Digital Mobility Twin (DMT):
good decisions, better mobility and smaller footprint

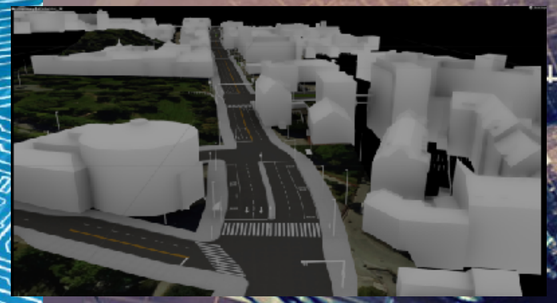
Levende Abelsgate, Fagdagen, 1. sept.

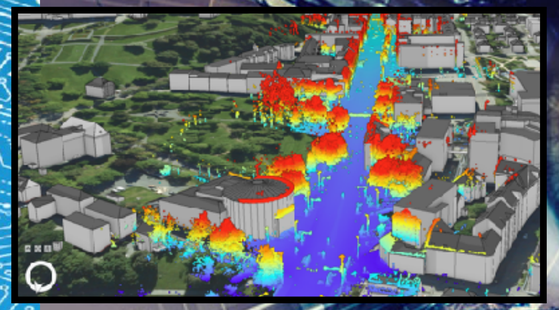
Frank Lindseth, NTNU, AI-lab and MoST-Digital Technologies

Knowledge for a better world

MoST / Mobilitets-lab

Digitalisering, automatisering, bærekraft og klimatilpasning





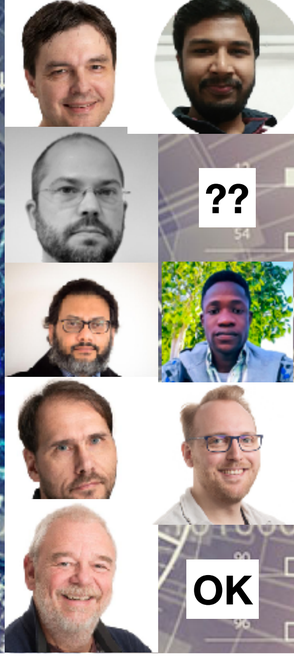
Helhetlig tenking..

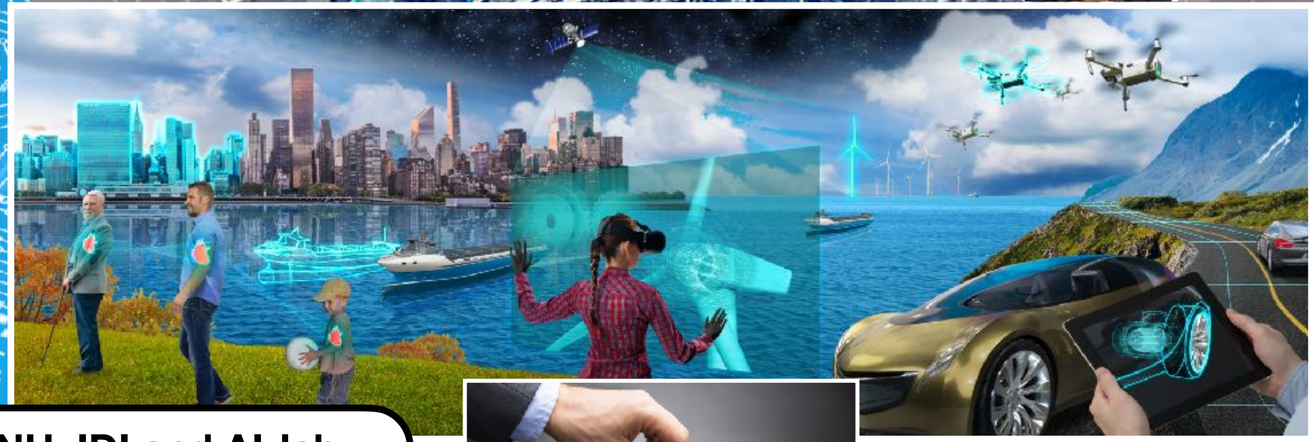
Fremkommelighet
- Mer mobilitet
  - Mindre biler, mer micro

Trafikksikkerhet

Bærekraft
- Klima og natur
- Økonomi
- Sosiale fohold

Klimatilpasning / Motstandsdyktighet





Frank Lindseth, NTNU: IDI and AI-lab

MoST - Område 3: Digitale Teknologier

Agenda

- Background
- Digital Mobility Twin (collaboration and simulation platform, value/phases, zoom)
  - Base / Static (automate): infrastructure, road++
  - Dynamic (real-time): traffic, counting (pedestrians, cyclists, public transportation, trucks, private cars)
- Data & AI: have (mobile), need, quality, value/insight
- Today: understand, manage, optimise, automate and control
- Future needs and “What if” scenarios, effect of interventions, optimise, best decisions before building.
- Stakeholder and citizen engagement, test options in XR (walking, cycling, driving++)
- Autonomous driving (training and validation)
- Sustainability (KPIs as part of the DT) and climate adaptation / extreme weather (e.g. extreme rain, floods, landslides)

Background

Green2050, MoST, DTs

Green2050
Centre for Green Shift in the Built Environment

Green2050 – Centre for Green Shift in the Built Environment

Green2050: Mobility

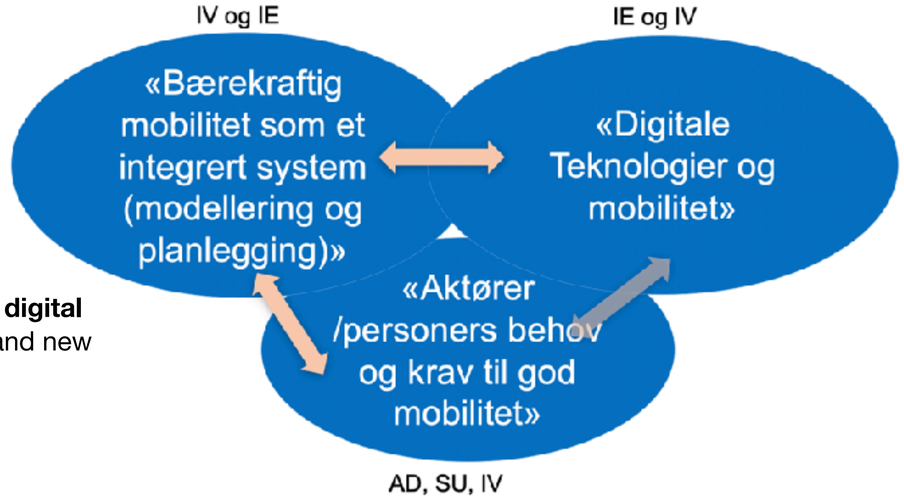
MOST

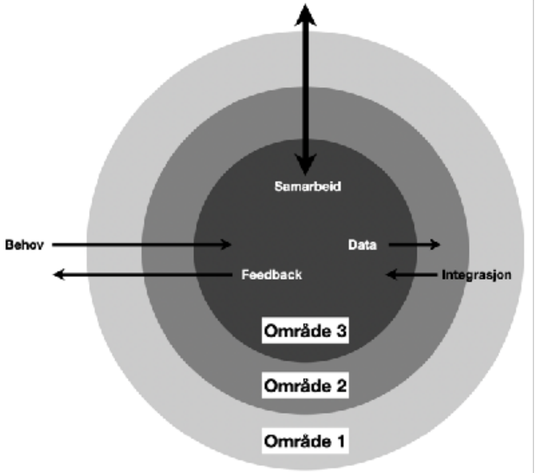
M●ST (Mobility lab)

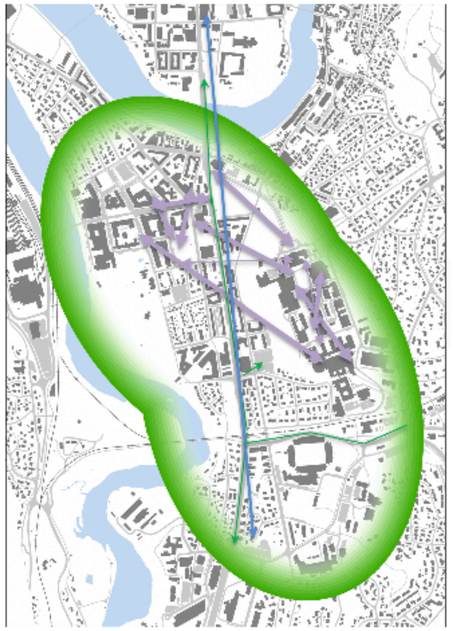
The **lab** will be a national force for research and development of future-oriented, sustainable urban **mobility** solutions

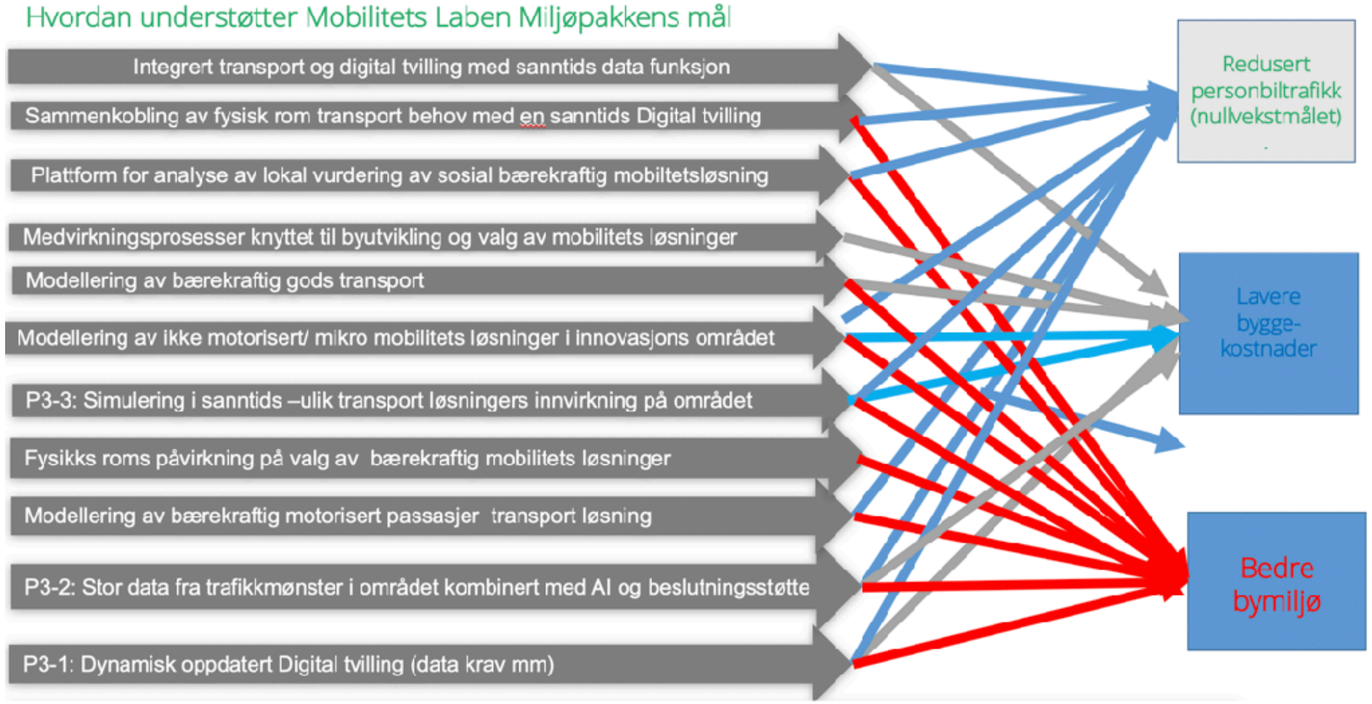
The **lab** will be a joint **arena** for developing new and better work **processes, methods, systems and solutions** for urban mobility

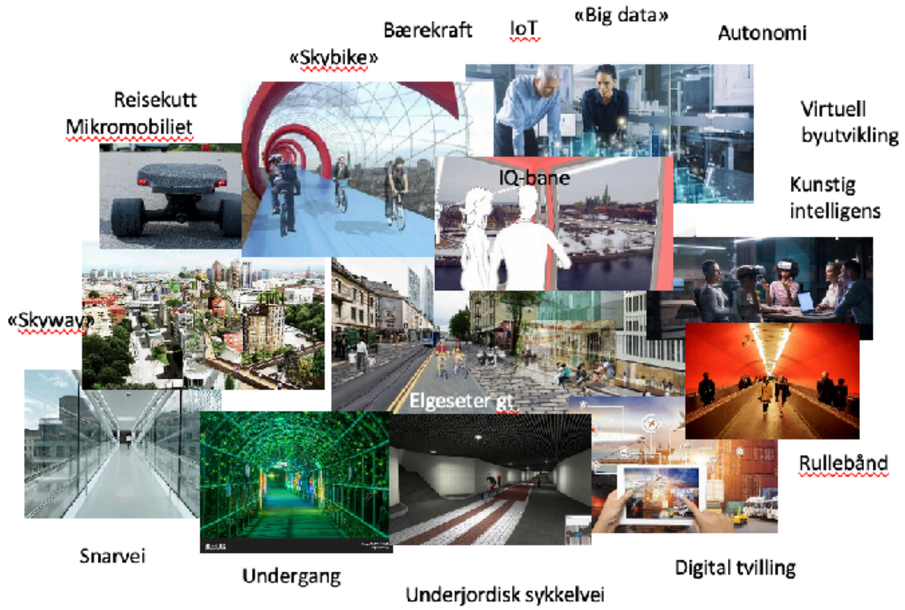
The **lab** will develop knowledge related to **digital technologies**, actors' needs for mobility and new transport modeling methods











Digital Twins (DTs)

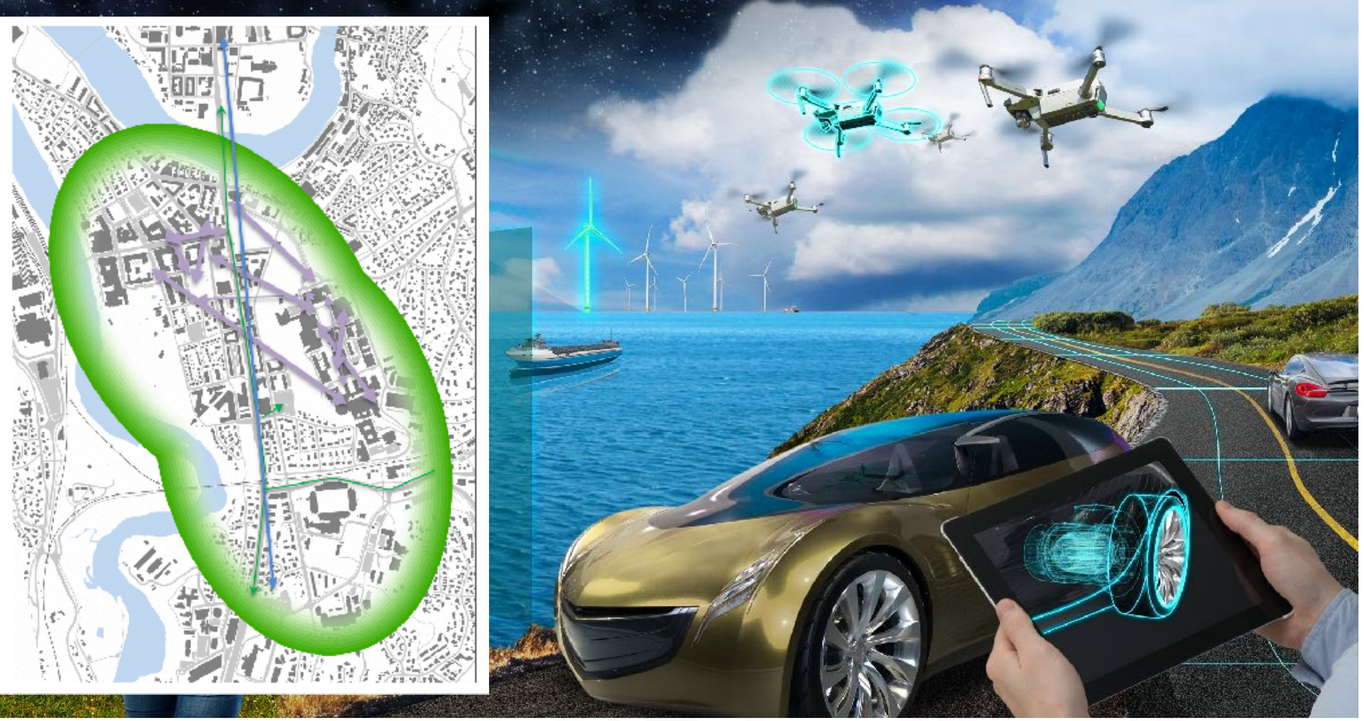
a digital **copy/model/rep.** of a physical asset (the PT) connected through sensors and actions

- Alle sektorer: **digital transformasjon**, digitalisering og AI, tilpasse seg en stadig mer data-drevet fremtid osv.
- **Den digitale veien:** like viktig som den fysiske fremover.. (SVV: ITS tek.dagen)
- **Digital Vei Tvilling** (NVDB++ -> HD-map -> DT (data og modeller)) og **Digital Mobilitets Tvilling** (vei + det oppå, og land, sjø, og luft med knutepunkter). **Single source of truth + intelligens.**

- **Digital Twins (DTs) = alle muliggjørende teknologier:**
  - Sensors / IoT / 5G etc.
  - BigData/DataLake
  - AI/ML/DL
  - Vis / XR,
  - Simulation and Collaboration (flerfaglig)
  - KPIs, Cybersecurity, Privacy, Ethics++

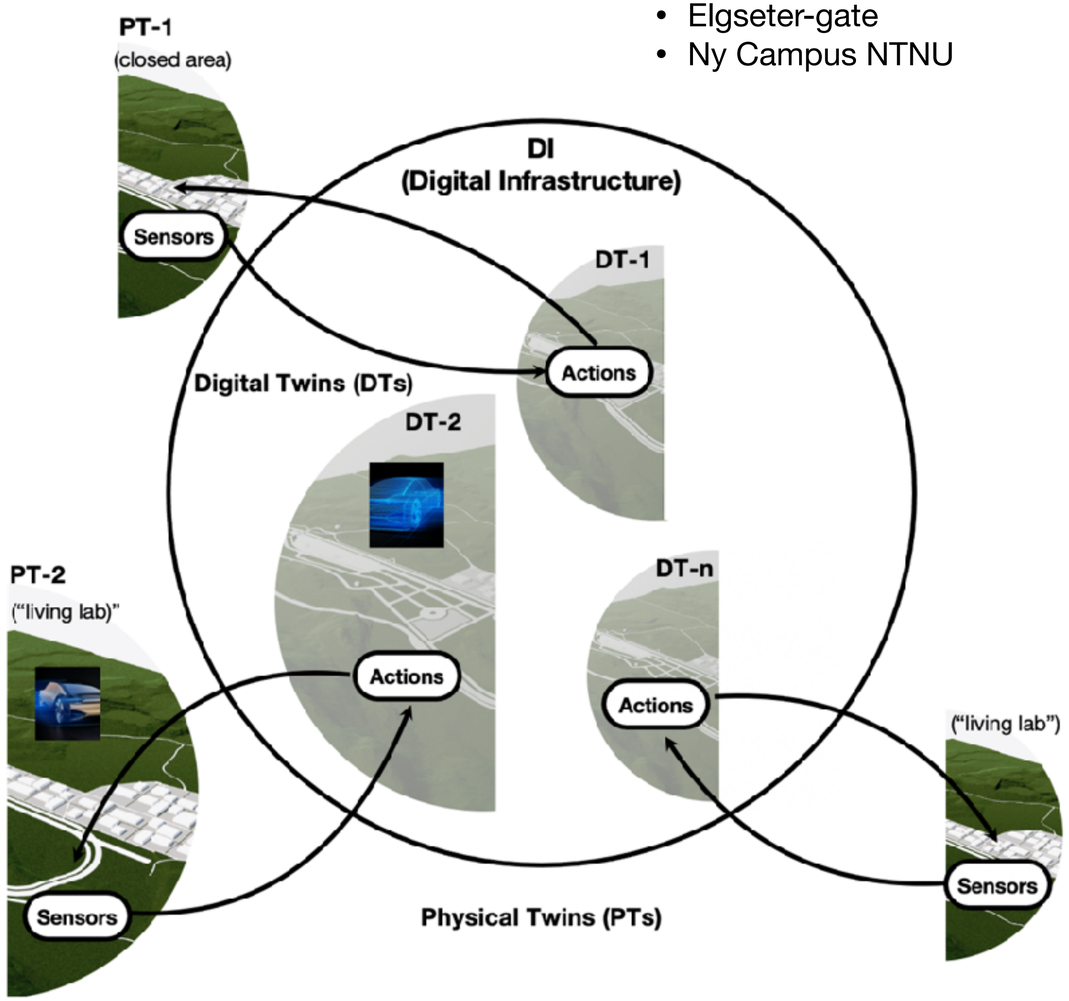
- **Capability levels of Digital Twins (DTs):**
  - Standalone (static)
  - Descriptive (dynamic, beskrive)
  - Diagnostic (forstå det som har skjedd)
  - **Predictive** (hva kommer skje)
  - **Prescriptive** (hva bør man gjøre)
  - **Automated** (automatisere)

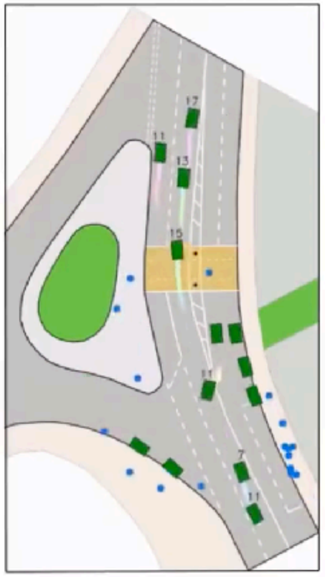
- **Life-cycle**: fra (før) vugge til (lenge etter) grav. Faser: **1)** Design and Planlegging, **2)** Bygging (simulering og optimalisering), **3)** Drift & Vedlikehold (monitorering, predikering, beslutningsstøtte, automatisering), **4)** Riving, Gjenbruk & Resirkulering.
- **Hierarchical**: zoome inn/ut, oversikt vs. detaljer. Vei: vei-segment, kryss, tuneller og broer. (fra det å stå virtuelt i et kryss å kunne observere ulike alternativer til transport-modeller for et større området)



Mulige case:

- Håkon VII-gate
- Nyhavna
- Bromstadruta
- Brundalsforbindelsen
- Elgseter-gate
- Ny Campus NTNU

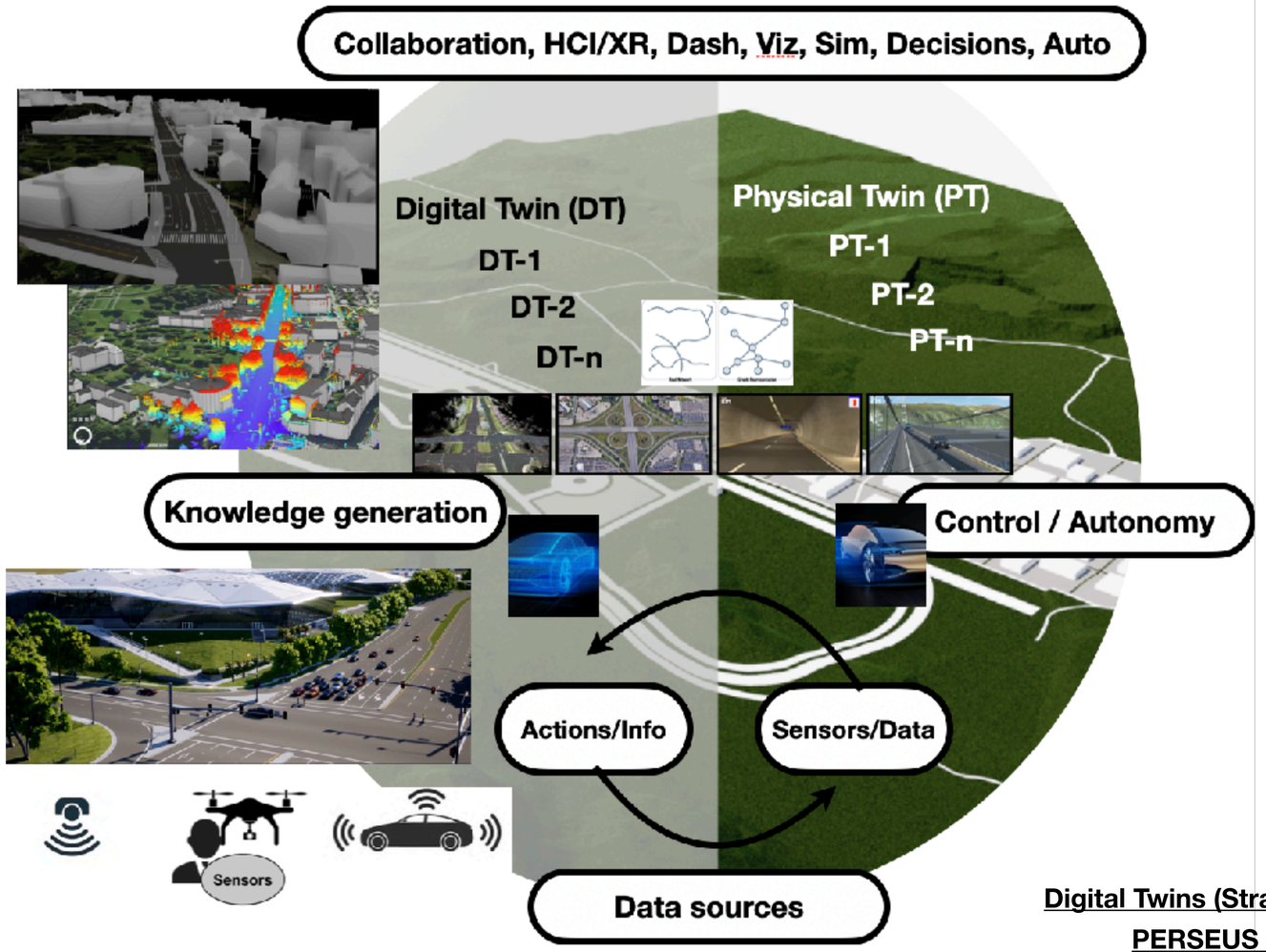


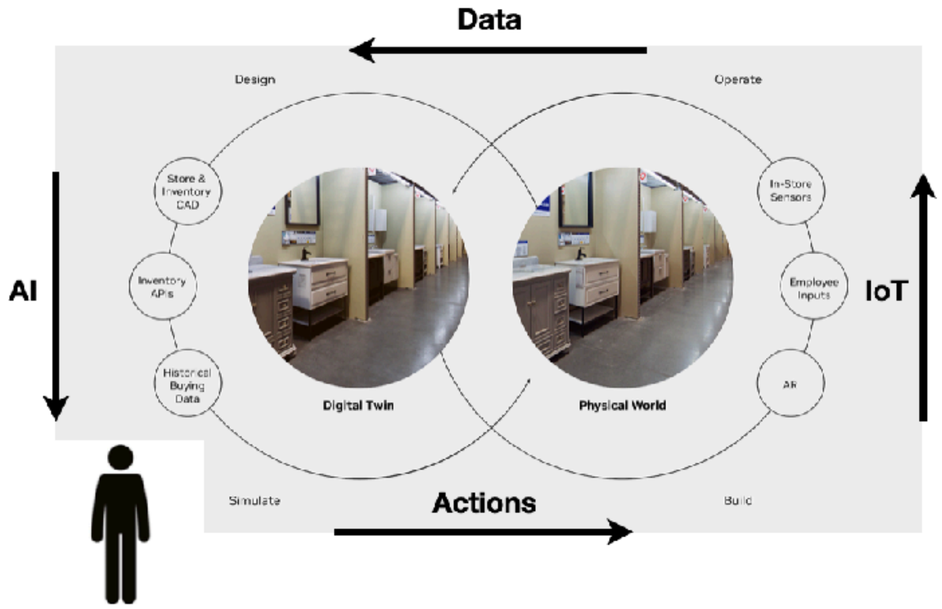


Bird's Eye View Mapping

Prespective View

DTs: data, models, views and value





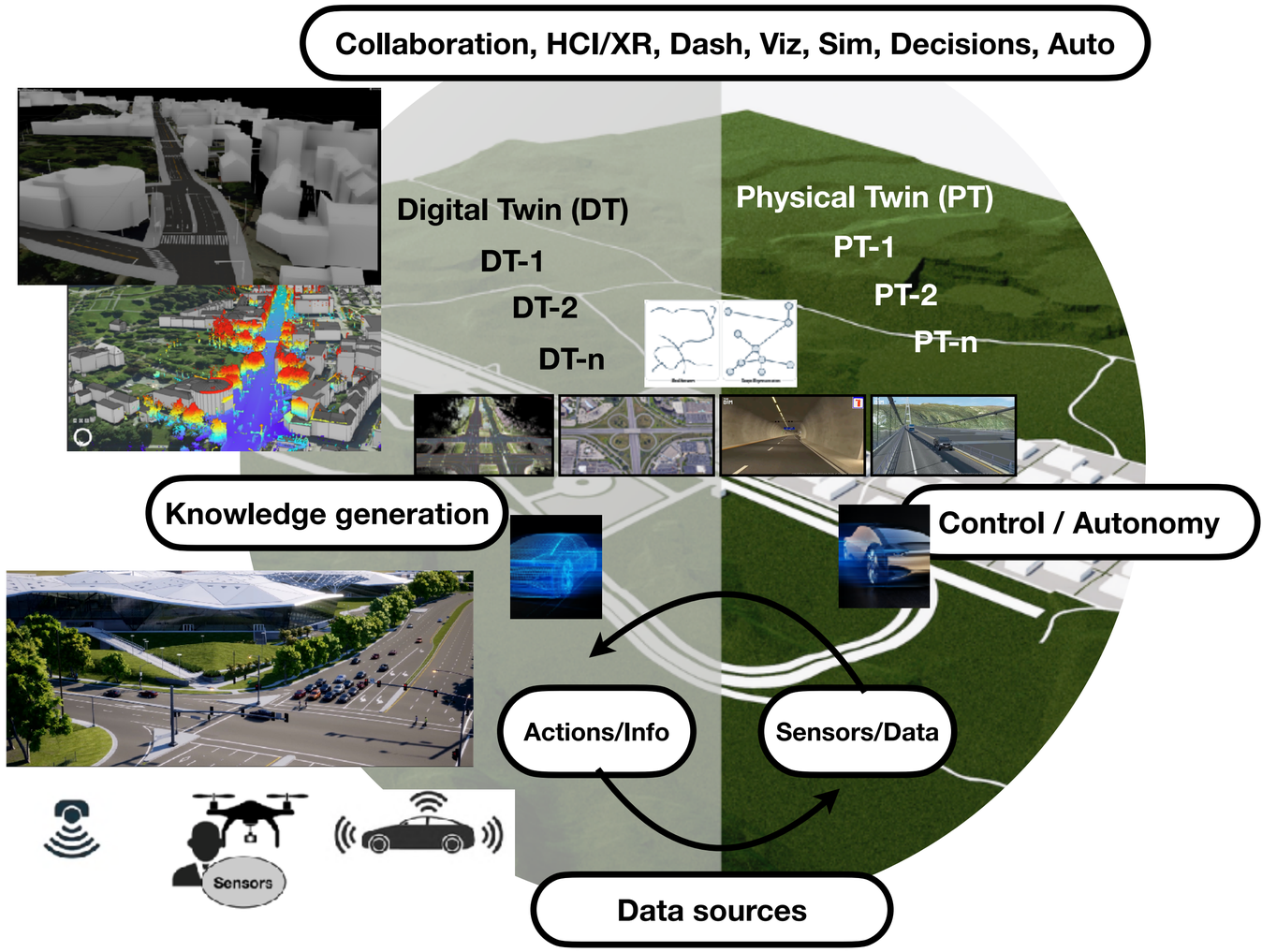
Digital Twins (Strategic research area, IE)

PERSEUS (Doctoral Programme, IE)

Digitale Tvillinger (EiT)

Digital (Mobility) Twins

- **PhD_3-1: Baseline / Static DT** (Collaboration platform, research & industry together, integrating exciting data, reality capture, rawdata-to-DT, viz/XR, what-if scenarios, sustainability/KPIs, etc.)
- **PhD_3-2: Updated / Dynamic DT** (Static and mobile sensors for harvesting data, communication/IoT/5G, receive, integrate and viz in existing DT, privacy and data security)
- **PhD_3-3: BigData and AI** (AI-based data-driven decision-support and automation, knowledge from data, predict ahead of time, DT for data-sharing (contribute data and get info), integration of transport models)
- **PhD_3-4: Simulation and Autonomy** (Simulation of dynamic "what if" scenarios, autonomous driving in winter using HD-maps/DT, fleet management, AI driver validation)
- **PhD_3-5: XR & Viz** (augmented reality, collaboration and citizen feedback throughout the life cycle, experience an intersection in XR (walking, cycling++)



DMTs

- **PhD_3-1: Baseline / Static D** research & industry together, reality capture, rawdata-to-DT scenarios, sustainability/KPIs
- **PhD_3-2: Updated / Dynami** sensors for harvesting data, c receive, integrate and viz in e data security)
- **PhD_3-3: BigData and AI** (A decision-support and automat predict ahead of time, DT for data and get info), integration
- **PhD_3-4: Simulation and Au** dynamic "what if" scenarios, a winter using HD-maps/DT, fle validation)
- **PhD_3-5: XR & Viz** (augmen and citizen feedback throughc experience an intersection in

Gabriel Kiss

Sachin Verma

Kimmo Kansanen

??

Adil Rasheed

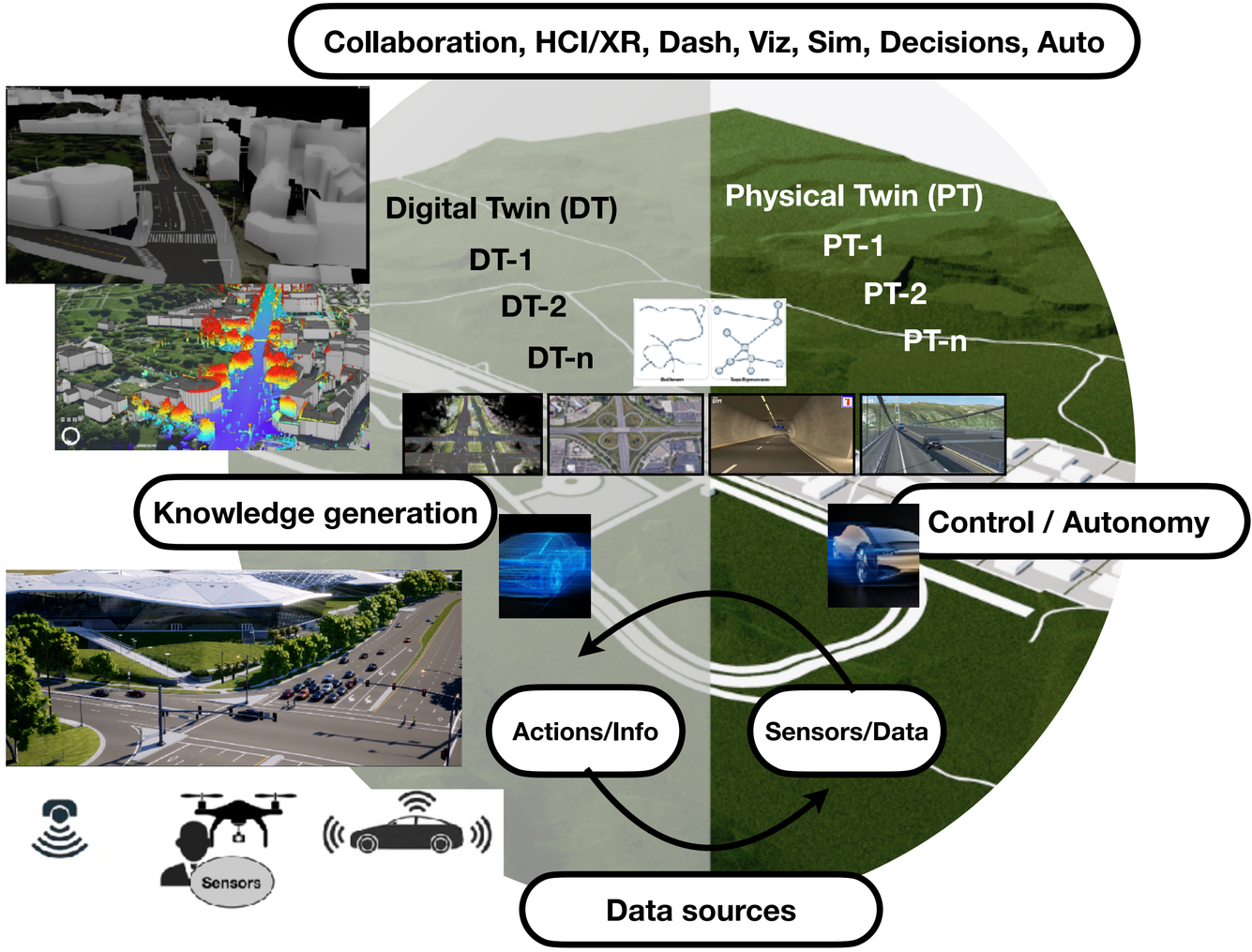
Oluwaleke Umar Yusuf

Frank Lindseth

Florian Wintel

Andrew Perkis

Baher Gunied



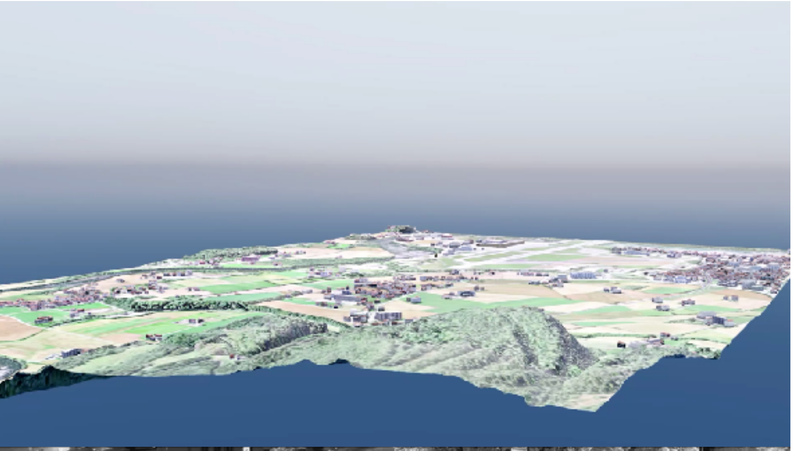
Miljøpakken – åpner nye muligheter

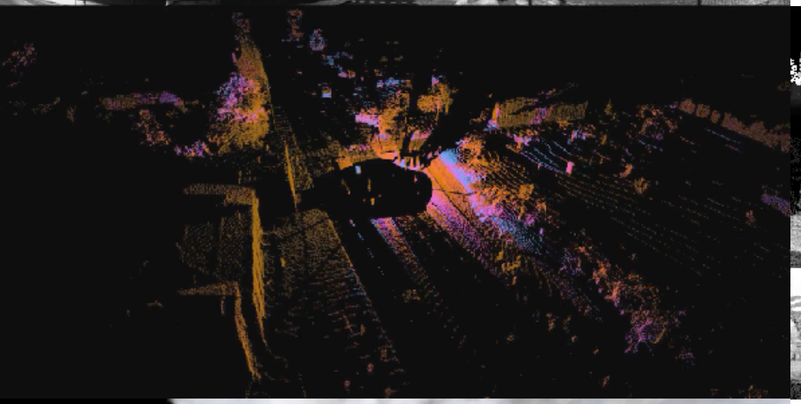
Trøndelag fylkeskommune Tröndelagen fylhkentjielte

TRONDHEIM KOMMUNE

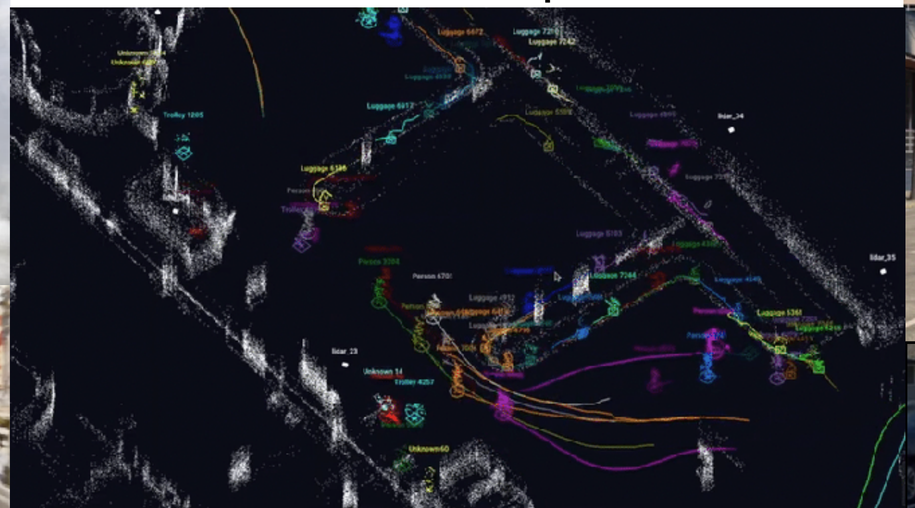
NTNU

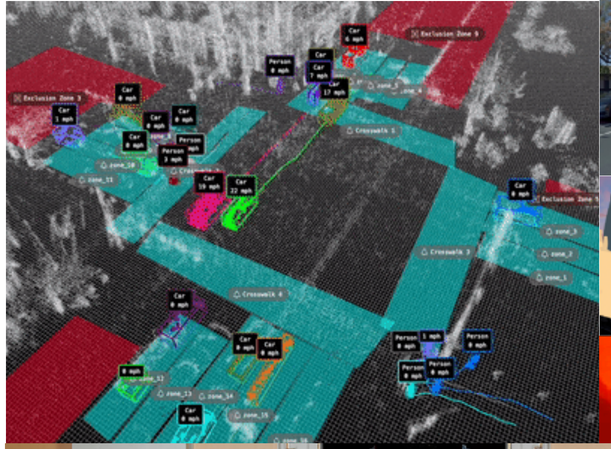
DTs:
Build
Use

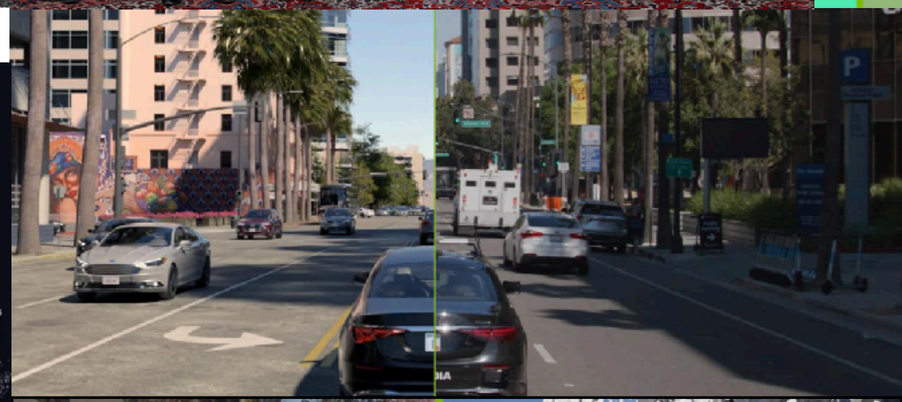




Some examples







Build DMT: baseline / static

Infrastructure

Automate

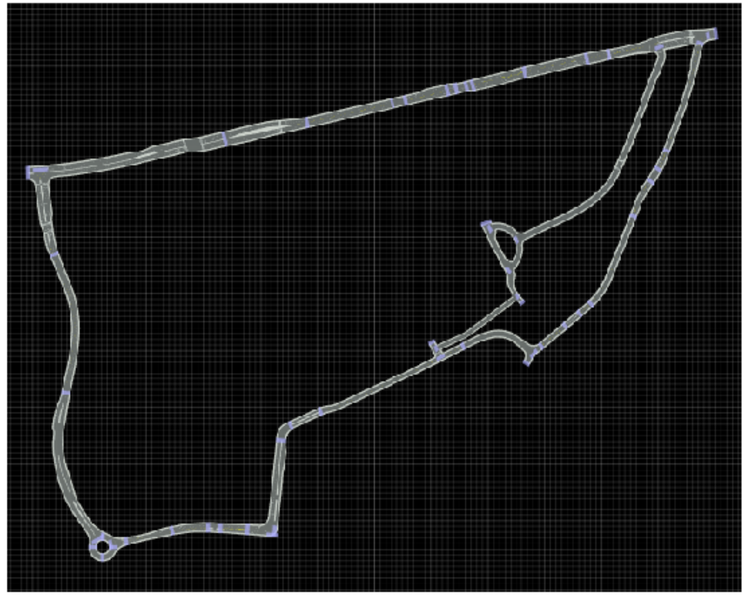
DTs: automatically generated

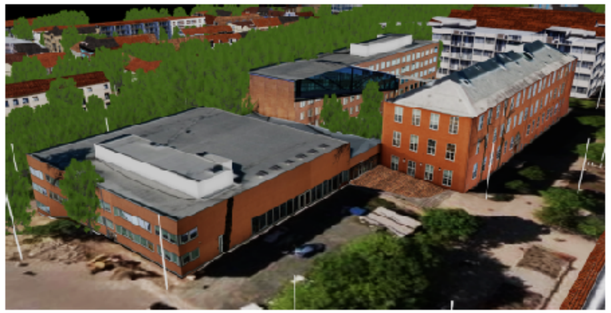
Alt. 1

Public Data

- Hight models
- Orthophoto
- Buildings (geometry)

DTs: Road network & Buildings

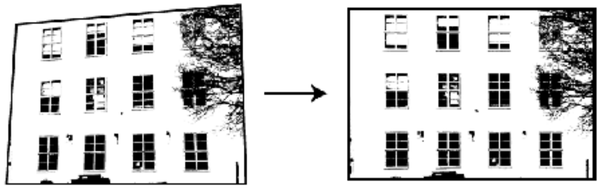




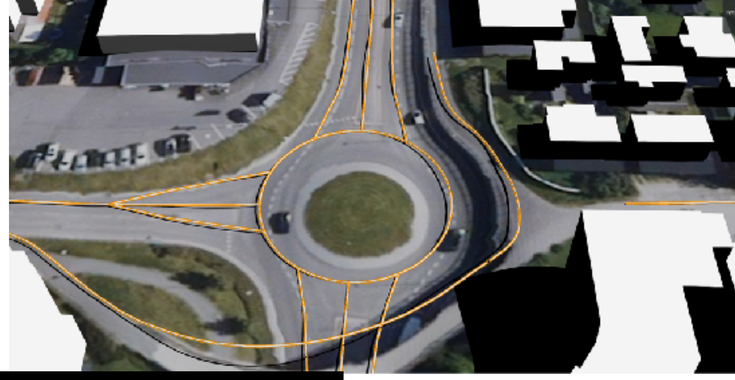
(a) Building 1

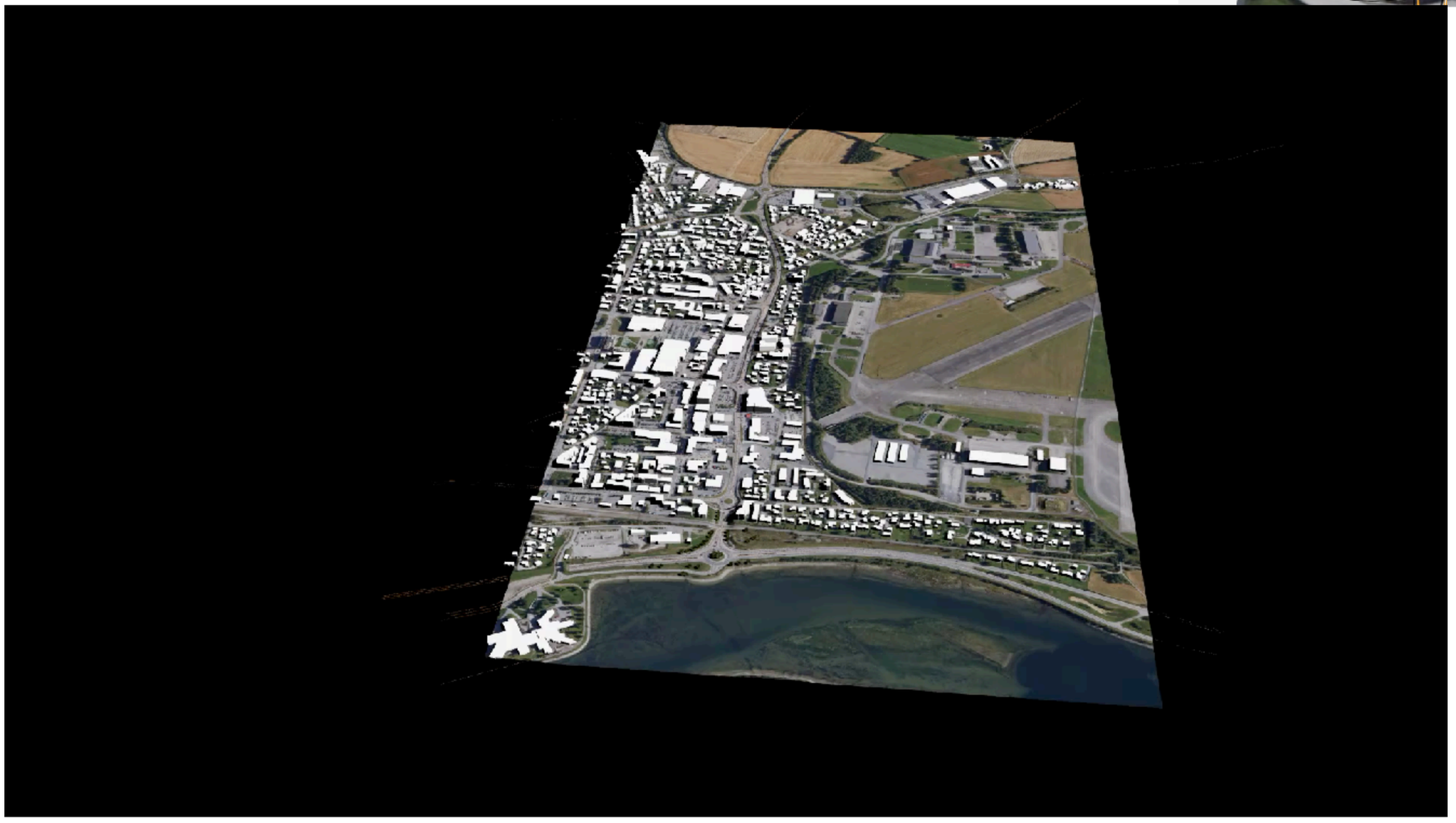
(b) Building 2

(c) Building 3

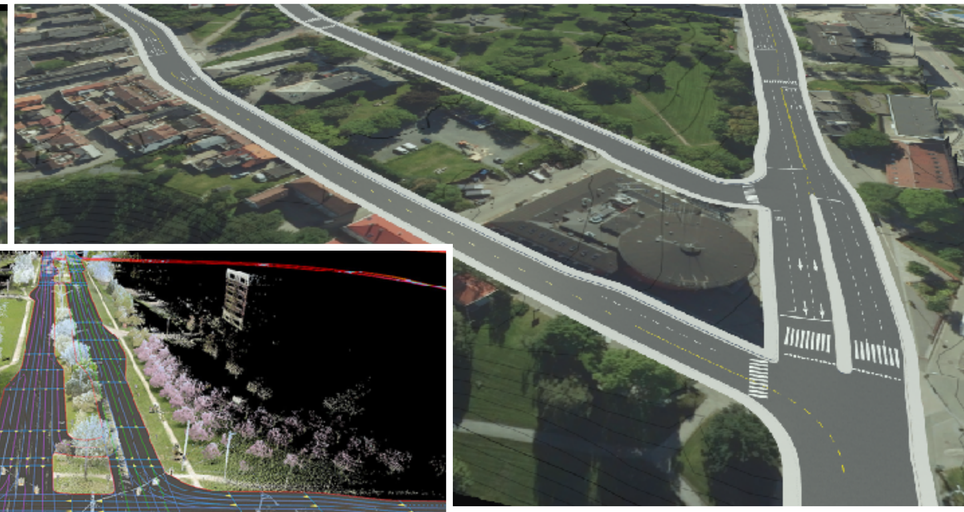


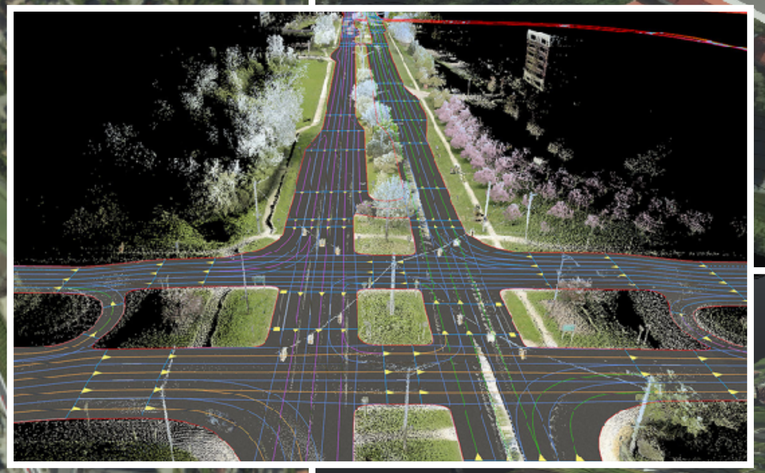
DTs: Road Network from NVDB

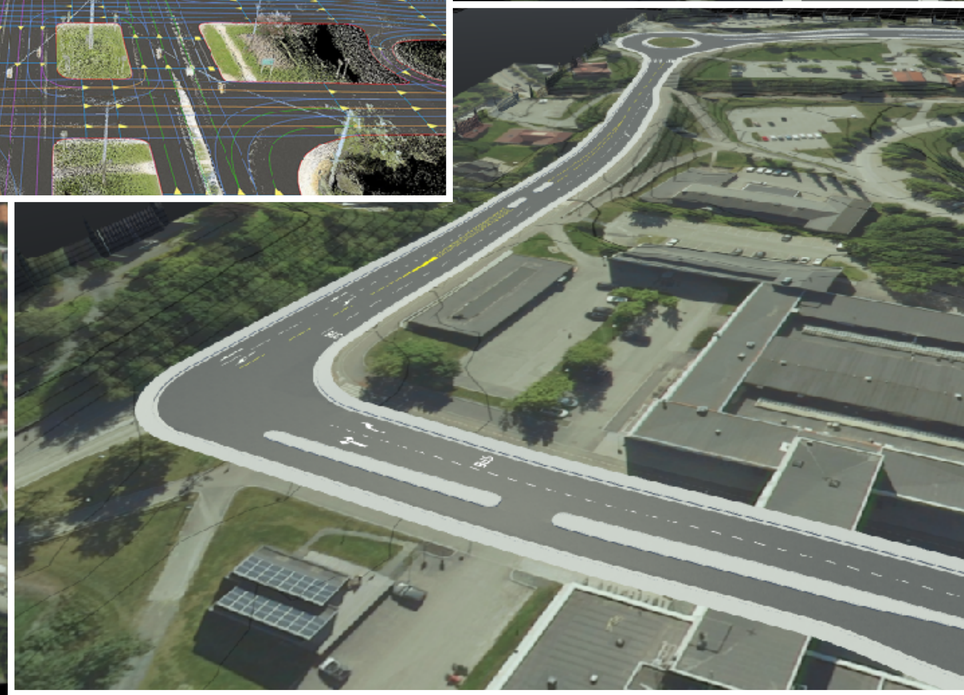




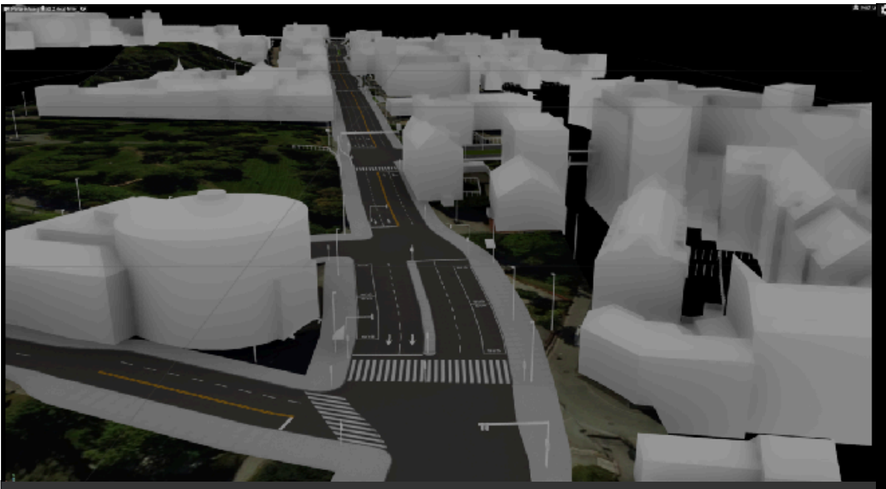
DTs: HD-maps of roads

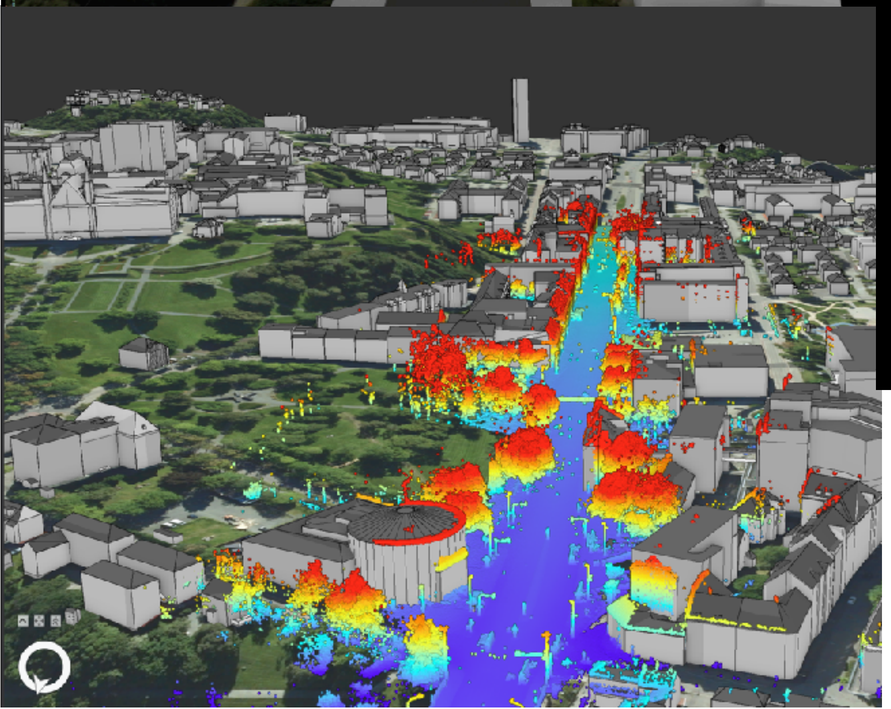


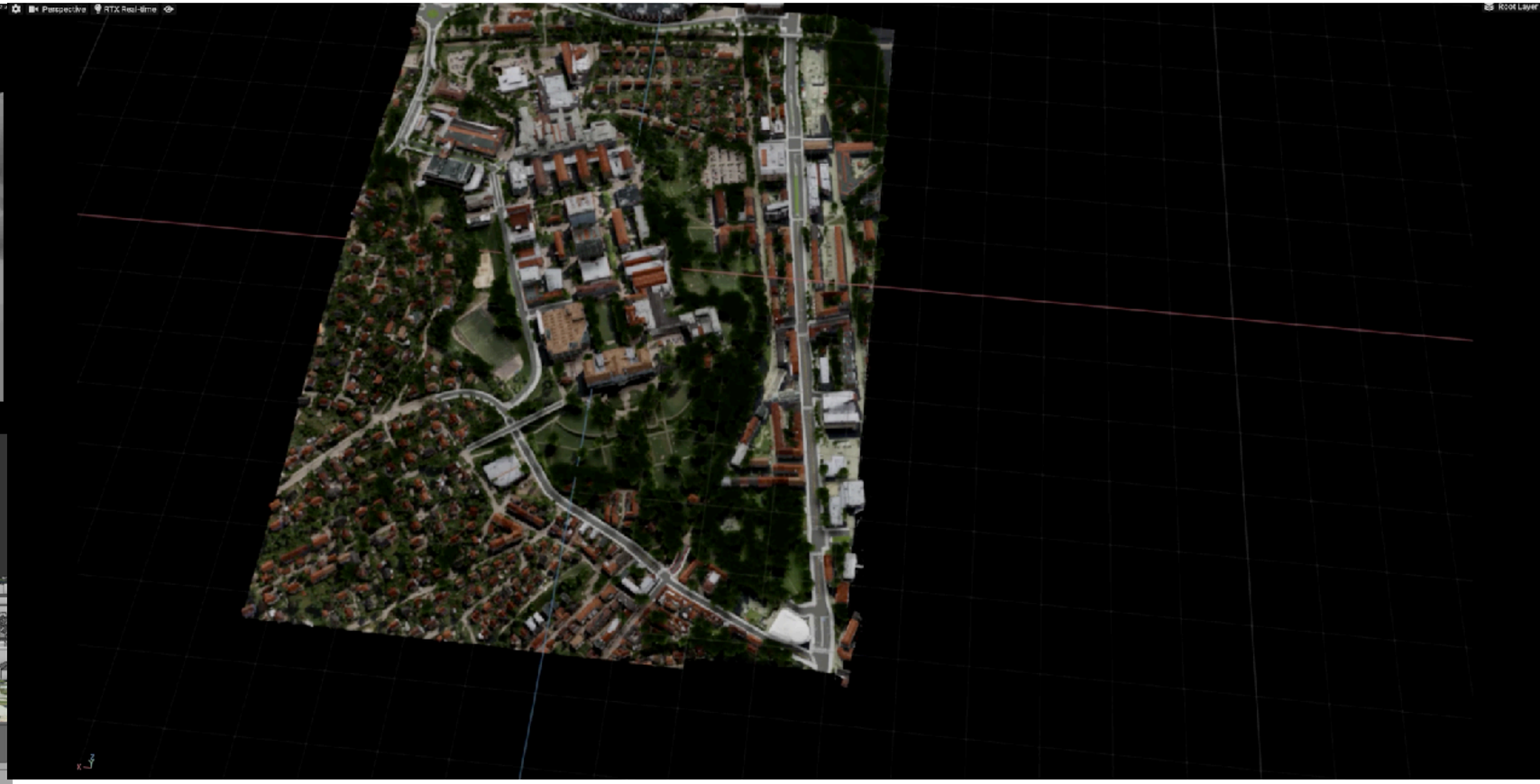


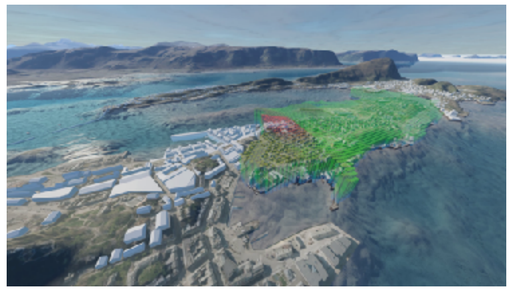


DTs: Gløs (Elgeseter-gate) with roads









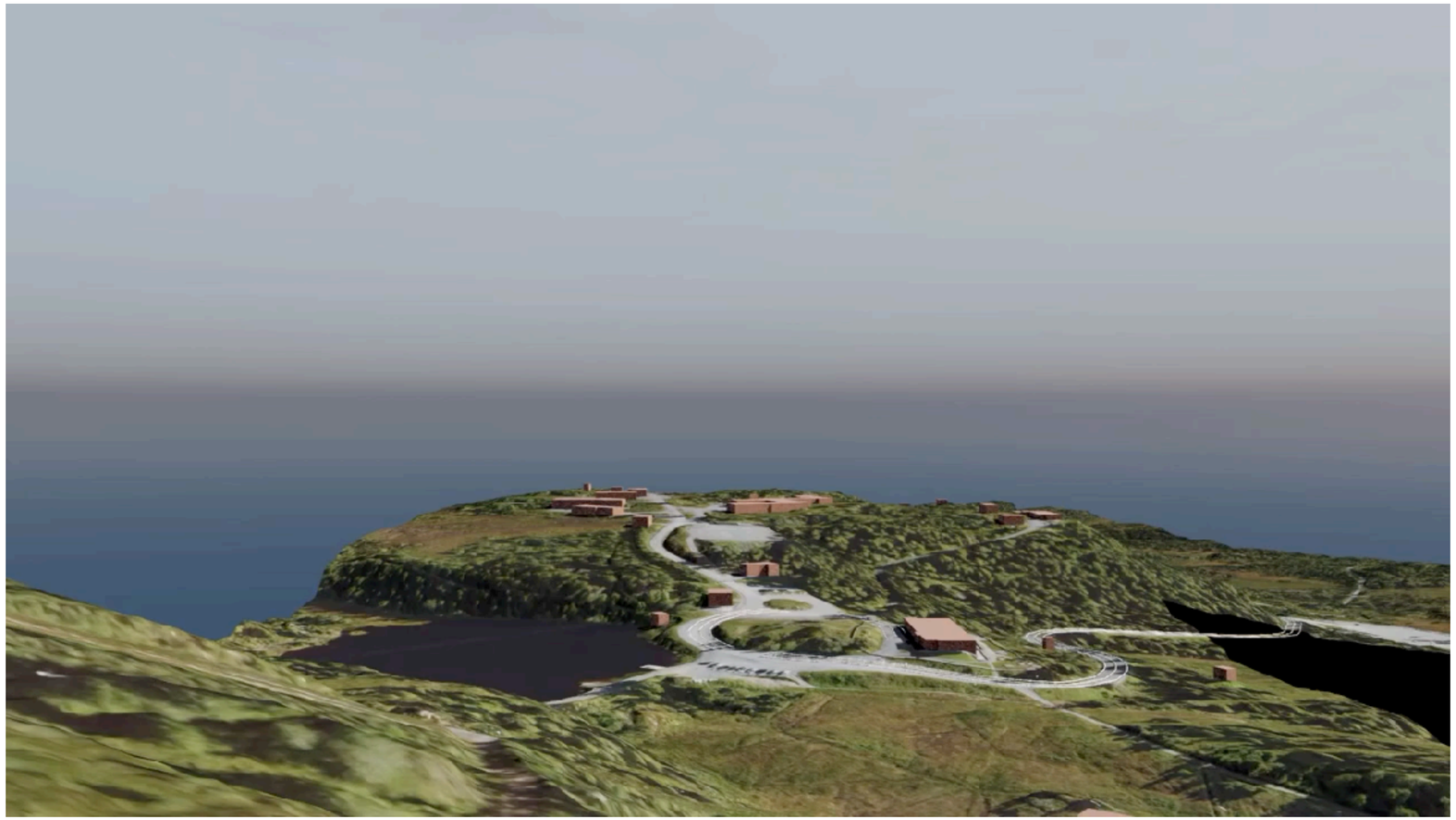
Augment City++
(KPI overlay)

DTs: Road and Signs

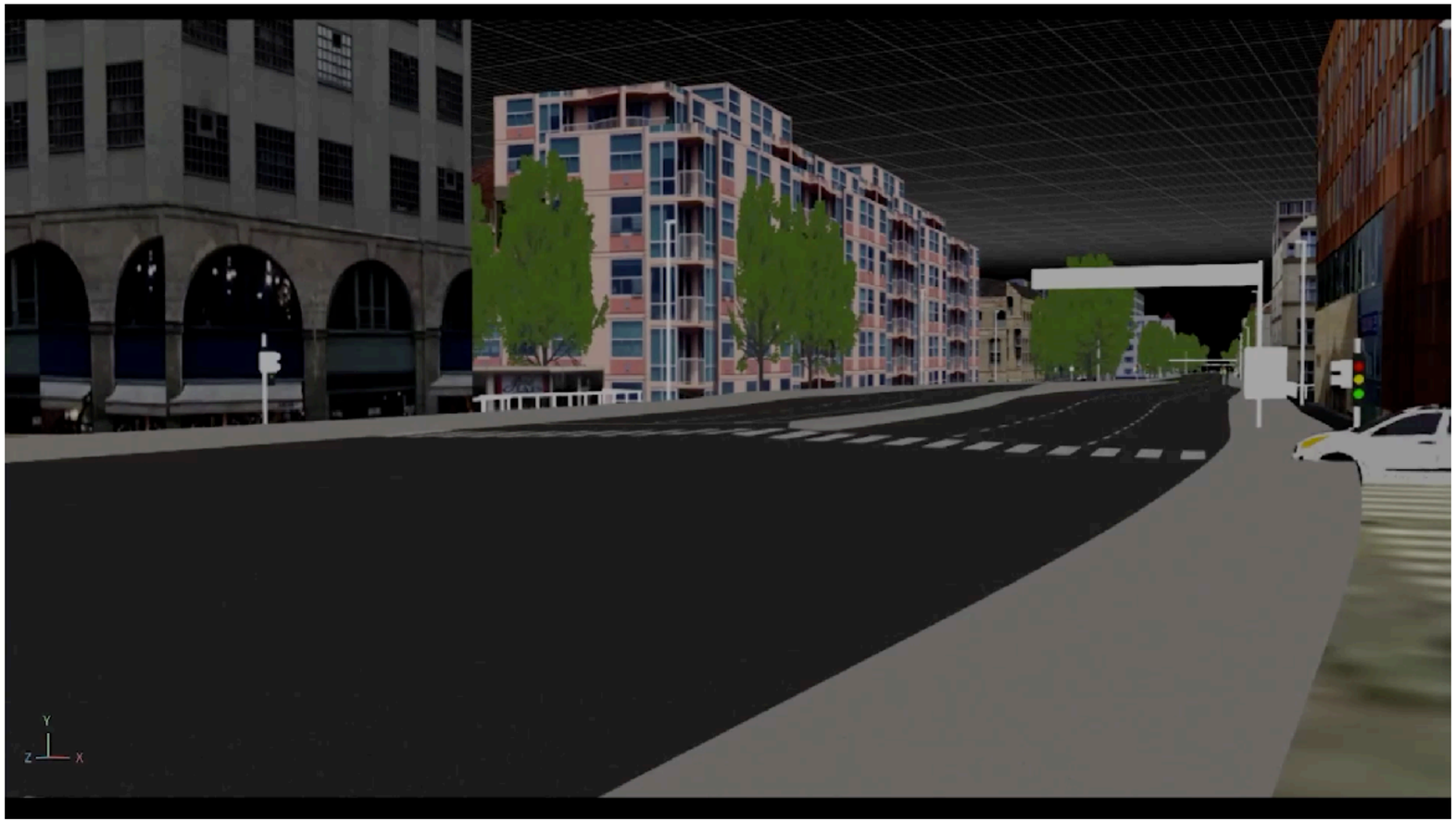
Hvor?

DTs: Roads, (Buildings), Car

DT: Live pos data from car



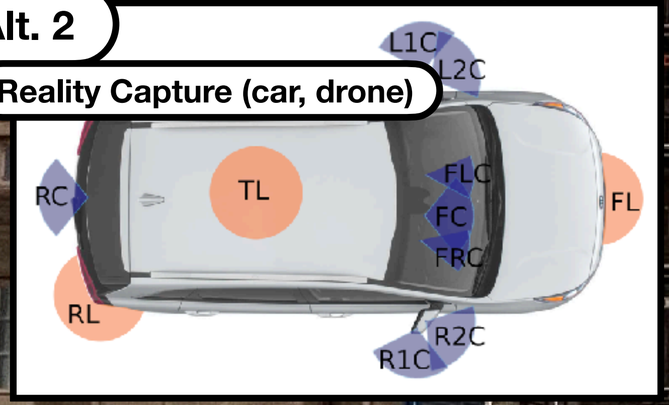
DTs: Animation

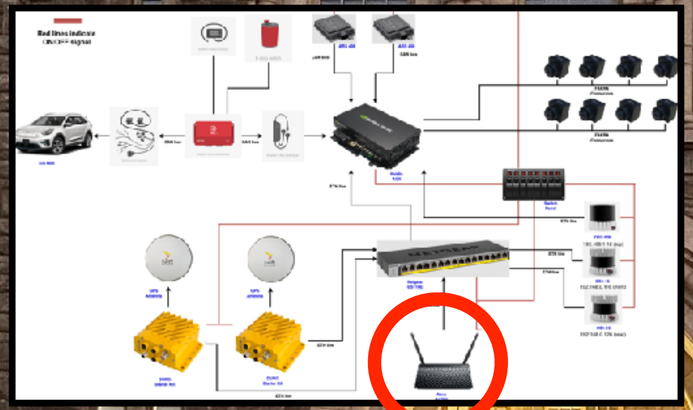


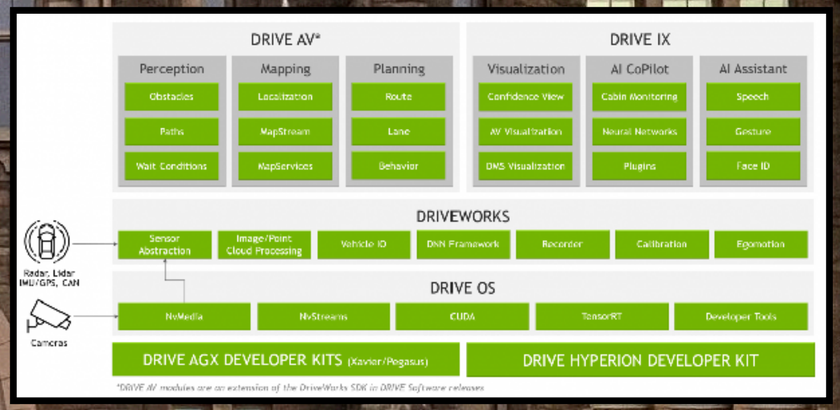
DTs: VR (XR)

Alt. 2

Reality Capture (car, drone)







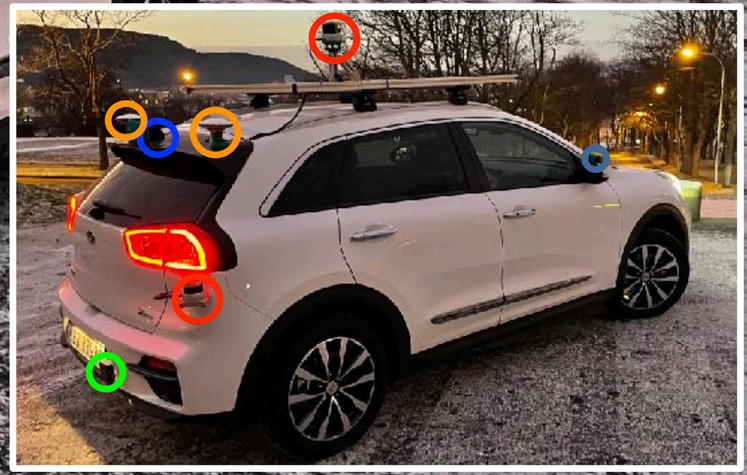
Modular approach:

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

Sense - Reason - Act

End-to-End approach:

- Imitation Learning
- Reinforcement Learning



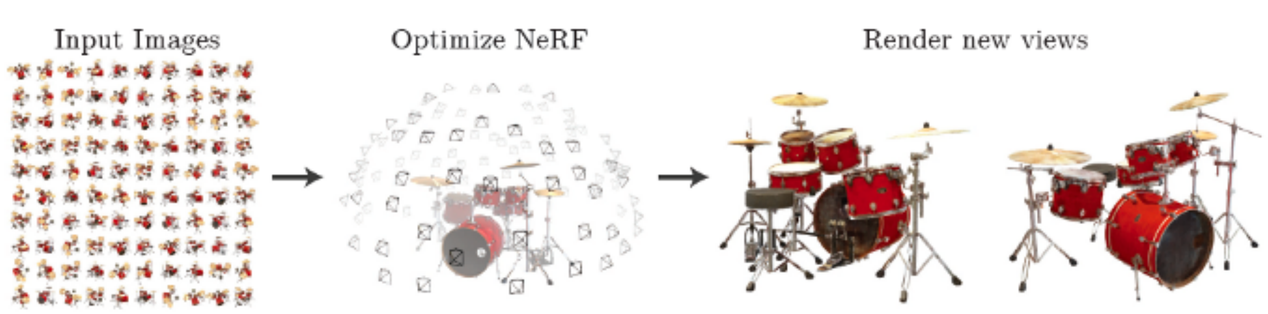

LiDAR

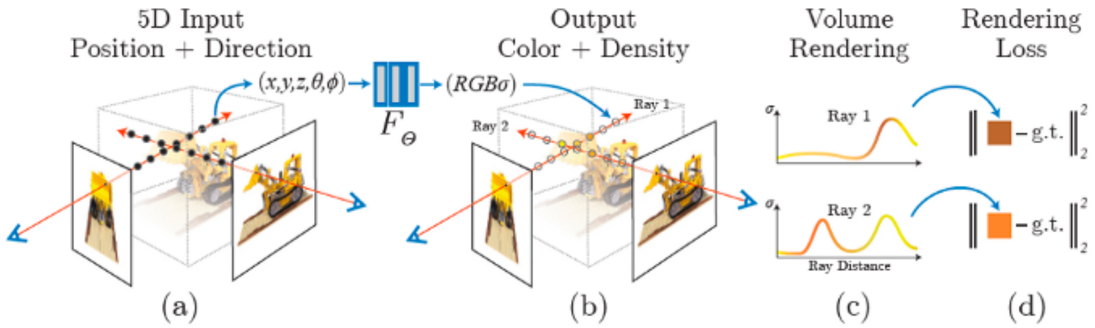
LiDAR-images

Anonymization

Raw

DeepPrivacy2



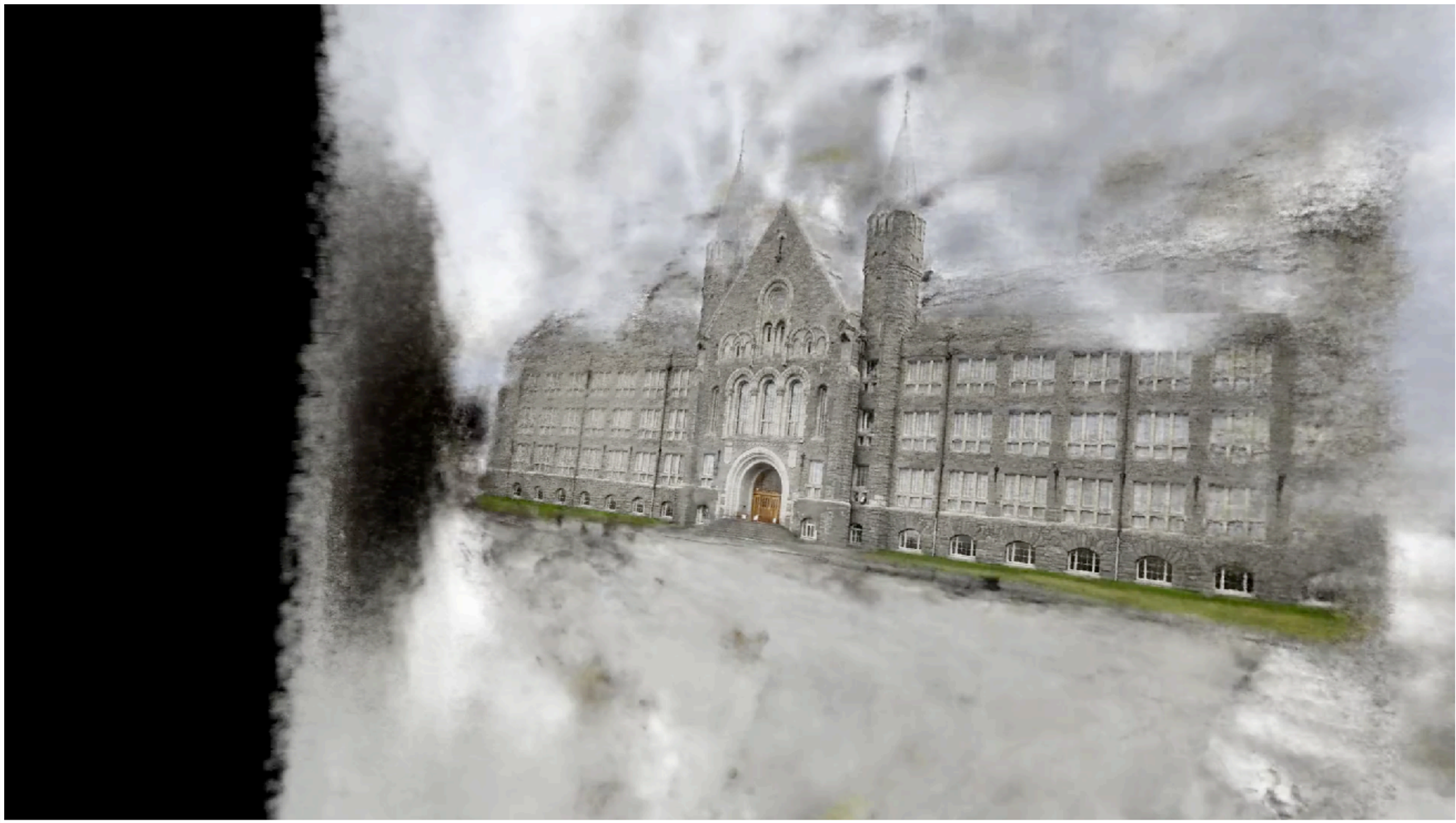


Alt. 3

NeRFs

NeRFs: Future?

NeRFs: Early attempt

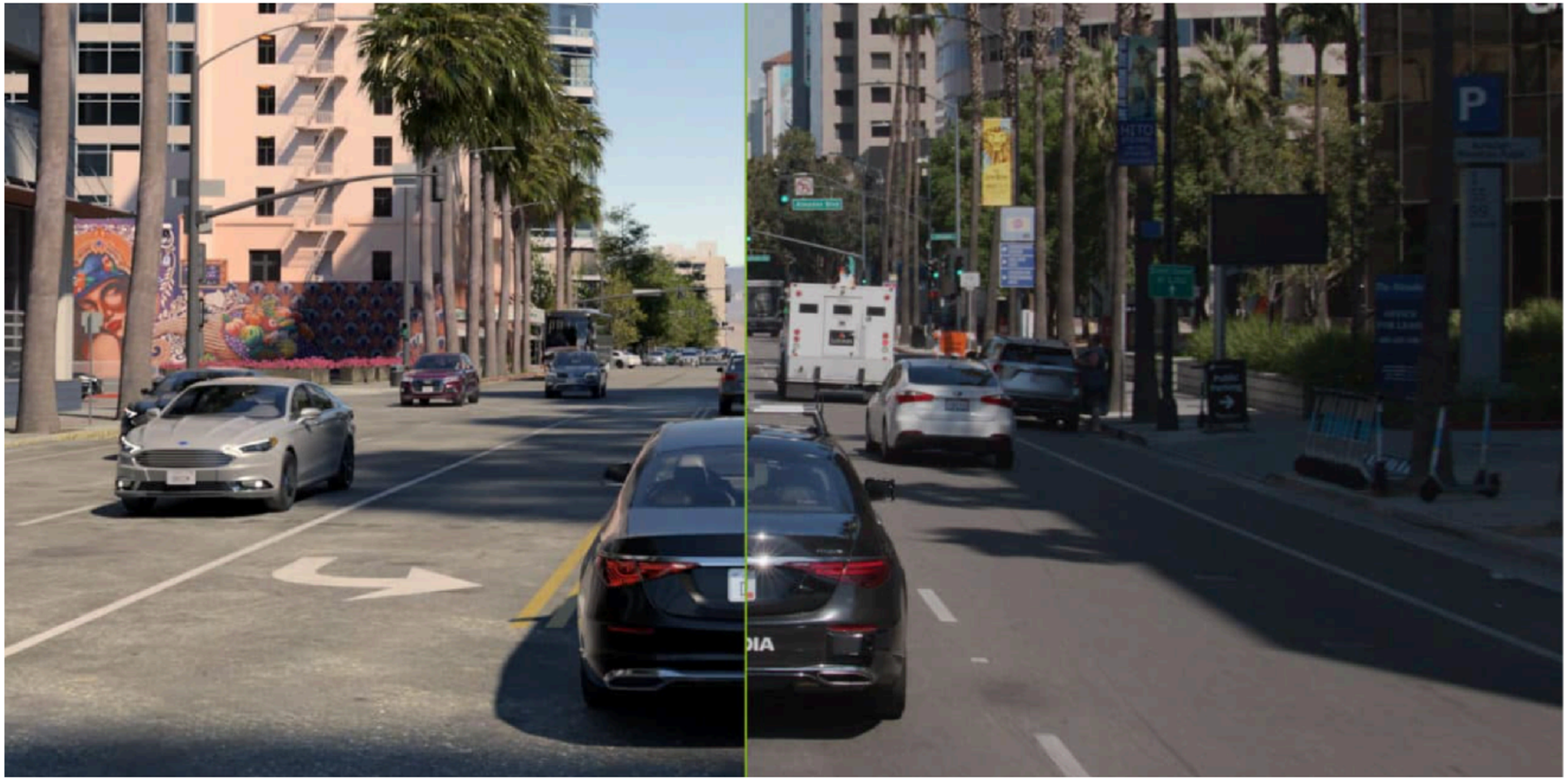


“Block-NeRF”:
Own in simulated environment

“Block-NeRF”:
Own in real environment

“Block-NeRF”:
Own in real environment
(view-point on data capture border)

NeRFs: in simulated environments?

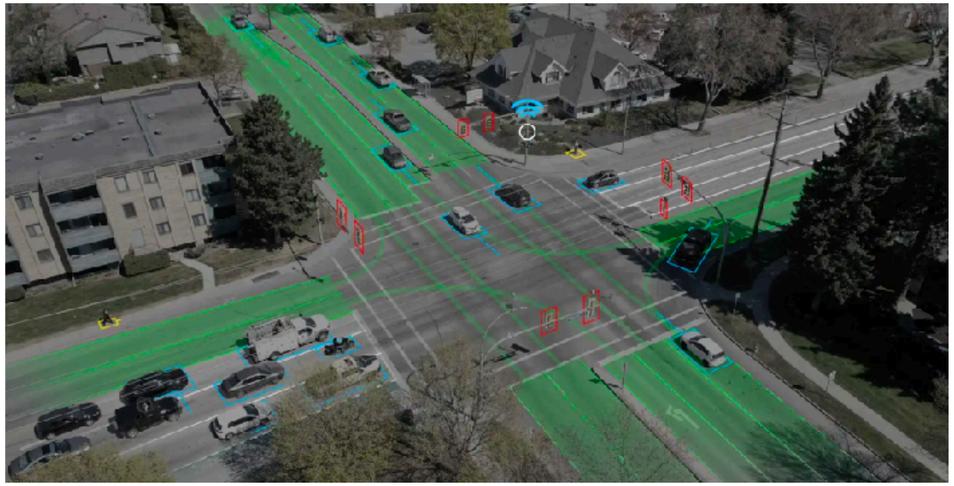


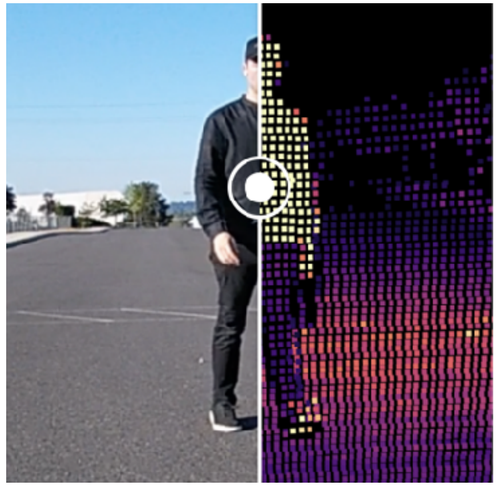
Build DMT: updated / dynamic

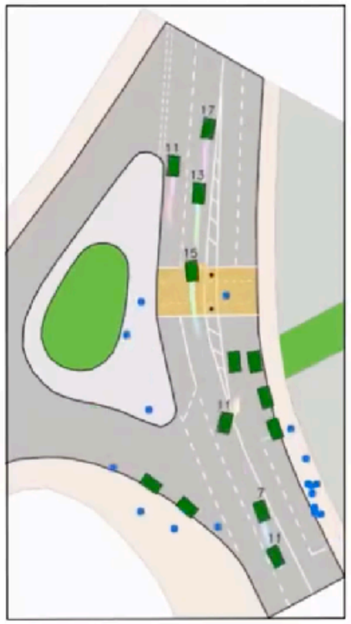
Using infrastructure (Walking, Cycling, Public, Private, Trucks)

Automate

Counting: Camera (vs. LiDAR)

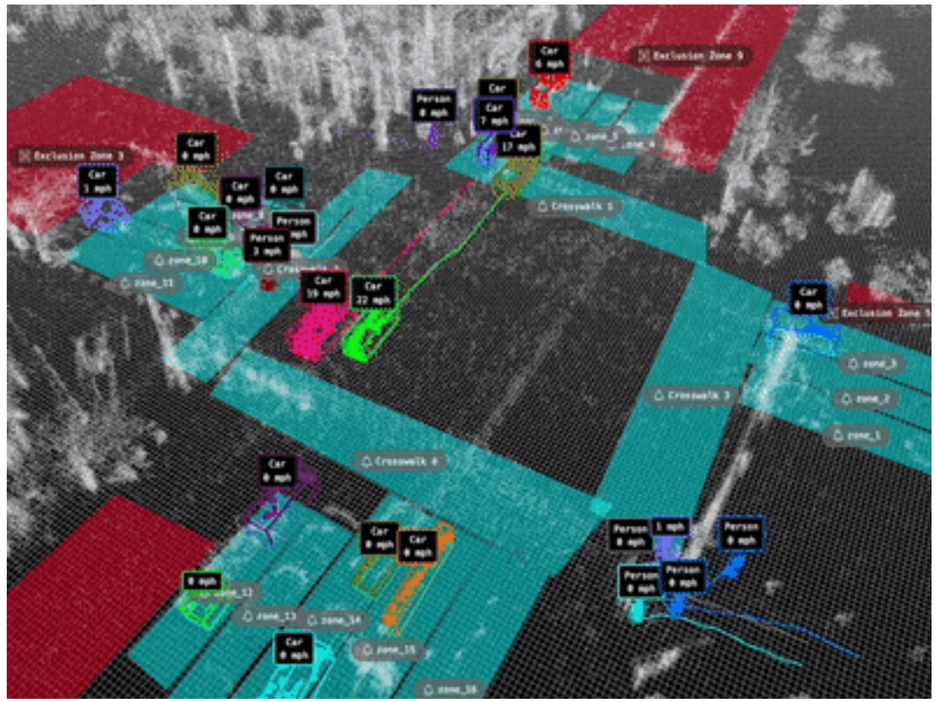




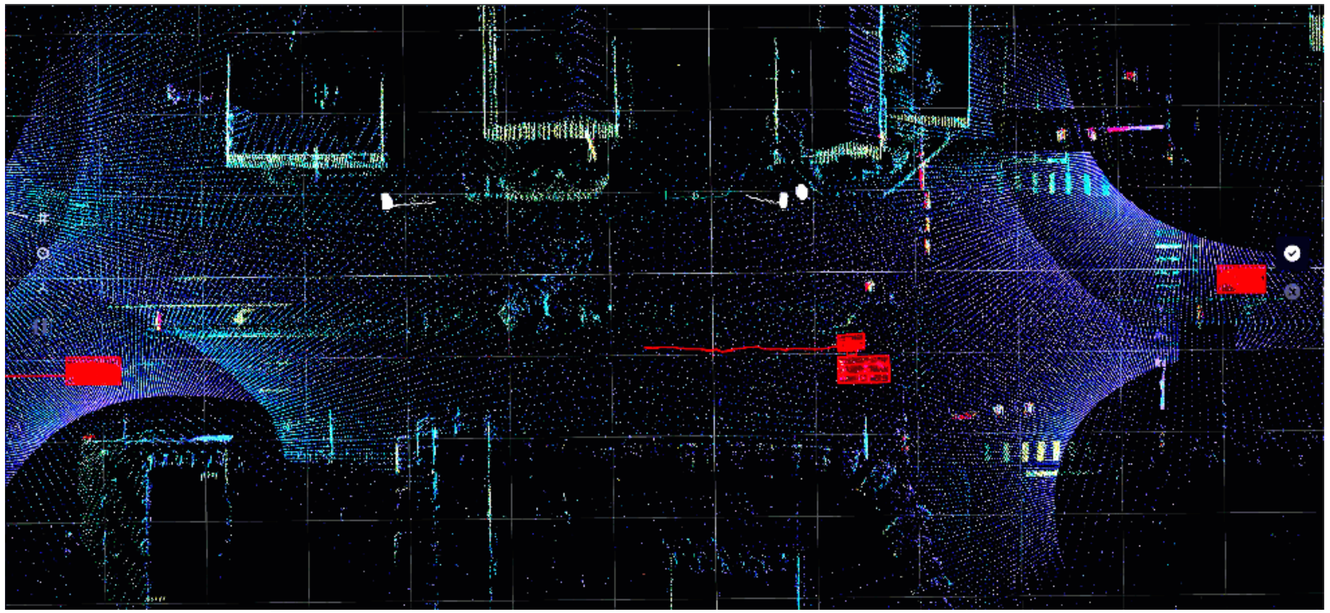


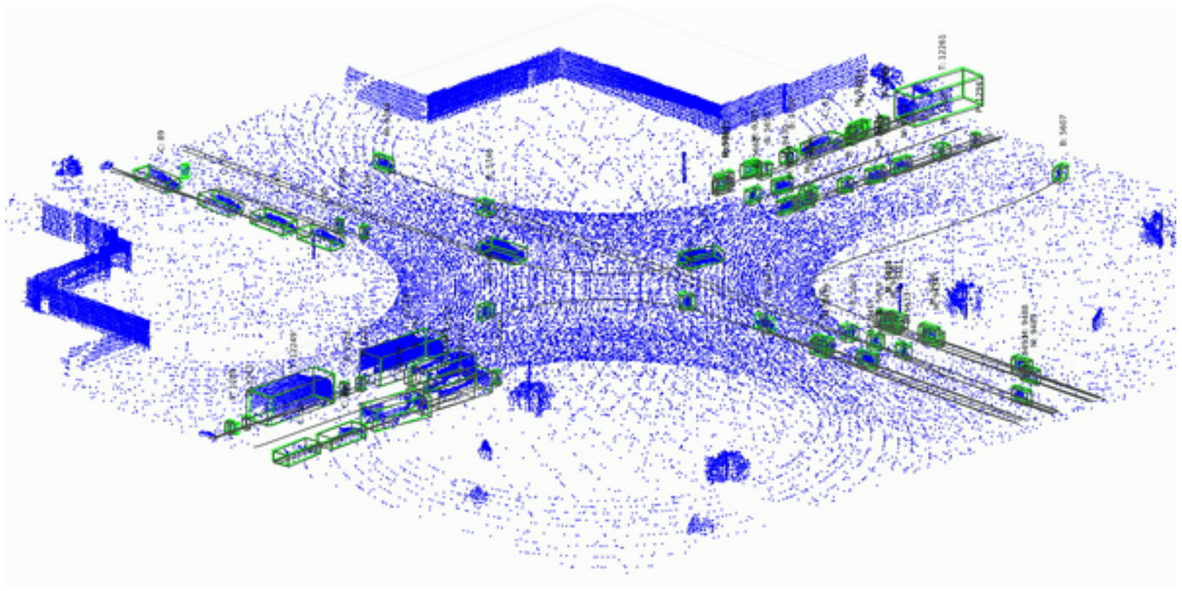
Bird's Eye View Mapping

Prespective View



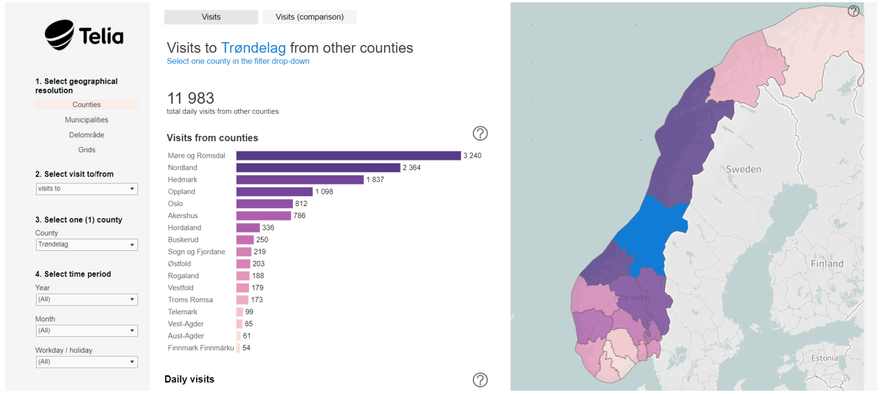
Counting: LiDAR





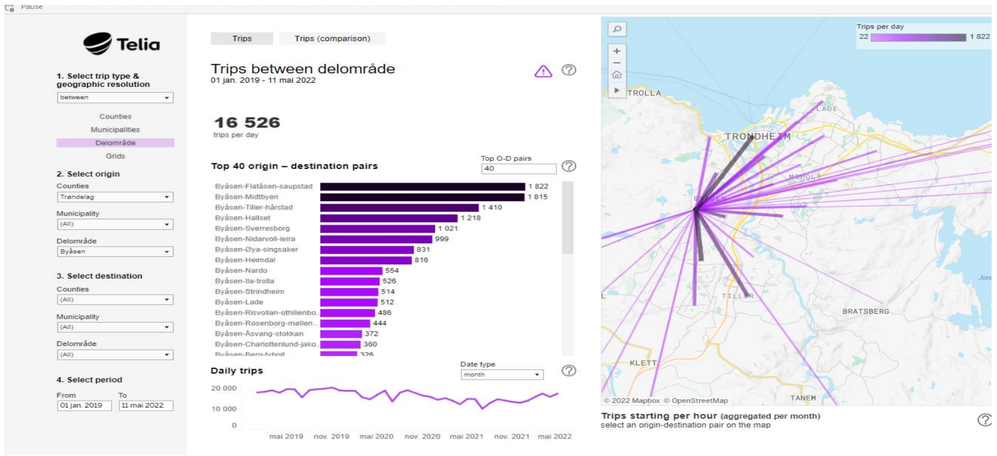
Counting: Mobility data (tracking mobiles)

Reiser til Trøndelag fra andre fylker.



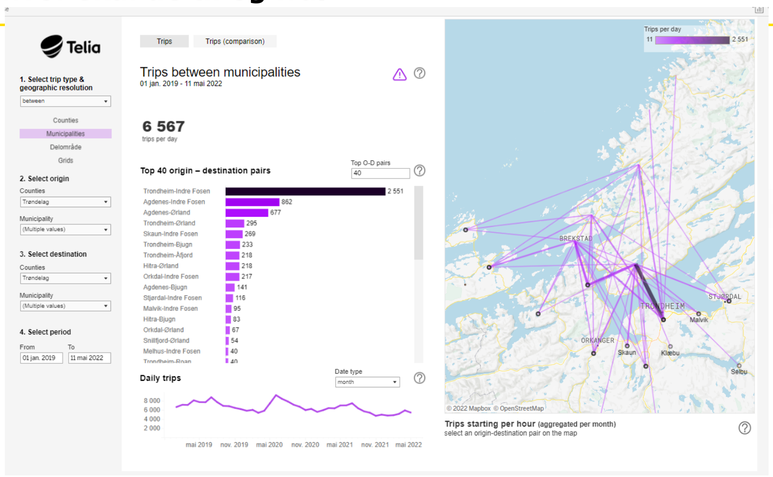
Bussrute/vegtrasé-planlegging.

Hvor skal folk som reiser fra …?

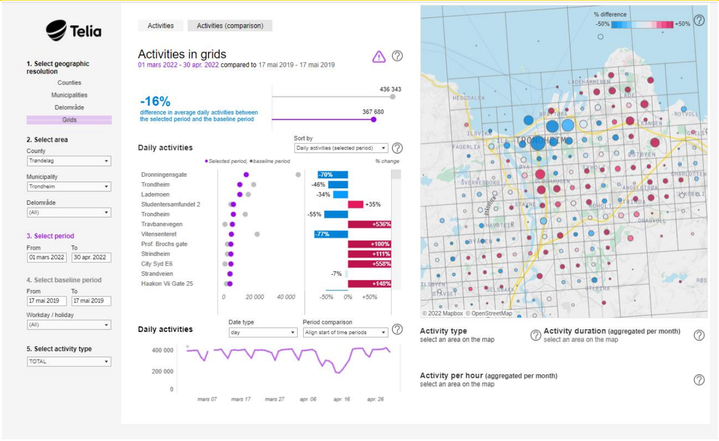


Ferjeplanlegging.

Hvor mange krysninger av Trondheimsfjorden hver dag. - og hvor skal de til og fra.



Eventplanlegging? Hvor var folk 17. mai?



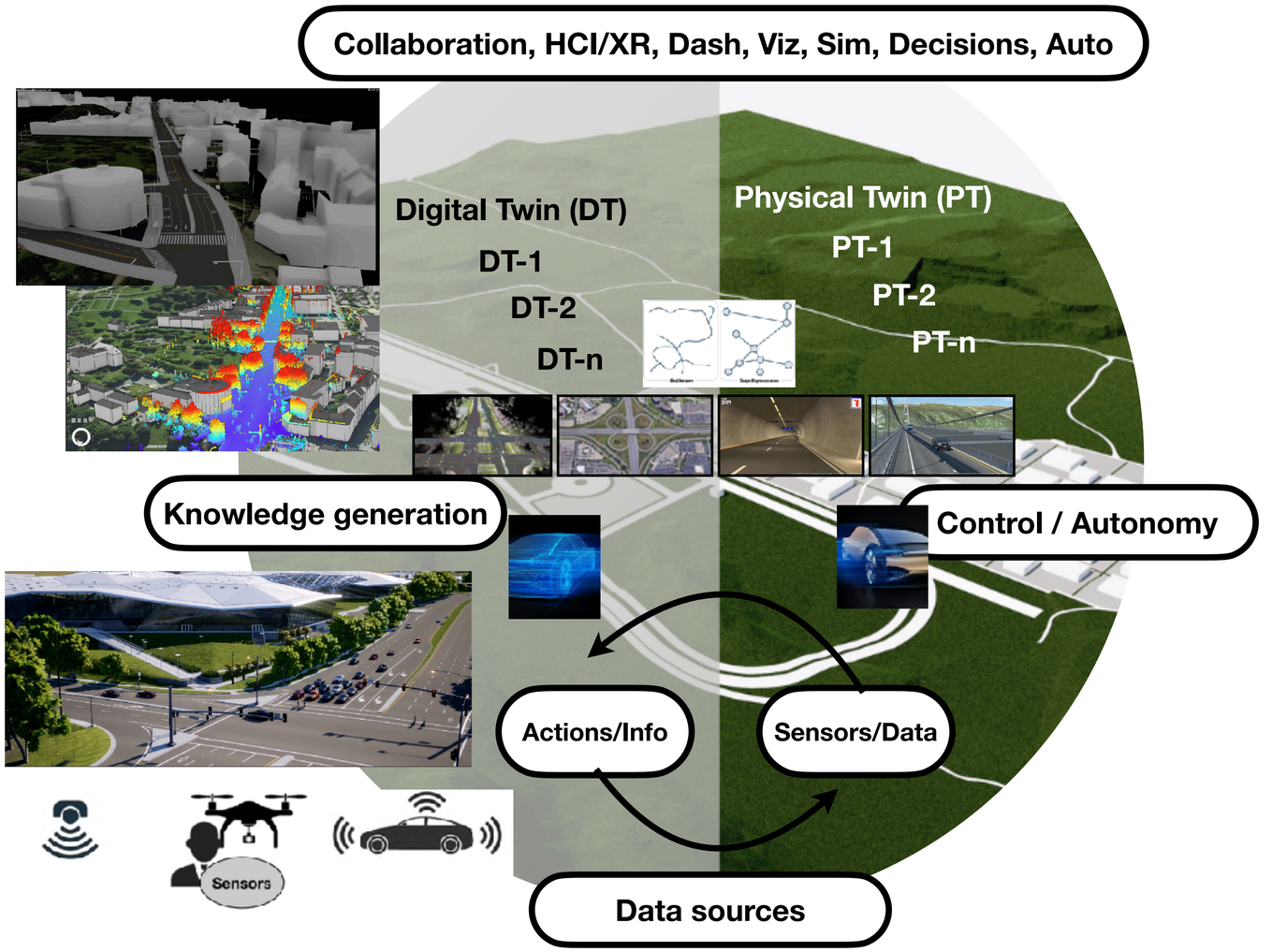
Of course, many other things can be measured:

- Weather
- Air quality
- Noise
- ++

Use DMT

Use DMT: 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)
- **TeleDrive / Remote Control / Flåtestyring** (busses, robo-taxi, car-sharing etc., monitor and take over if needed, HD-map important)
- **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)



Use DMT: Data -> Value

Decision support (human in the loop)

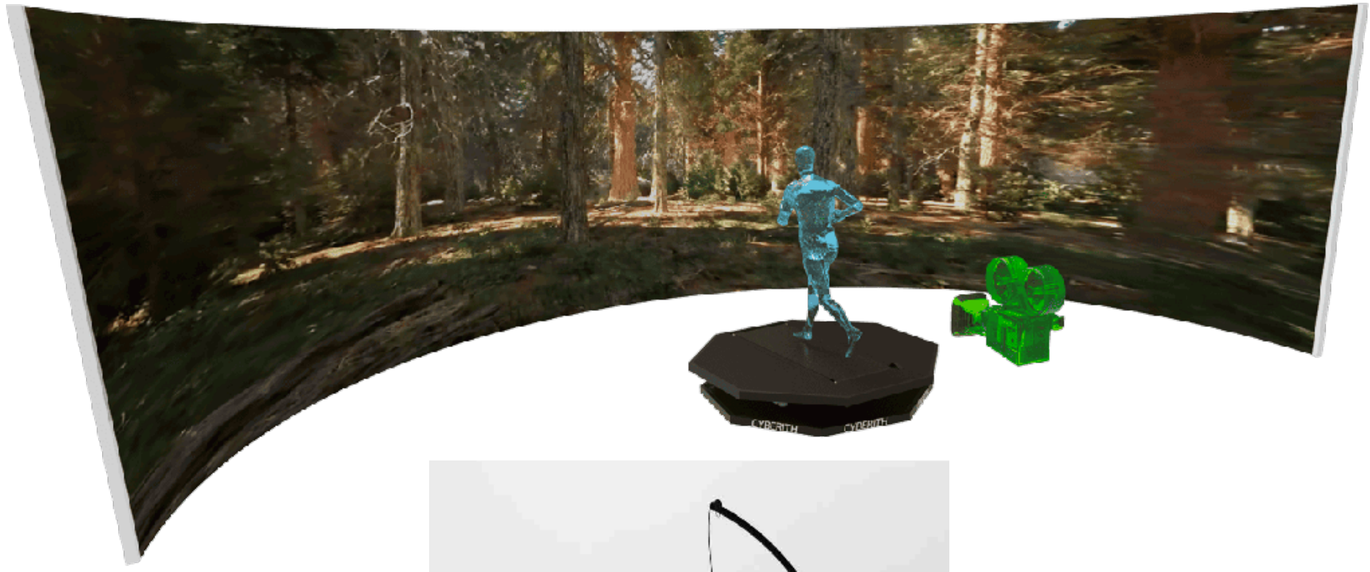
Automation

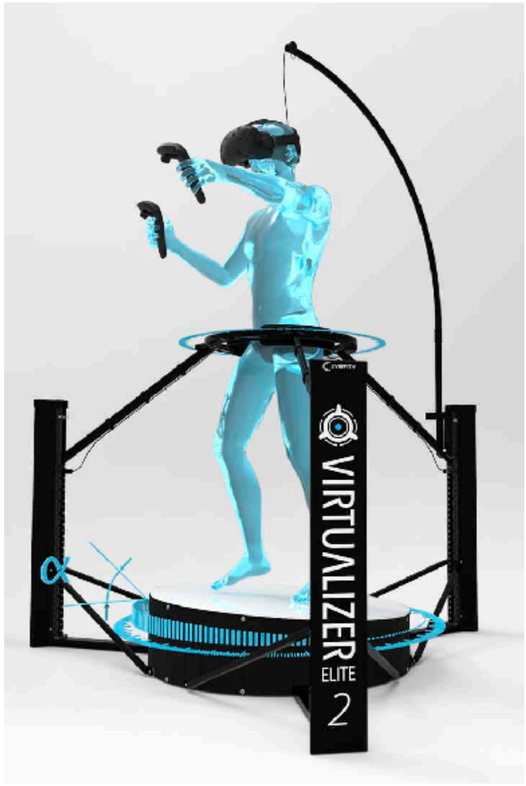
Use DMT: People

Citizens, Stakeholders Engagement and Empowerment

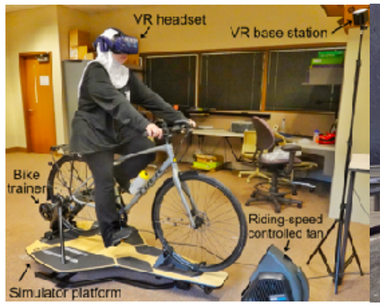
(Walking, Cycling, Driving)

Walking





Cycling


VR headset
VR base station
Bike trainer
Riding-speed controller fan
Simulator platform

Driving

Use DMT: AI-agents

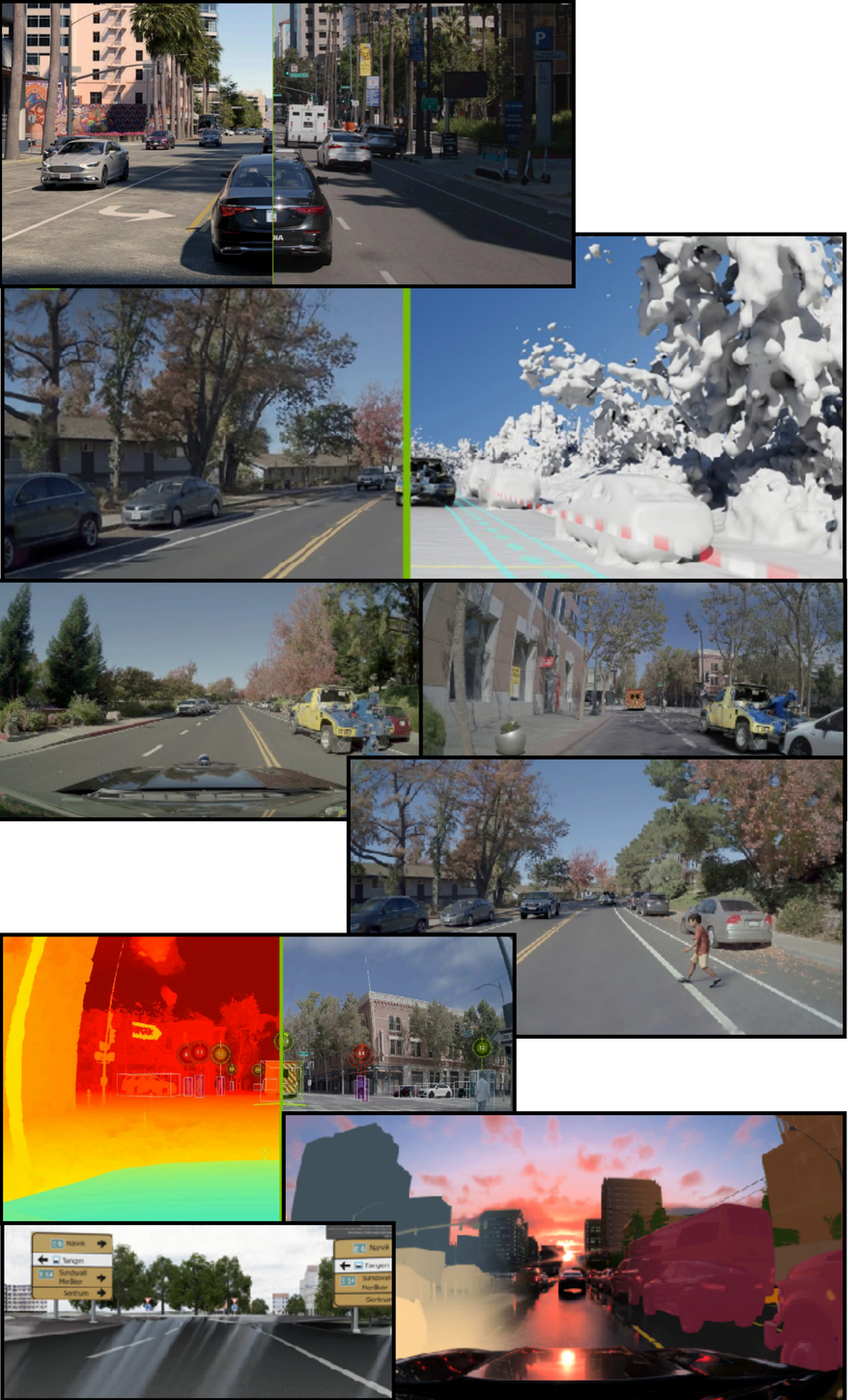
Autonomous Driving (RoboTaxis, LastMile)

Human vs. AI drivers

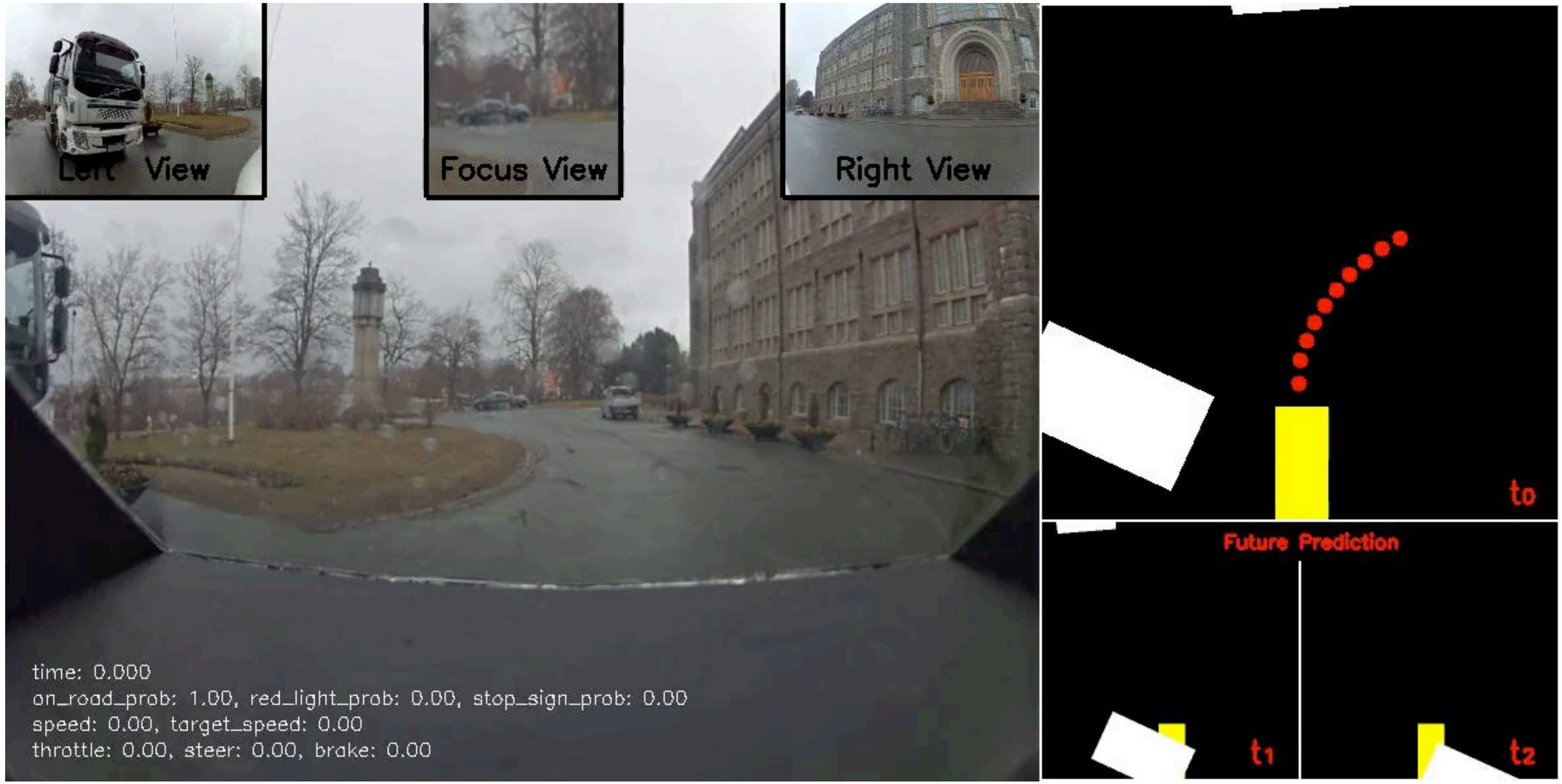
People (walking, cycling) vs. AI drivers

TeleDrive / Remote Control / Fleet management

Autonomy in Sim



Agent: Train in Sim, Test in Real

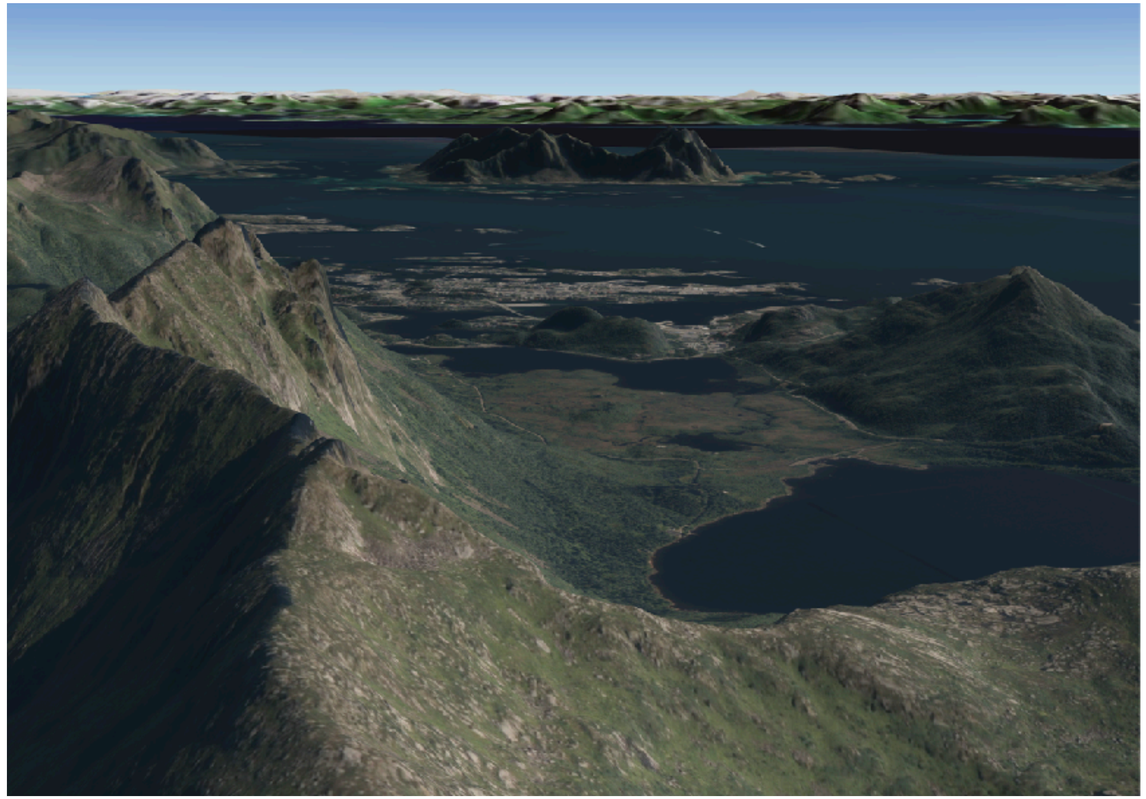


Use DMT:
Resilience / Climate Adaptation

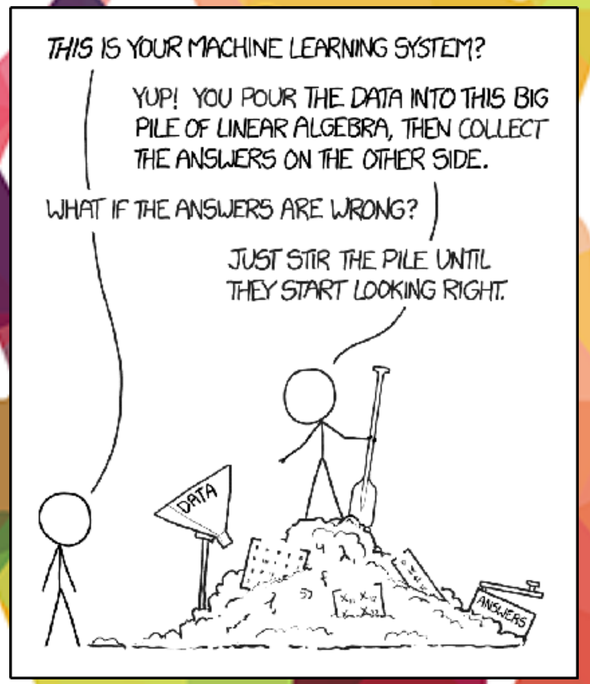
(klimatilpasning)

Resilience / Climate Adaptation

- Extreme weather:
  - E.g. Extreme rain:
    - floods?
    - landslides?



Questions?



Thank you for the attention

frankl@ntnu.no