

Smart, digitalised, and
autonomous systems for
efficient mining and
processes.



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Engineering
EyobuNjineli
Ingenieurswese



Dr Callen Fisher and Prof Lijun Zhang ~ Mining

Faculty of Engineering

Industry Showcase 2025

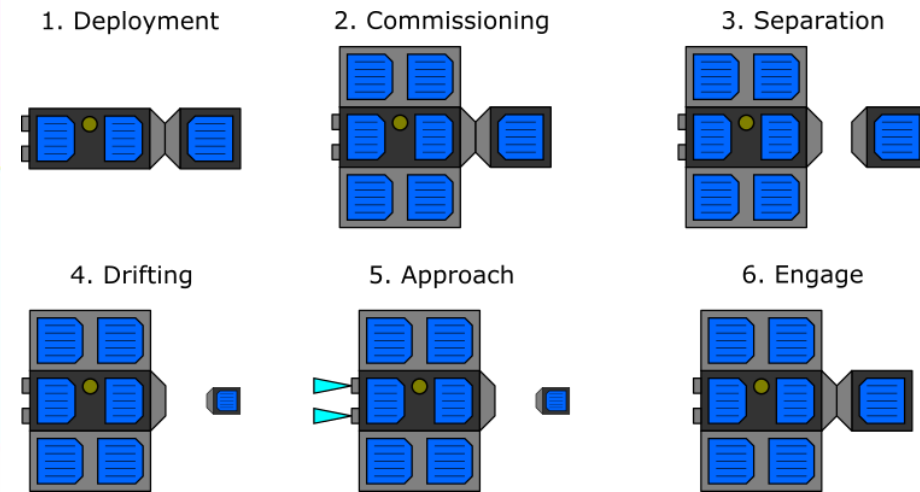
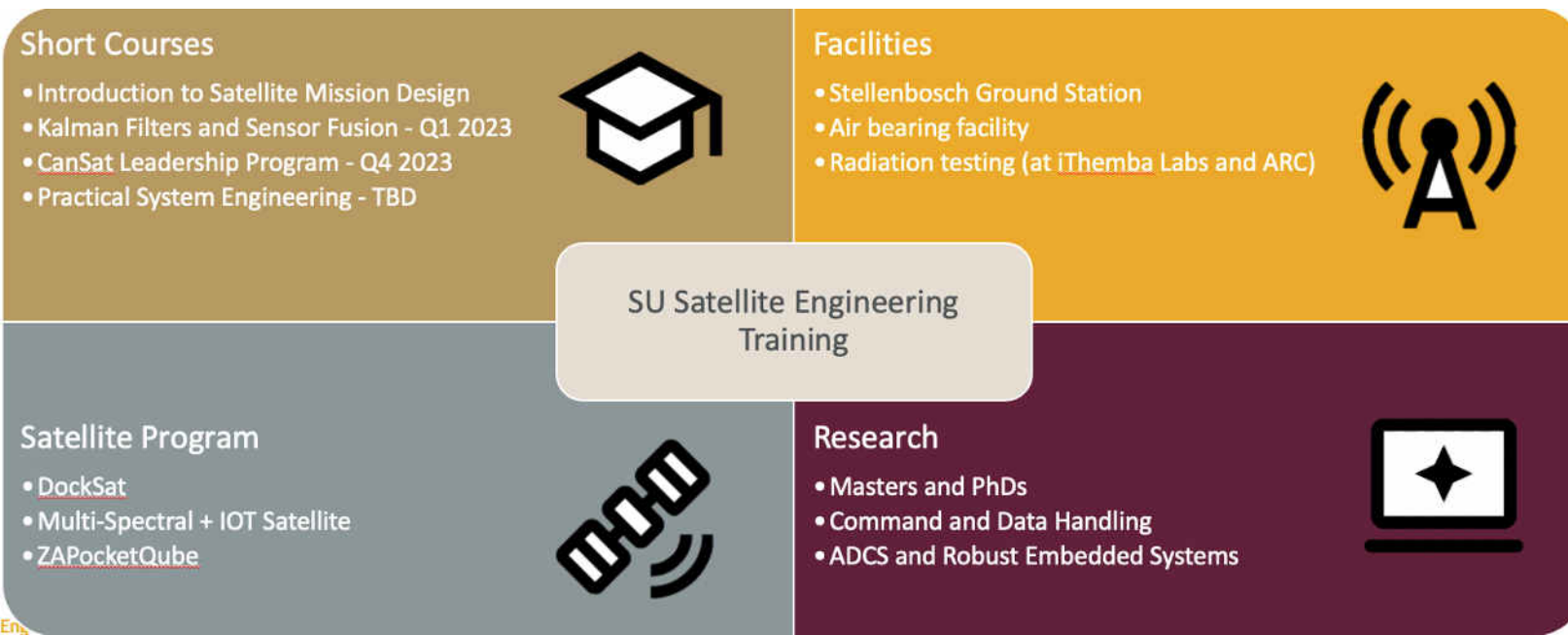
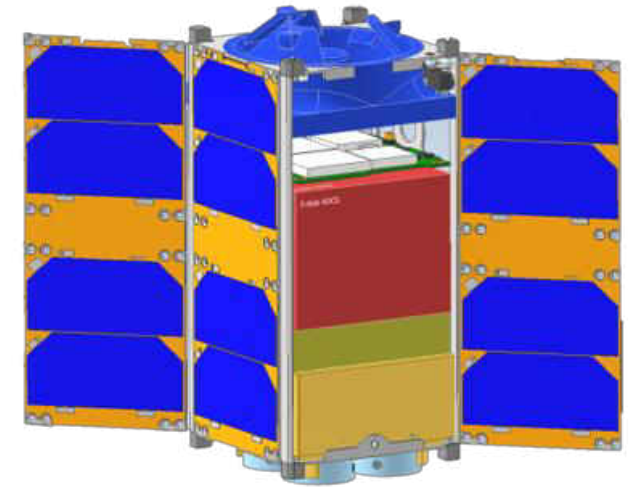
Satellite Engineering Ecosystem



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- SunSat (ZASAT-001, SO-35)
 - Africa's first satellite
 - 60kg LEO EO micro-sat, launched 1999, Vanderberg AFB
- SumbandilaSat (ZASAT-002, SO-67)
 - 81kg LEO EO micro-sat, launched 2009, Baikonur Cosmodrome



Unmanned Aerial Vehicles

Damage-Tolerant Flight Control

- Robust flight control for partial wing loss

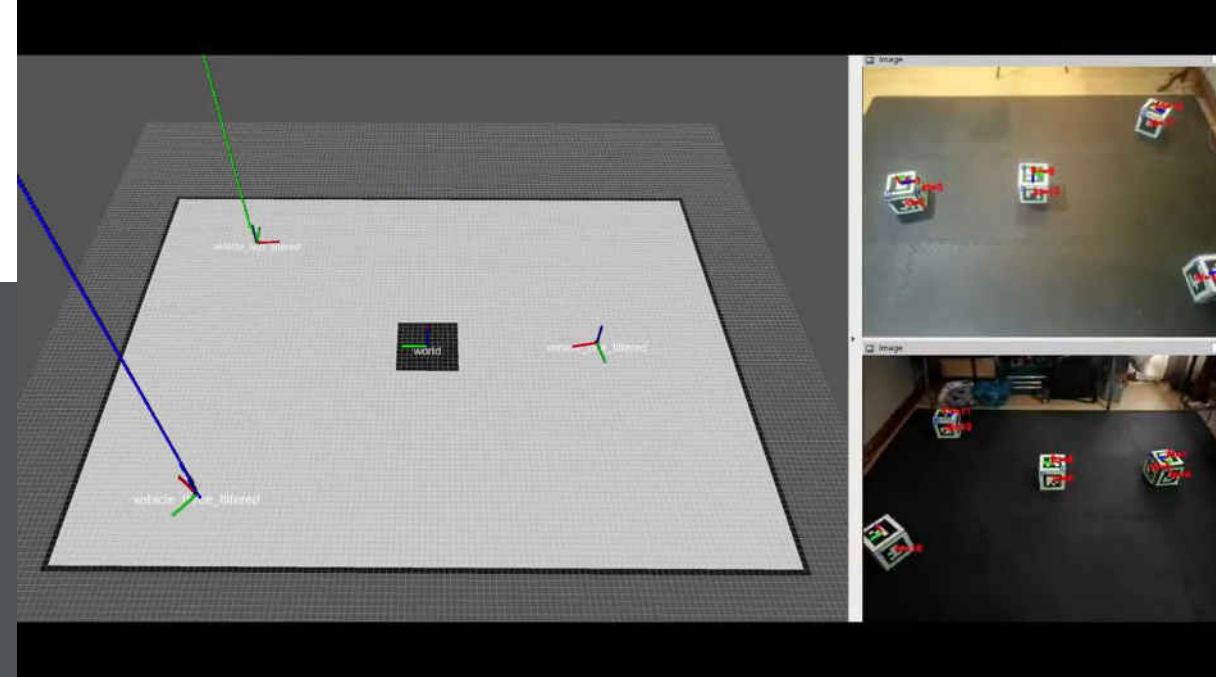


Drones with Cable-Suspended Loads

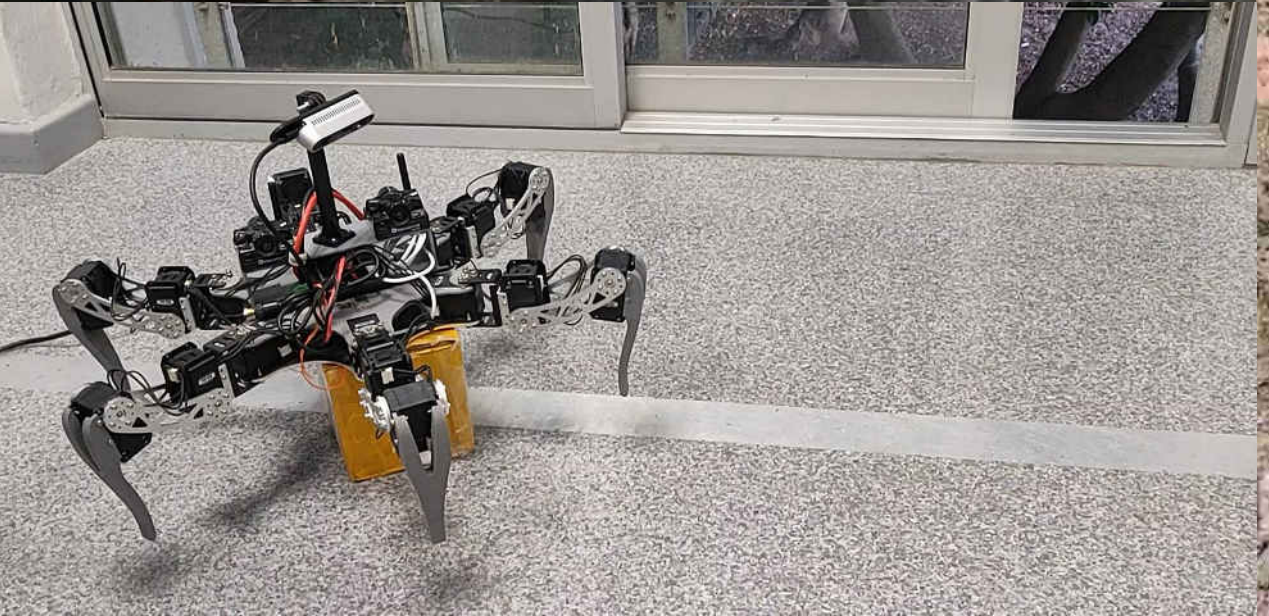
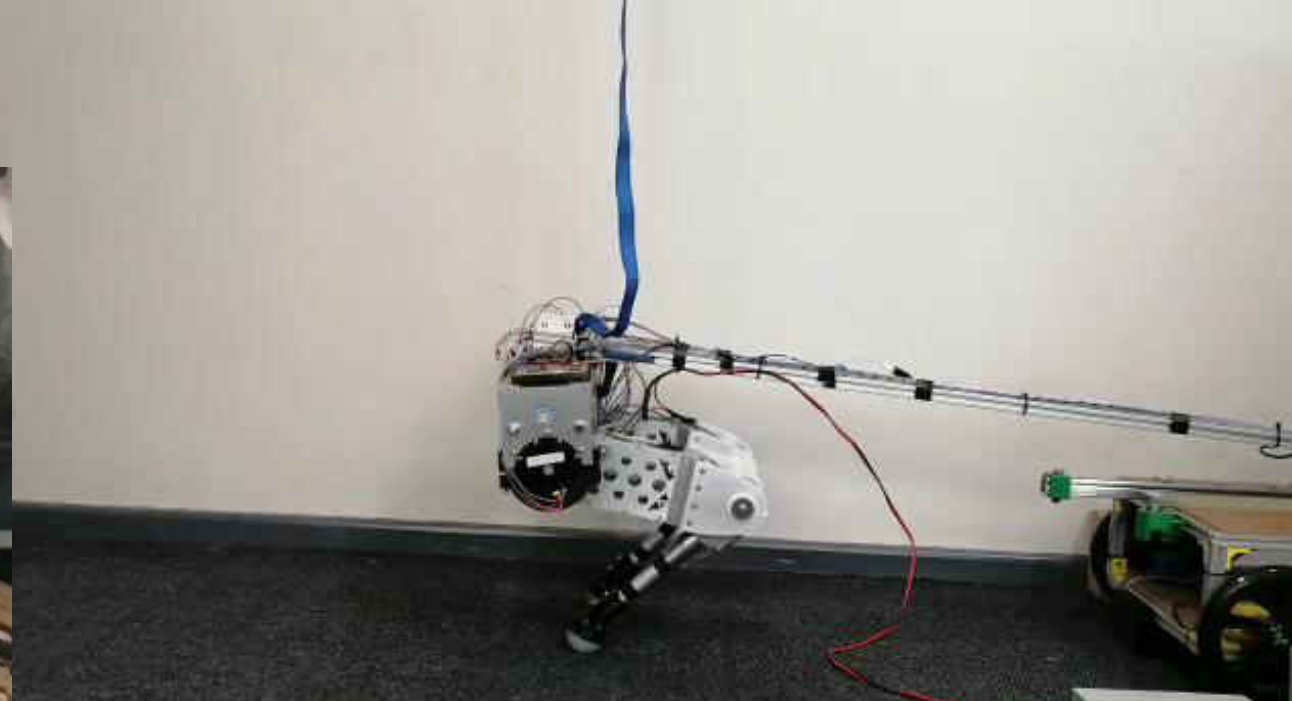
- Robust / adaptive control to accommodate variable cable length and cargo mass



Autonomous Ground Vehicles



Legged Robots



Autonomous inspection rover for subterranean environments



Enaex Africa Announces A Strategic Partnership With Stellenbosch University To Revolutionise Mining Safety Through AI And Robotics

From Left: Johan Fourie, Francisco Baudrand, Dr. Callen Fisher, Ruben Olivier

Enaex Africa Research chair in mining robotics

- Aim:
 - Upskill students
 - Develop an autonomous inspection robot
 - Improve AI capabilities in mining robotics
 - Improve safety of underground mines
- Project duration:
 - January 2024 to December 2026



Prof Lijun Zhang: Robotics Chair to advance safe mining and process digitalisation

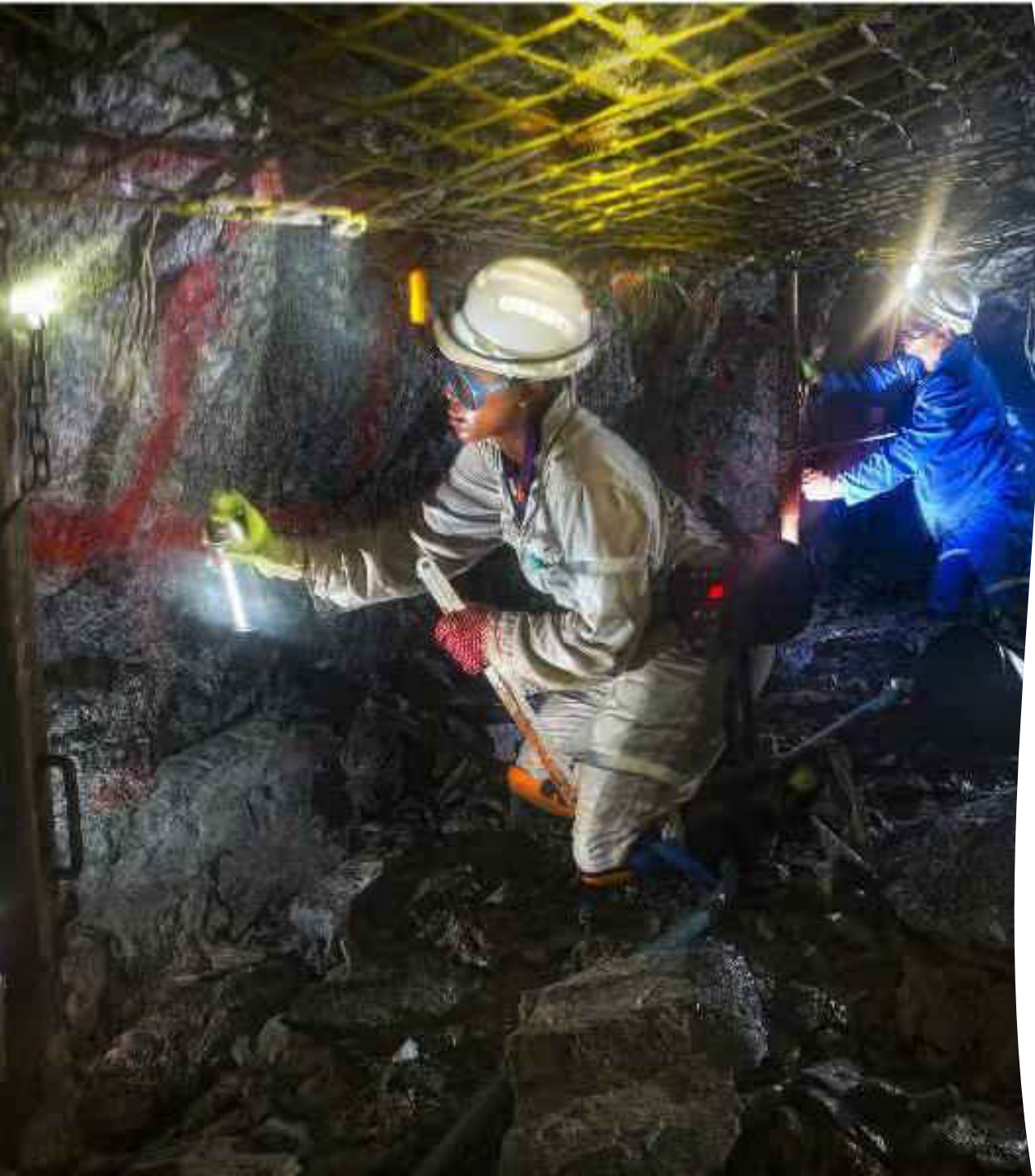
- Previous work focus:
 - Demand side management
 - Process controls
 - Industry digitalisation
- Collaborated with Exxaro Resources on mining energy efficiency projects.
- **Long-term goal:** Establish a well-known mining research center in Africa and the world with high-impact publications, tangible engineering solutions, and good facilities for human capacity development.



Trends in the mining industry in SA

- Going deeper and narrower
 - avoid waste
 - follow the reef thickness
- Very hazardous conditions
 - ever increasing demand for raw materials
- Mapping and inspection:
 - Labor intensive
 - Manual process





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Why do we need inspection and mine mapping?

- Improve the safety of the mine
 - ENAEX: Humanize mining
 - Don't send a human to do a machines job
- Avoid mine disasters
- Keep humans away from dangerous areas
 - Extremely hazardous environments
 - Determine hazardous areas
- Accurate maps for disasters management and robotics

Need to detect:

Loose rocks
Sagging walls
Fall of ground
Collapse
Gas build up

Current methods of inspection and limitations

- Visual inspection
 - Manual measurements
 - Remote (static) sensors
 - Conventional (manned) inspection vehicles
-
- Very manual process
 - Time consuming
 - Low spatial resolution with fixed sensors



QueCreek mine disaster

- July 2002, Pennsylvania
- 9 miners nearly killed
 - drilled into an abandoned flooded mine
- Trapped for 77 hours
- Relied on an outdated surveyor's maps
- Accurate maps can prevent disasters
- Unknowingly drilled within three feet of the long-abandoned Saxman Mine



Environment challenges: Cluttered



Our vision

- Develop AI capabilities in mining robotics
- Form local industry and academic ties
- Develop an autonomous inspection robot for hazardous subterranean environments
- Develop Robotic Engineers for mining applications



End Goal: Develop an Autonomous Rover

Autonomously inspect an area

- Before/after seismic activity (proactive/reactive)
- Predict future events
- Autonomously map and explore an area

Gain a better understanding of geological features

- Slope mapping
- Terrain classification

Transmit this information to a “base station”

- Deploy a mesh network
- Feed into the mines fibre network
- Handle conductive ore bodies



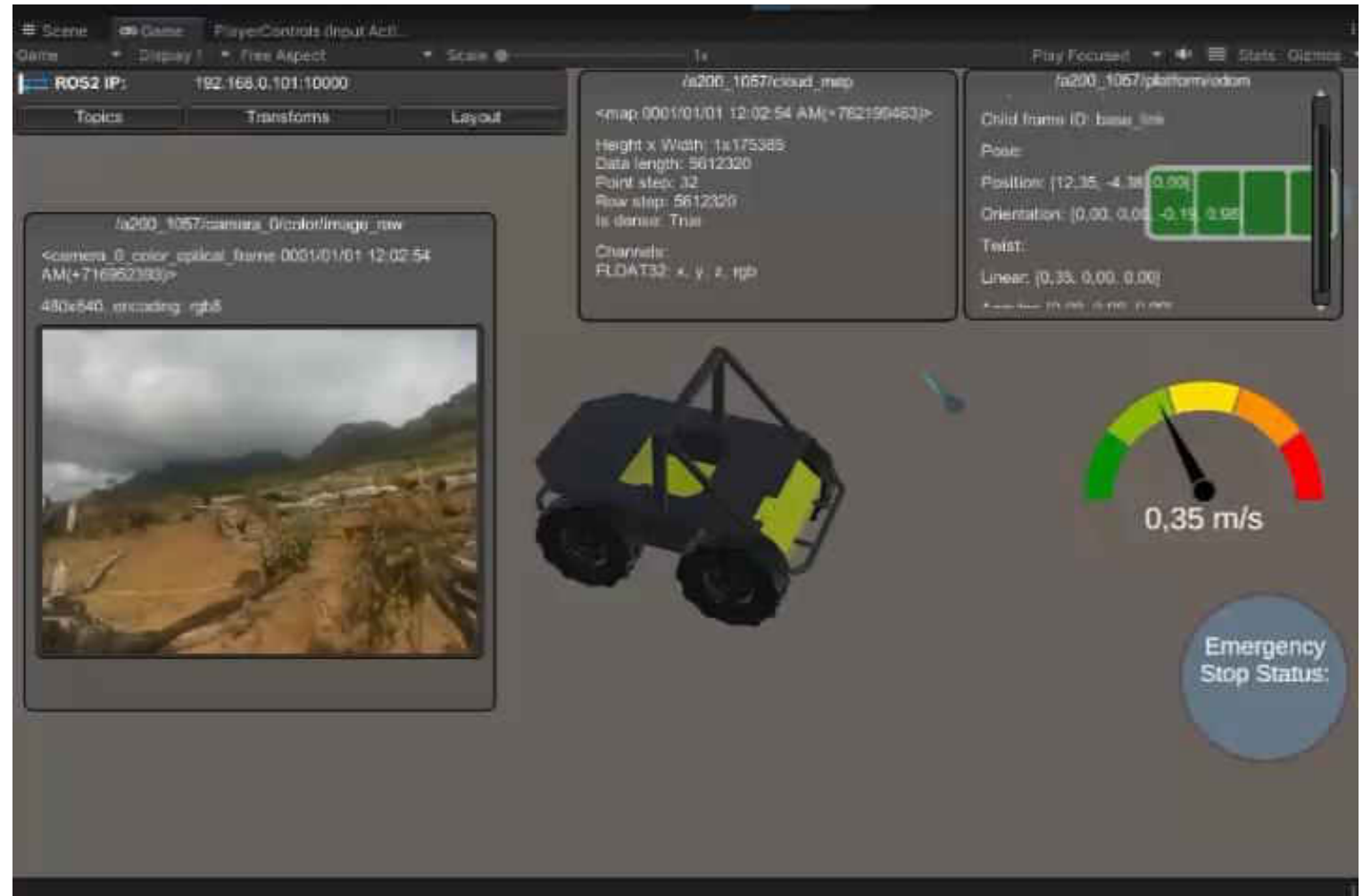
Digital twin and user interface



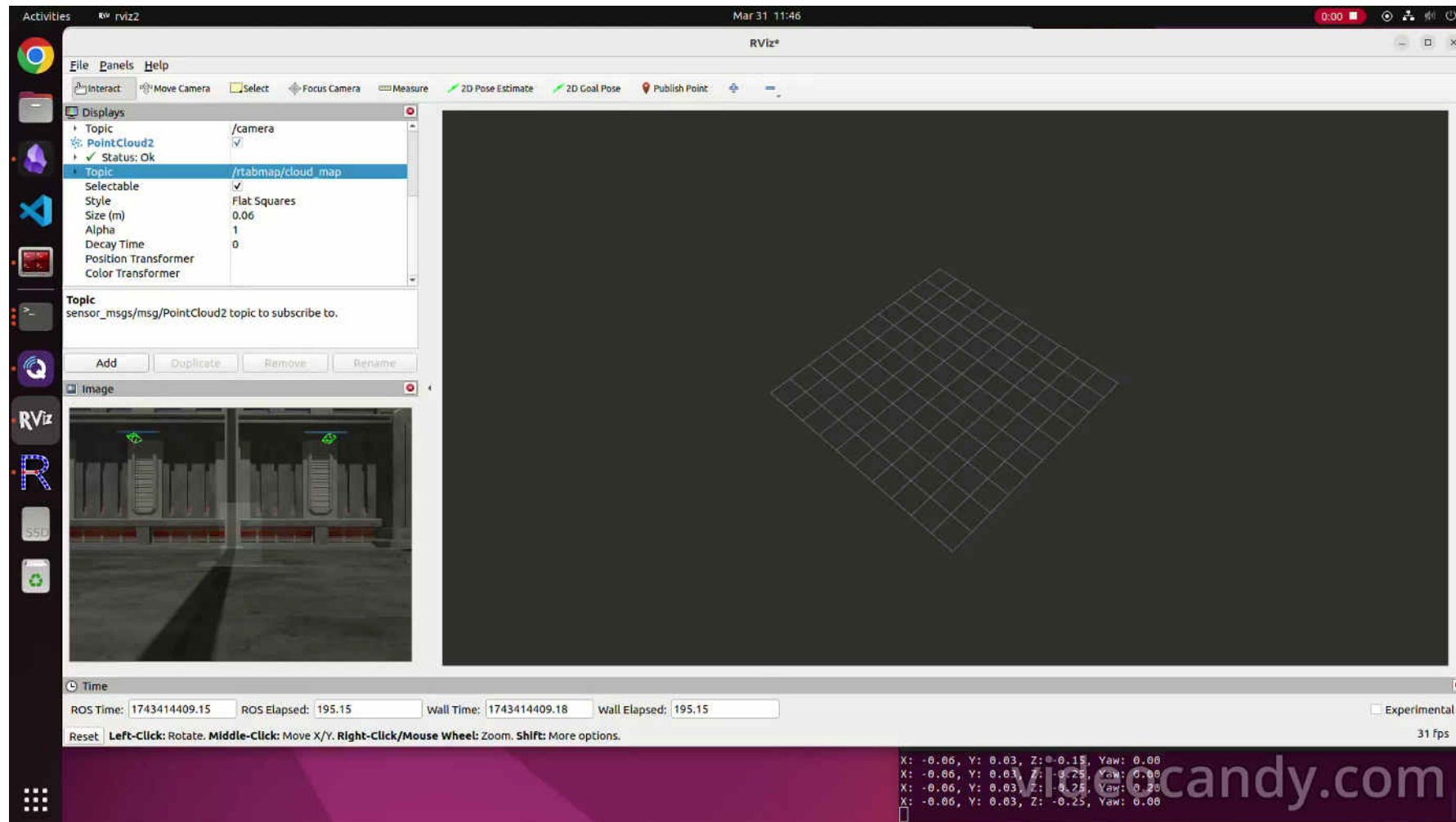
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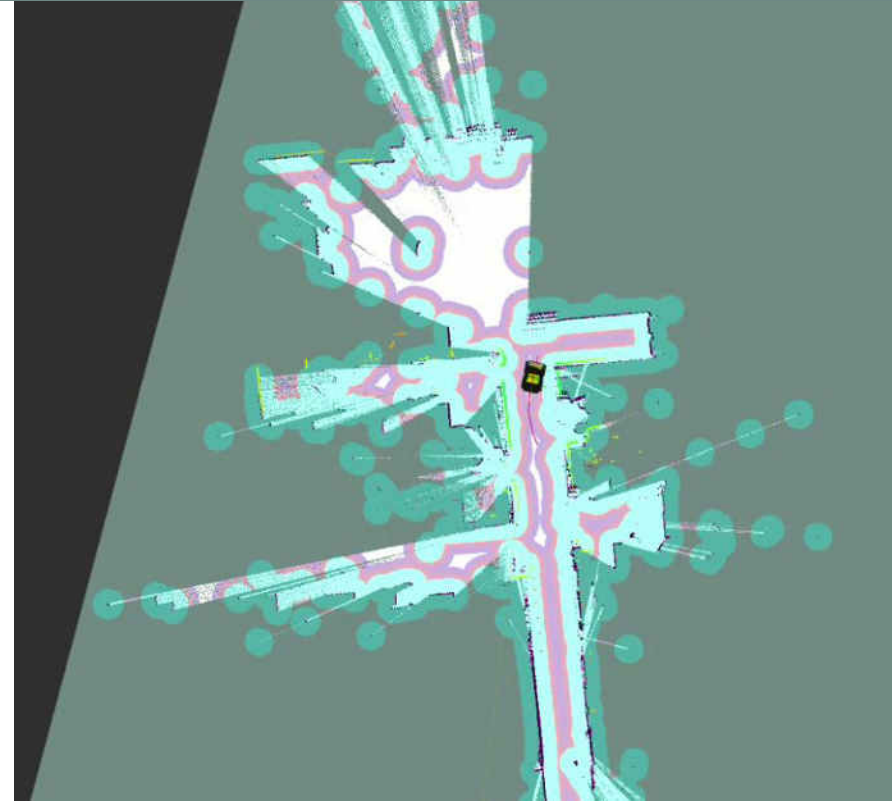
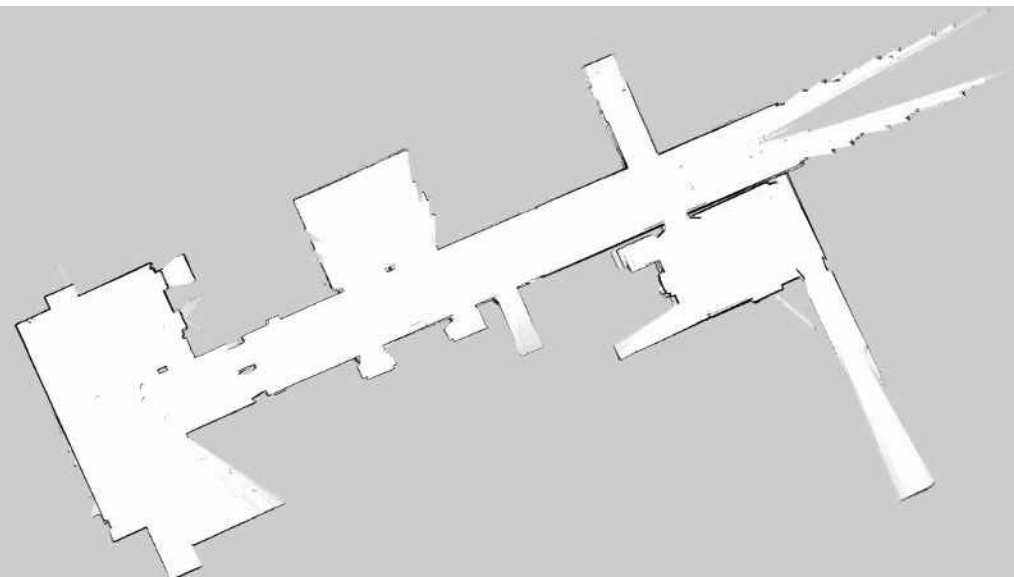
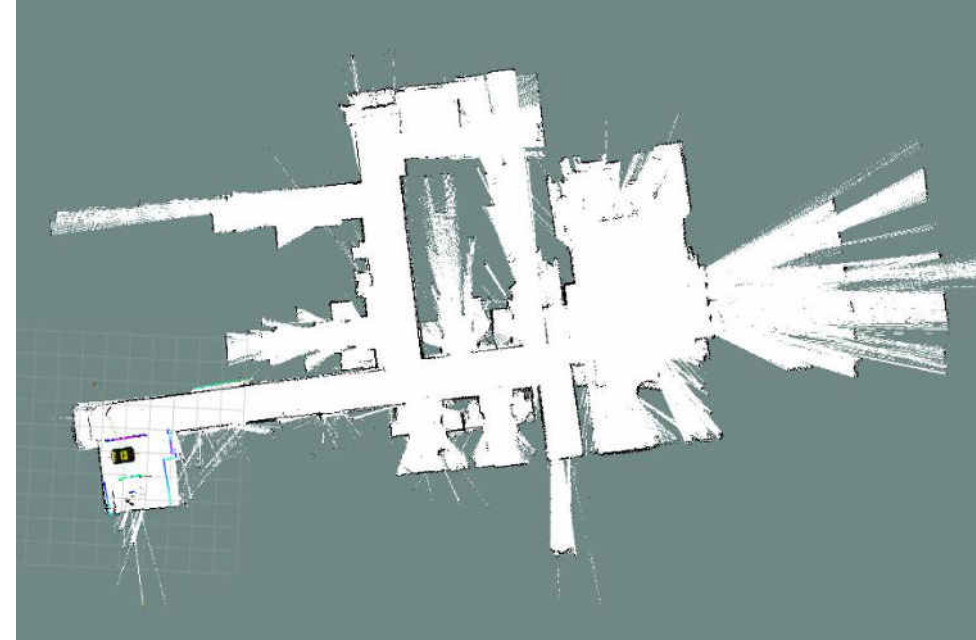
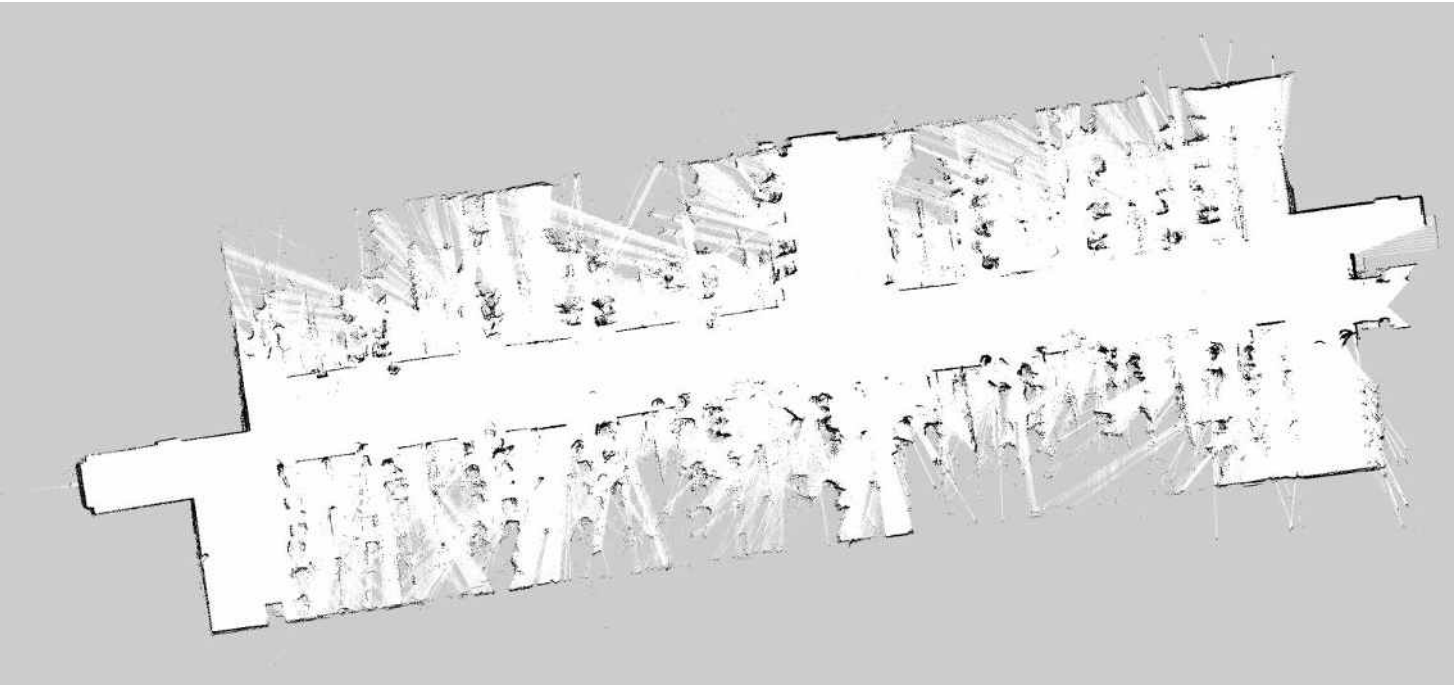
- Headless mode
- Enables:
 - Command line
 - Tele-op
 - Replaying saved data



Full underground simulation with Drone and Husky robot

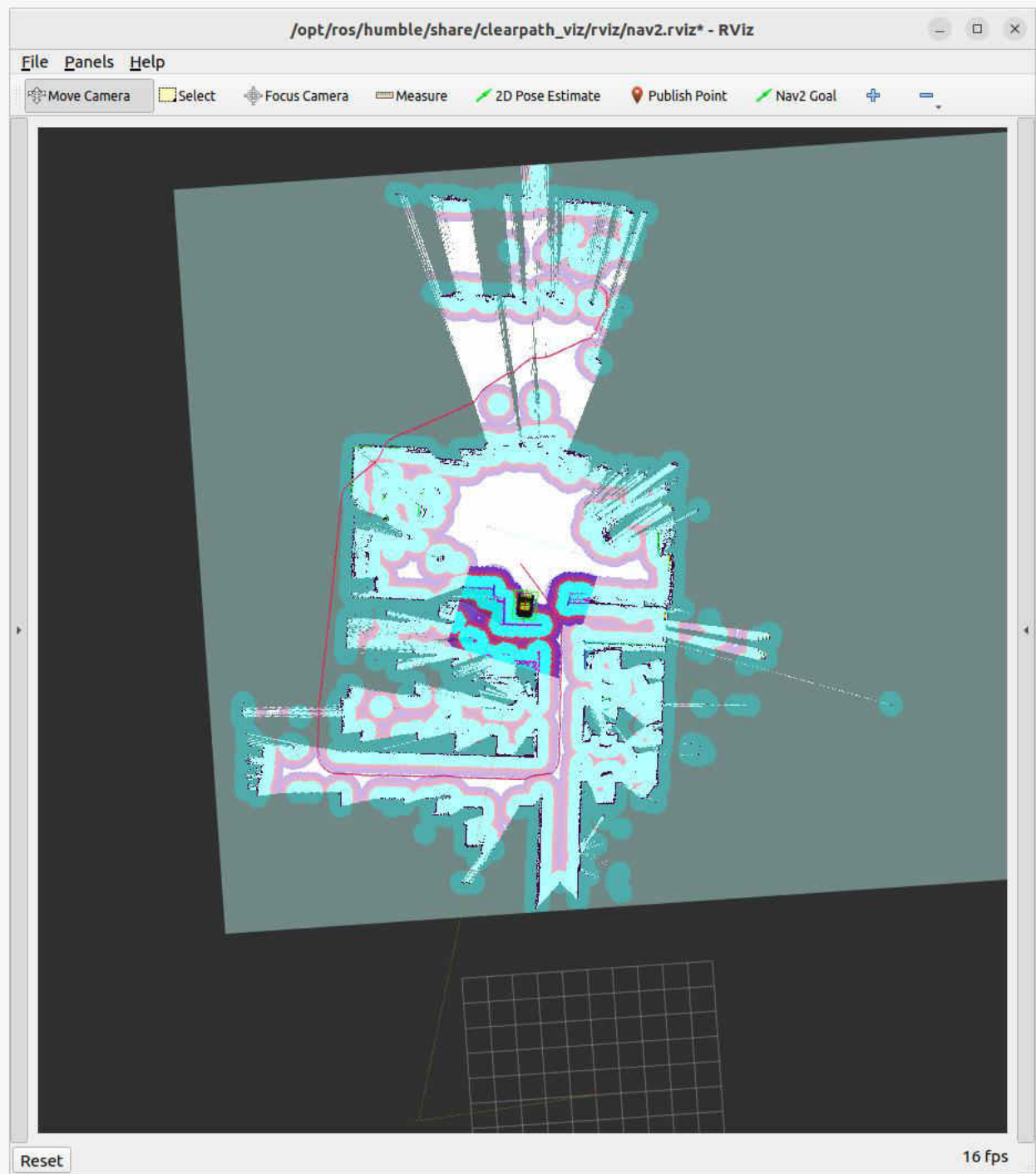
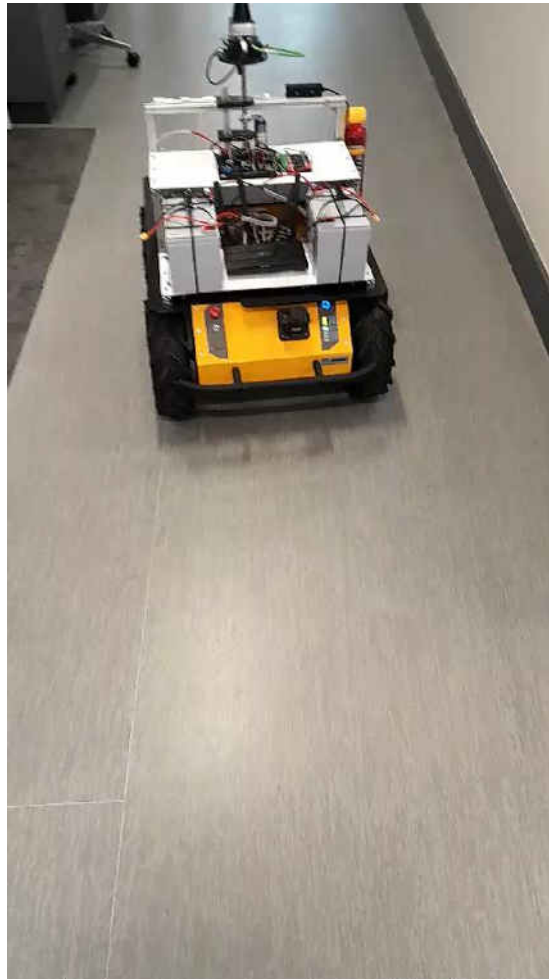


Mapping

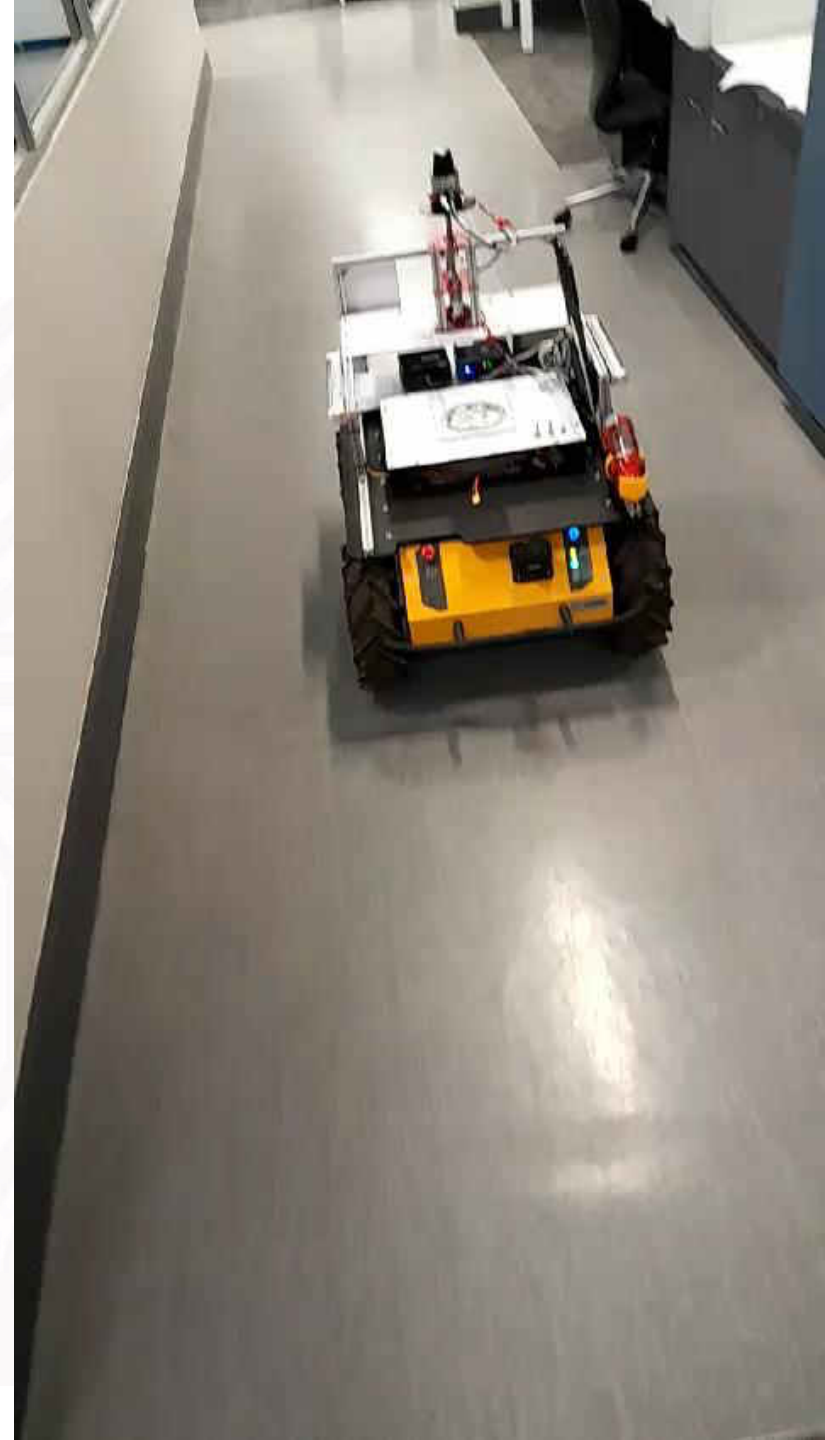
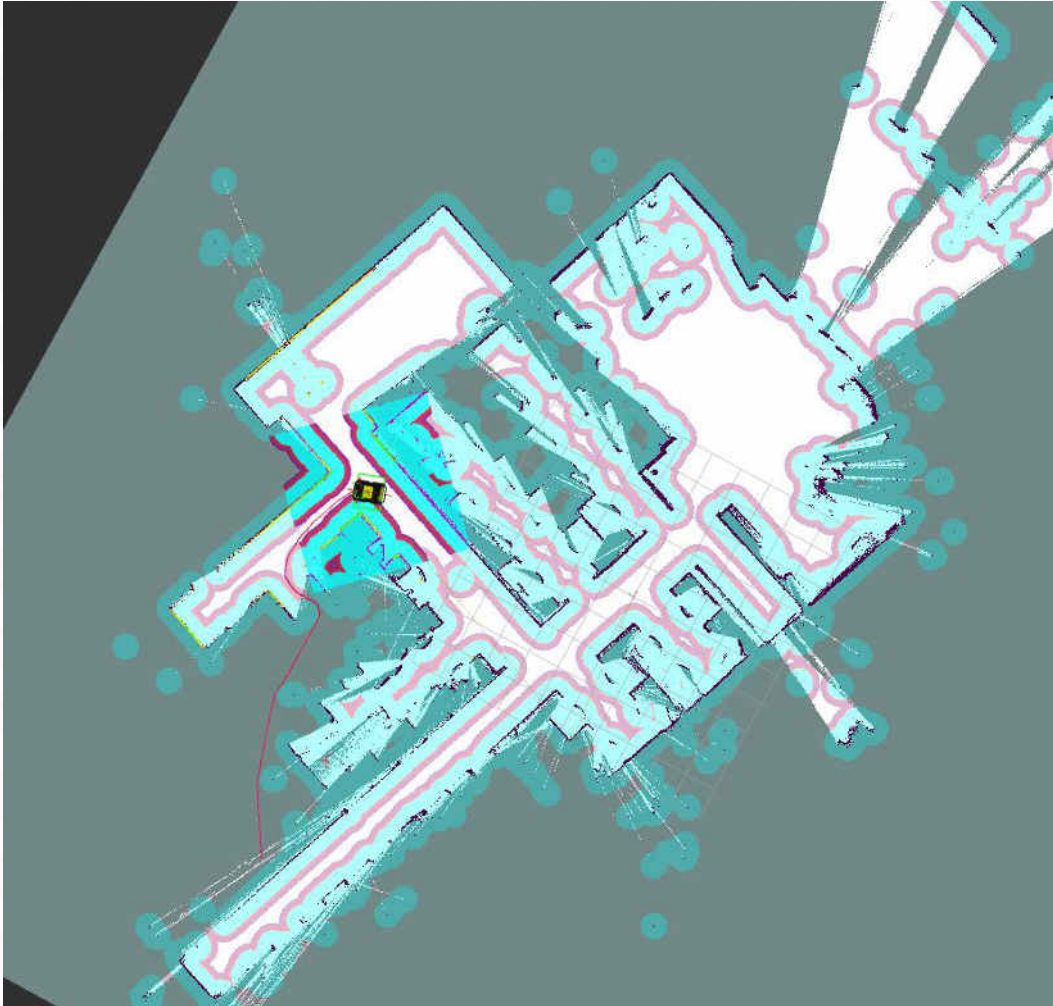


Autonomous Navigation

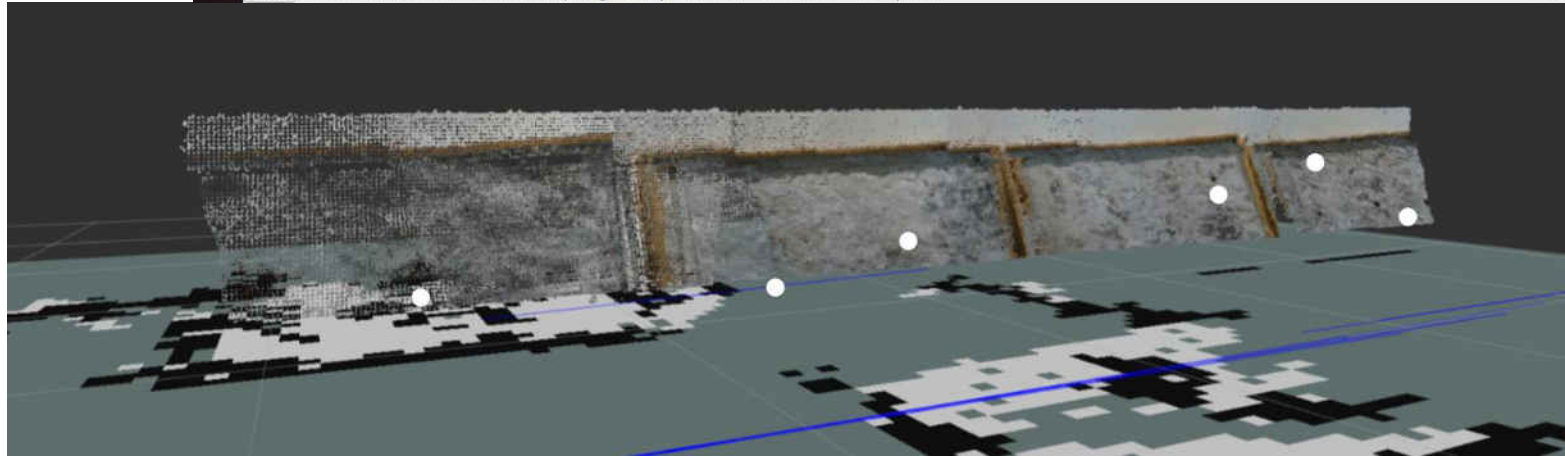
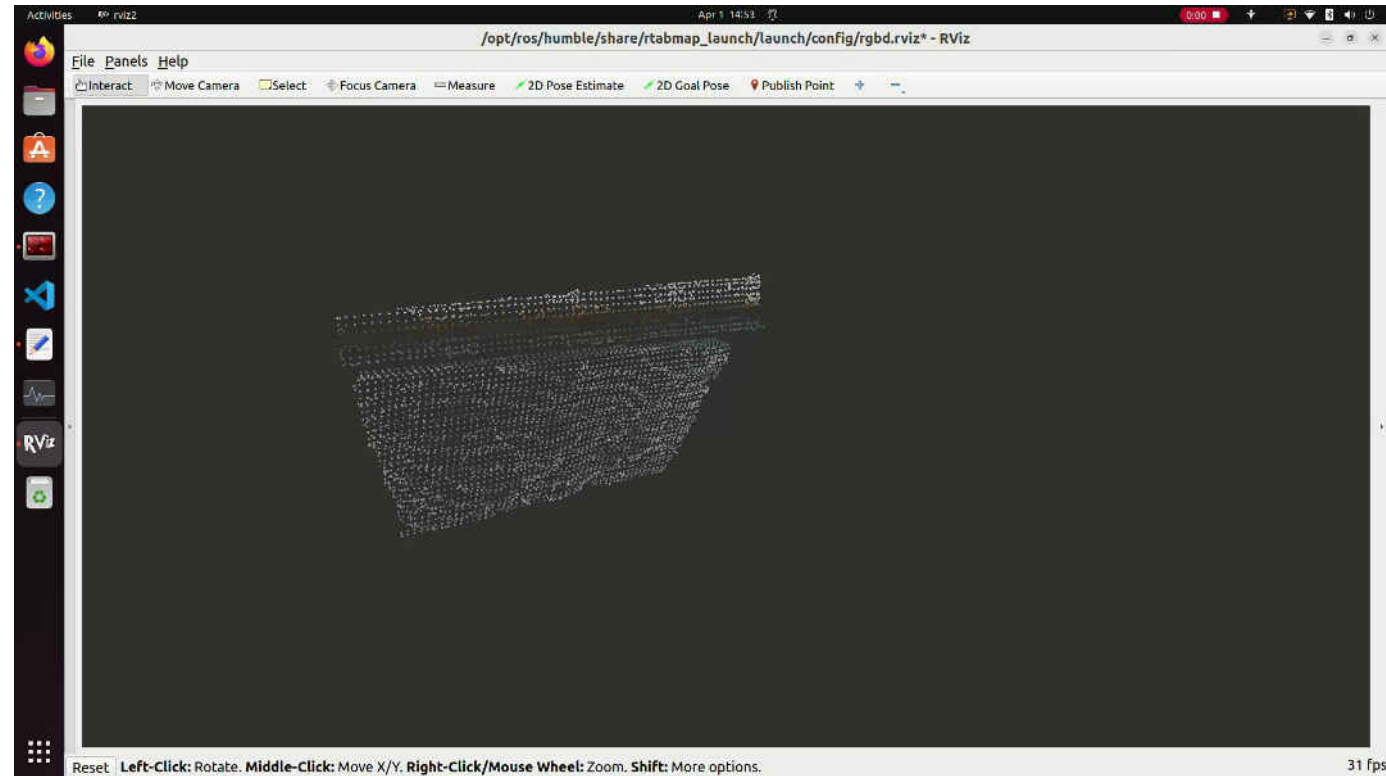
- Full exploration working indoors



Autonomous Exploration

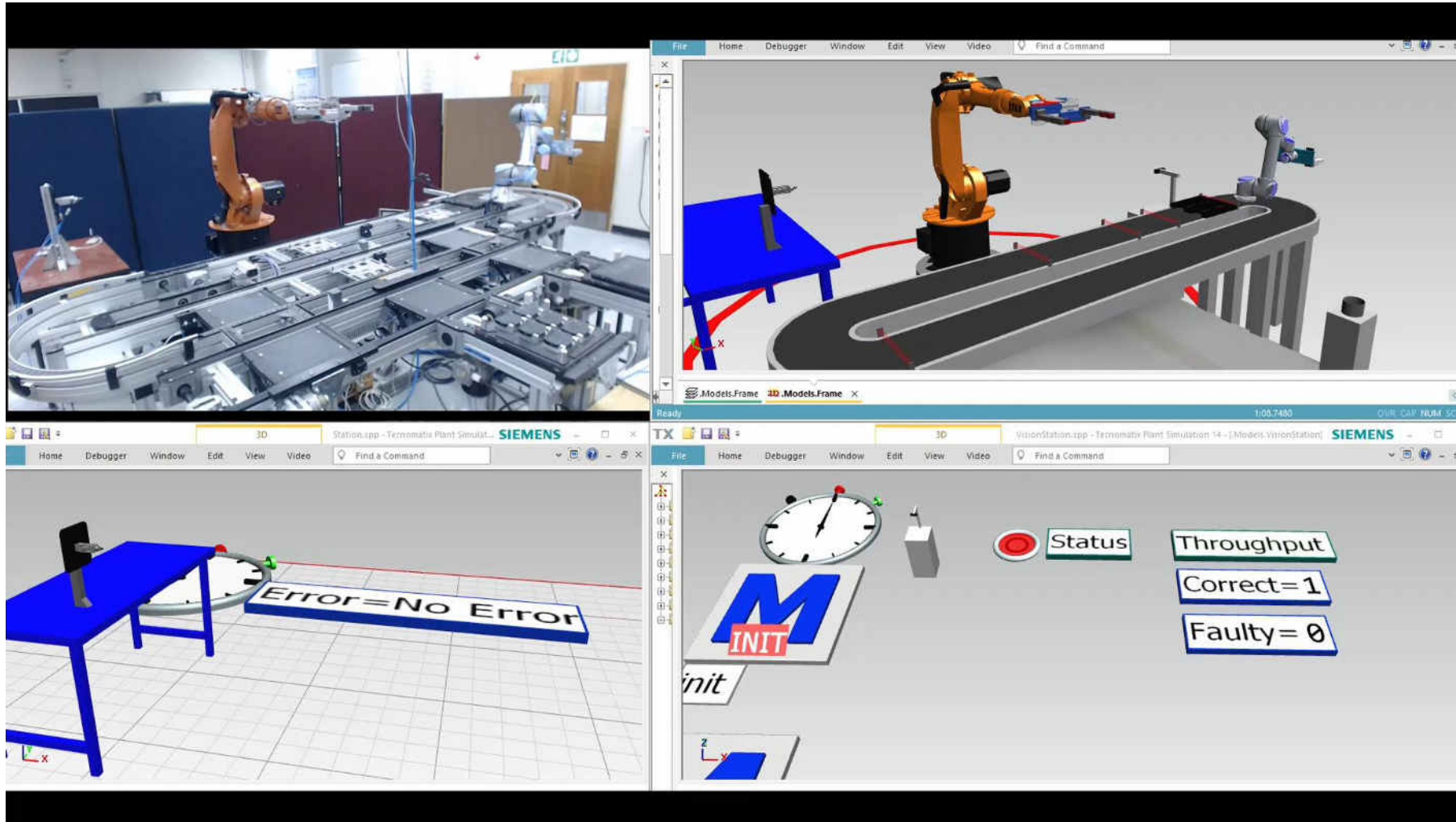


Stope mapping in real time



M&M Lab facilities for efficient mining

Robotic arm & conveyor belt

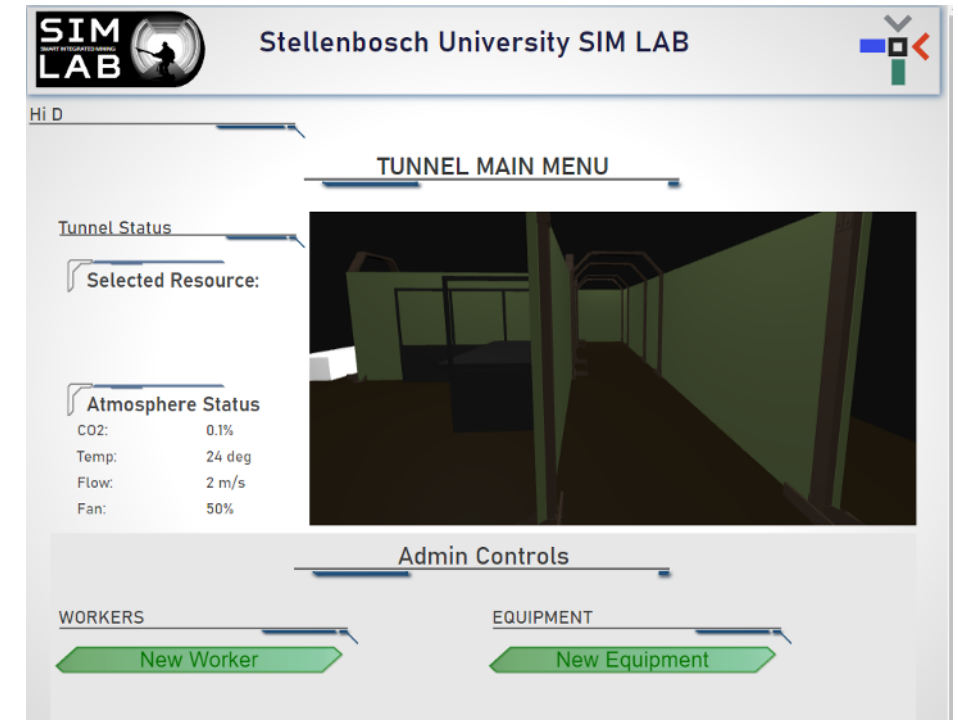


Digital Twins: Integrating Humans and Machines for Industry 4.0

Automation lab: robotic arms and the digital twin in operation.

M&M Lab facilities for efficient mining

Smart, integrated solutions for underground mining



Underground tune and its monitoring and control research platform

Smart, integrated solutions for underground mining

M&M Lab facilities for efficient mining

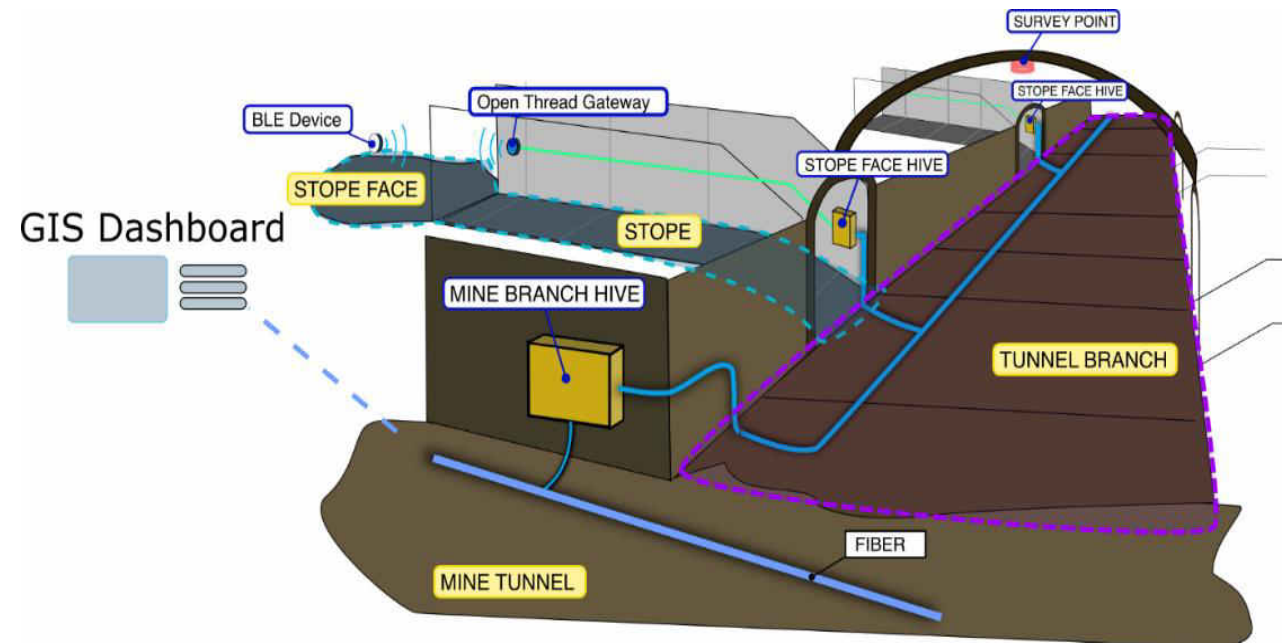
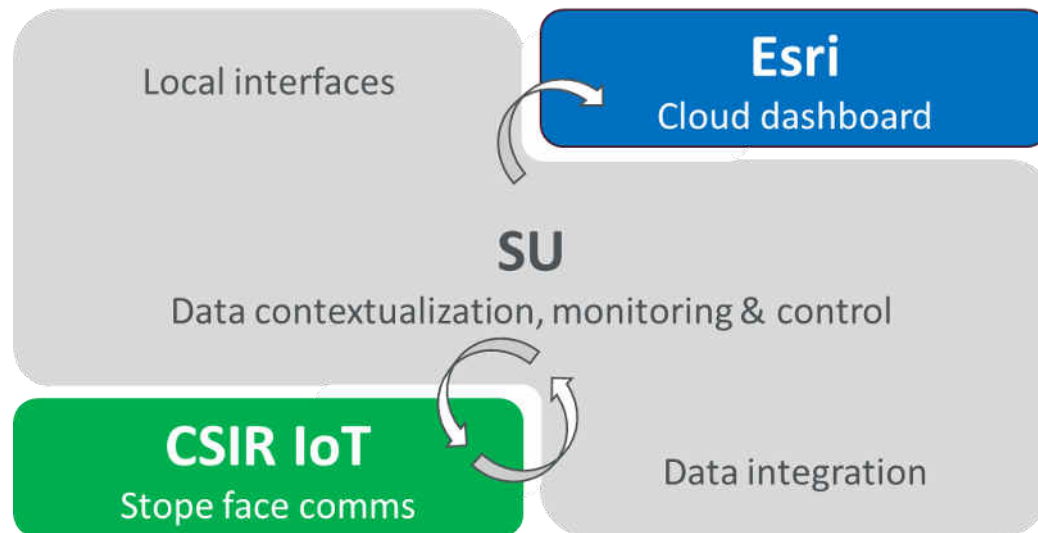
Smart, integrated solutions for underground mining



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- Research projects for the Mandela Mining Precinct “Real Time Information Management Systems” program
- SU, CSIR IoT, Esri & M3SH (Canada based) have complimentary skills and interests
- Collaboration supports development of a stope face to Cloud solution for monitoring and coordinating underground operations



M&M Lab facilities for efficient mining

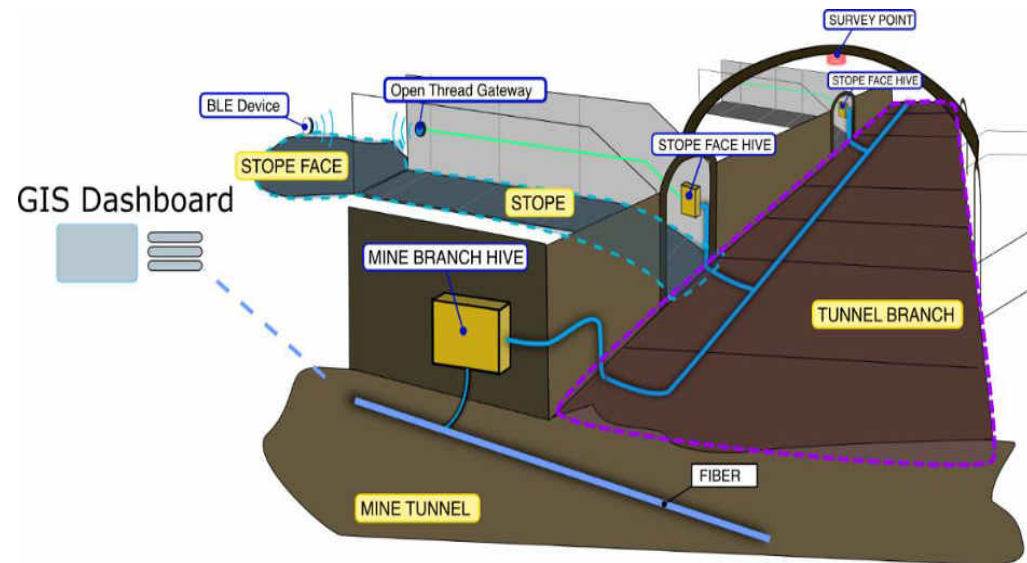
Smart, integrated solutions for underground mining

Support research and development of technology for:

- Smart, integrated mining
- Smart, connected, safe mineworkers

Industry needs:

- Replicate mine tunnel and stope
- Reconfigurable
- Vendor agnostic
- Safe



Demonstration use case

Monitoring and coordination of underground operations related to a Blasting Activity business process.

Supports:

- Visibility
- Traceability
- decision support

M&M Lab facilities for efficient mining: Gibela Engineering Research Chair

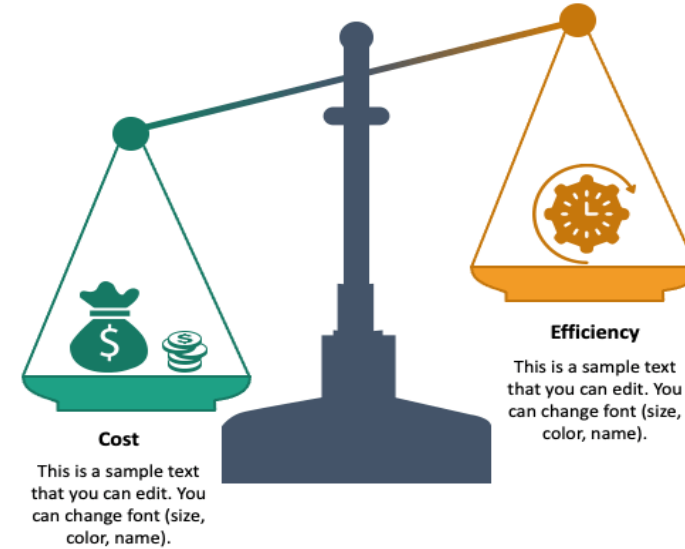


Process digitalization, optimization & control

Digital twin enabled decision support



**Process
digitalisation**



**Cost-
effectiveness**



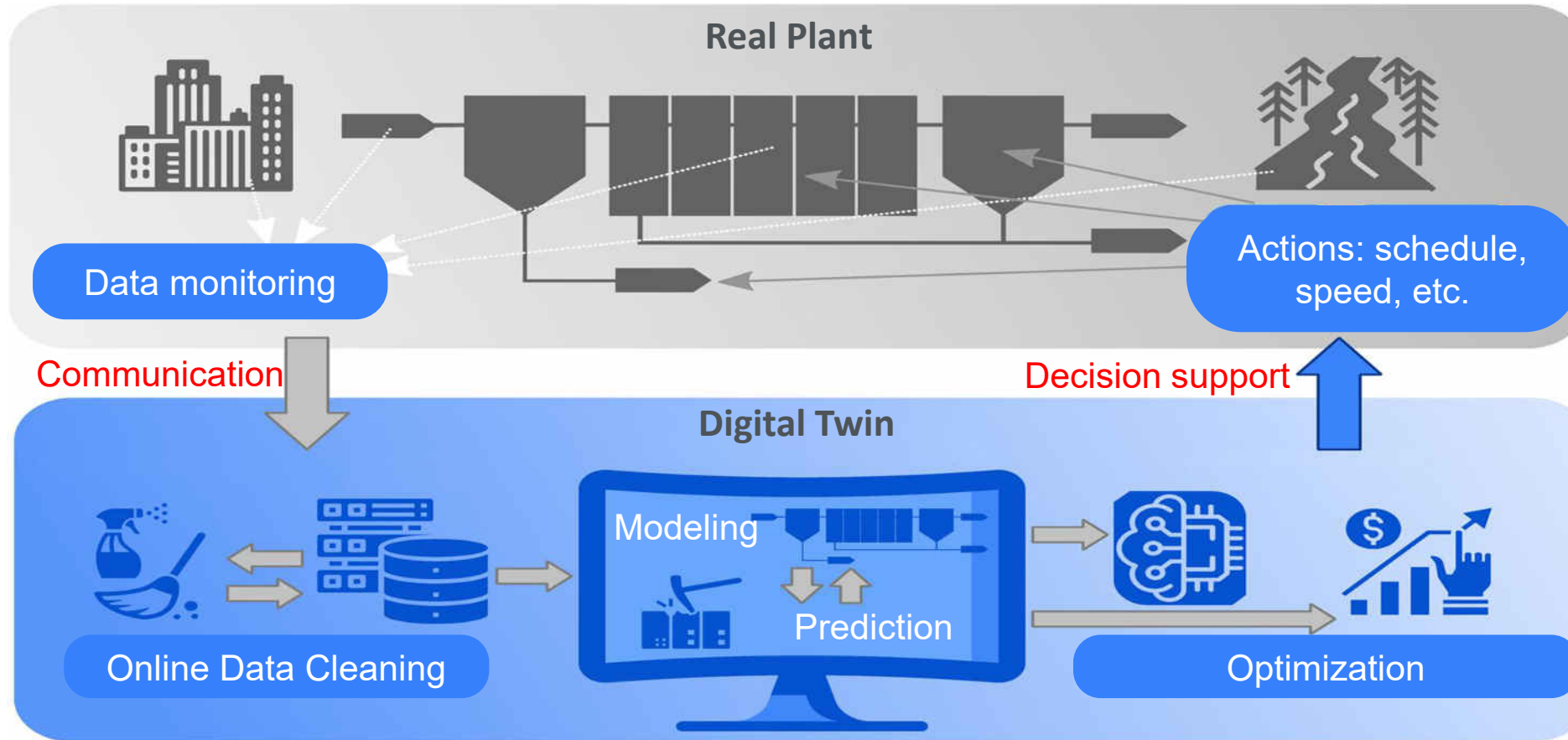
**Environmental
sustainability**



**Autonomous
operation**

Process digitalization, optimization & control

Digital twin enabled decision support



- Optimized O&M
- Less cost
- Less manpower

- Create a Virtual replica of the real plant
- Optimize the plant's operation

Process digitalization, optimization & control

Core functions

Data

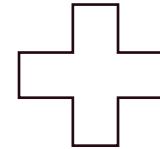
Process

Cleansing

- AD
- Imputation

Analytics

- Time series forecasting
- Alarming
- ML-based process modelling



Modelling

- Mechanistic
- Optimisation & Control**
- MPC, RL

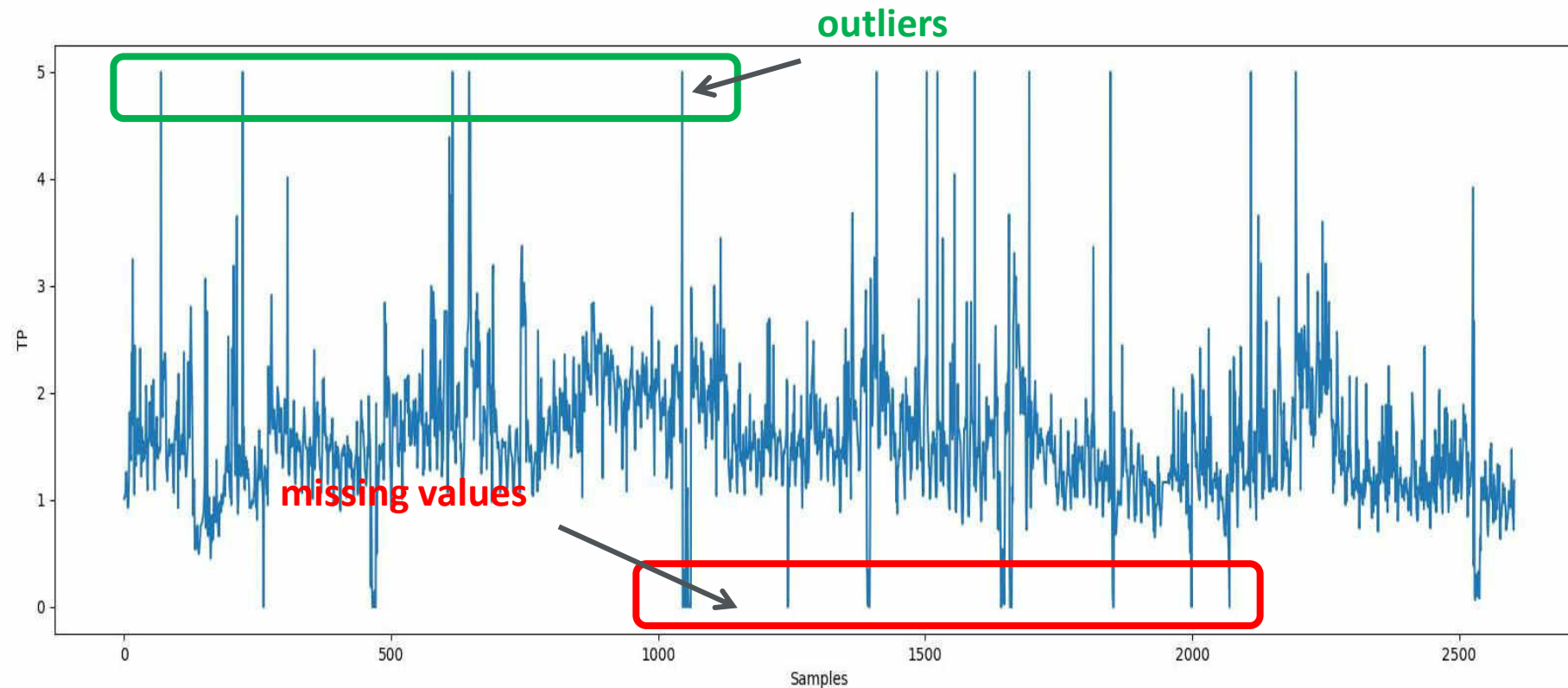
Visualization

- 3D BIM plant model and data monitoring
- Data visualisation

Digital + Intelligent

- Data analytics
- Decision support
- Real-time control

Sensor data cleansing



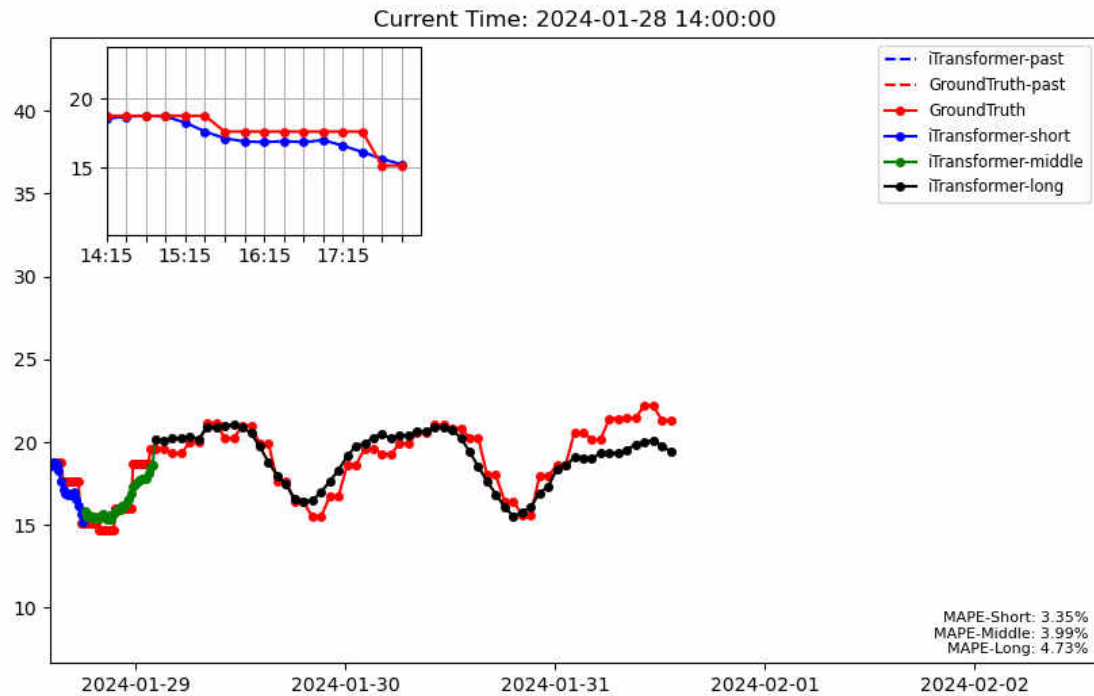
Performance Indicators:

- False negative rate $\leq 2\%$,
- false alarm rate $\leq 6\%$,
- detection delay $\leq 5s$,
- accuracy $\geq 90\%$, and
- F1-Score $\geq 90\%$.

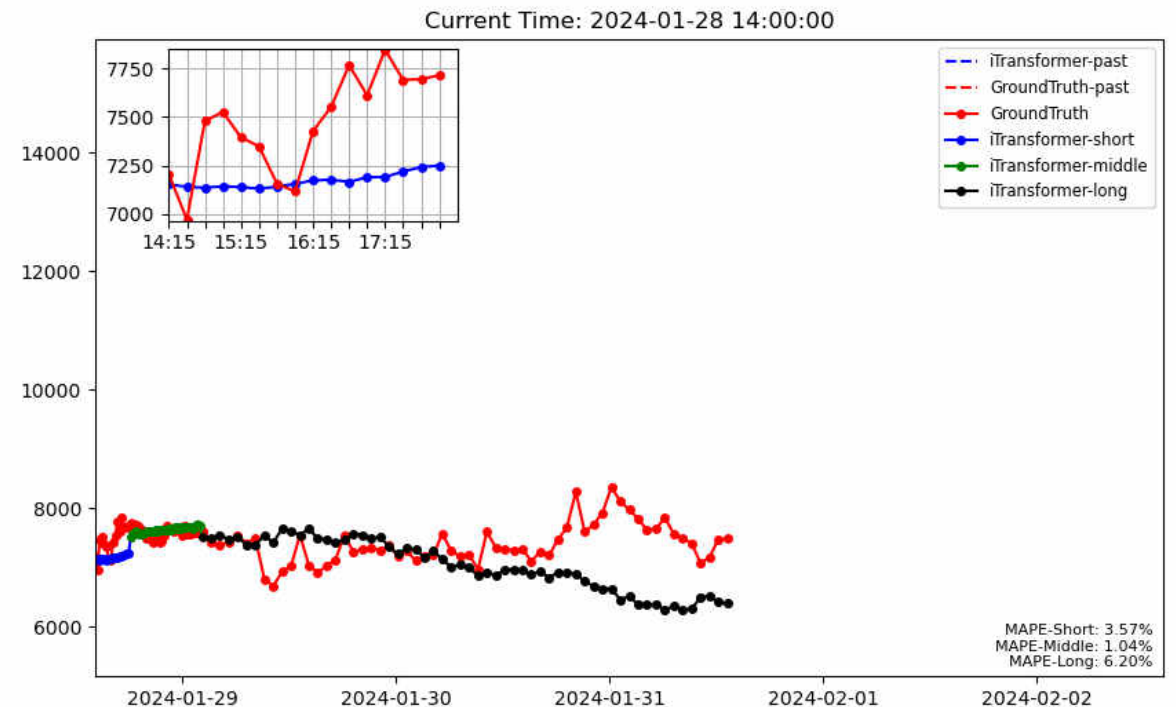
Process digitalization, optimization & control

Core functions

Long-, medium- and short-term time series data forecasting



Influent total nitrogen forecasting



Influent flow rate forecasting

Operation optimization and control

01 Sensitivity analysis

Operating conditions clustering
Parameter sensitivity analysis

02 Parallel computing

Parallelize the process model
Parallelize the optimization algorithm

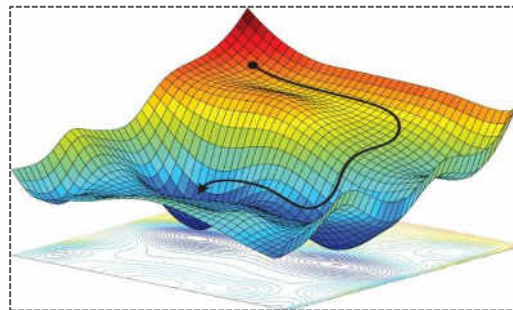
04 Model predictive control

MPC for constraint-compliant
proactive control
Combination with reinforcement
learning for real-time application

Support features

03 In-house optimization algorithm

Swarm intelligence based meta-
heuristic optimization algorithm
tailored for applications



Process digitalization, optimization & control

Real-world application

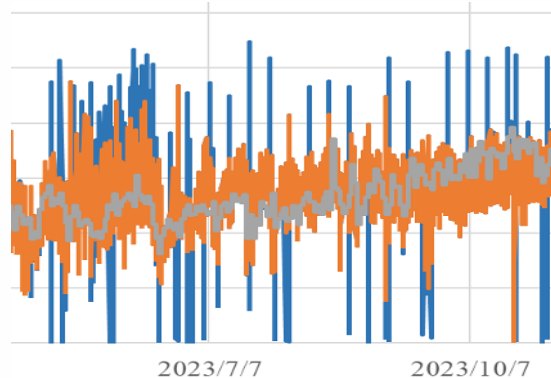
The architecture

Operation optimization & control

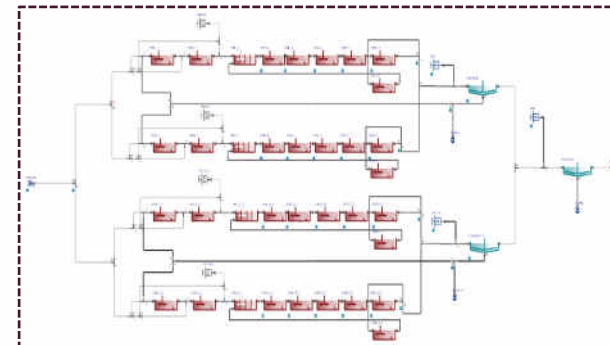
3D interface: one-to-one mapping



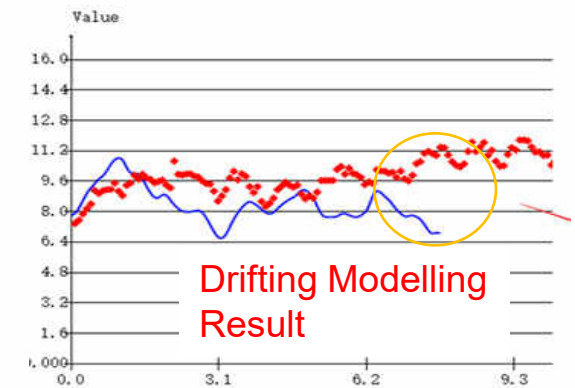
Sensor data imputation



First principle process models using ASM



ML based model calibration

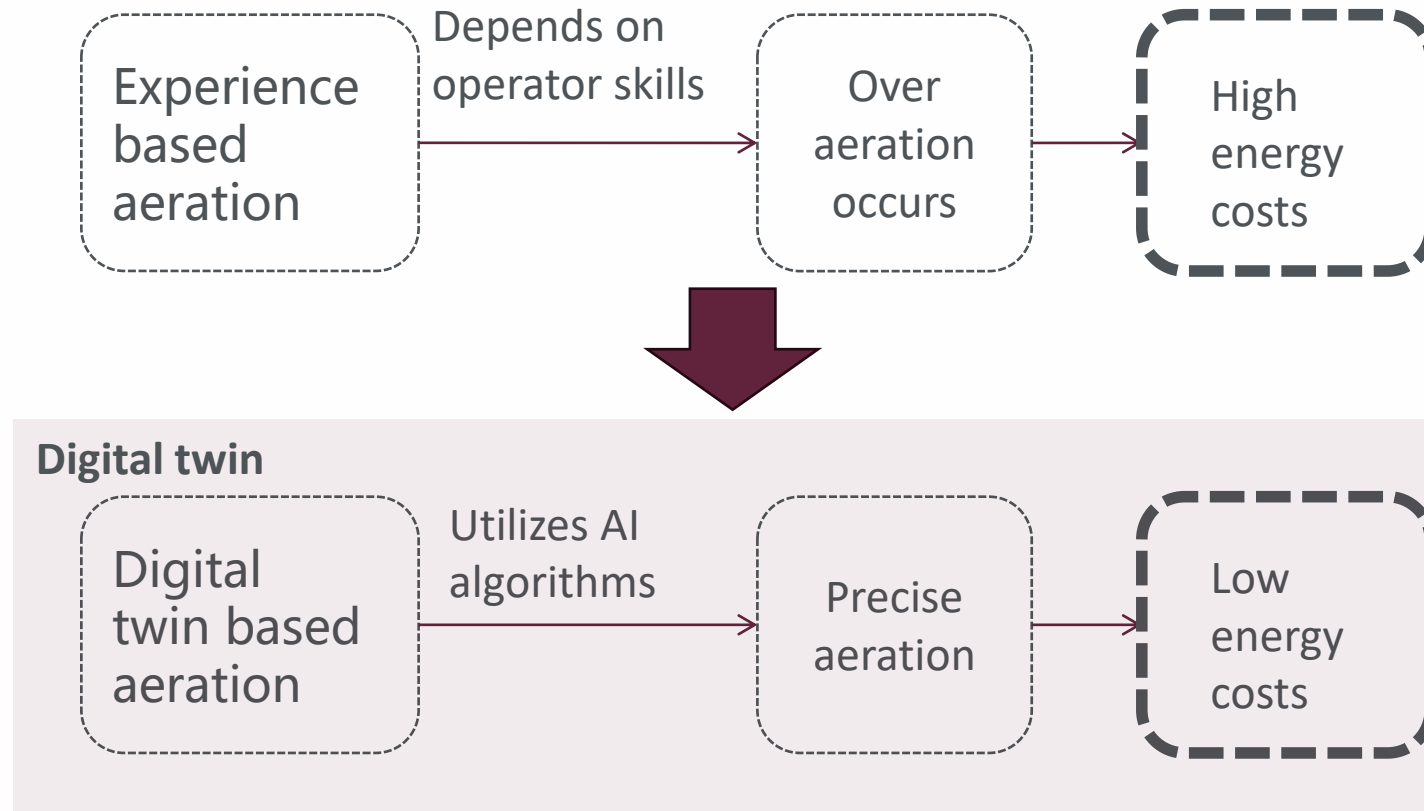


Process digitalization, optimization & control

Real-world application

Wastewater treatment plant aeration optimization for energy/cost savings

Aeration Optimization



- Decision support
- Supervised operation
- 10-40% energy savings

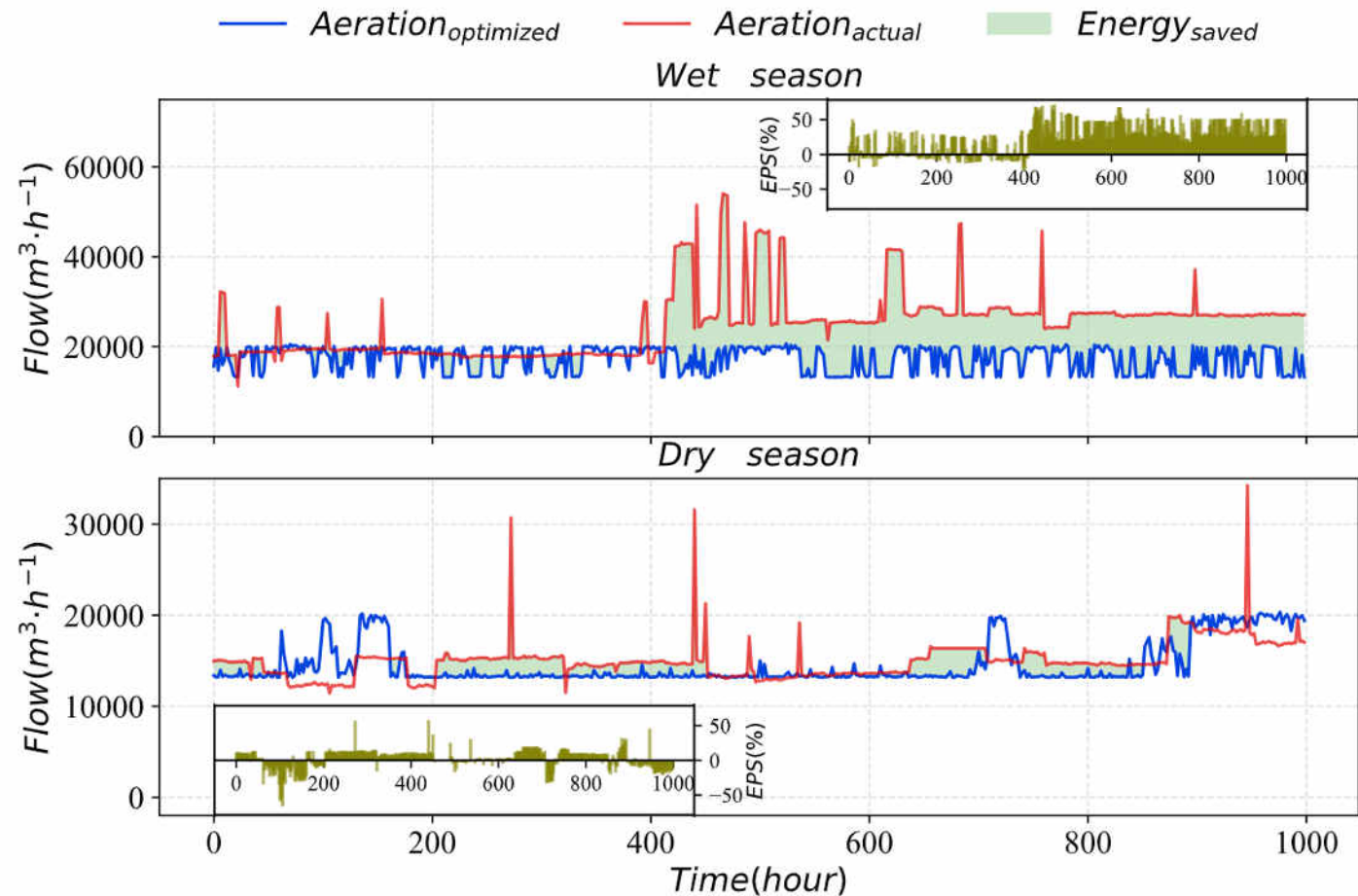
Process digitalization, optimization & control

Real-world application

Illustrative example of energy savings achieved through AI aeration optimization.

Dynamic Operational Parameter Optimization

- Optimize operational parameters based on equipment settings, real-time data, and process models.
- Reduce aeration and chemical dosing while ensuring effluent quality
- Achieve energy savings, cost savings, and emission reductions.





Digital Twin for Shek Wu Hui

STW

User login

User

admin123

Password

.....

Login

Quit

Process digitalization, optimization & control

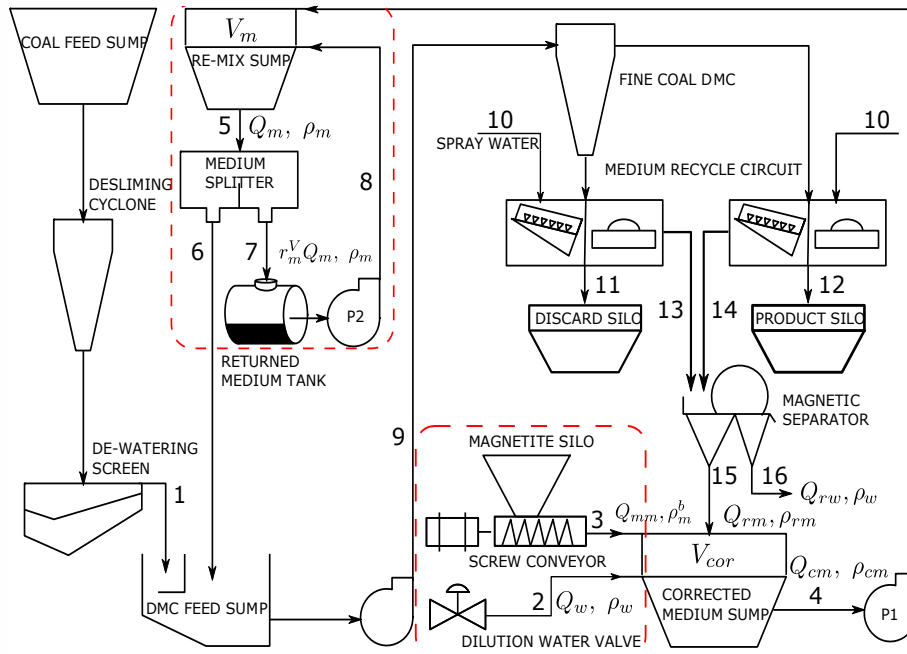
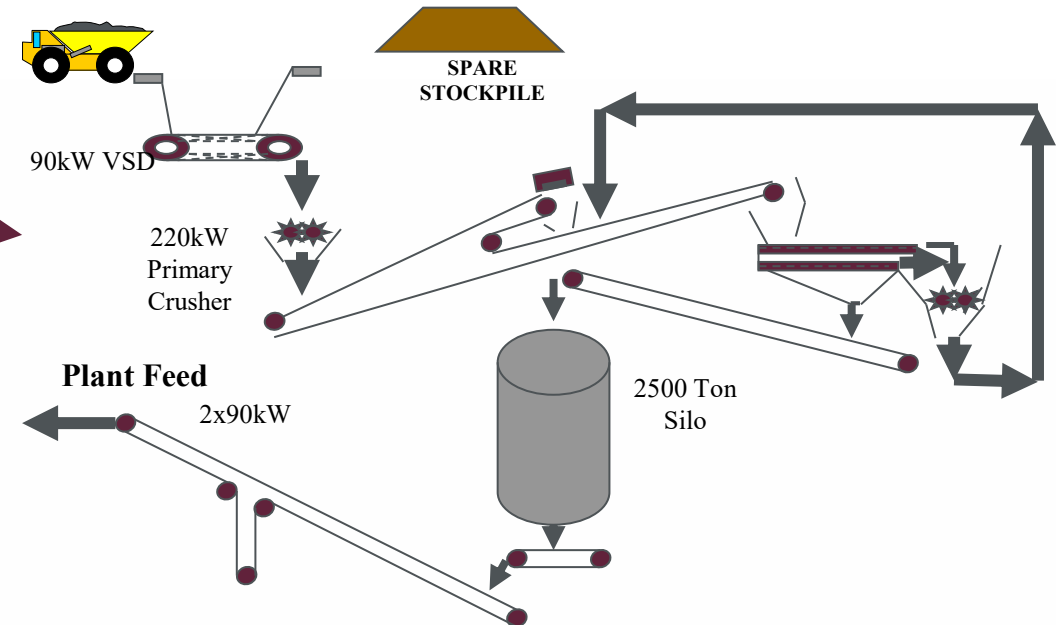
Other applications



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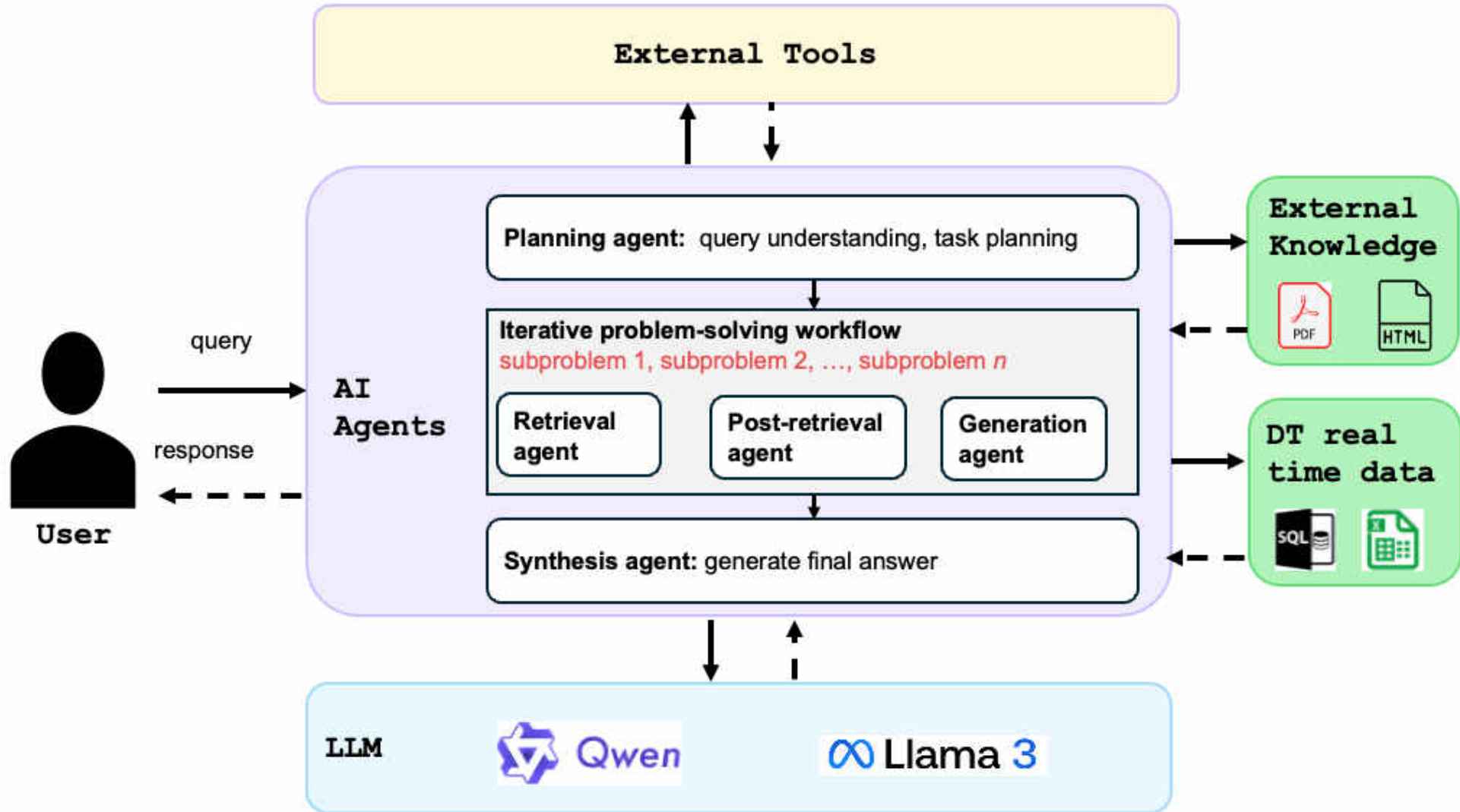
- Conveyor belts
- Pumping systems
- Crushers



- Rock winders
- Coal washing cyclones
- Ventilation systems
- Heavy haul trains

Process digitalization, optimization & control

Integration with large language models



Process digitalization, optimization & control

Integration with large language models

Source document display

New chat

how to determine the ...

how to determine the flooding load and size and select suitable pump accordingly?

To determine the flooding load and size a pumping station and select suitable pumps accordingly, follow these guidelines:

- Determine Design Capacity:**
 - The design capacity for all duty pumps should handle rainstorm runoffs collected inside the polder with a return period of 10 years.
 - Stand-by pumps must be available to take over failed duty pumps automatically.
 - Both duty and stand-by pumps should be interchangeable.
- Consider Pumping Requirements:**
 - The desirable design freeboard for floodwater storage facilities is 300 mm for a storm with a 10-year return period.
 - Formulate combinations of stand-by and duty pumps to maintain the station's design capacity even during maintenance or mechanical failure.
 - Ensure that the total maximum pumping capacity (duty plus stand-by) can accommodate a storm with a 50-year return period.
- Select Pump Type:**
 - Archimedian screw pump is suitable for large pumping rates at low head, robust and efficient but massive, noisy, and visually intrusive.
 - Centrifugal pumps are prone to damage due to clogging but are best for high pumping heads; design carefully to avoid hydraulic problems.
- Number of Pumps:**

LLM ☒ RAG

Send

Clear

Exit

Settings

87

vehicular access to the pond shall be provided to enable mechanised maintenance at regular interval.

(c) Floodwater Storage Tank

A floodwater storage tank is usually an enclosed underground chamber and differs distinctly from a pond. Adequate ventilation and other necessary provisions for enclosed area should be considered. Openings, accesses and heavy duty lifting appliances should be provided to enable future maintenance. Cat-ladder shall be provided at the side of the access manhole. In addition, the floodwater storage tank shall be regularly drained to avoid any water/contaminants detained inside from becoming septic.

14.6 FLOODWATER PUMPING STATION

14.6.1 General Requirements

Floodwater pumping stations should be designed to operate automatically with appropriate type of pumps which are controlled by water level sensors installed in the pump sump. Accumulated stormwater from the flood storage facilities is pumped to the nearest main drainage channel outside the polder.

A good appearance is one of the functional requirements of pumping stations. This is particularly important for pumping stations located in urban areas and exposed to public views. For those in village areas, local residents should be consulted as far as possible. To enhance the appearance of pumping stations, external finishes are usually provided for superstructure above ground. The construction cost for finishes together with the future maintenance cost should be taken into account in selecting the type of finishes to be used. To save cost, fair concrete finishes may be considered for internal walls of unmanned pumping station. However, the floor of pumping station should be painted with anti-skidding coats. Architectural Services Department should be consulted for their advice on the aesthetic design of pumping stations.

14.6.2 Design Capacity

The design capacity for all duty pumps should be adequate to handle rainstorm runoffs collected inside the polder with a return period of 10 years. Stand-by pumps must be available and should be able to automatically take over the failed duty pumps. Both duty pumps and stand-by pumps should be interchangeable. The standby pumps should be so designed such that they can also be activated in case of exceptionally severe rainstorms.

In the determination of the pumping requirements, the following guidelines should be followed:

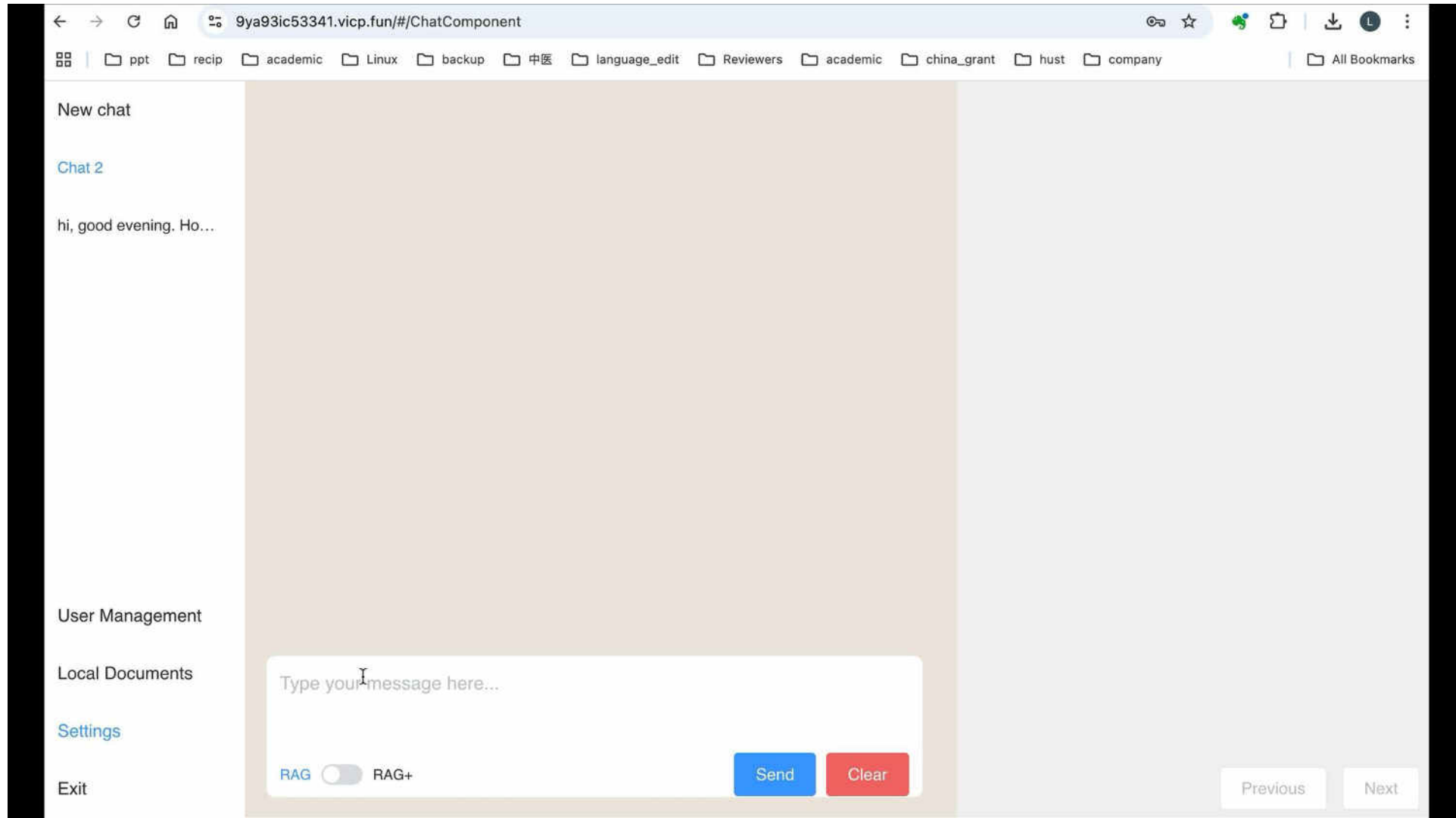
- The desirable design freeboard for floodwater storage facilities should be 300 mm for a storm with a 10-year return period.
- Combinations of stand-by pumps and duty pumps can be formulated for an individual village flood protection scheme so that should any of the duty pumps in the station be inoperable due to routine maintenance or mechanical

12345

PreviousNext

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Thank you
Enkosi
Dankie



Photo by Stefan Els

Any Questions?



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