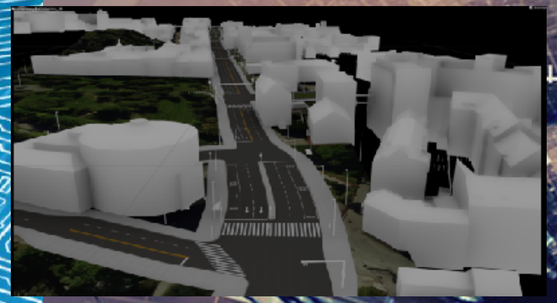
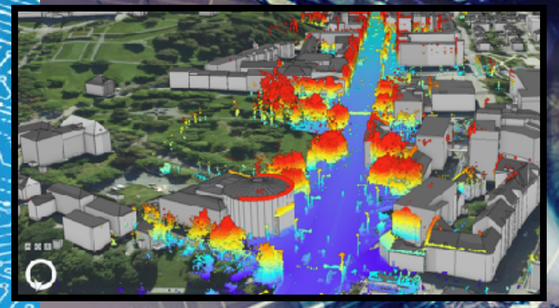
MoST / Mobilitetslab kick-off meeting, 2022-12-13

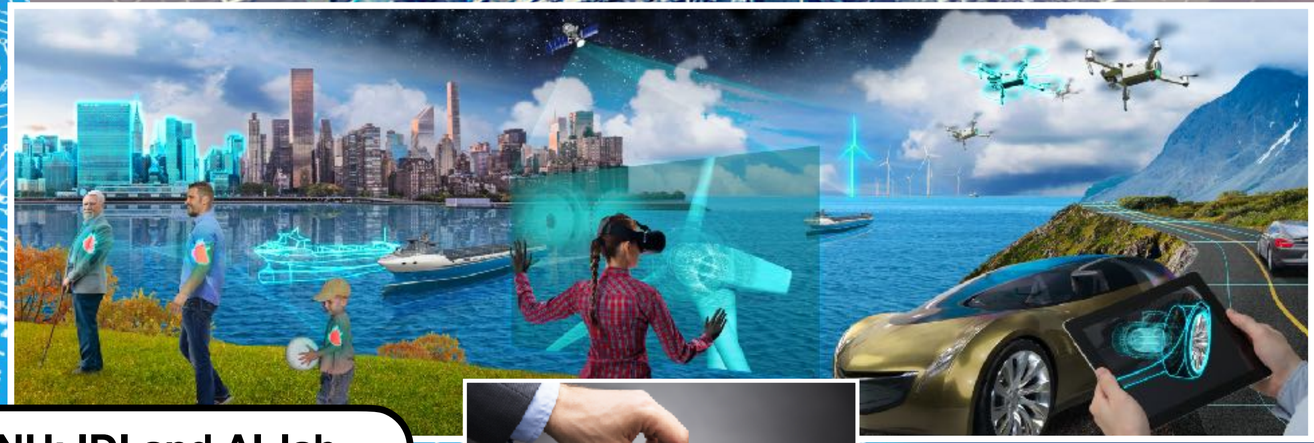
Helhetlig tenking..

Trafikksikkerhet
Fremkommelighet
- **Mer mobilitet**
  - **Mindre biler, mer micro**

Bærekraft
- **Klima og miljø**
- **Økonomi**
- **Sosiale fohold**





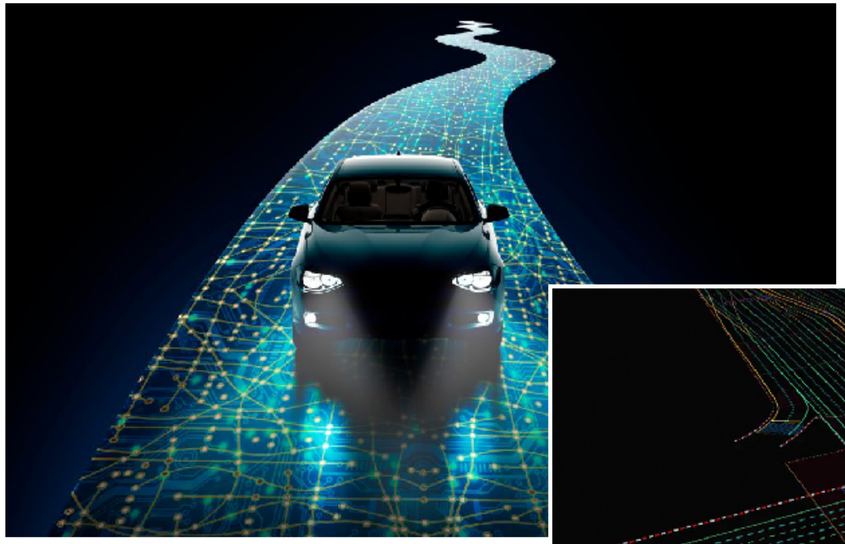


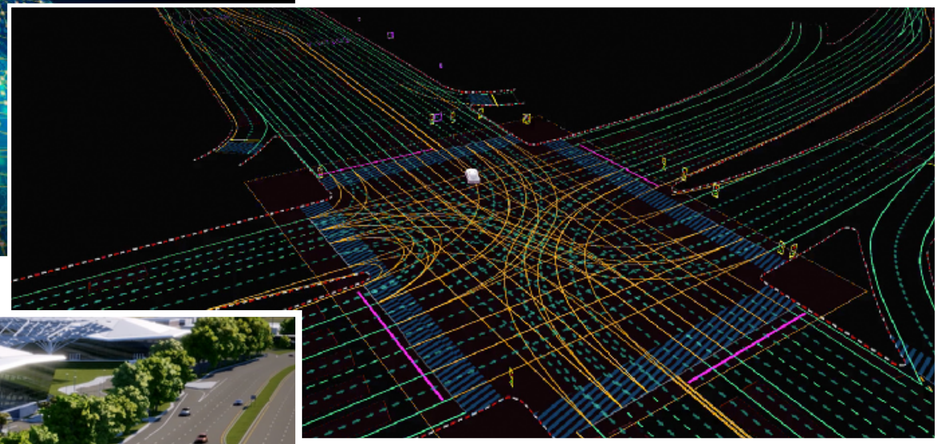
Frank Lindseth, NTNU: IDI and AI-lab

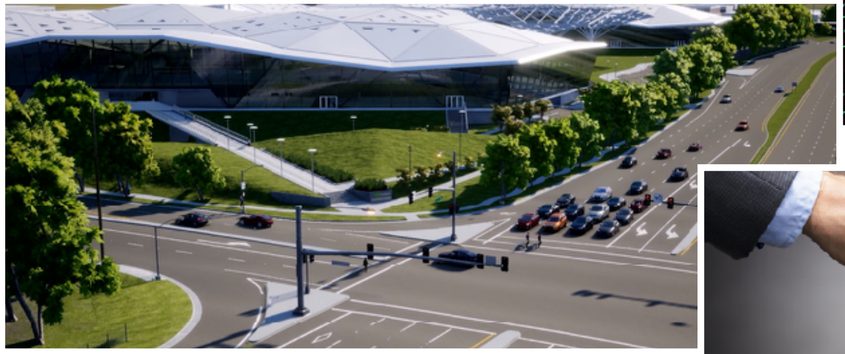
MoST - Area 3: DT

Agenda

- Hva er en DT
- Hvordan generere DTs
- Hvordan bruke DTs
- MoST - Area 3: PhDs
- Relaterte prosjekter







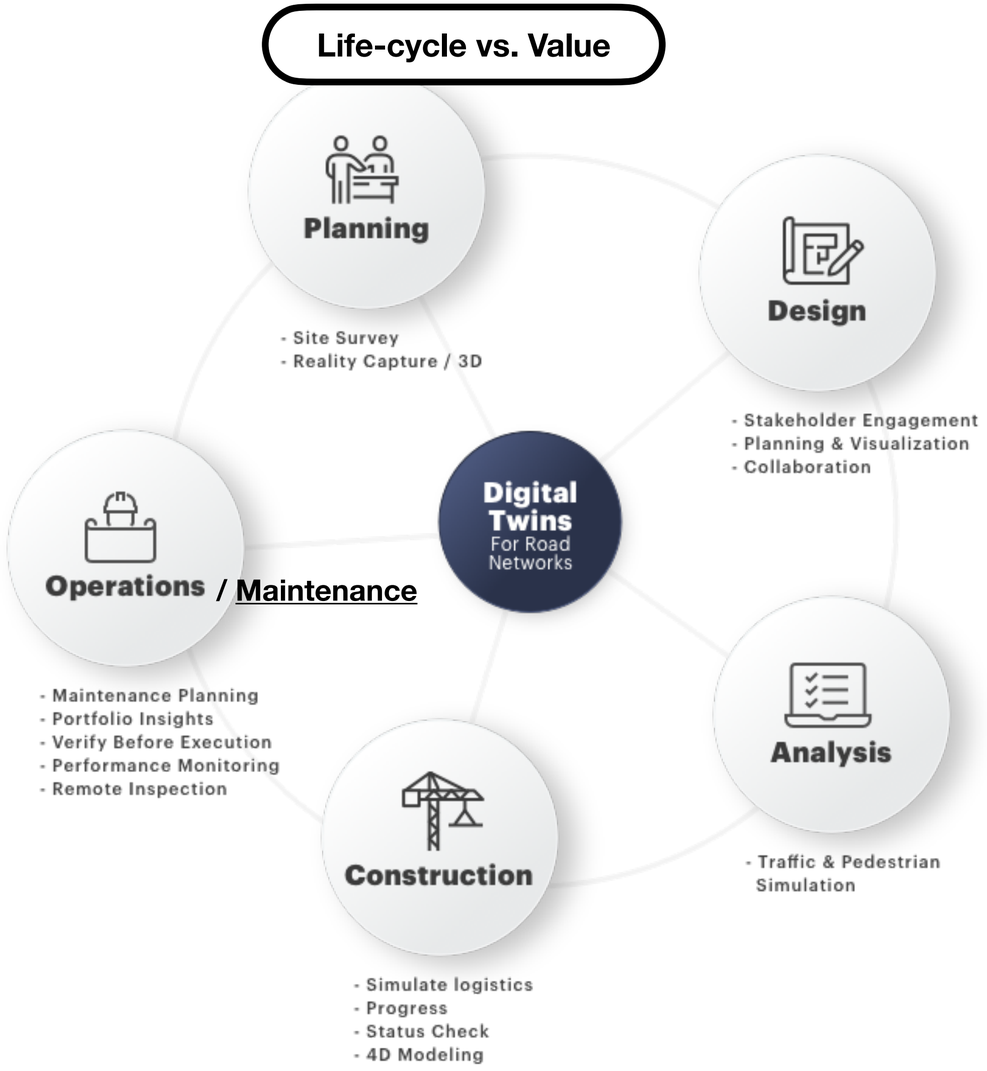
Hva er en DT

Digital Twins (DTs)

- **DT**: a digital copy/model/rep. of a physical asset (the PT) connected through sensors/data and actions.
  - Digital Twin - **Digital Technologies** - Digital Transformation (and a single source of truth)
  - AI/BigData, IoT/Sensors/5G, XR/Viz, Collaboration, Simulation, Cybersecurity and Privacy
  - **Life-cycle**: from (long before) cradle to (long after) grave (documentation) - planning, design, simulations, optimisation, manufacturing, monitoring, prevention, diagnostic, predict, prescribe / decision support, automation, maintenance and destruction.
  - **Hierarchical**: different scales / zoom in&out, from complex systems down to the smallest detail.
  - **Digital (Mobility) Twins (DMTs)**: Trafikksikker, Fremkommelig og Bærekraftig (miljø/natur, økonomi, sosialt/den gode reisen)

Digital (Mobility) Twins (DMTs)

- Standalone
- Descriptive
- Diagnostic
- **Predictive**
- **Prescriptive**
- **Autonomy**



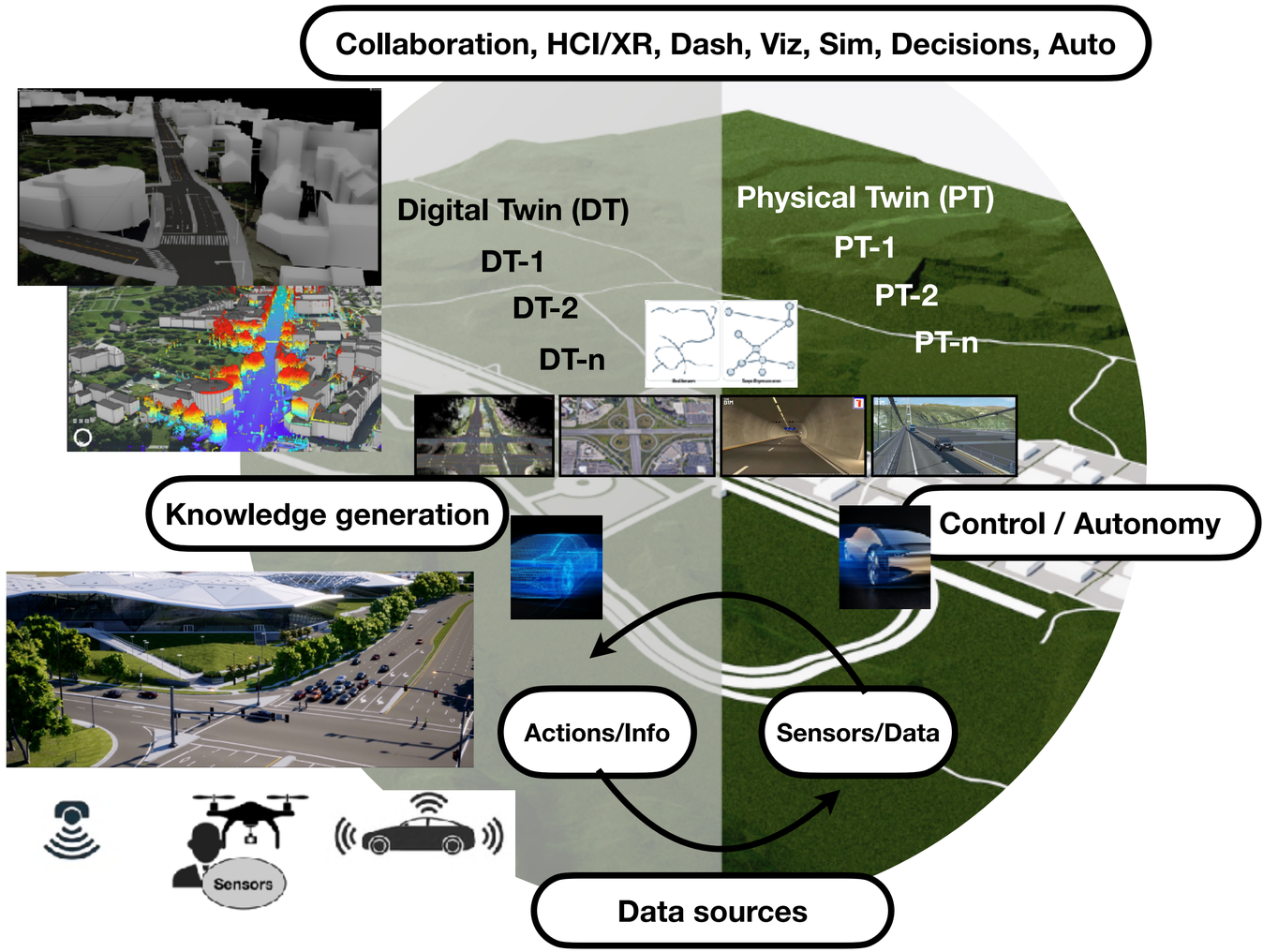
Digital Twins (Strategic research area, IE)

PERSEUS (Doctoral Programme, IE)

Digitale Tvillinger (EiT)

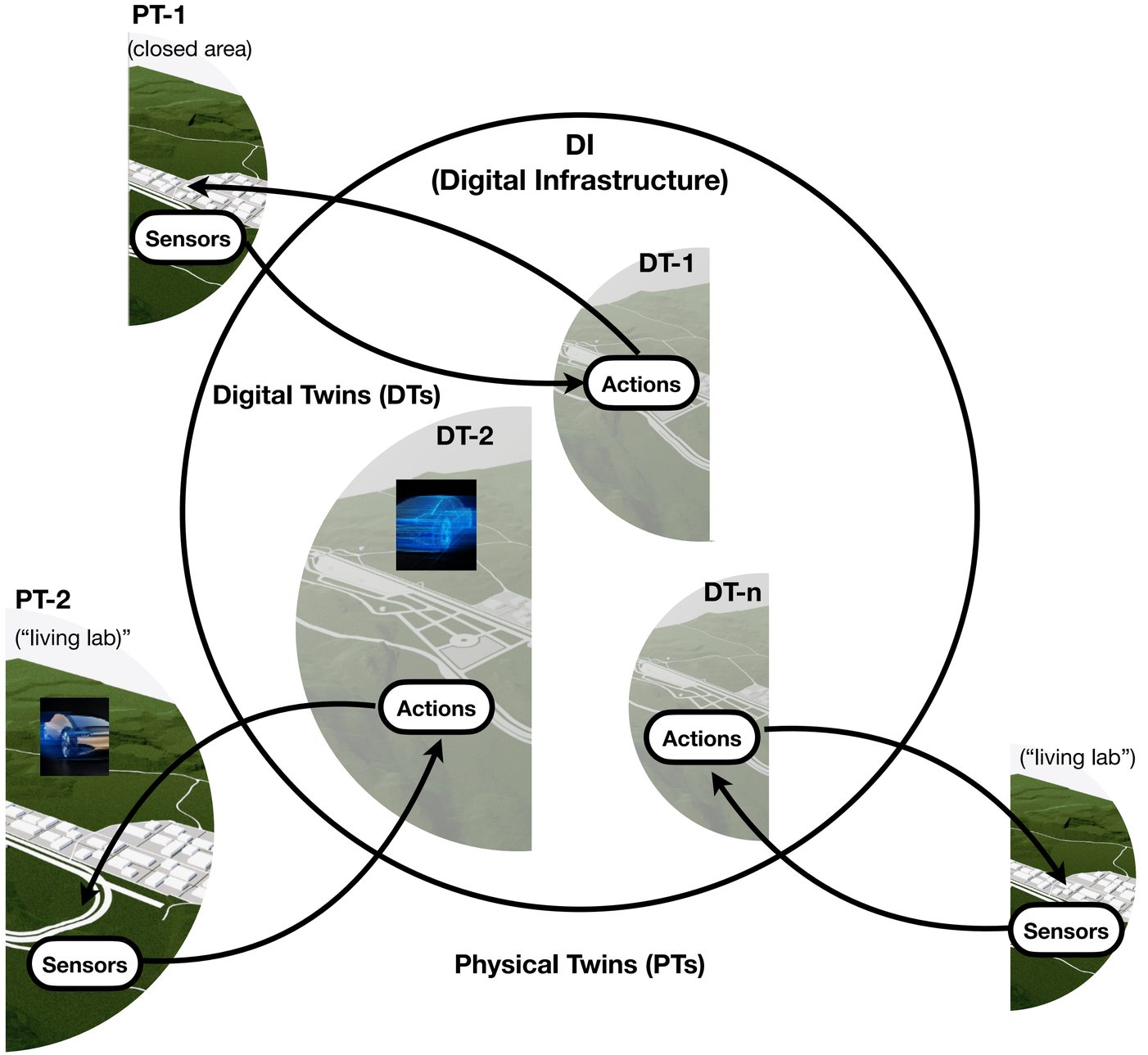
Digital (Mobility) Twins (2)

- **PhD_3-1: Basis / Standalone DT** (Samarbeidsplattform, forskning & kommers i lag, integrere eksiterende data, reality capture, rawdata-to-DT, viz/XR, hva hvis scenarier osv.)
- **PhD_3-2: Oppdatert / Dynamisk DT** (Statiske og mobile sensorer for høsting av data, kommunik./IoT/5G, motta, integrere og viz i eksisterende DT, personvern og data-sikkerhet)
- **PhD_3-3: BigData og AI** (AI-basert data-dreven beslutning-støtte og automatisering, kunnskap fra data, predikere frem i tid, DT for data-deling (bidra med data og få info), integrerer transport modeller)
- **PhD_3-4: Simulering og Autonomi** (Simulering av dynamiske «hva hvis» scenarier, predikative modeller, f.eks. stå i et kryss og oppleve, autonom kjøring om vinter vha. HD-maps/DT, flåtestyring, opplæring av AI-sjåfør)
- **PhD_3-5: XR & Viz** (utvidet virkelighet, samarbeid og inbygger feedback gjennom hele livsløpet)



Digital (Mobility) Twins (3)

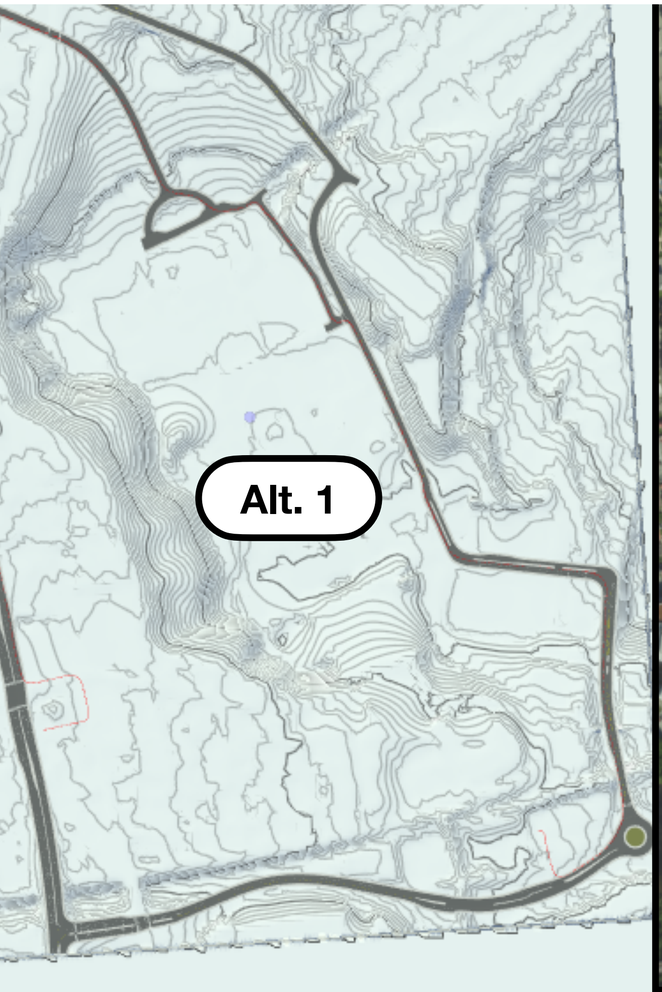
- “Next-generation Digital twins for lifecycle management and automation of smart transportation Infrastructure and future mobiliTy solutions (DigIT)”
- Digital Research Infrastructure

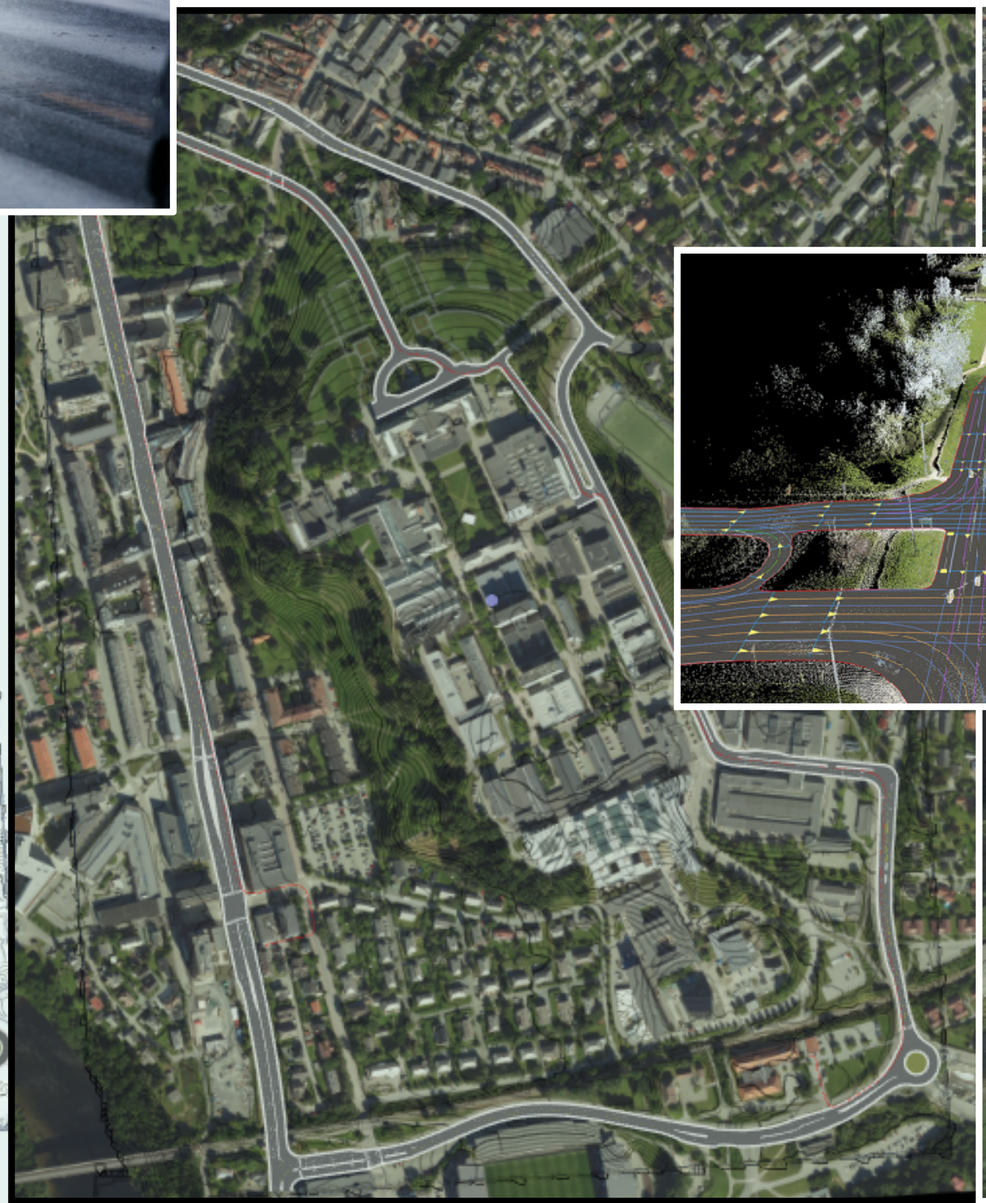


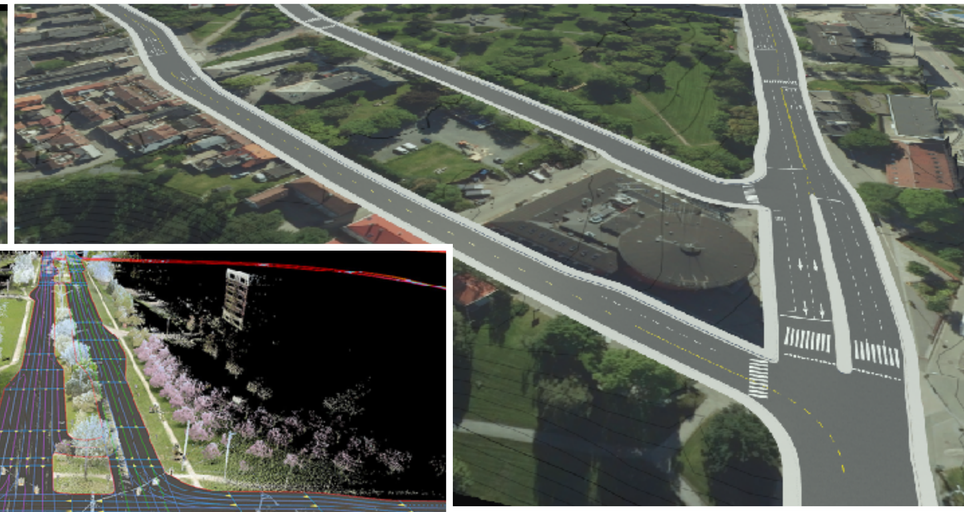
Hvordan generere DTs

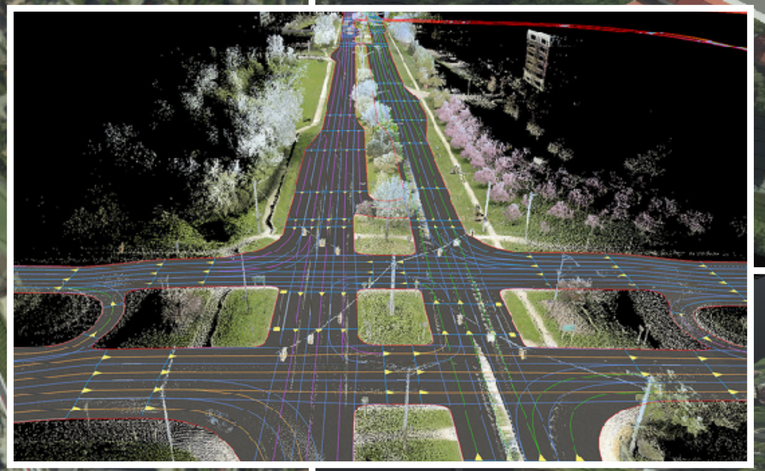
Sette sammen offentlige data, f.eks. høyde-modeller, orto-foto etc.
Site surveys / AVs med sensorer
NeRFs

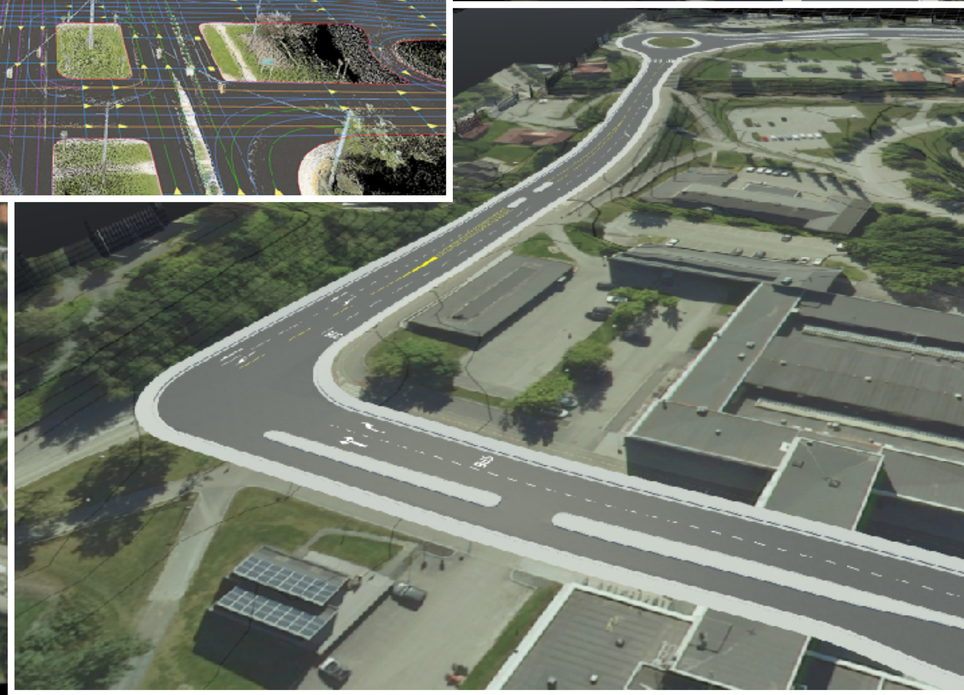
DTs: HD-maps -> Digital Twins



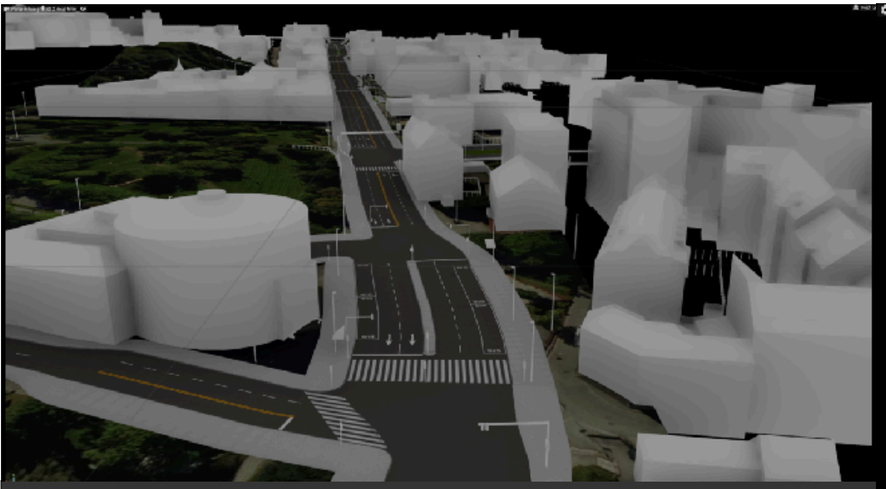


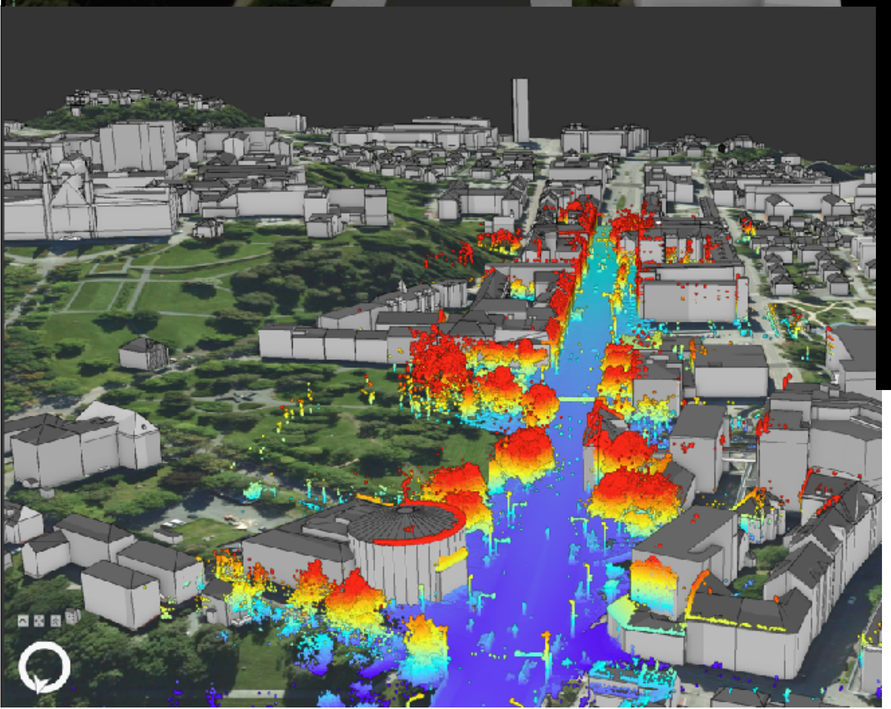


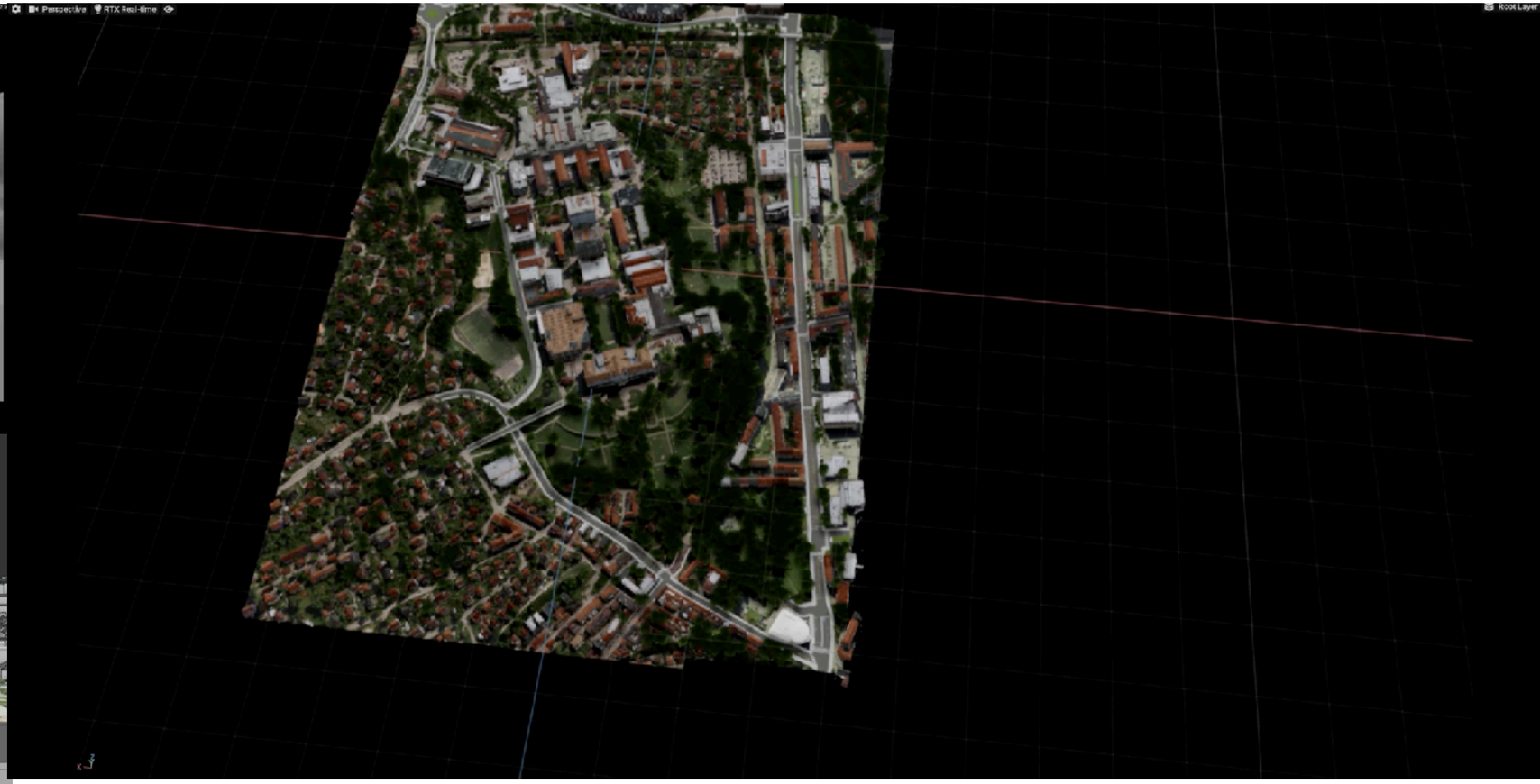


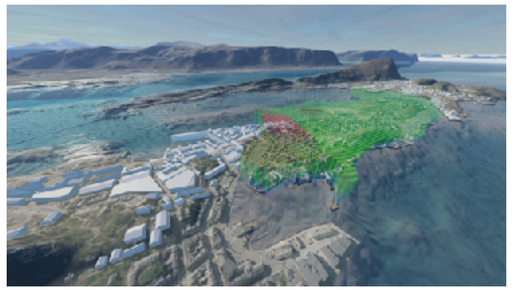


DTs: Elgeseter-gate



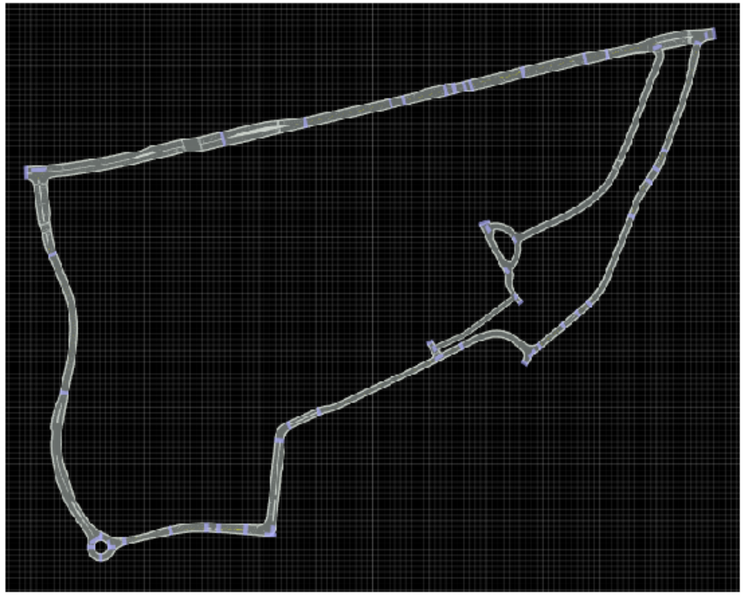


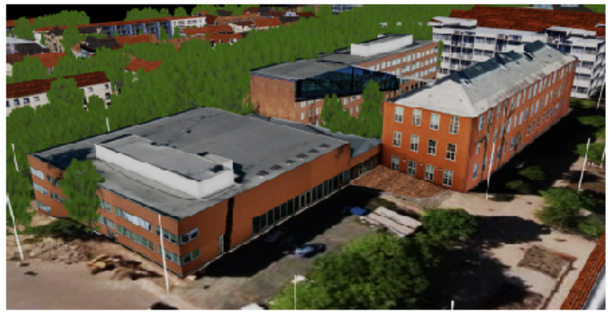




Augment City++
(KPI overlay)

DTs: Road network & Buildings



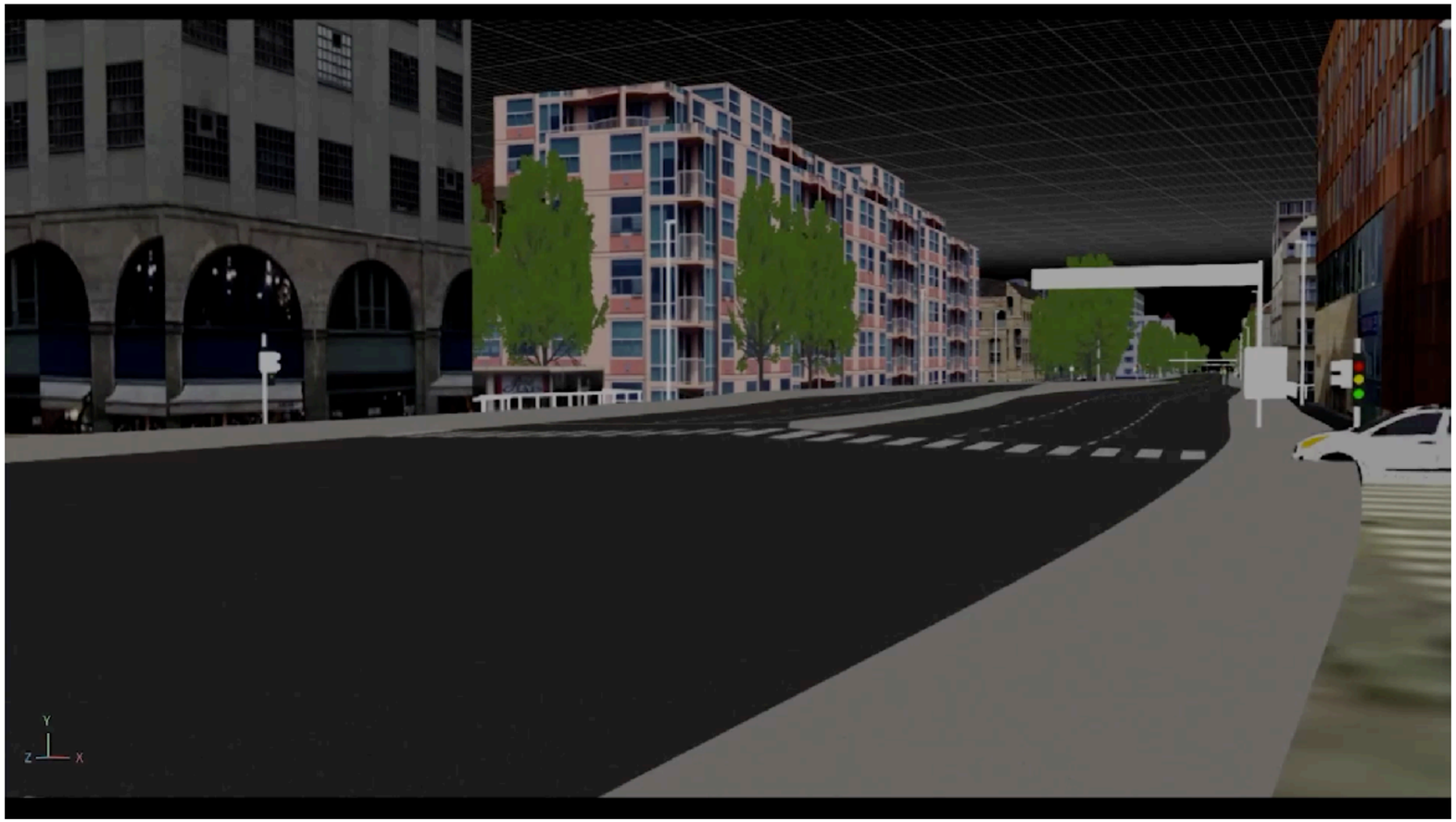


(a) Building 1

(b) Building 2

(c) Building 3

DTs: Animation

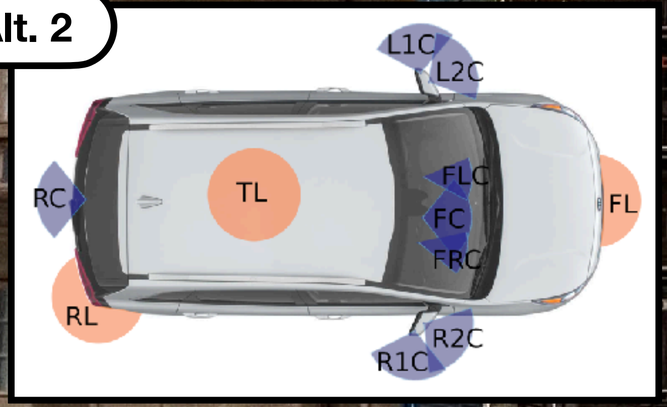


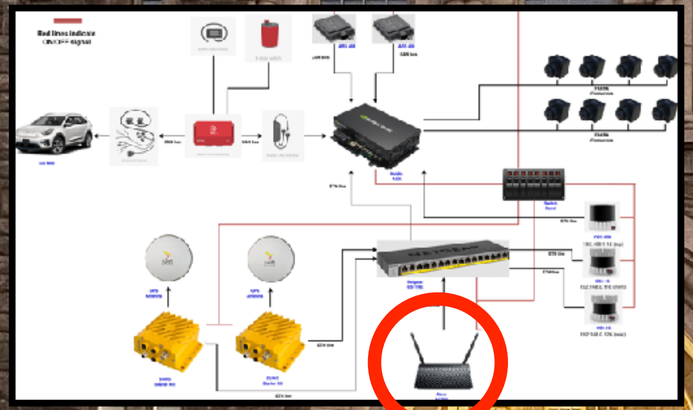
DTs: VR

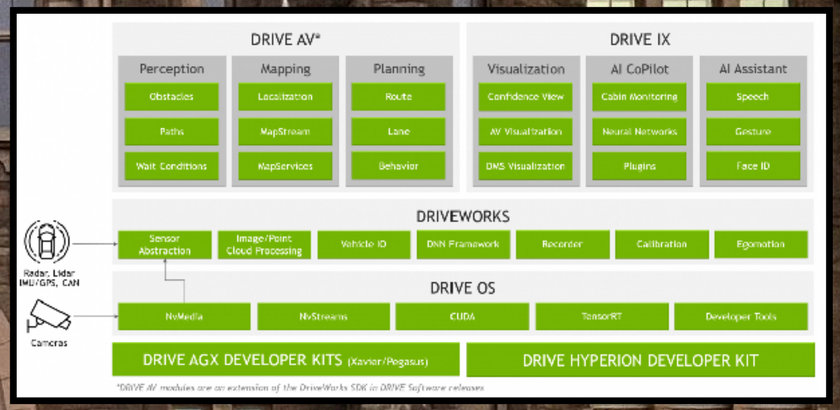
DTs: Simulation

Hvor?

Alt. 2







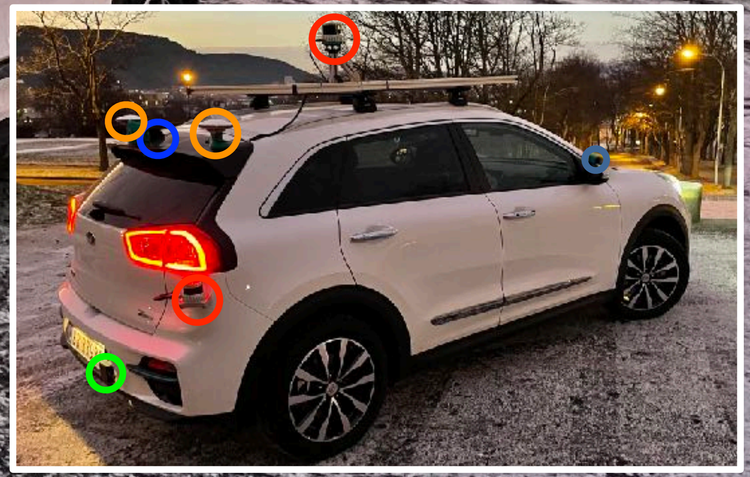
Modular approach:

- Mapping & Localisation
- Perception & Prediction
- Planning & Control

Sense - Reason - Act

End-to-End approach:

- Imitation Learning
- Reinforcement Learning




LiDAR

LiDAR-images

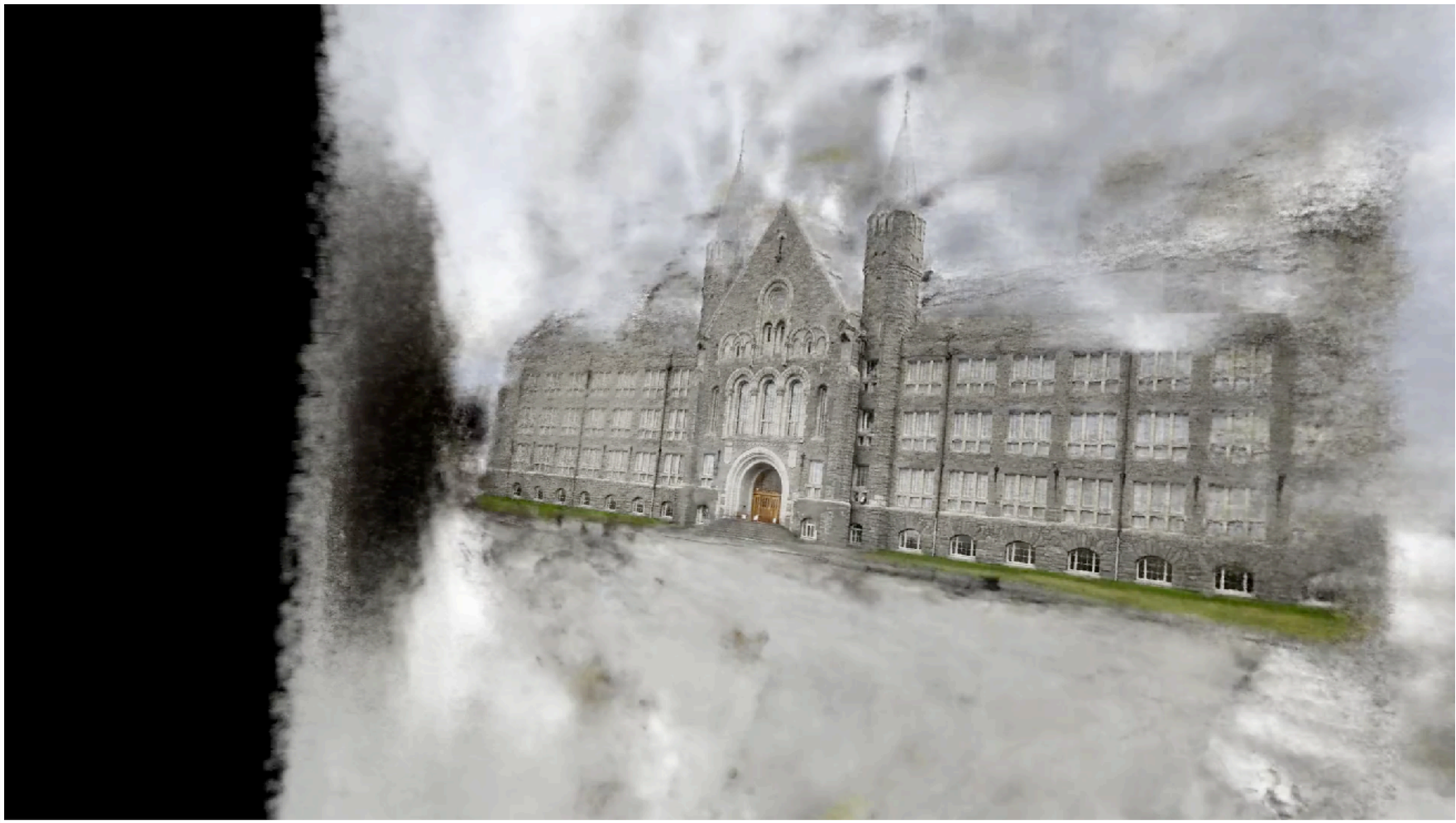
Anonymization

Raw

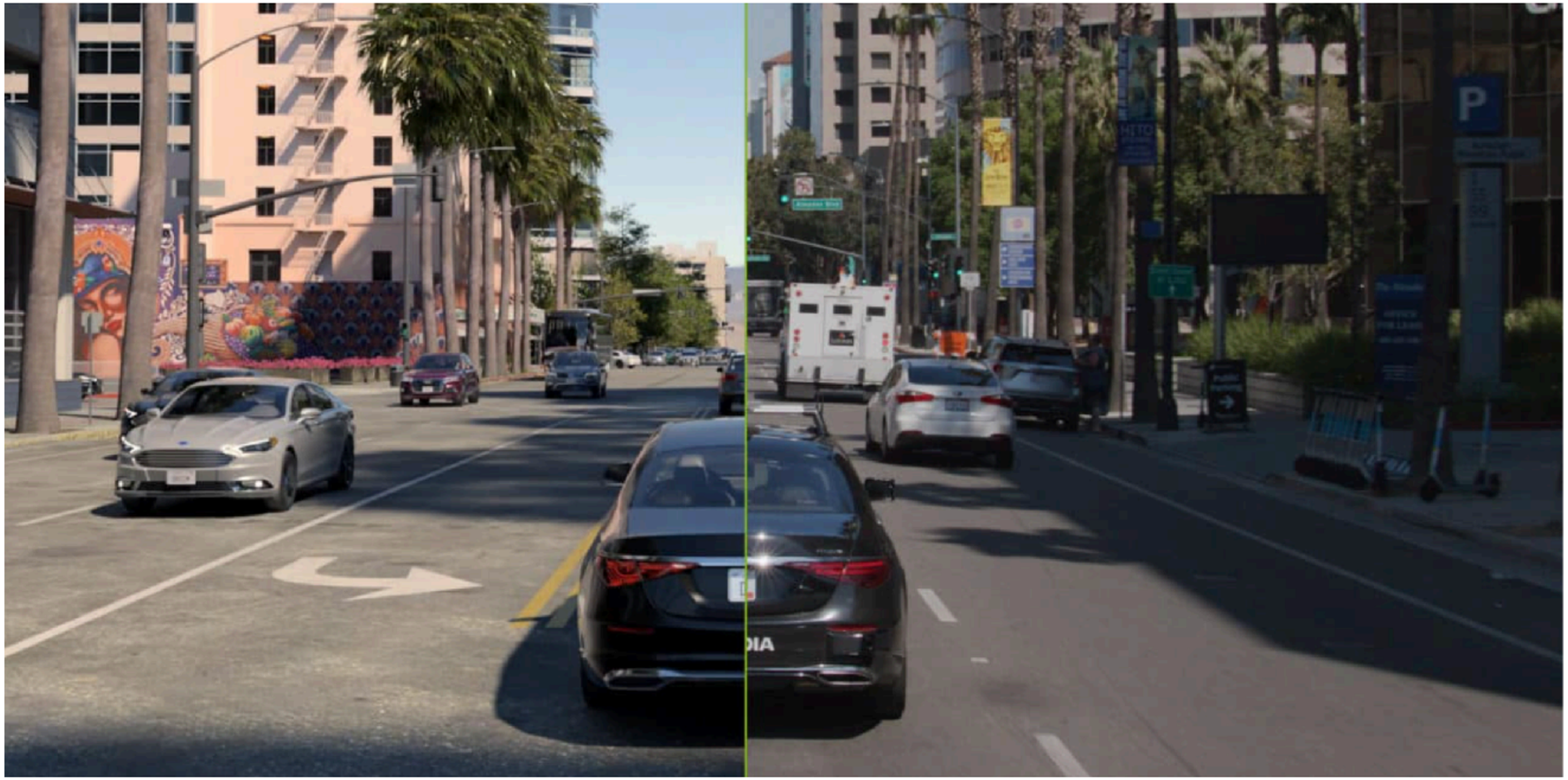
Alt. 3

Future: NeRF?

Early attempt



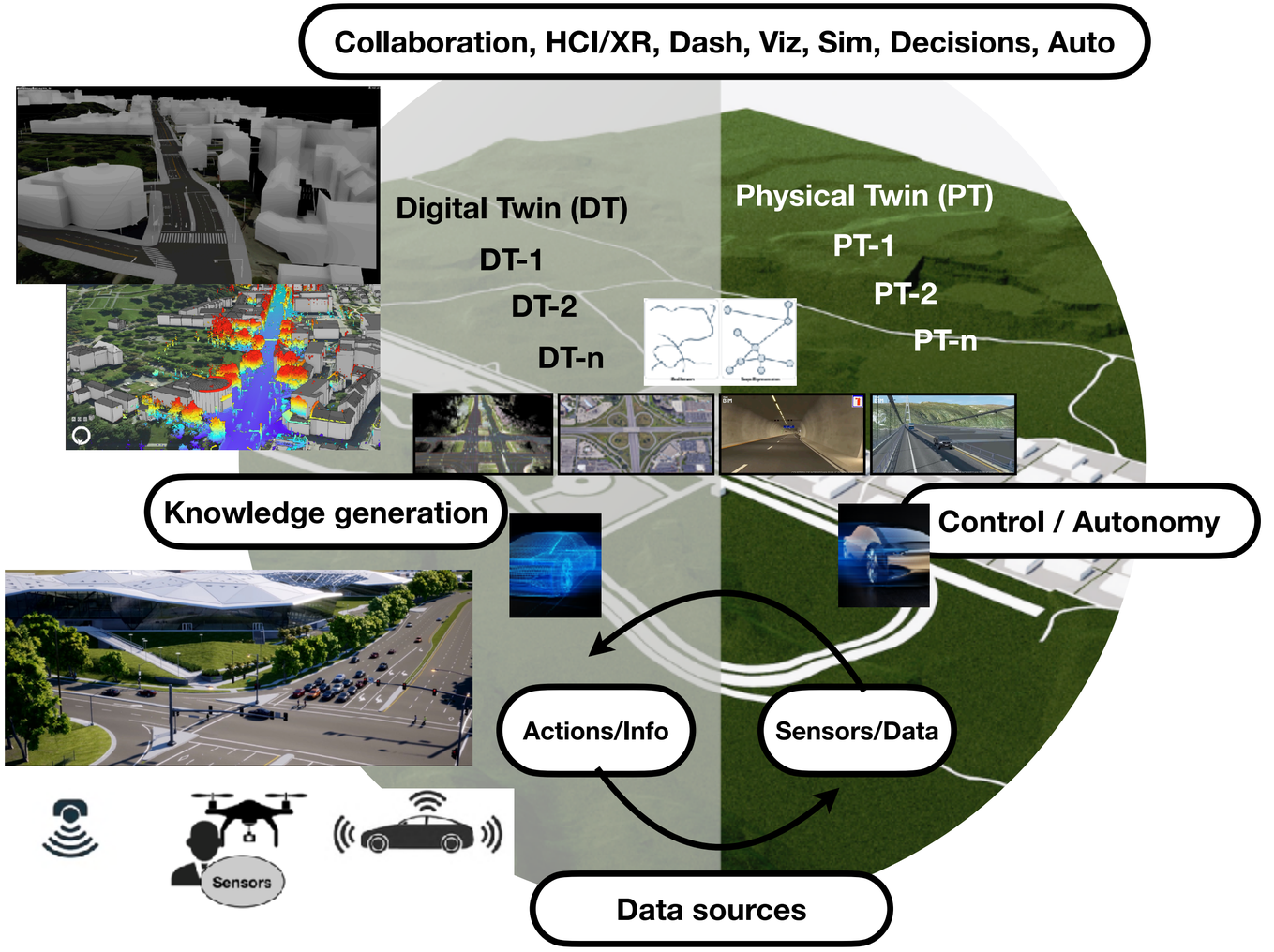
Future: NeRF in Simulators?



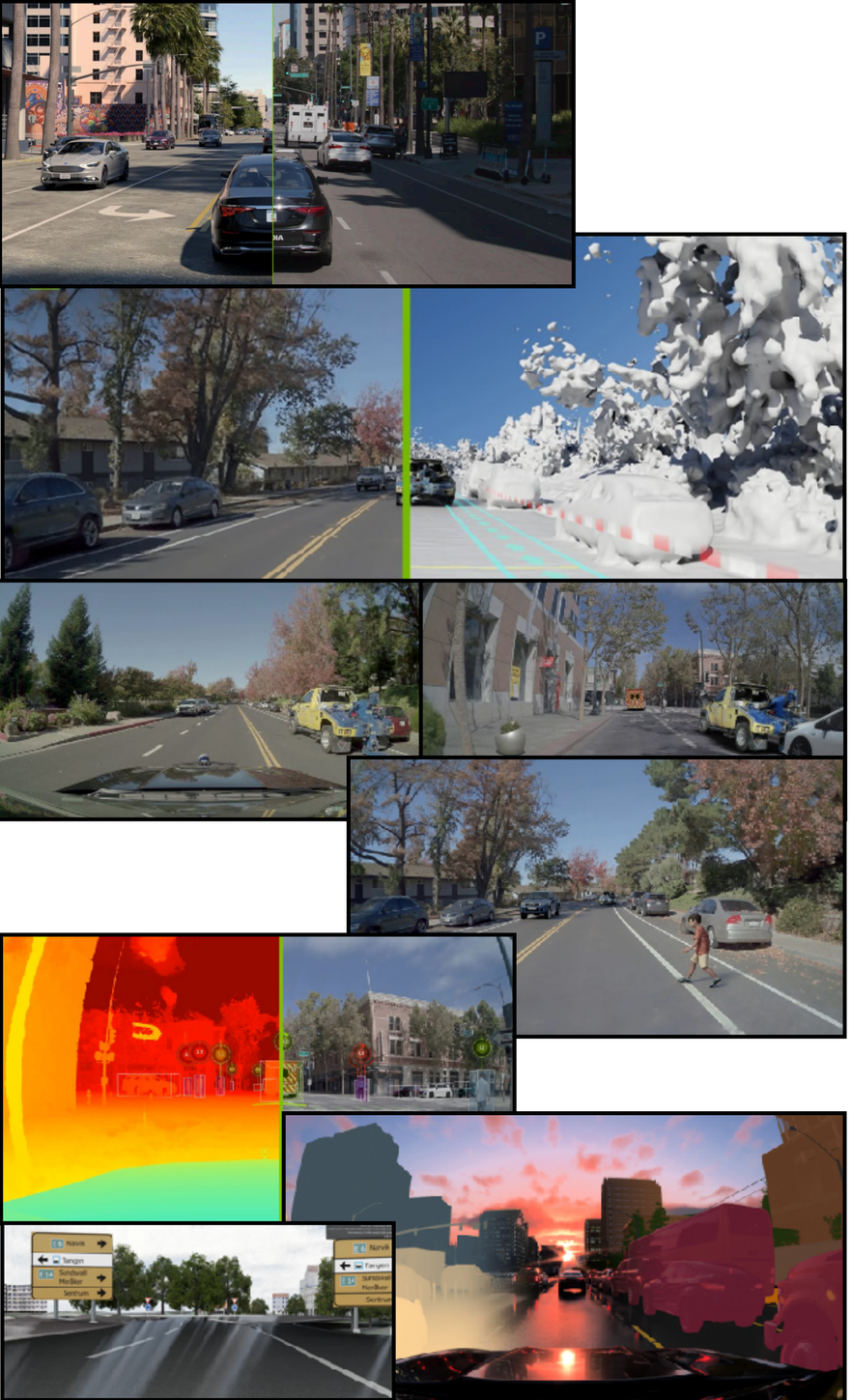
Hvordan bruke DTs

Some examples..

- **Collaboration** (Dynamic DT: how it is today): within MoST (area 1/2/3) and externally (show, understand, discuss and get feedback)
- **Simulate** “what if scenarios” (to find the optimal solution digitally before doing something physically with an area)
- **Decision support and automation** (generate predictive models from the available data streams and automate processes, e.g. traffic management)
- **Carbon-footprint** (build into the system, all phases, inc. material for construction, operation and maintenance)
- **Autonomous driving / operations** (learn and agent/AI to operate in a simulated environment almost identical to the real, mange små vs. få store - ta vare på i stedet for å bygge nytt, ulike transport modi - knutepunkter)
- **TeleDrive / Remote Control / Flåtestyring** (busses, robo-taxi, car-sharing etc., monitor and take over if needed, HD-map important)



Autonomy in Sim



TeleDrive / Remote Control / Flåtestyring

MoST - Area 3: PhDs

DT: Digital Technologies - Digital Twins - Digital Transformation

MoST - Area 3

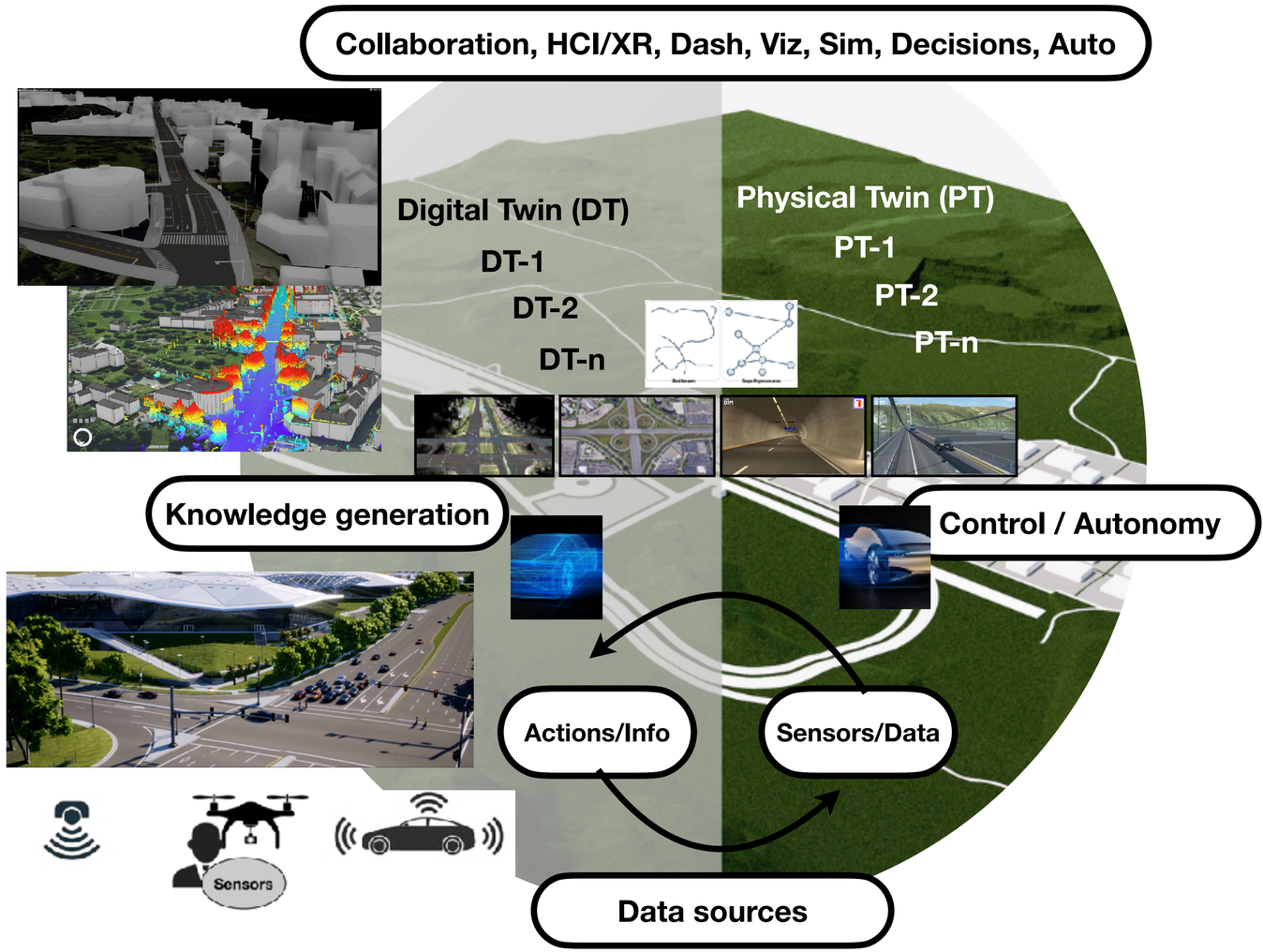
- **MoST**: The PhD positions are part of a new large interdisciplinary initiative called Mobility Lab Stor-Trondheim (MoST). The center is divided into the three focus areas 1) stakeholder needs for good mobility, 2) mobility as a system / transportation models, and 3) digital technologies for green mobility, that will work closely together to realize innovative and sustainable future mobility solutions in the urban environment. Within area 3) various enabling technologies will be used to automate the process of building and using digital mobility infrastructure twins (i.e. holistic/unified, life cycle, hierarchical, integrated, dynamic/updated representations of the physical road network) for collaboration, simulation, carbon/energy footprint calculations, road condition monitoring, predictive maintenance, automated traffic management and other forms for value creation (general knowledge will be developed that can be scaled up and used elsewhere).

- **Area 3**: To realize the objectives of focus area 3) several PhD candidates with partly overlapping competences will work closely together, each focusing on one of the following technology areas: 1) baseline Digital Mobility Twin (DMT) using site surveys and available geo-located data, 2) dynamically updated DMT using IoT, sensors, 5G and edge computing, 3) BigData and AI to create value from all the sensor data sent from the physical twin, e.g. in the form of decision support and automation, 4) autonomy and simulation (this PhD position) to train AI agents and simulate “what-if” scenarios, and 5) XR and Visualization to interact with the DMT throughout its life-cycle (construction and use) and increase citizens engagement and feedback before things have been built physically.

- I**nteraction**: Throughout the overall MoST project there will be tight interaction with the other two focus areas, e.g. providing sensor data and visualizations to the two other areas, get feedback from area 1) regarding user needs and integrate transportation models from 2) in the DMT.

MoST - Area 3 (2)

- **PhD_3-1: Basis / Standalone DT** (Samarbeidsplattform, forskning & kommers i lag, integrere eksiterende data, reality capture, rawdata-to-DT, viz/XR, hva hvis scenarier osv.)
- **PhD_3-2: Oppdatert / Dynamisk DT** (Statiske og mobile sensorer for høsting av data, kommunik./IoT/5G, motta, integrere og viz i eksisterende DT, personvern og data-sikkerhet)
- **PhD_3-3: BigData og AI** (AI-basert data-dreven beslutning-støtte og automatisering, kunnskap fra data, predikere frem i tid, DT for data-deling (bidra med data og få info), integrerer transport modeller)
- **PhD_3-4: Simulering og Autonomi** (Simulering av dynamiske «hva hvis» scenarier, prediktive modeller, f.eks. stå i et kryss og oppleve, autonom kjøring om vinter vha. HD-maps/DT, flåtestyring, opplæring av AI-sjåfør)
- **PhD_3-5: XR & Viz**



PhD_3-1

MoST – Mobilitet Stor-Trondheim

PERSEUS PhD project:

«Digital Twins for future mobility and infrastructure solutions»

Automated AI / Computer Vision driven generation of Digital Twins for sustainable mobility infrastructure

Duration: 23-26

Main supervisor:
Gabriel Kiss
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Co-supervisors:
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Hongchao Fan (IBM, IV)
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The main aim of this project is to build a static digital twin of the MobilityLab's focus area that will act as a baseline for all further simulations and will be extended to be able to receive dynamic information from IoT sensors.

An accurate digital representation of the focus area will be created, based on existing geometric information and high-resolution aerial photographs. Raw data is already available for the project either as public or previously acquired datasets, additionally during the project more raw-data will be acquired with our in-house full scale research platforms (Kia e-Niro with an NVIDIA DriveWorks stack as well as dedicated high-resolution surveying drones). The final aim of the project is full automation of the conversion process from raw data to a usable digital twin representation (i.e. AI based methods and handling of Big Data arriving in real-time from the research platforms).

Miljøpakken – bedre by

Trøndelag fylkeskommune
Tröndelagen fylhkentjïelte

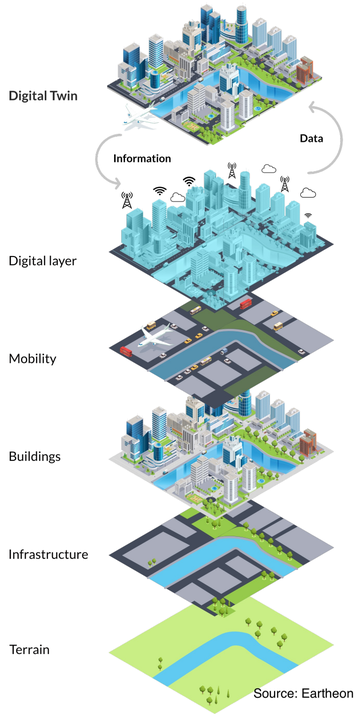
NTNU
Norwegian University of Science and Technology

PhD_3-2

MoST – Mobilitet Stor-Trondheim

PhD: Dynamic Digital Twins

Duration: 23-26



Main supervisor:
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Co-supervisors:
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Stefan Werner (IES, IE)
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A digital twin

- is a *virtual representation* of a physical asset or *process*
- enabled through data and simulators
- for real-time prediction, optimization, monitoring, control, and improved decision making.

For *real-time operation*, the twin requires continuous updating with new measurements from its observation platforms.

All observations are not equally *time-critical*, and not equally *important* for the twin. We need pre-processing, optimization and communication strategies to support accurate twin operation using limited communication resources. Machine learning and AI-based strategies that learn and adapt to the characteristics of the sensors, and the requirements of the twin will be of special interest.

Miljøpakken – bedre by

Trøndelag fylkeskommune
Tröndelagen fylhkentjïelte

NTNU
Norwegian University of Science and Technology

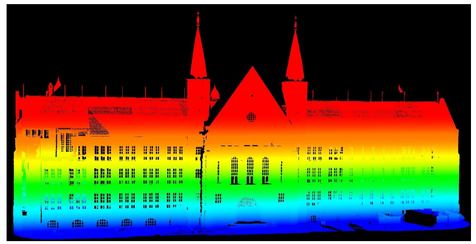
PhD_3-3

MoST – Mobilitet Stor-Trondheim

PERSEUS PhD project:

«BigData and AI for Future Mobility Solutions»

Duration: 2023-2026



Main supervisor:
Adil Rasheed (ITK, IE)
Adil.rasheed@ntnu.no
Co-supervisors:
Frank Lindseth (IDI)
frankl@ntnu.no
Kelly Pitera (IBM, IV)
Kelly.pitera@ntnu.no

The aim of the project will be to develop and exploit big data and artificial intelligence-driven digital twin of urban mobility infrastructures to solve challenges in achieving a carbon-neutral mobility future. A digital twin is a virtual representation of a physical asset or process enabled through data and simulators for real-time prediction, optimization, monitoring, control, and improved decision-making. The project aims to develop enabling technologies to instill physical realism in such a digital twin. The enabling technologies will consist of data acquisition, pre-processing, fusion, and postprocessing techniques using an array of physics-based, data-driven, and hybrid models. In addition, the work will also involve the development of tools for communicating insights in a way that facilitates informed public opinion-building and decision-making.

Miljøpakken
– åpner nye muligheter

Trøndelag fylkeskommune
Tröndelagen fylhkentjïelte

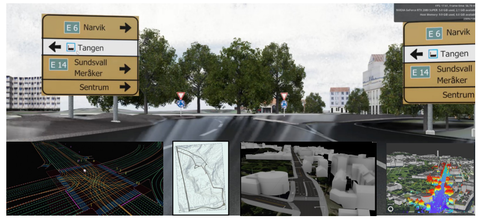
NTNU
Norwegian University of Science and Technology

PhD_3-4

MoST – Mobilitet Stor-Trondheim

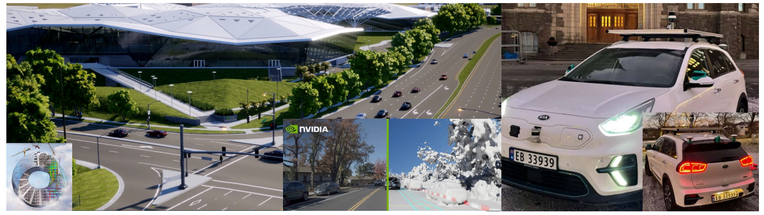
PERSEUS PhD project:
«Autonomy and Simulation for Future Mobility Solutions »

Candidate: Florian Wintel, Germany
Duration: 2023-2026



Main supervisor:
Frank Lindseth (IDI, IE)
frankl@ntnu.no
Co-supervisors:
Adil Rasheed (ITK, IE)
Adil.rasheed@ntnu.no
NN (IV)

The aim of the project will be to explore the use of simulated environments of real physical MoST pilot areas to train agents to operate fully autonomously and to simulate various “what-if” scenarios for a sustainable and carbon- neutral mobility future. The PhD project will investigate both modular (mapping and localization, perception and prediction, planning and control) and end-to-end (imitation and reinforcement learning) approaches to autonomous driving in a Nordic environment. Training and validation of autonomous agents (from shuttle busses to last-mile delivery robots) will be done in simulated environments (e.g. CARLA, NVIDIA DRIVE Sim) using a HD-map / Digital Twin representation of the area in question, as well as in the real-world environment using our in-house full-scale research platform for autonomous driving. Agents should learn to co-exist with humans in a real-world mobility setting. Current traffic patterns will be visualized and future “what-if” scenarios will be simulated (e.g. NVIDIA Omniverse) before physically constructing the optimal solution for a given area.



Miljøpakken
– bedre by

Trøndelag fylkeskommune
Tröndelagen fylhkentjïelte

NTNU
Norwegian University of Science and Technology

PhD_3-5

MoST – Mobilitet Stor-Trondheim

PhD project:
«PERSEUS - PhD Candidate in Extended Reality (XR) for Future Mobility and Infrastructure Solutions»

Duration: 23-26

Supervisor:
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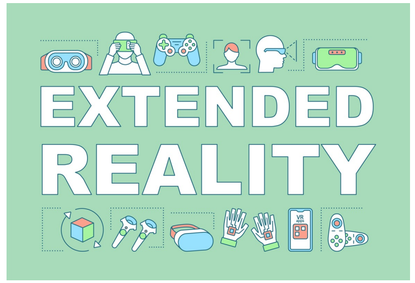

The Department of Electronic systems (IES) is looking for a PhD candidate in the area of XR for visualization and gamification of mobility and infrastructure. For the XR experience the PhD will be researching on the use of Interactive Digital Narratives (IDNs) as a framework to build and assess the experiences.

Interactive digital narratives (IDN) is an expressive narrative form in digital media implemented as a computational system and experienced though a participatory process. Currently the application of interactive digital narratives (IDN) has various forms (Narrative-focused games, interactive documentaries, journalistic interactives, installation pieces, XR experiences, narrative interfaces to big data, etc). IDN allows its audiences to experience the consequences of a series of choices and reconsider these choices through replay as well as ability to record change. In addition, IDN can contain multiple competing perspectives in a single work and enable its audiences to experience them within a single comprehensive space.

Miljøpakken
– bedre by

Trøndelag fylkeskommune
Tröndelagen fylhkentjïelte

NTNU
Norwegian University of Science and Technology

Relaterte prosjekter

Noen utvalgte

Green2050
Centre for Green Shift in the Built Environment

Green2050 – Centre for Green Shift in the Built Environment

Green2050: Mobility

Sustainable and CarbonNatural Road Sector

- SVV
- Forprosjekt

Karbonnøytral vegsektor i Norge i 2050 (3)

Ny kunnskap og kandidater innen

arkitektur/planlegging, kunstig intelligens, IoT, digital tvilling, IKT-sikkerhet, kyberteknikk, bærekraftsanalyse, biologisk mangfold materialstrøm, transport, logistikk, facility management, forretningsmodeller, naturfare, psykologi, sosiologi, geografi, energi, samfunnssikkerhet, fysisk sikkerhet, sirkulærøkonomi, samfunnsøkonomi, anskaffelser, helse, samfunnsmedisin, teknologiledelse,….

i et samspill med fagfolk fra SVV vil være avgjørende for måloppnåelsen

Alle fakulteter ved NTNU er med i dag

NTNU Kunnskap for en bedre verden

Gemini-senter:
Digitalisering og automatisering av fremtidens veitransport

- SINTEF og NTNU
  - SVV
  - TFK
  - TK
  - Nord Univ.

Machine Sensible Infrastructure under Nordic Conditions (**MCSINC**)

- SINTEF, NTNU and SVV
- IDI
  - PostDoc (3 years)
  - Researcher (1 year)
  - Some stud activities

Machine Sensible Infrastructure under Nordic Conditions (MCSINC)

0. Relevance to the call

The vehicle industry, as well as software and hardware providers are rapidly developing sensor systems and artificial intelligence (AI) methods for sensing the road environment. Connected and Automated Vehicles (CAVs) are argued to have a large potential for accelerating traffic safety and efficiency. Since human factors contribute to more than 90% of all road accidents, CAVs are expected to significantly reduce crashes (Konstantinopoulou and Jamieson, 2020), and cooperative systems and exchange of information will enhance traffic flow efficiency (Milakis et al., 2017). Autonomous driving (AD) is about developing systems that are able to sense, reason and act: More specifically to map the environment and localize the vehicle, perceive dynamic objects and predict where they will be in the close future, plan to get from A to B and navigation (throttle, brake, steering and shifting) of the CAV. However, the vehicle industry, often referred to as original equipment manufacturers (OEMs), is characterized by proprietary solutions, and insights into the limitations of these systems are not openly available information, nor do different companies align their strategies on how the vehicle should sense the road environment. There is therefore a strong need for more open scientific studies publishing AI software and results on CAV technology, information which is not available from the vehicle industry today.

For the suggested benefits related to safety and efficiency to be realized, the vehicles need to be operational in most situations and contexts, often referred to as the vehicles' *operational design domain* (Lee and Hess, 2020). This also includes that CAVs must be functional under harsh winter conditions, and more scientific studies on the limitations of these technologies caused by Nordic conditions are needed. Particularly important is uncovering how the limitations may set other requirements for road design and winter maintenance, as one cannot assume that the OEMs will resolve all issues alone (Storsæter et al., 2020). Research should uncover the limitations of such systems as input to road authorities and decision makers. Hence, if the road authorities have more information on how CAVs perform under Nordic conditions, they can adjust roads and maintenance to increase the sensibility of the vehicle, so that the vehicle and the infrastructure together can preform well.

In this project, we address the research gaps concerning openly available AI research for CAVs and AD performance under Nordic conditions by utilizing our own research platform for AD, i.e. a vehicle with AD capabilities (Figure 1). We will develop AI-assisted annotation of ground truth (GT) data, explore automatic generation of High Definition (HD) maps and construct, and evaluate state of the art AI vision-based localization algorithms on public roads. By using a research platform for AD, the project will contribute to with new methods for navigation of CAVs, and new knowledge on AD for national stakeholders such as road authorities, and with this overcoming the proprietary nature of the vehicle industry. Moreover, high emphasis on pilot activities is needed for technically evaluating the machine sensing systems, but also as an arena to disclose knowledge gaps concerning regulation and business and spark discussions among the stakeholders in the ecosystem needed for realizing the positive effects of CAVs.

Figure 1: NTNU research platform.

Questions?

Makes sense? Possible? Improvements? Other approaches / strategies? Contribute?

Thank you for the attention

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