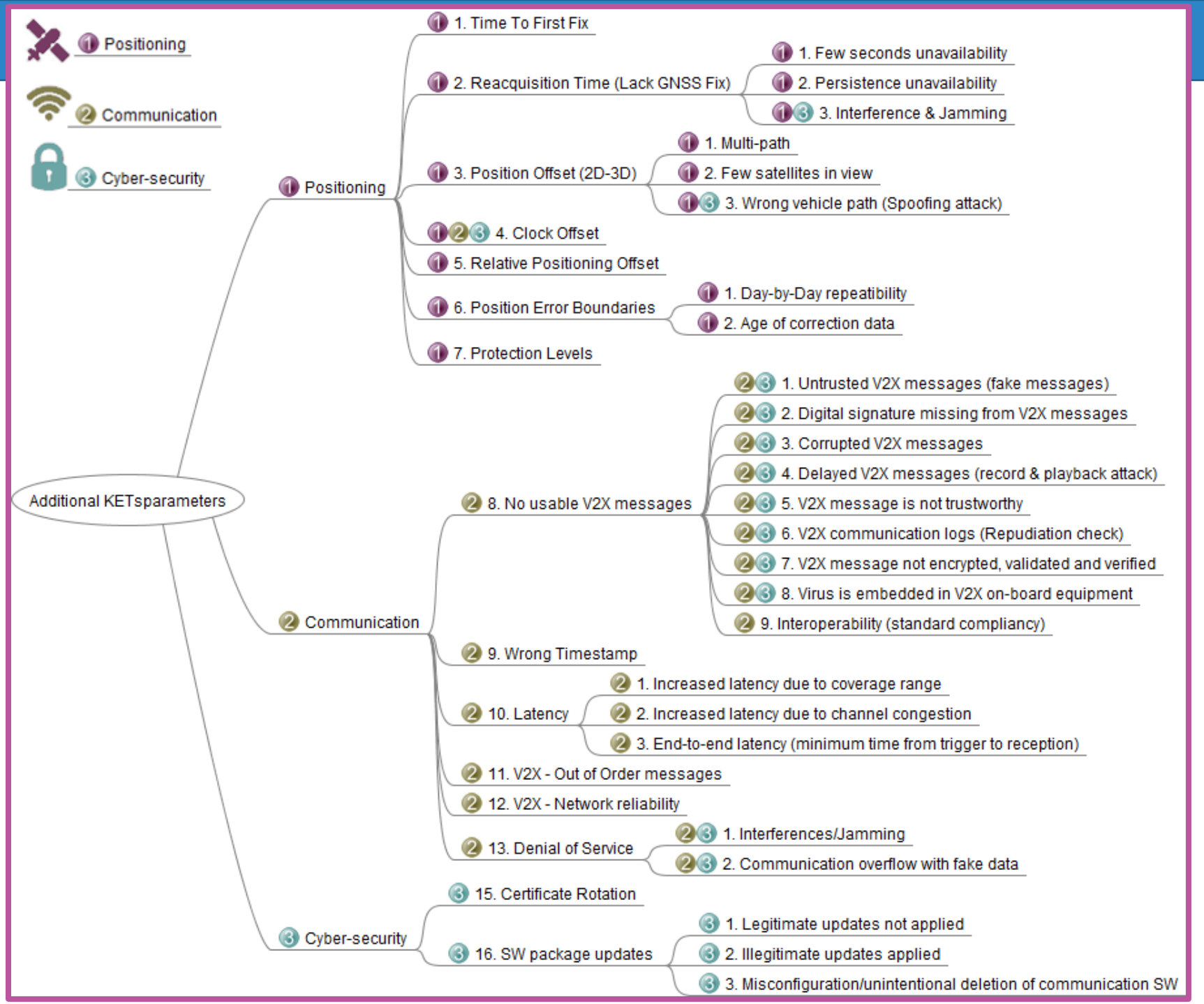
1. Detection of the platoon,
2. Joining procedure,
3. Cooperative driving.



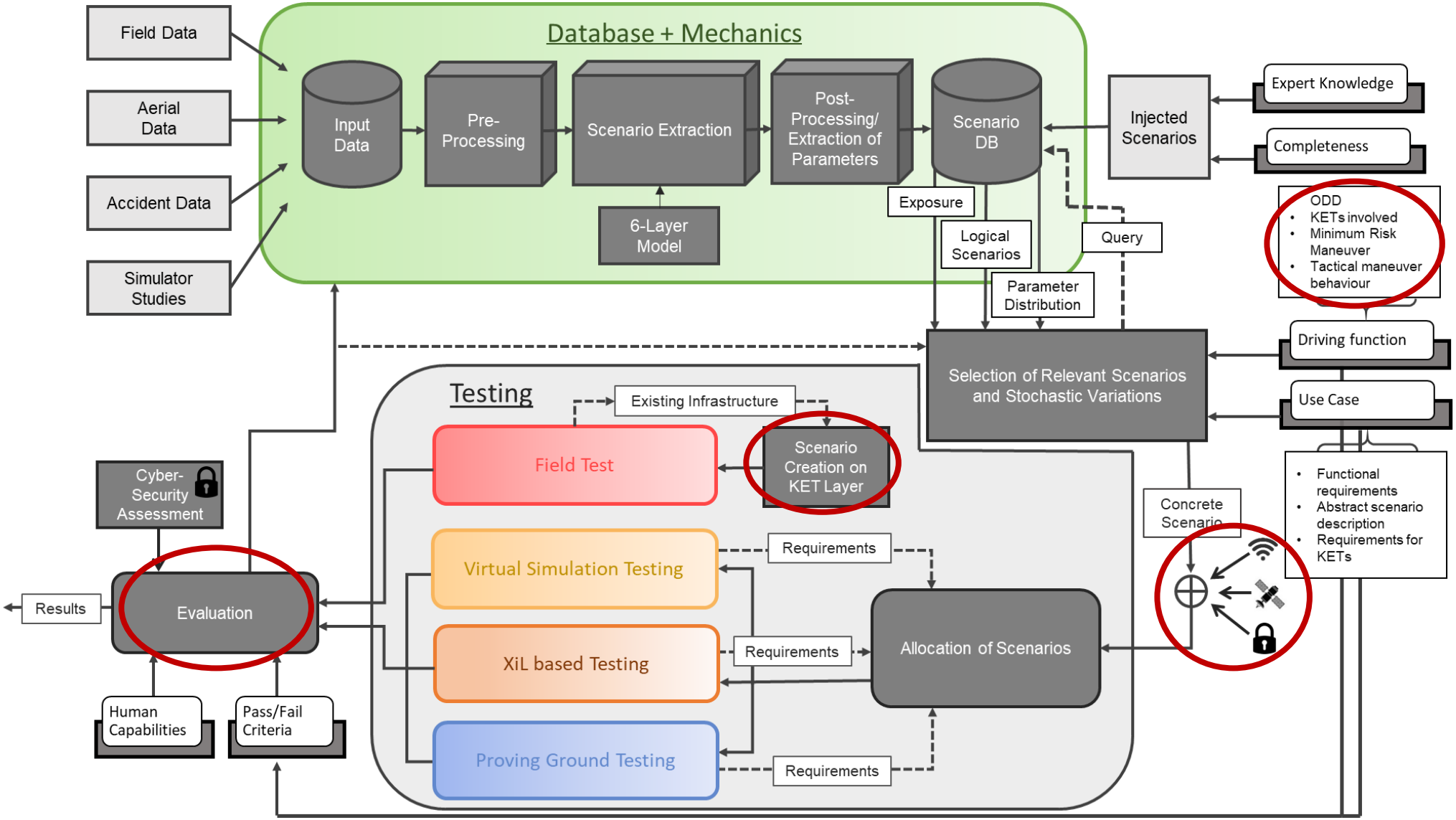
New information channels

New failure possibilities

- Additional parameters in the validation methodology
- Cross-dependencies among these parameters



Integration of Positioning & Communication V2X

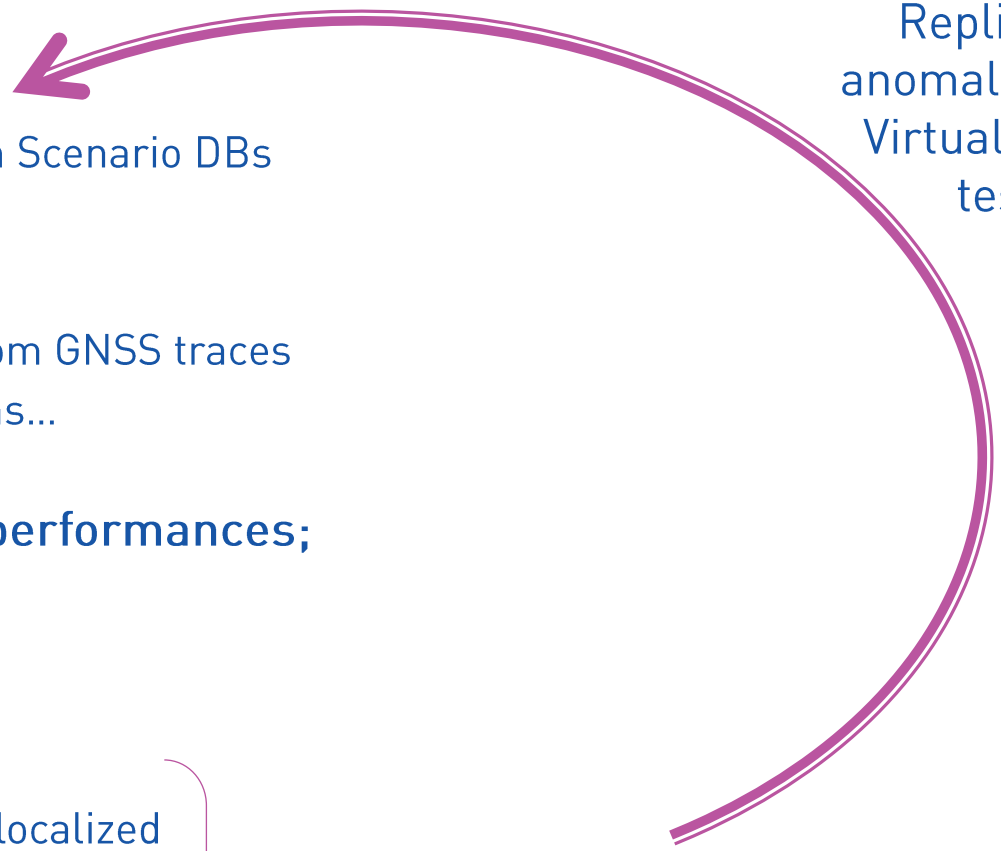


KETs integration

1) **Virtual Tests**
   - Stochastic Variation of parameters starting from Scenario DBs
   - Ideal, probabilistic, physical sensor models
2) **Hardware & Software in the Loop**
   - Creation of simulated V2X messages starting from GNSS traces
   - Injection of RF errors: losses, delays, corruptions…

Comparison of driving function performances;
Improvement of fidelity testing.

3) **Proving Ground**
   - Validation of driving function relying on the geo-localized information in a controlled environment
4) **Field Tests**
   - Validation of driving function in a real-world: interaction with unpredictable obstacles



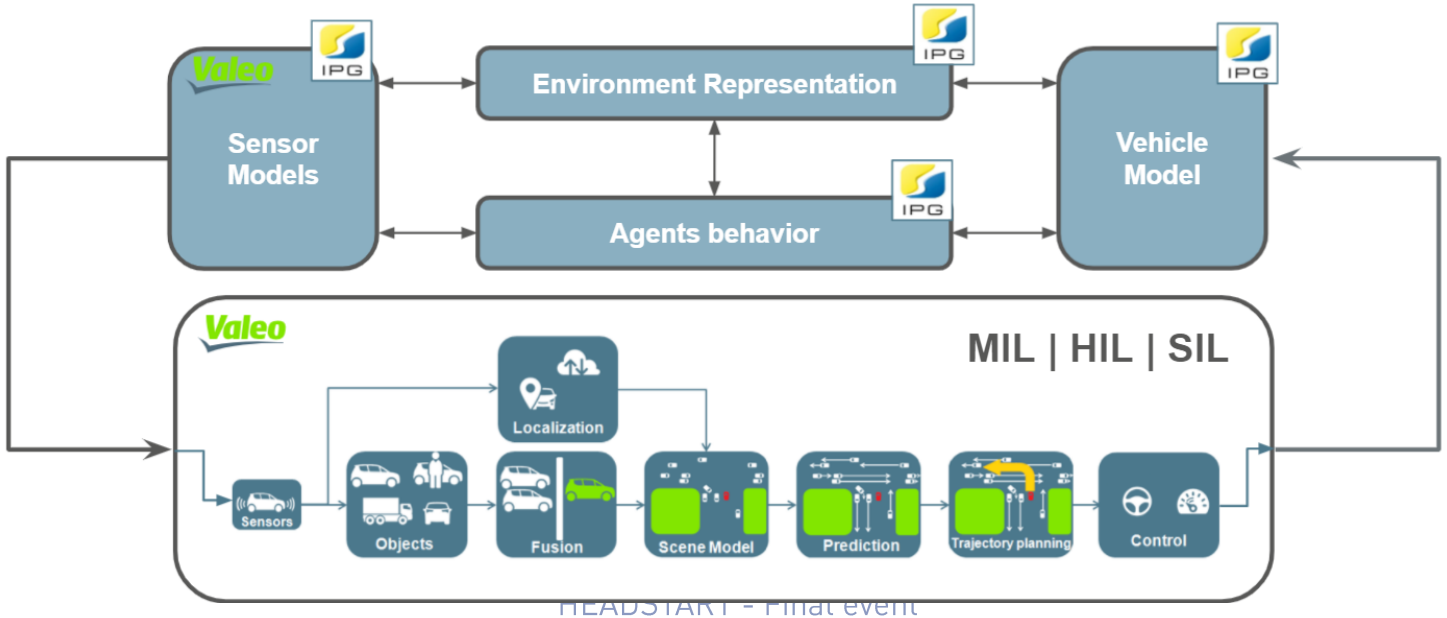
Virtual Tests

✓ V2X needs can be part of scenario **considering different "modes of operation"**:

- Technologies: IEEE 802.11p, C-V2X (PC5), LTE/5G (UU/MEC), other short-range tech.,
- Informative (e.g. for driver) VS Cooperative maneuvers (e.g. for AD-functions).

X Lack of existing scenario databases for HD Positioning & V2X.

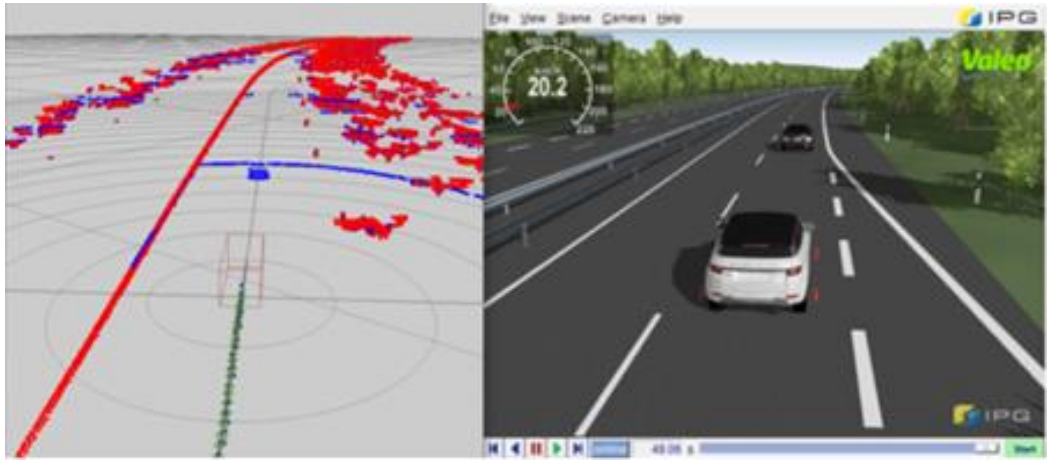
\- Simulated position traces available but without realistic errors.



Software & Hardware in the Loop testing

✓ **Suitable within many scenario categories:**

- Creation of synthetic scenarios to test the AD function,
- Multi-actor interactions: complex scenarios are possible,
- Repeatable testing including rare events: stress testing, noise injection.



✗ **Many difficulties for black-box systems:**

- Data-fusion prevents to test the input components independently.
- Connectivity extend the complexity of the system → external agents will impact into the AD output.

Proving Ground & Field tests

- ✓ V2X output is a standardized interface to validate the Positioning & Communication capabilities.
  - GNSS/IMU system experience real-life dynamics,
  - No need to understand the contribution of each component to verify the AD output.

- X Support from the car-makers is still necessary to perform a complete analysis of AD function relying on V2X and Positioning.
  - Data-fusion for localization task,
  - Dependency on HD-maps or Corrections data.

Conclusions

- ✓ **Extending scenarios with V2X comm. & Positioning adds a layer of complexity**
  - Absolute positioning is strongly connected to V2X,
  - Together they can trigger new AD functions → preventive trigger & maneuver coordination,
  - V2X Communication can be safety-critical → cooperative truck platooning use case,
  - Scenario-based assessment very suitable to identify algorithms vulnerabilities.

- ✓ **Verification & Validation must be performed at several levels:**
  - **Virtual Testing**: application level,
  - **Software/Hardware in the Loop**: component level,
  - **Proving Ground and Field Tests**: realistic environment for the complete system (or system-of-vehicles).

- ✓ **Post-processing will play a crucial role:**
  - Currently highly relying on expert knowledge,
  - Common data formats must be identified → to gain knowledge from many vehicles.