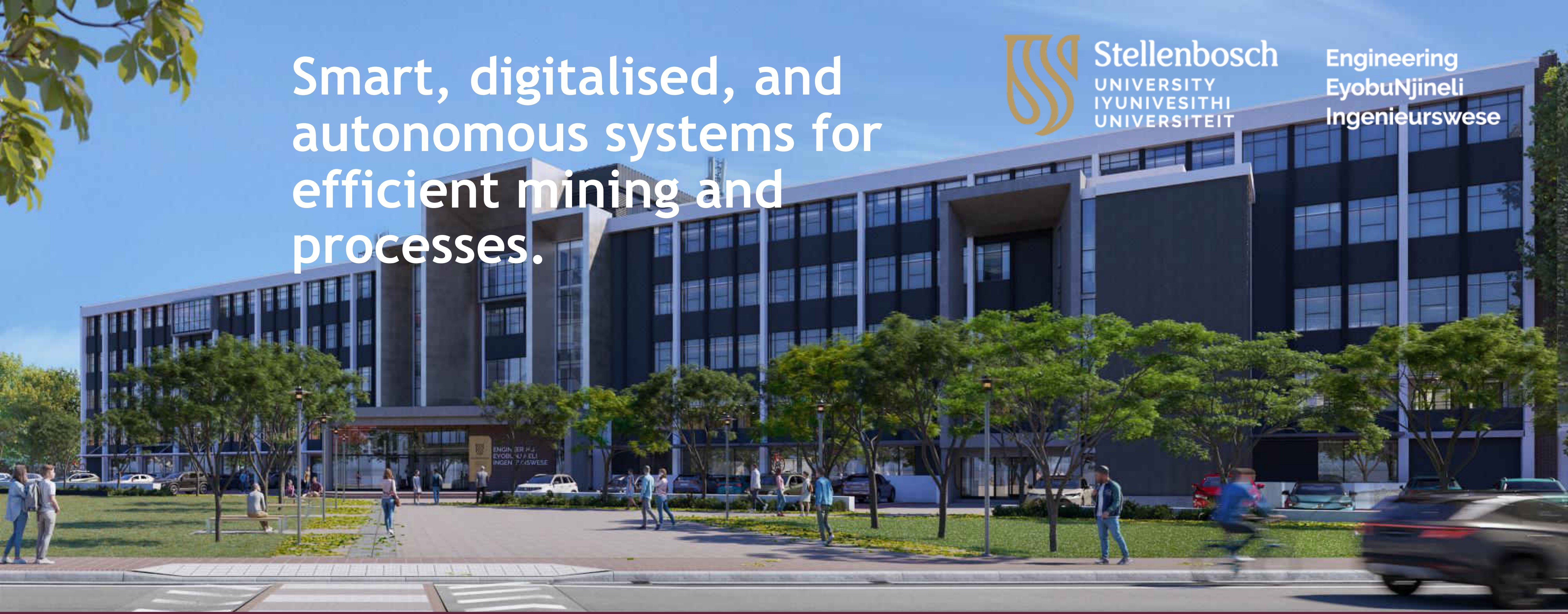

Smart, digitalised, and autonomous systems for efficient mining and processes.

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Engineering
EyobuNjineli
Ingenieurswese

Dr Callen Fisher and Prof Lijun Zhang ~ Mining

Faculty of Engineering

Industry Showcase 2025

Satellite Engineering Ecosystem

ESL
Electronic Systems Laboratory

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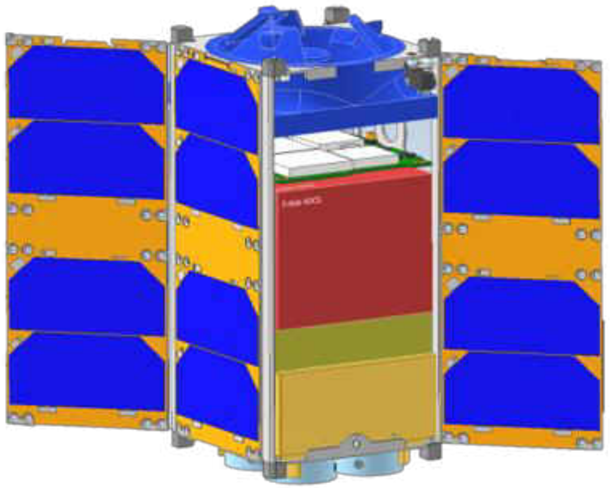
- SunSat (ZASAT-001, SO-35)
  - Africa's first satellite
  - 60kg LEO EO micro-sat, launched 1999, Vanderberg AFB

- SumbandilaSat (ZASAT-002, SO-67)
  - 81kg LEO EO micro-sat, launched 2009, Baikonur Cosmodrome



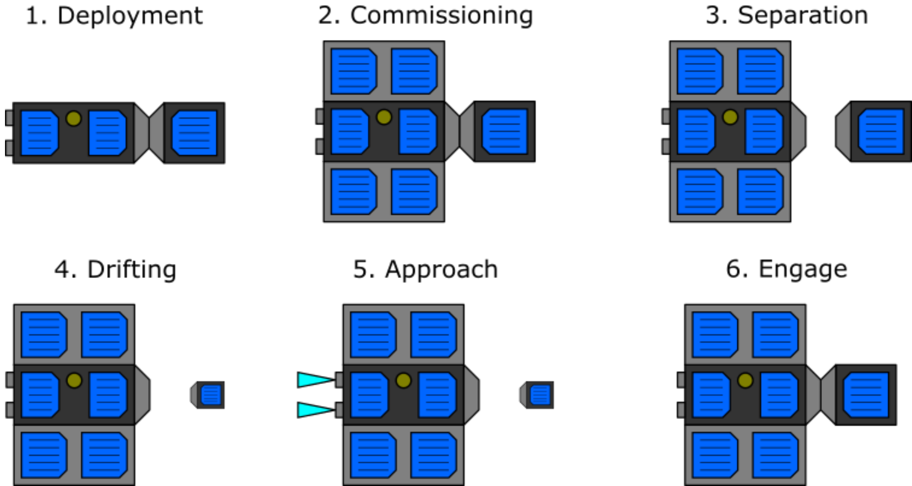
Short Courses
- Introduction to Satellite Mission Design
- Kalman Filters and Sensor Fusion - Q1 2023
- CanSat Leadership Program - Q4 2023
- Practical System Engineering - TBD

Facilities
- Stellenbosch Ground Station
- Air bearing facility
- Radiation testing (at iThemba Labs and ARC)

SU Satellite Engineering Training

Satellite Program
- DockSat
- Multi-Spectral + IOT Satellite
- ZAPocketQube

Research
- Masters and PhDs
- Command and Data Handling
- ADCS and Robust Embedded Systems



Unmanned Aerial Vehicles

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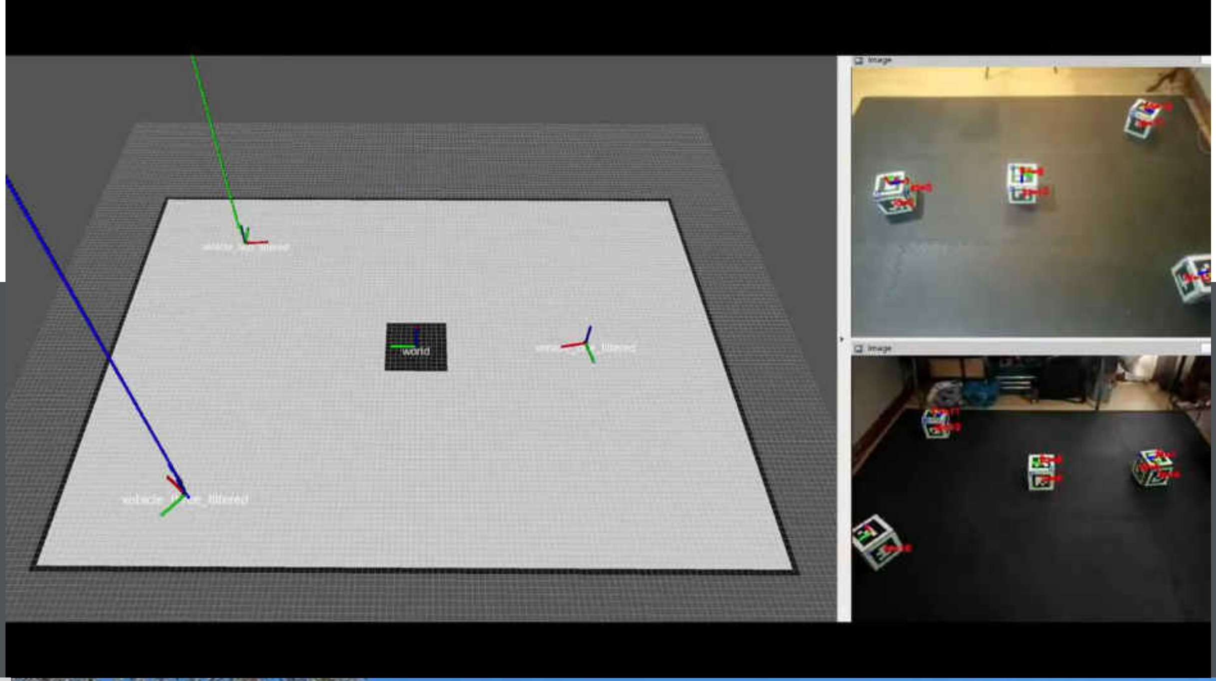
Damage-Tolerant Flight Control

- Robust flight control for partial wing loss

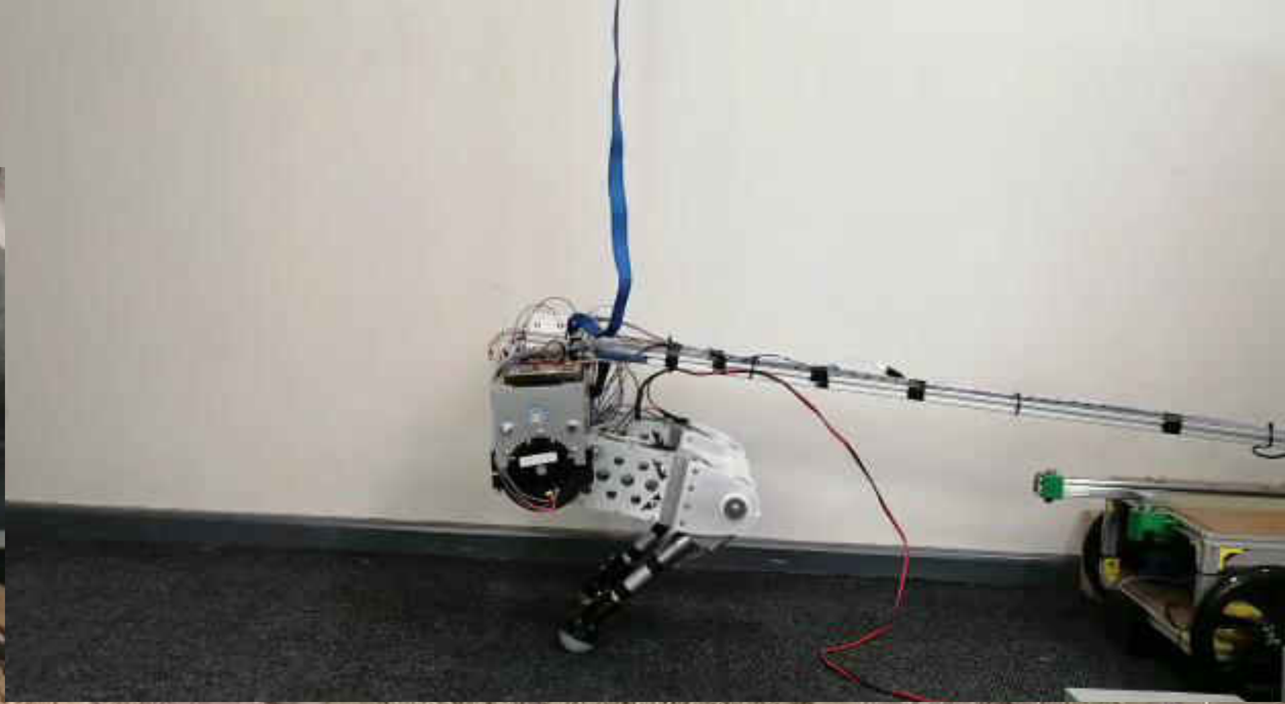
Drones with Cable-Suspended Loads

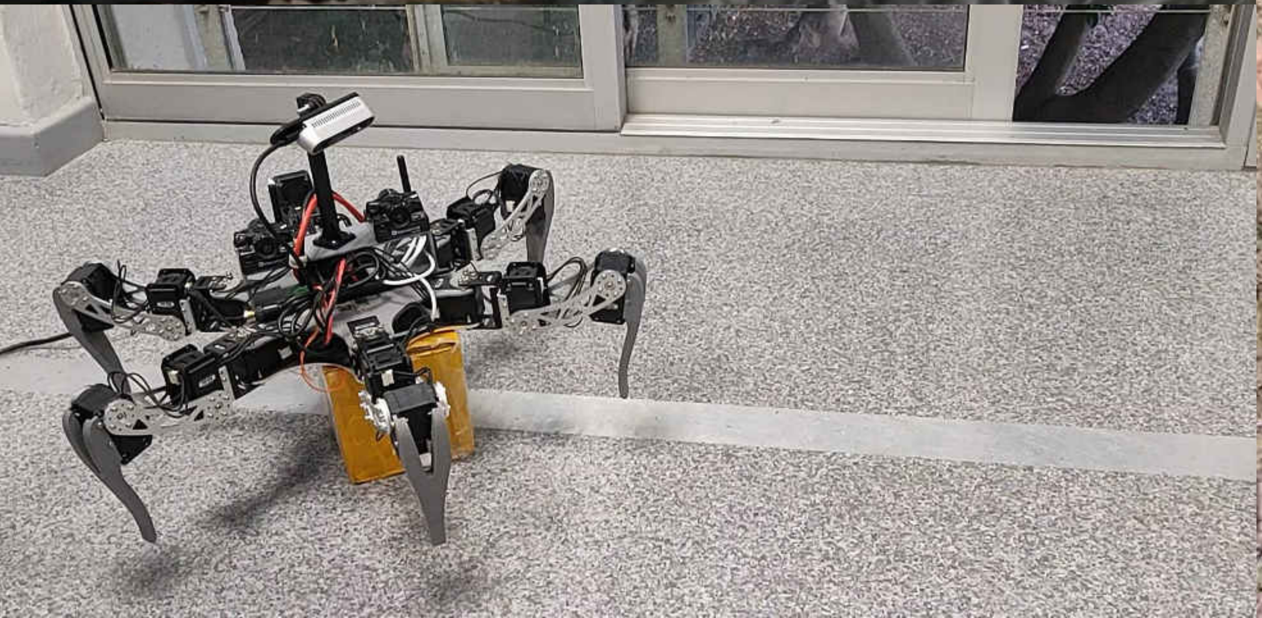
- Robust / adaptive control to accommodate variable cable length and cargo mass

Autonomous Ground Vehicles



Legged Robots





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Autonomous inspection rover for subterranean environments

Photo by Stefan Els

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

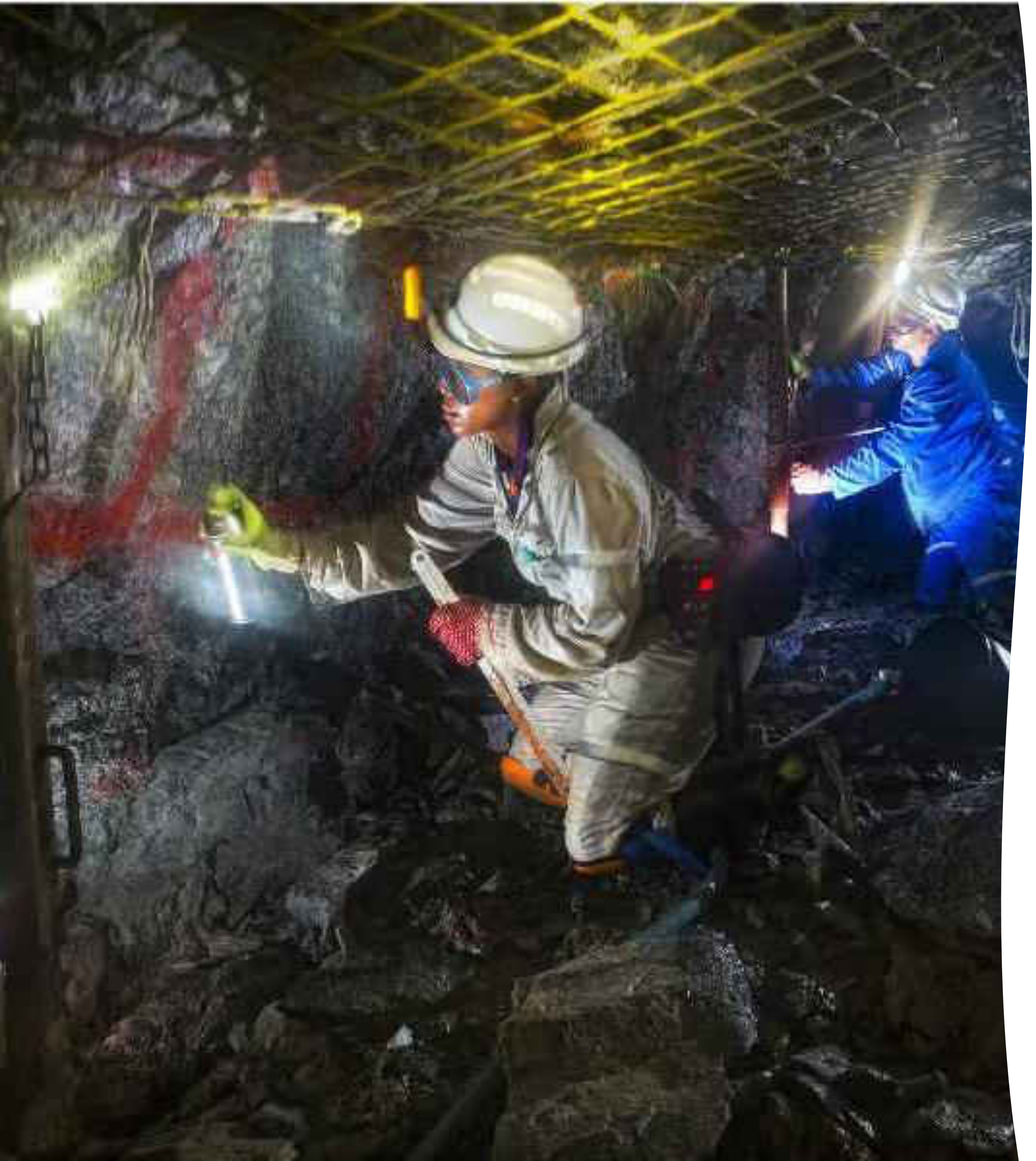
- Previous work focus:
  - Demand side management
  - Process controls
  - Industry digitalisation
- Collaborated with Exxaro Resources on mining energy efficiency projects.
- **Long-term goal:** Establish a well-known mining research center in Africa and the world with high-impact publications, tangible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

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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

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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

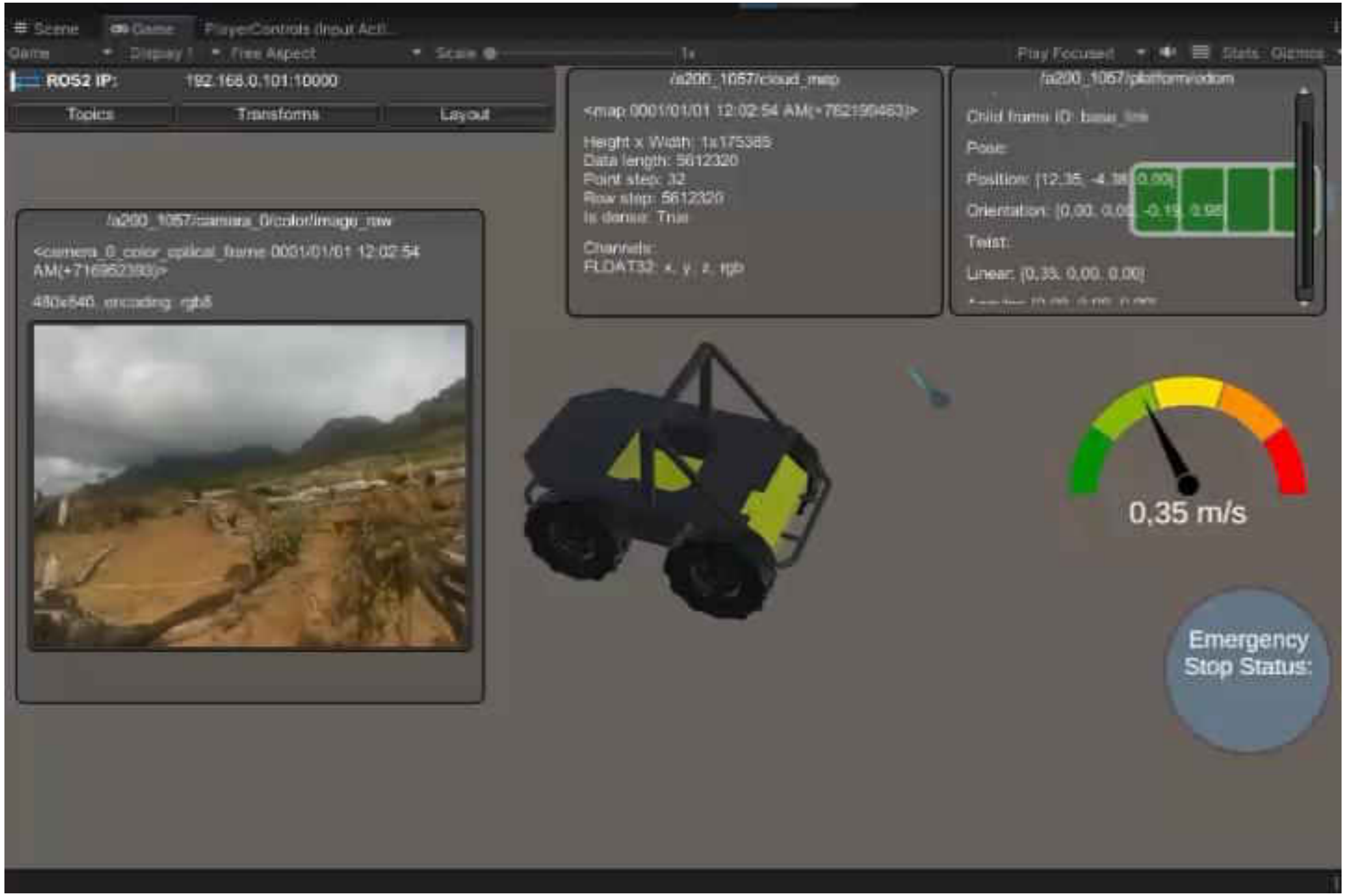
- Stope mapping
- Terrain classification

Transmit this information to a “base station”

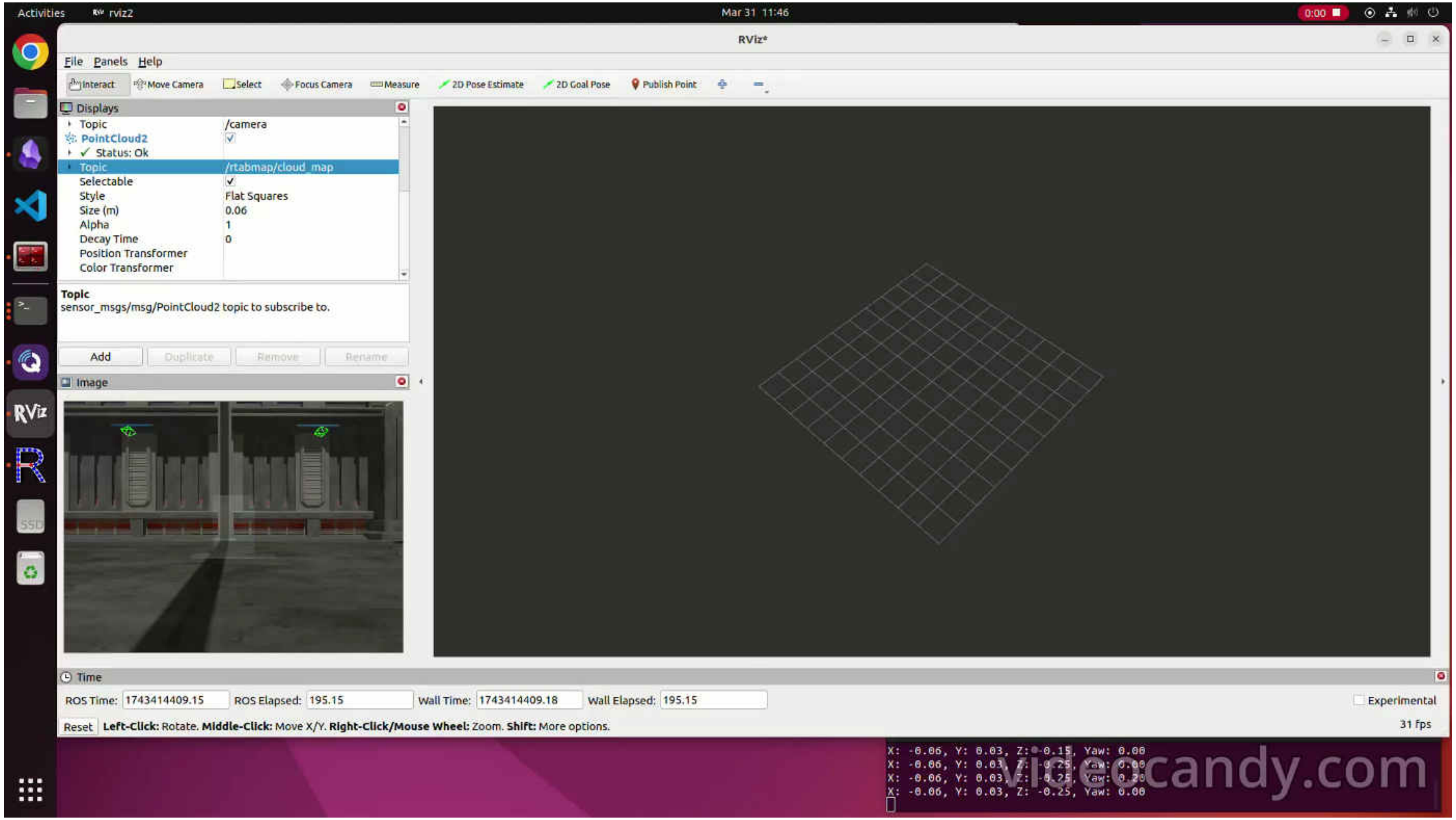
- Deploy a mesh network
- Feed into the mines fibre network
- Handle conductive ore bodies

Digital twin and user interface

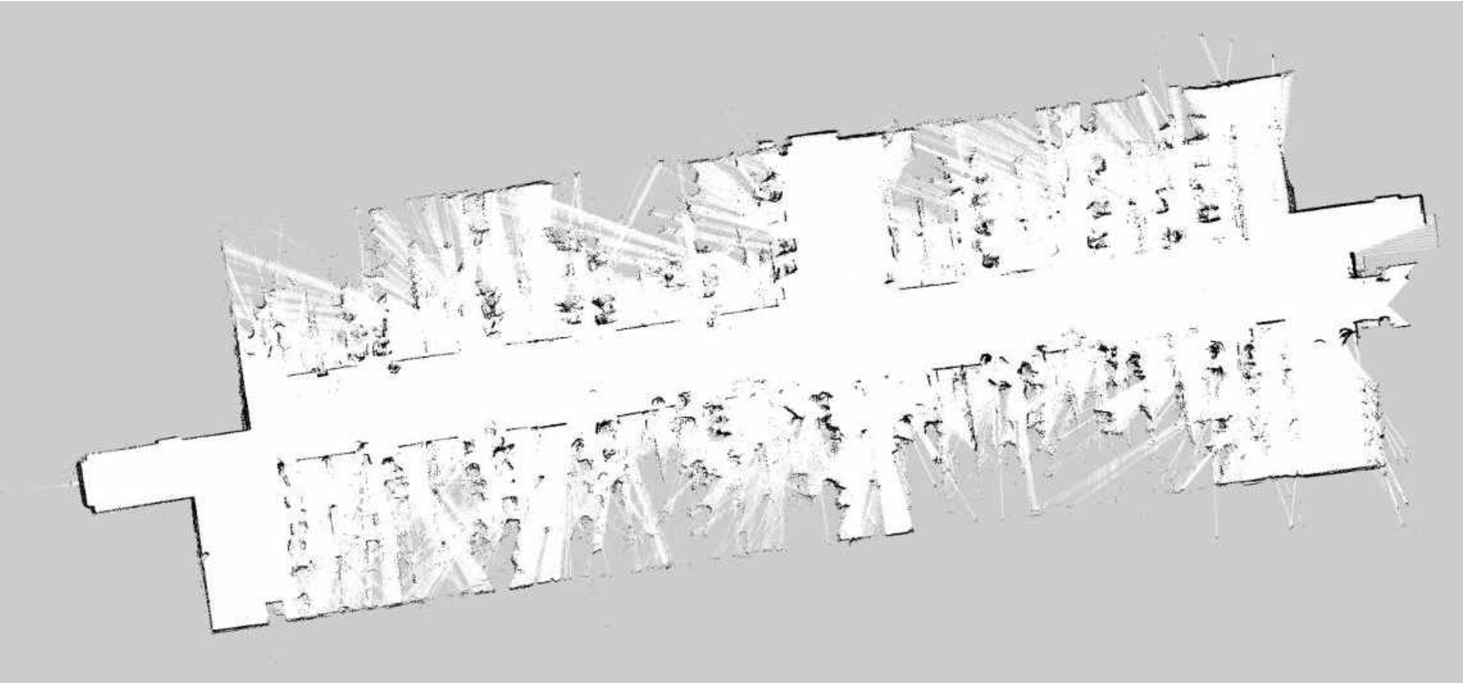
- Headless mode
- Enables:
    - Command line
    - Tele-op
    - Replaying saved data

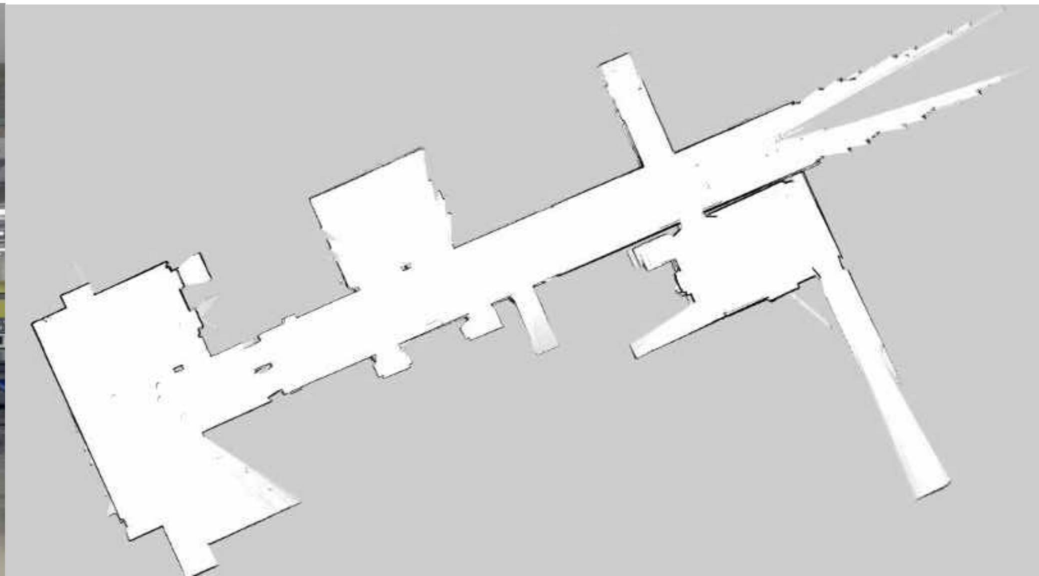


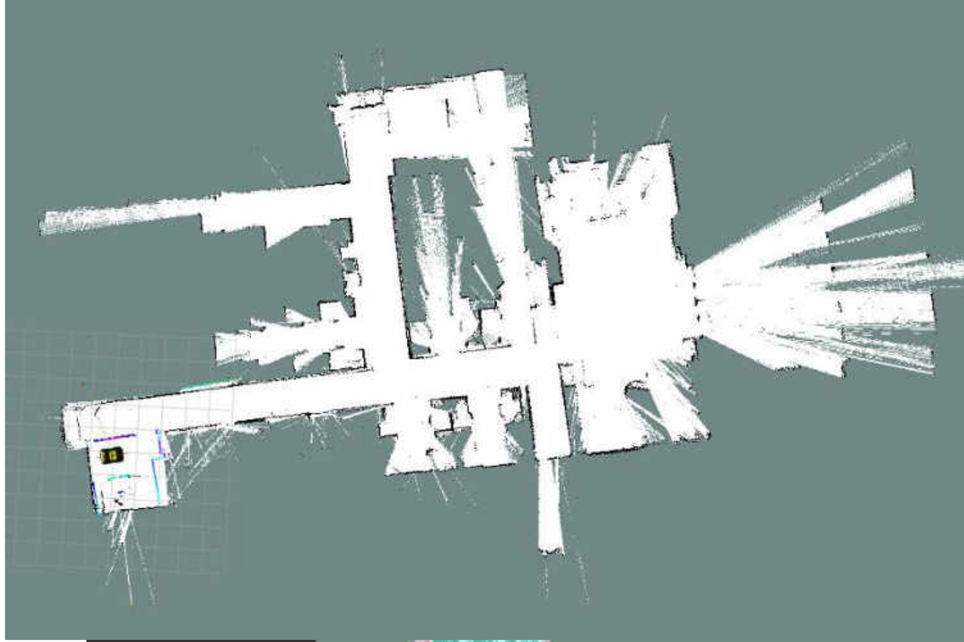
Full underground simulation with Drone and Husky robot

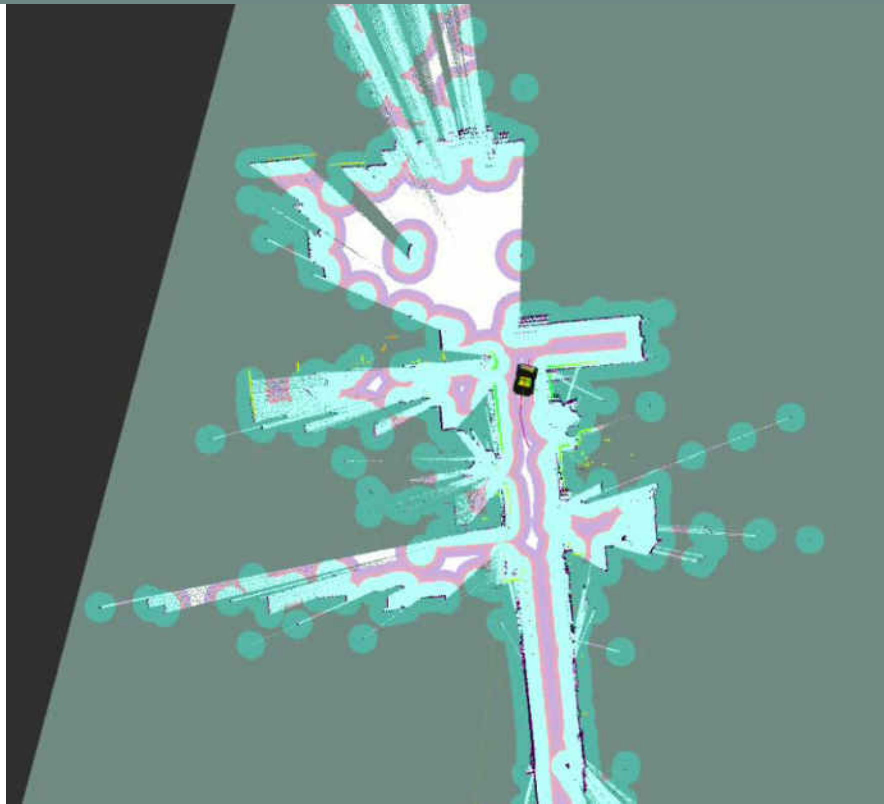


Mapping



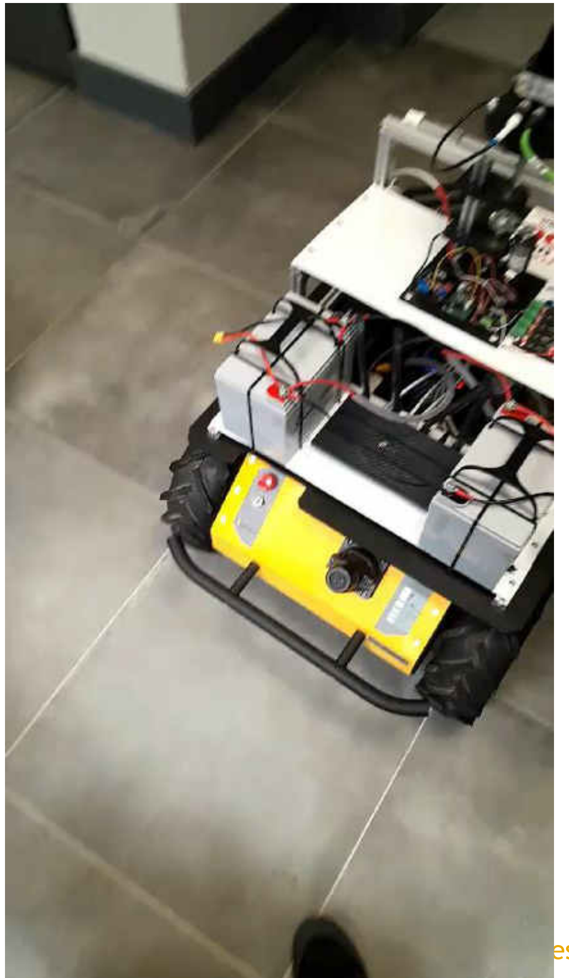


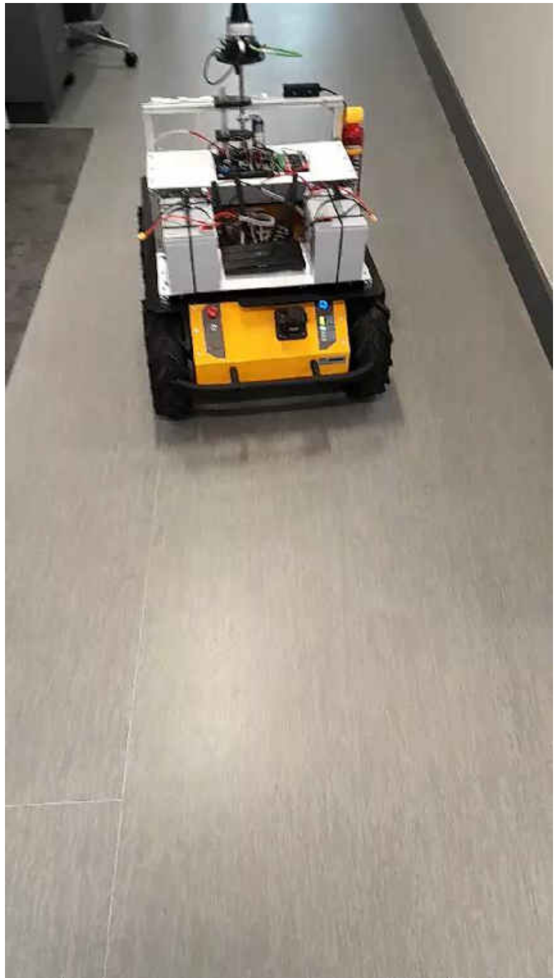


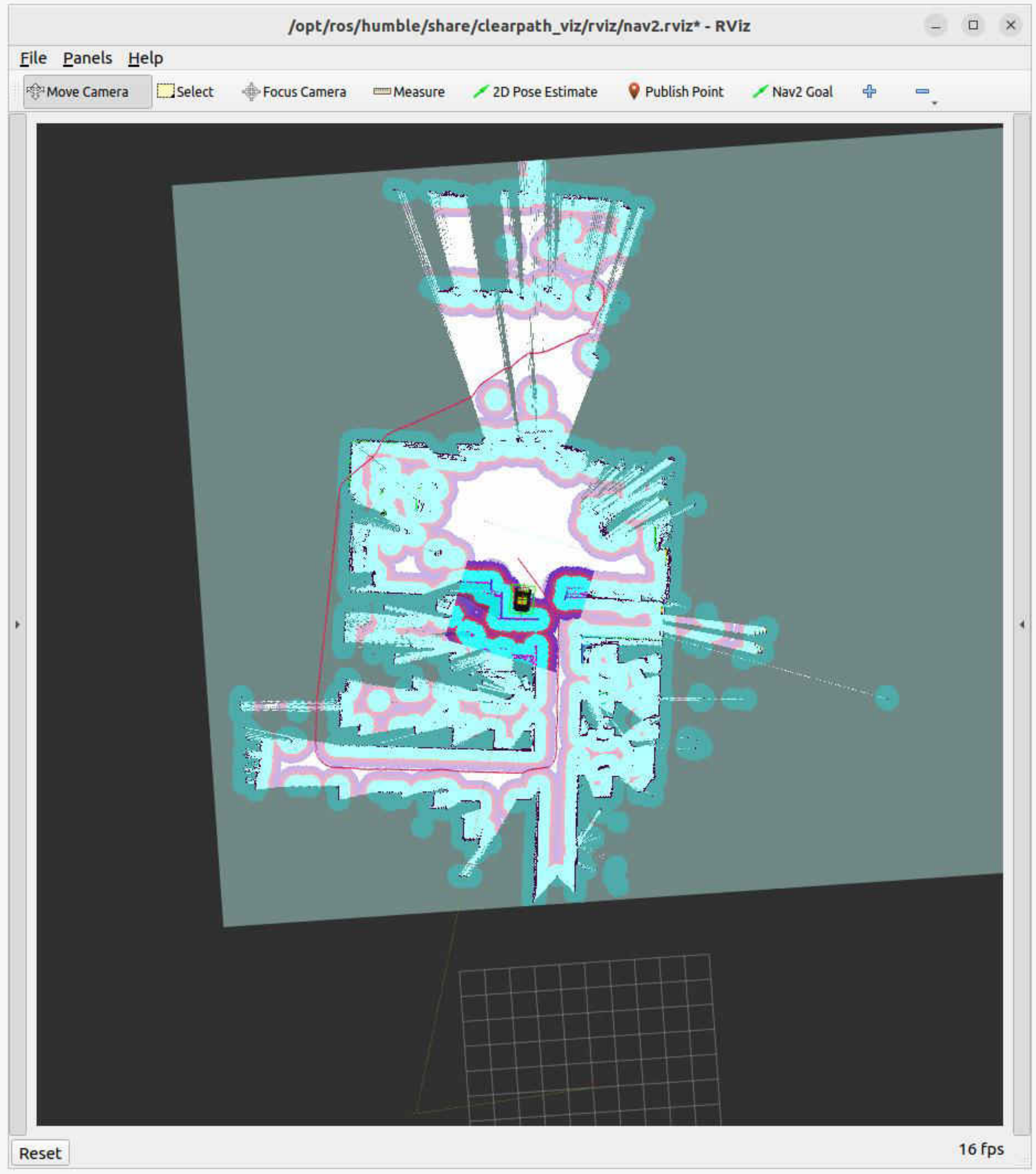


Autonomous Navigation

- Full exploration working indoors







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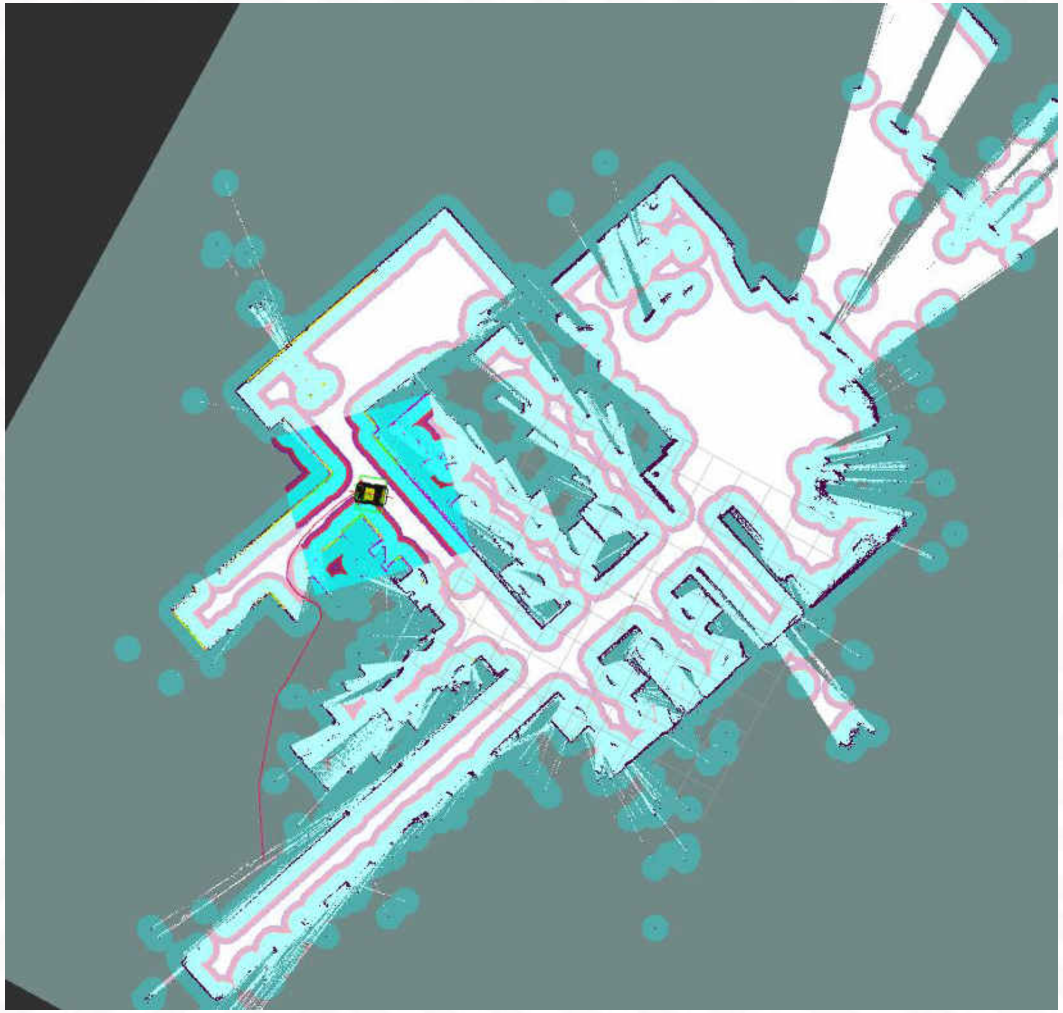
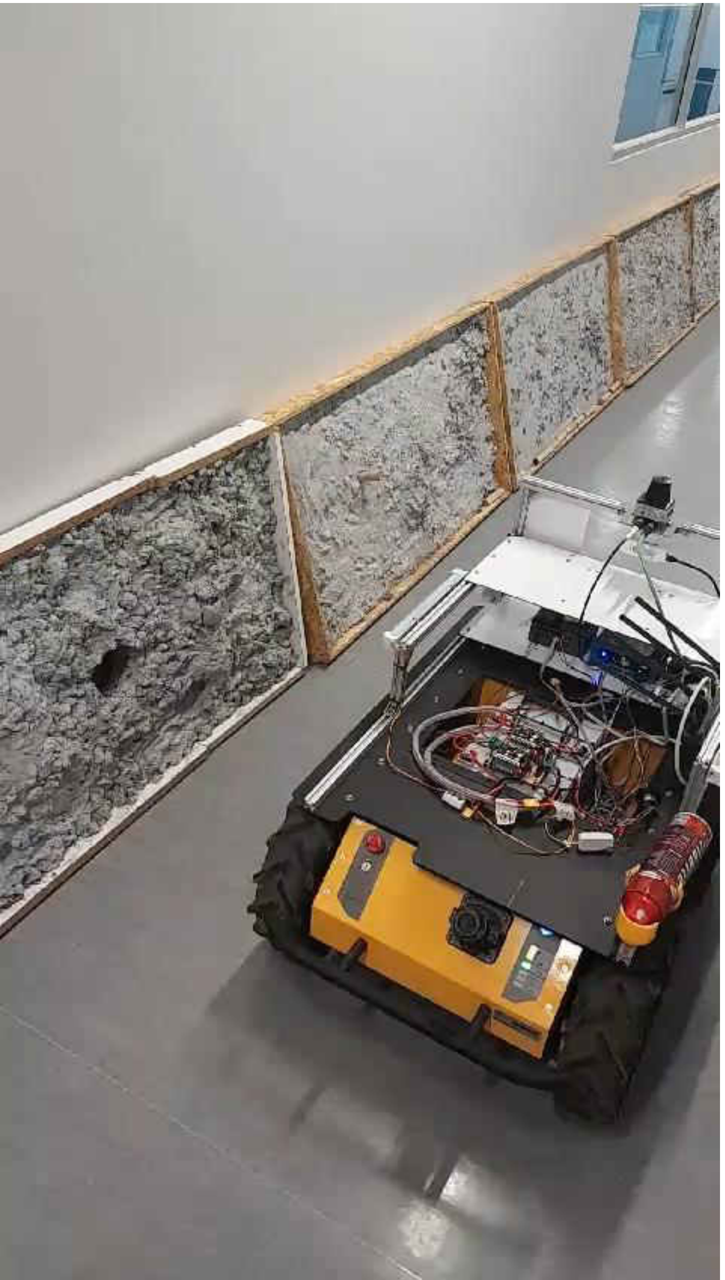
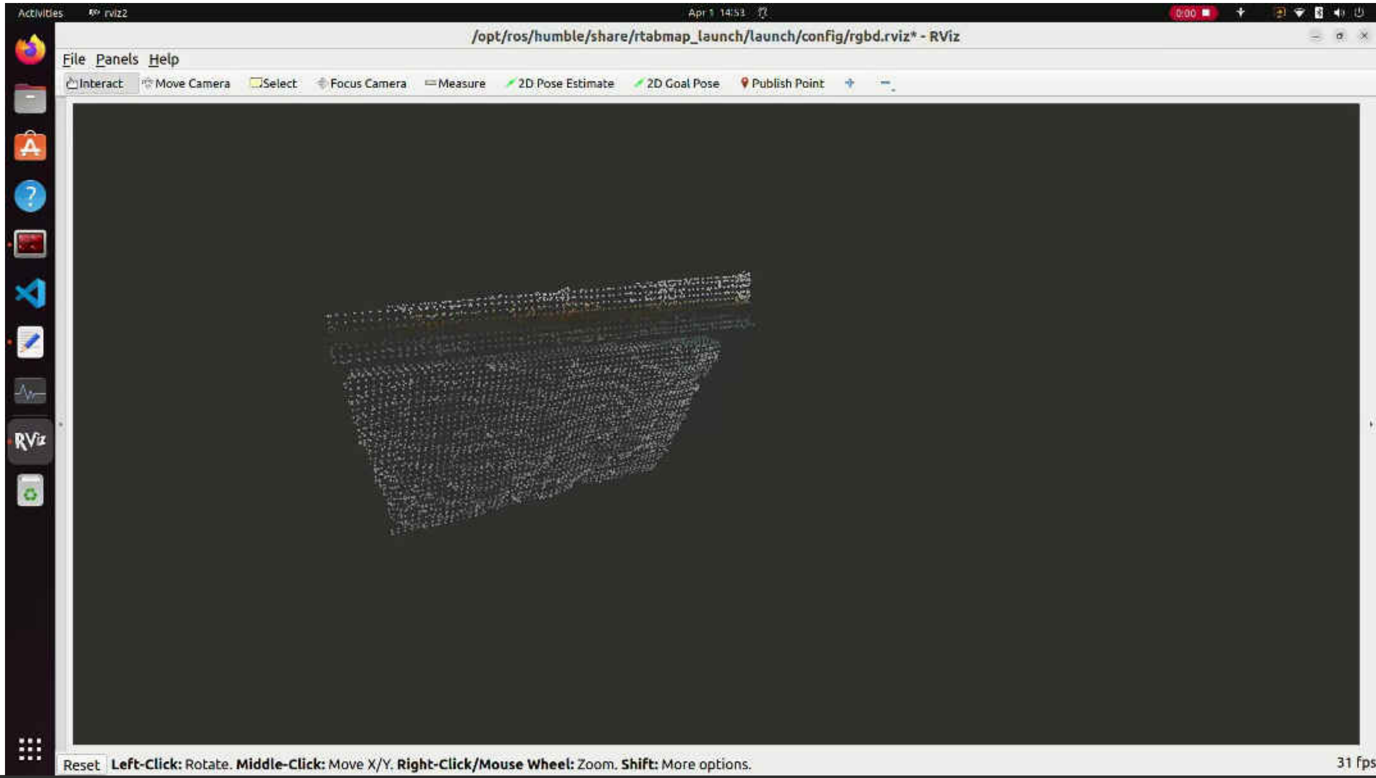
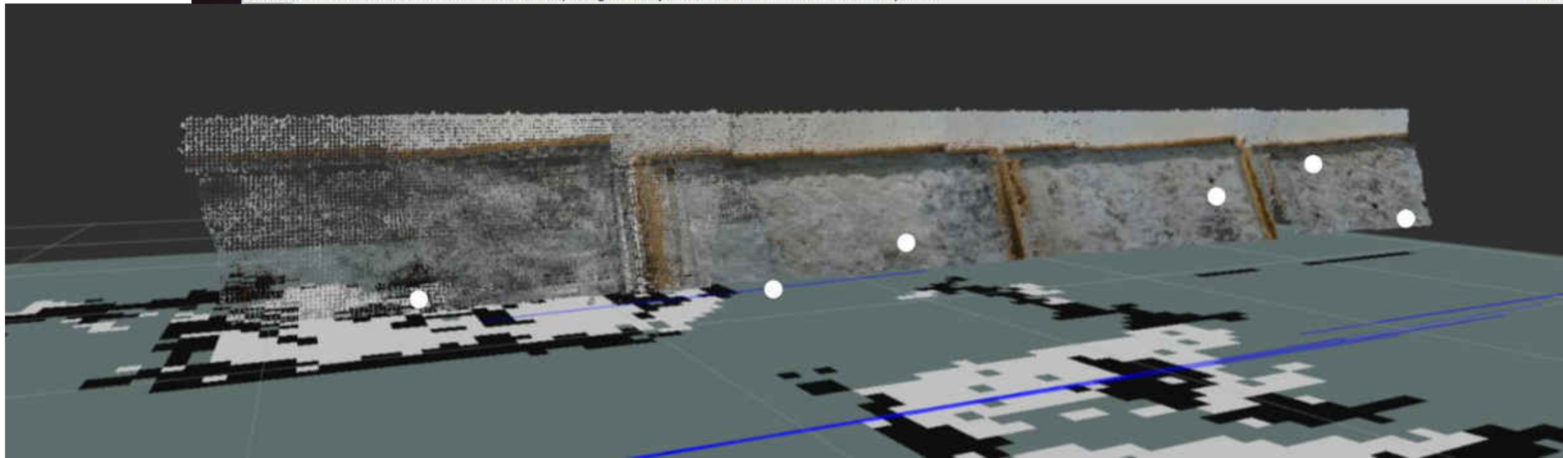
Autonomous Exploration



Stope mapping in real time







M&M Lab facilities for efficient mining

Robotic arm & conveyor belt

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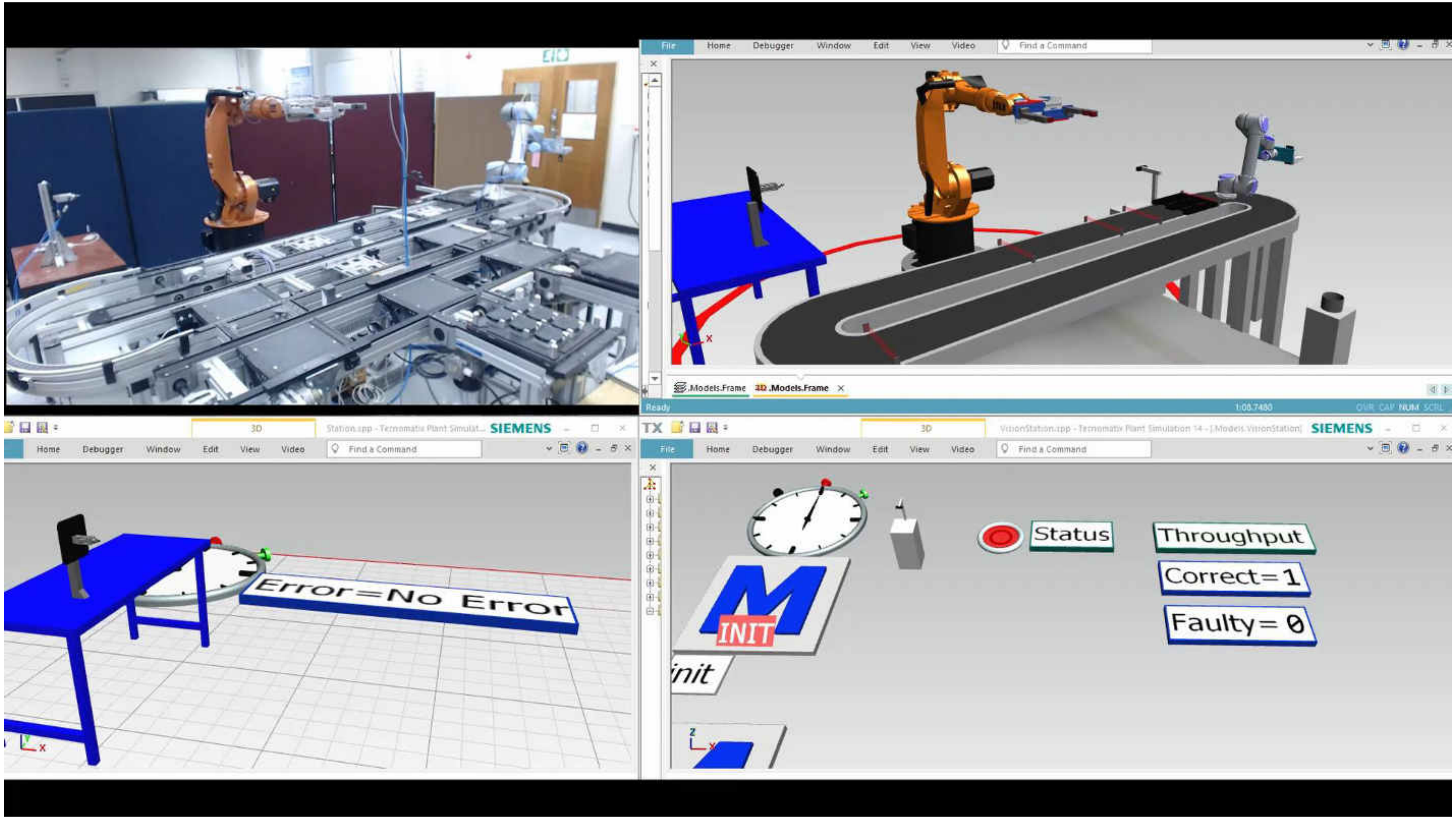

Digital Twins: Integrating Humans and Machines for Industry 4.0

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

M&M Lab facilities for efficient mining

Smart, integrated solutions for underground mining

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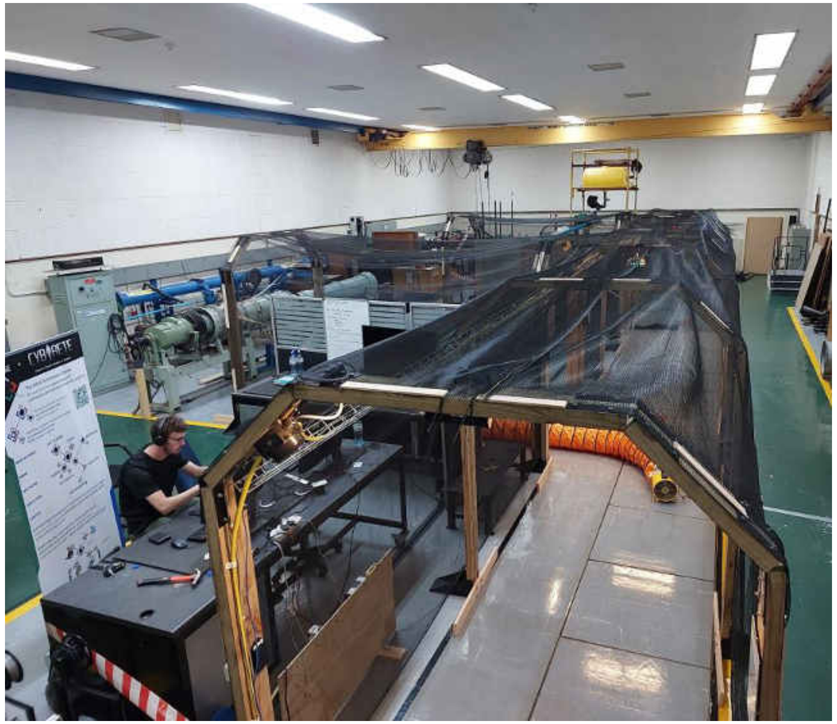

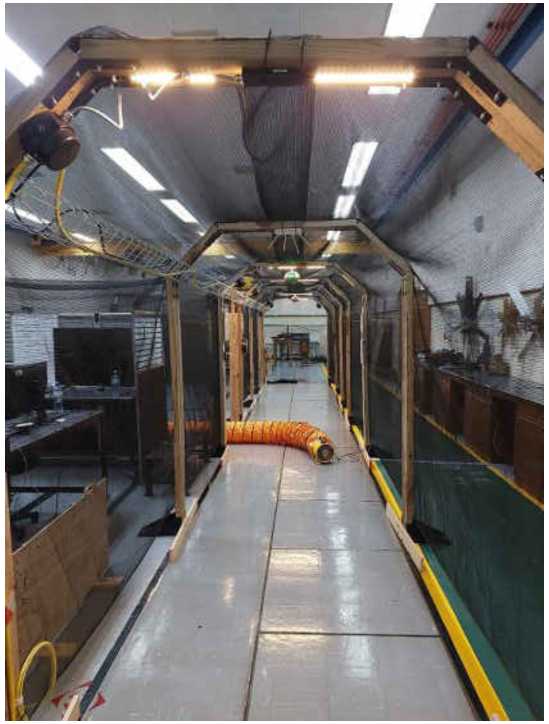

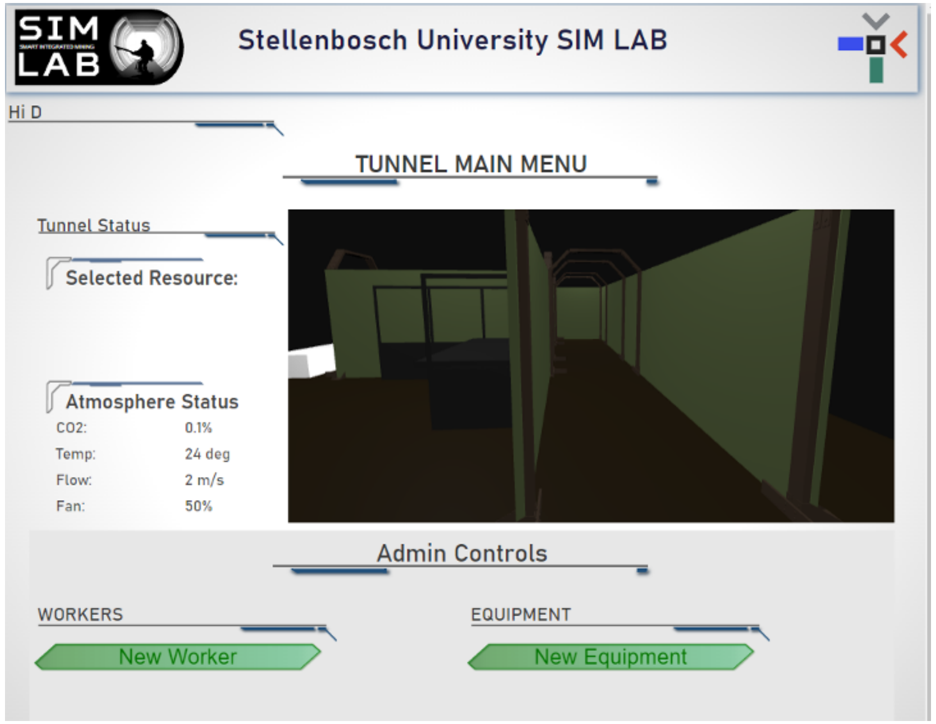

Underground tune and its monitoring and control research platform

Smart, integrated solutions for underground mining

M&M Lab facilities for efficient mining
Smart, integrated solutions for underground mining

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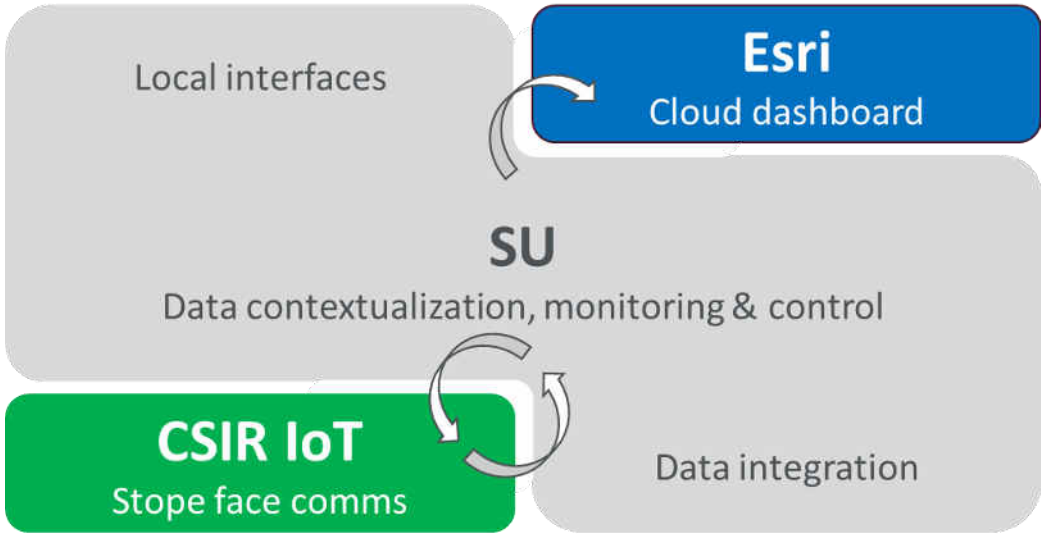
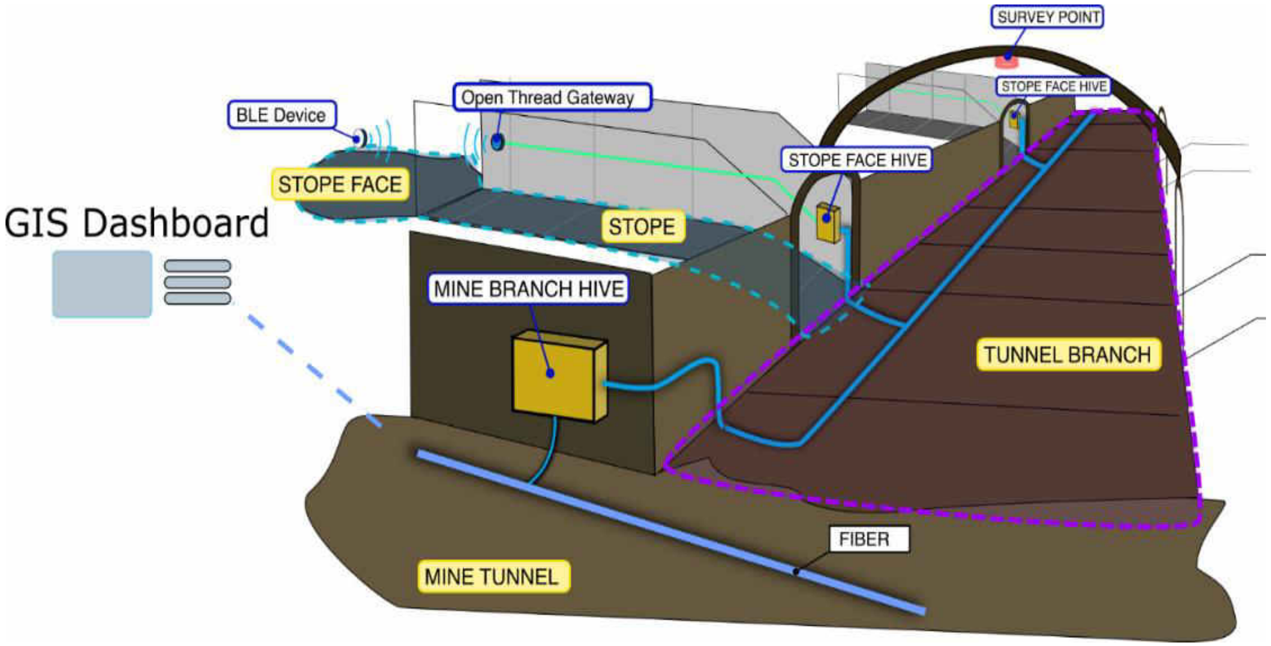
- Research projects for the **Mandela Mining Precinct "Real Time Information Management Systems" program**
- SU, CSIR IoT, Esri & M3SH (Canada based) have complimentary skills and interests
- Collaboration supports **development of a stope face to Cloud solution for monitoring and coordinating underground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





M&M Lab facilities for efficient mining

Smart, integrated solutions for underground mining

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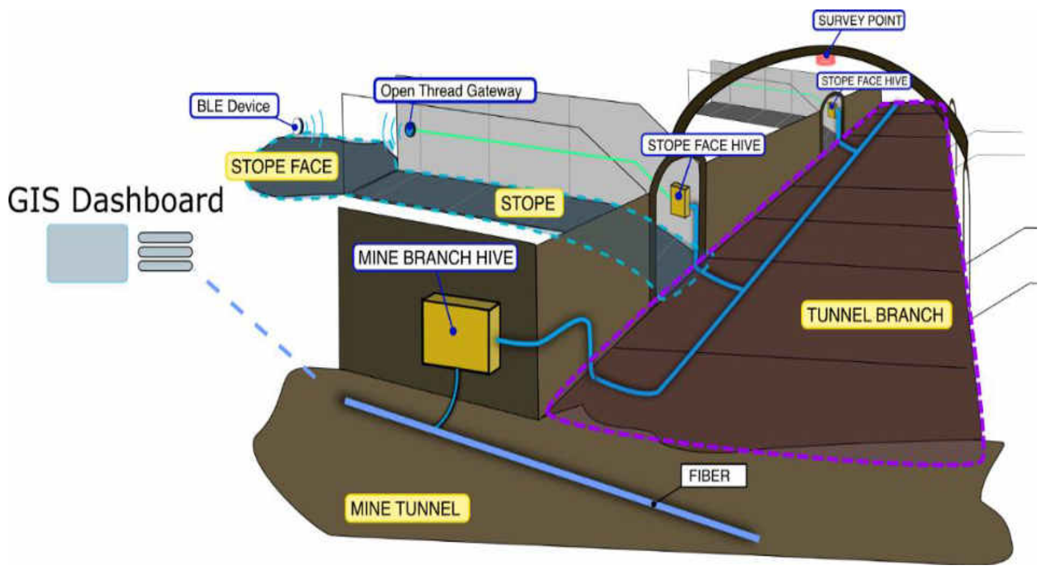
Support research and development of technology for:

- 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

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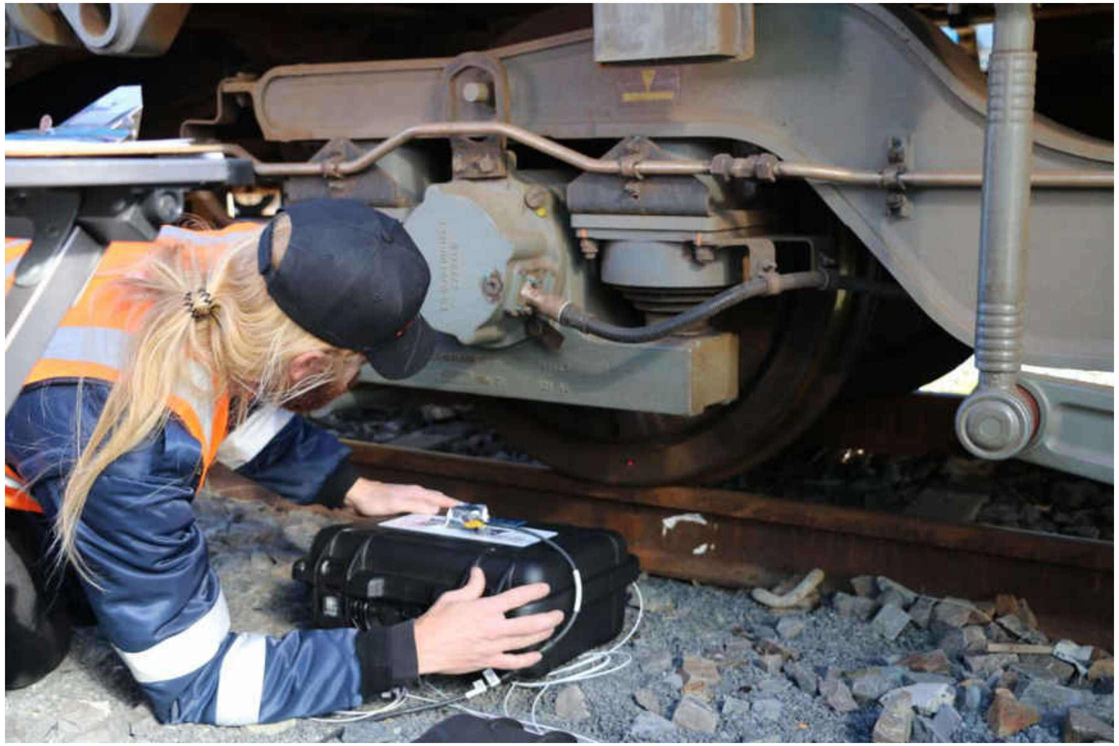
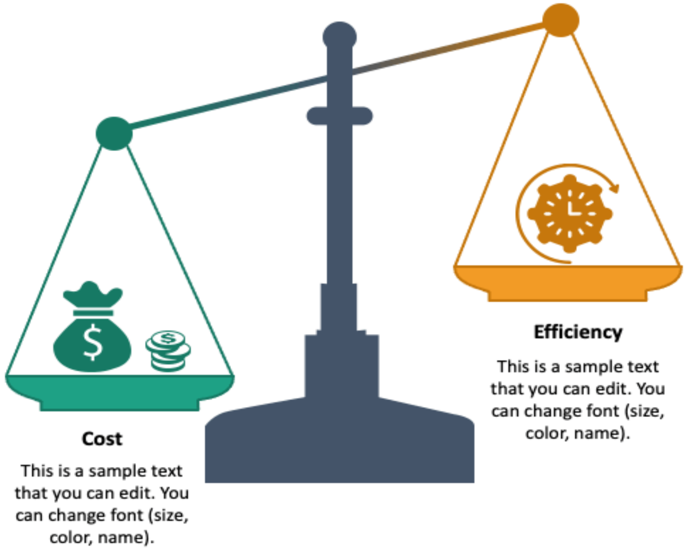


Process digitalization, optimization & control

Digital twin enabled decision support

Process digitalisation



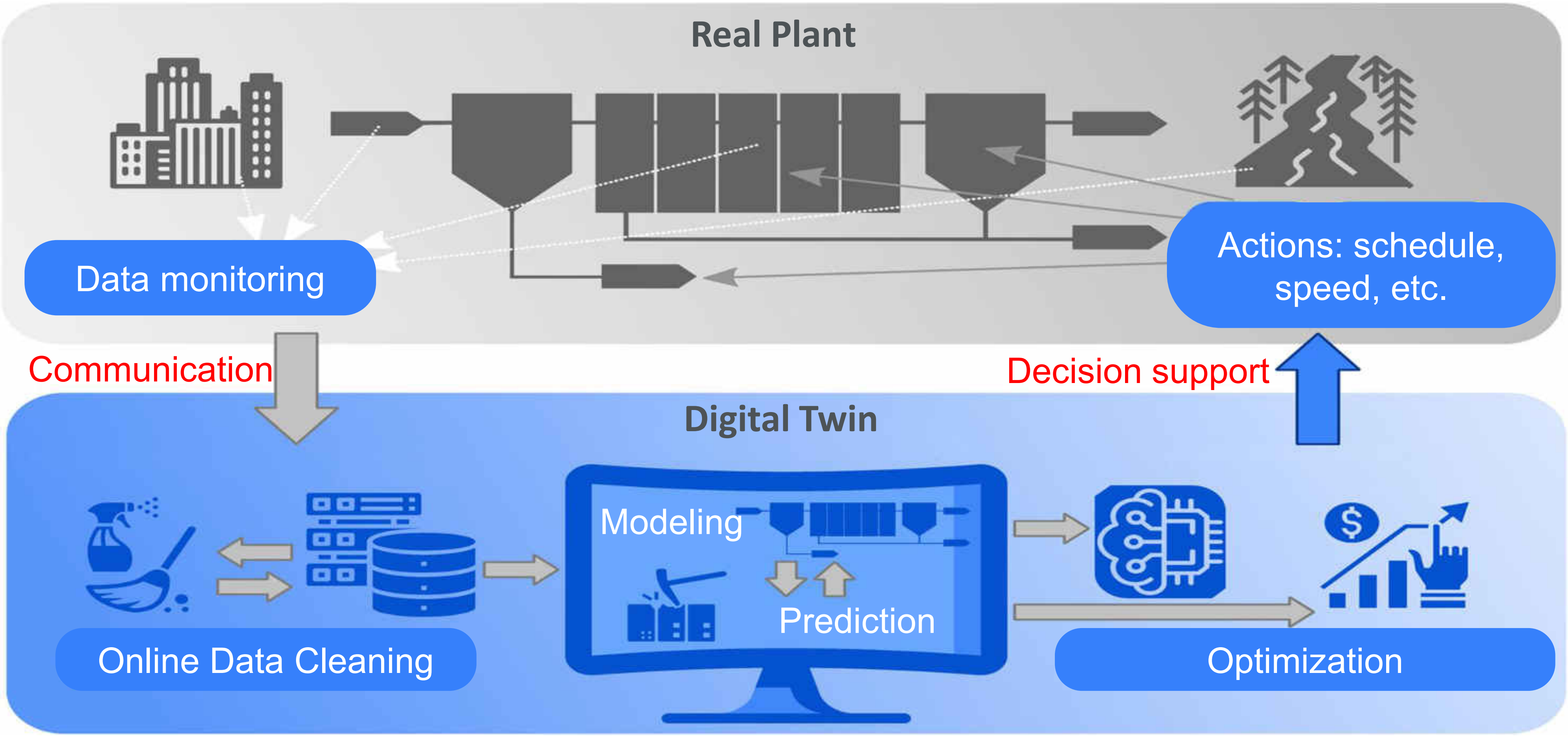
Cost-effectiveness

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

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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

Process digitalization, optimization & control

Core functions

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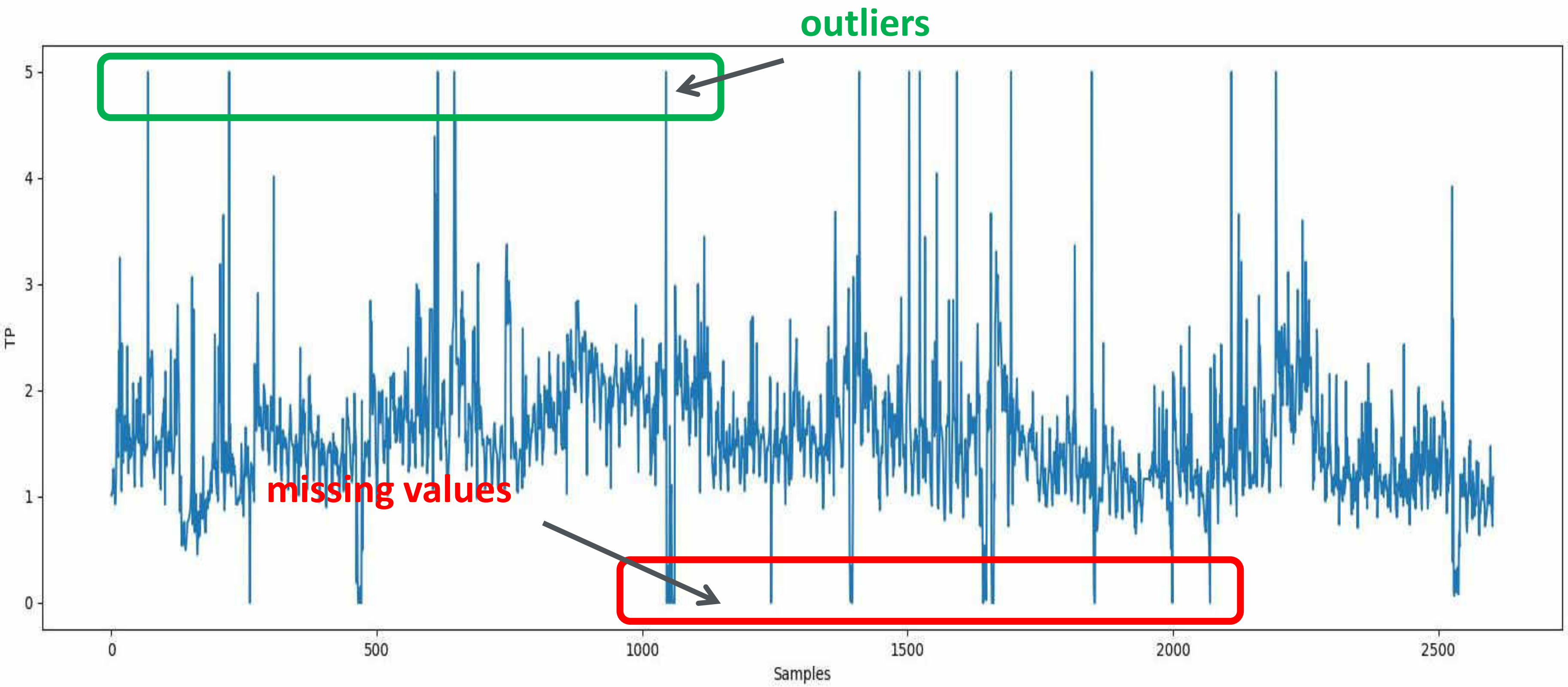
Sensor data cleansing



Performance Indicators:

- False negative rate ≤ 2%,
- false alarm rate ≤ 6%,
- detection delay ≤ 5s,
- accuracy ≥ 90%, and
- F1-Score ≥ 90%.

Process digitalization, optimization & control
Core functions

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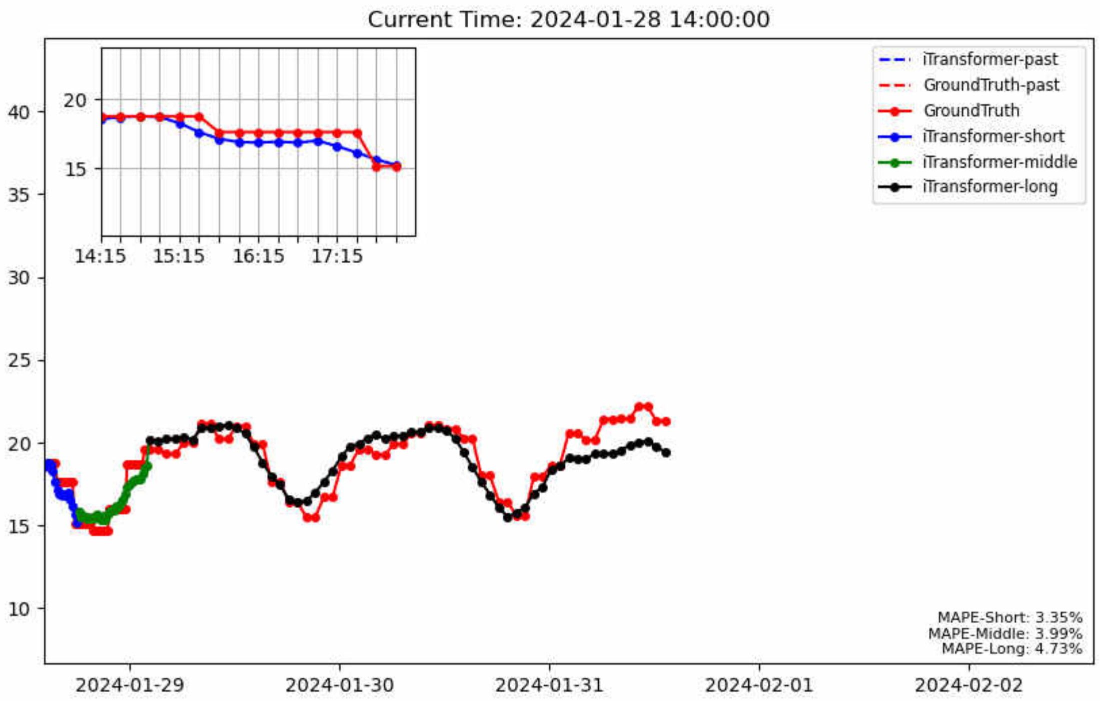
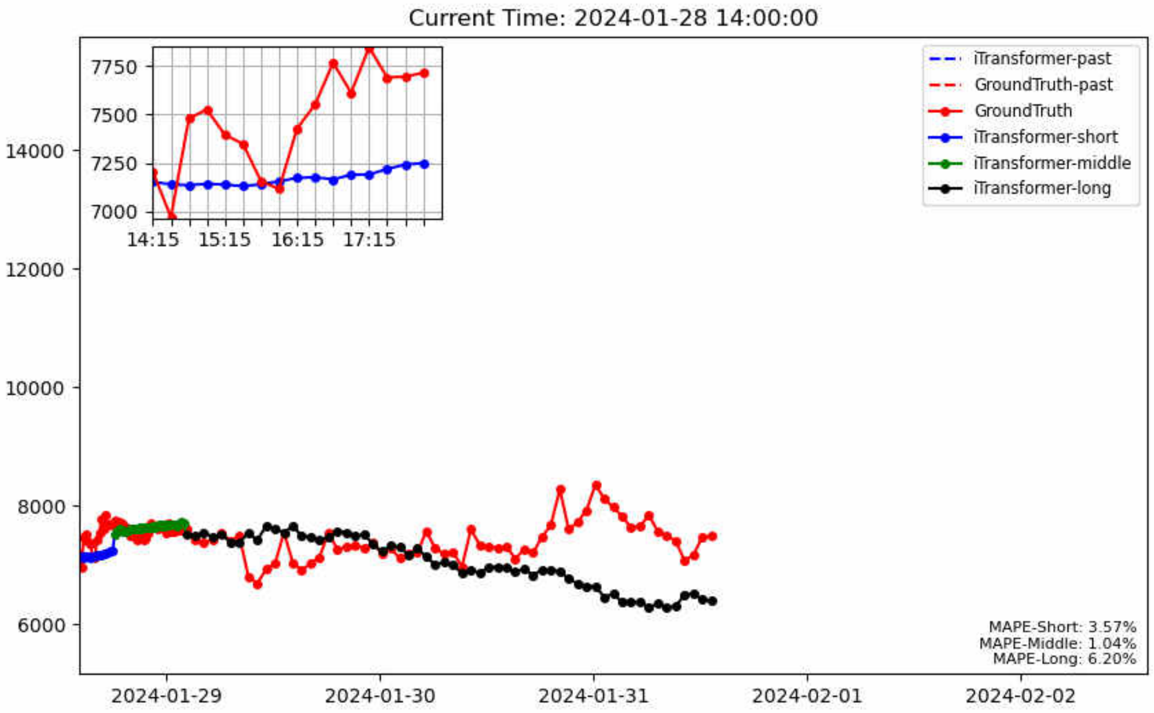
Long-, medium- and short-term time series data forecasting



Influent total nitrogen forecasting



Influent flow rate forecasting

Process digitalization, optimization & control

Core functions

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Operation optimization and control

01 **Sensitivity analysis**

Operating conditions clustering
Parameter sensitivity analysis

02 **Parallel computing**

Parallelize the process model
Parallelize the optimization algorithm

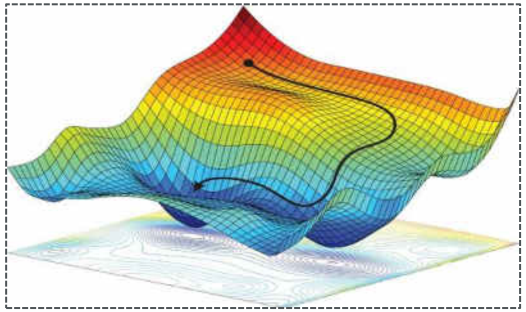
Support features

03 **In-house optimization algorithm**

Swarm intelligence based meta-heuristic optimization algorithm tailored for applications

04 **Model predictive control**

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



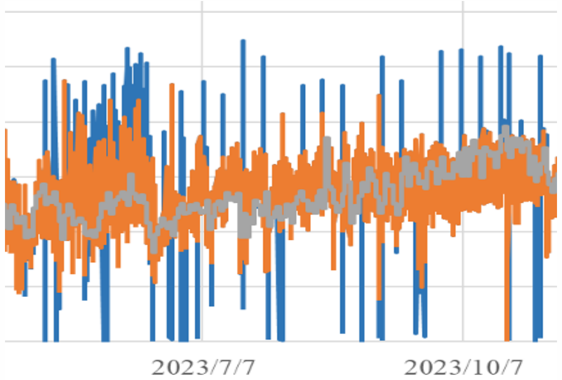
Process digitalization, optimization & control

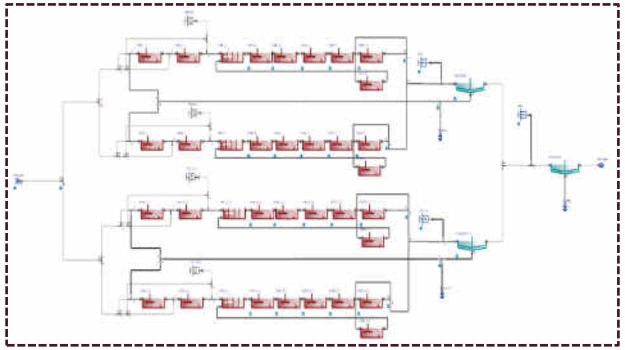
Real-world application

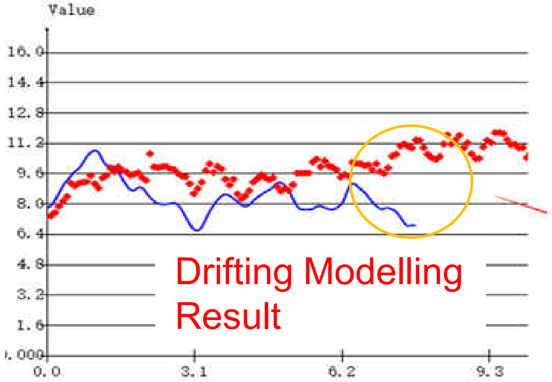
The architecture

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

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Wastewater treatment plant aeration optimization for energy/cost savings

Aeration Optimization

Experience based aeration → Depends on operator skills → Over aeration occurs → High energy costs

Digital twin

Digital twin based aeration → Utilizes AI algorithms → Precise aeration → Low energy costs

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

Process digitalization, optimization & control
Real-world application

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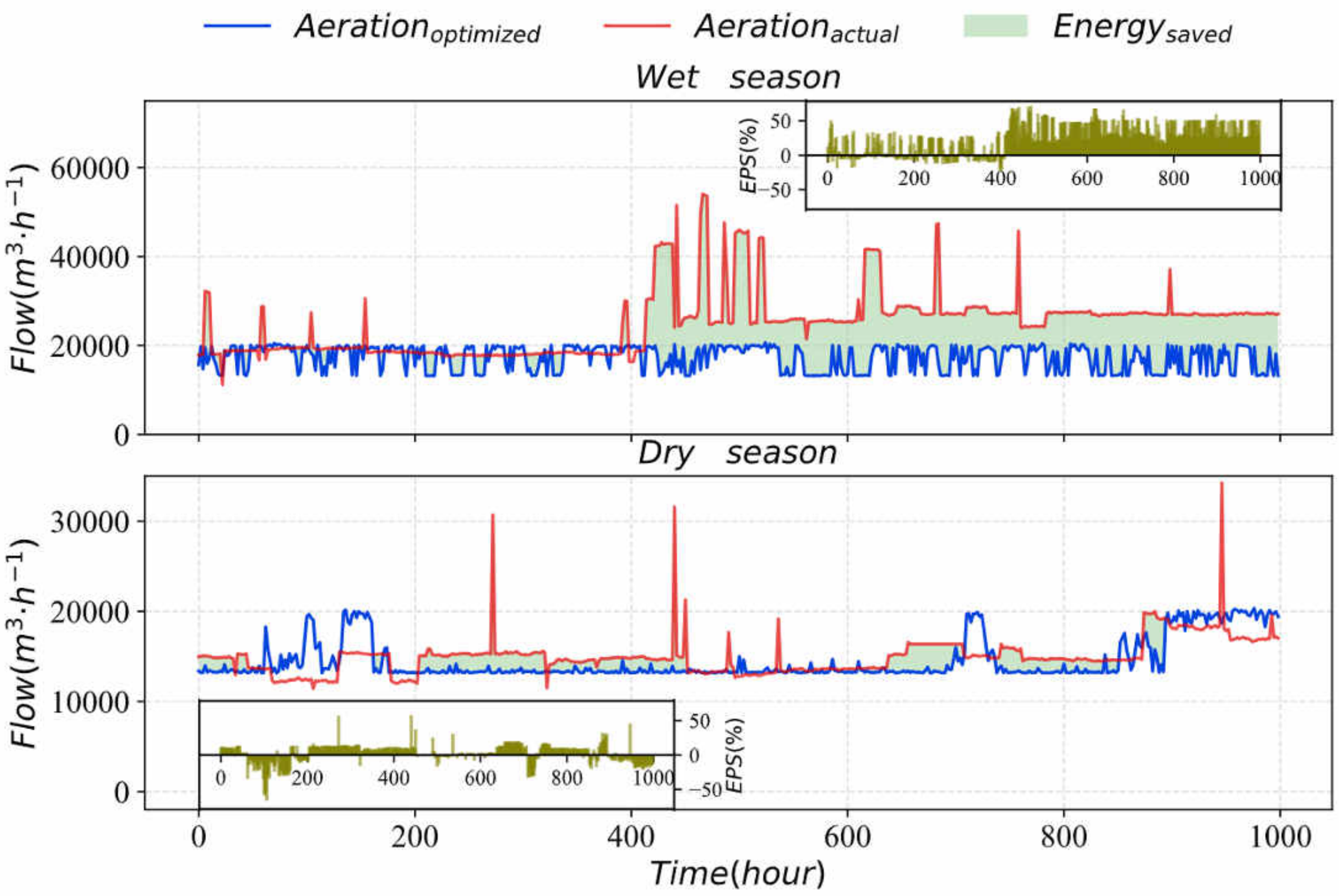
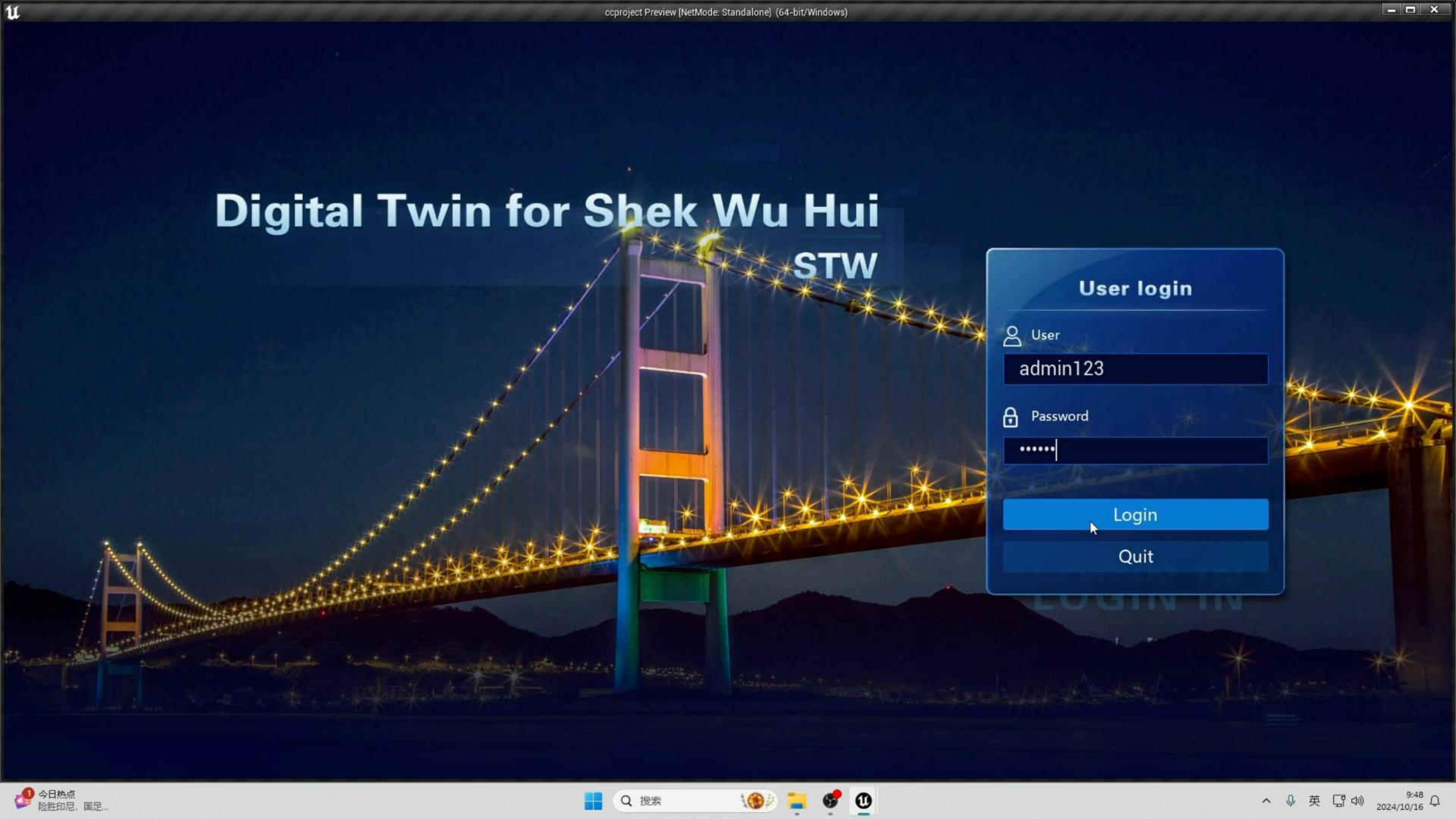
Illustrative example of energy savings achieved through AI aeration optimization.

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.

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Digital Twin for Shek Wu Hui
STW
User login
User
admin123
Password
Login
Quit
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Process digitalization, optimization & control

Other applications

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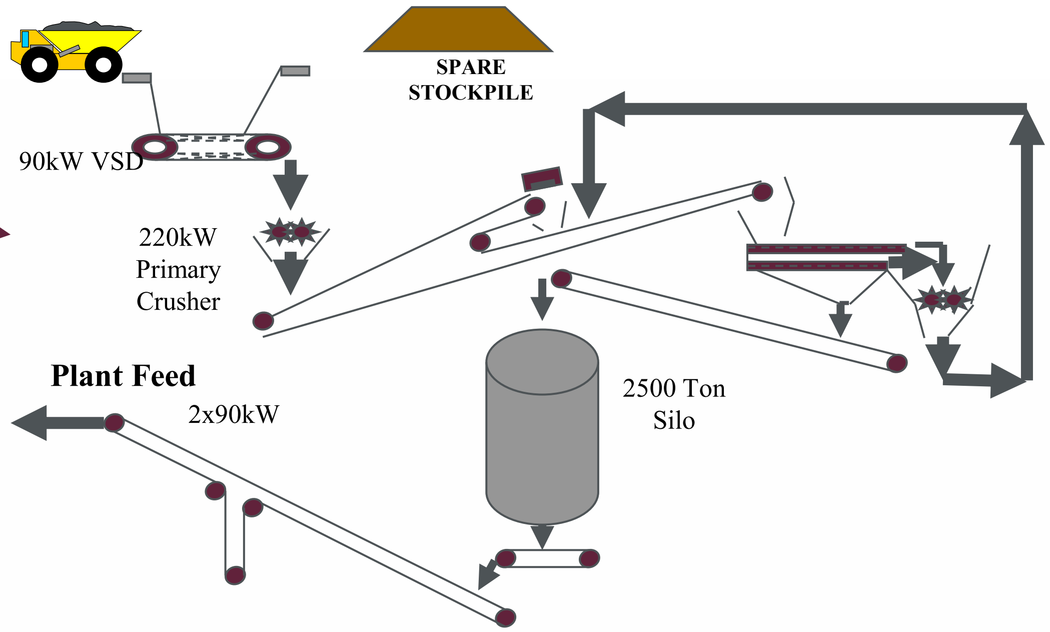
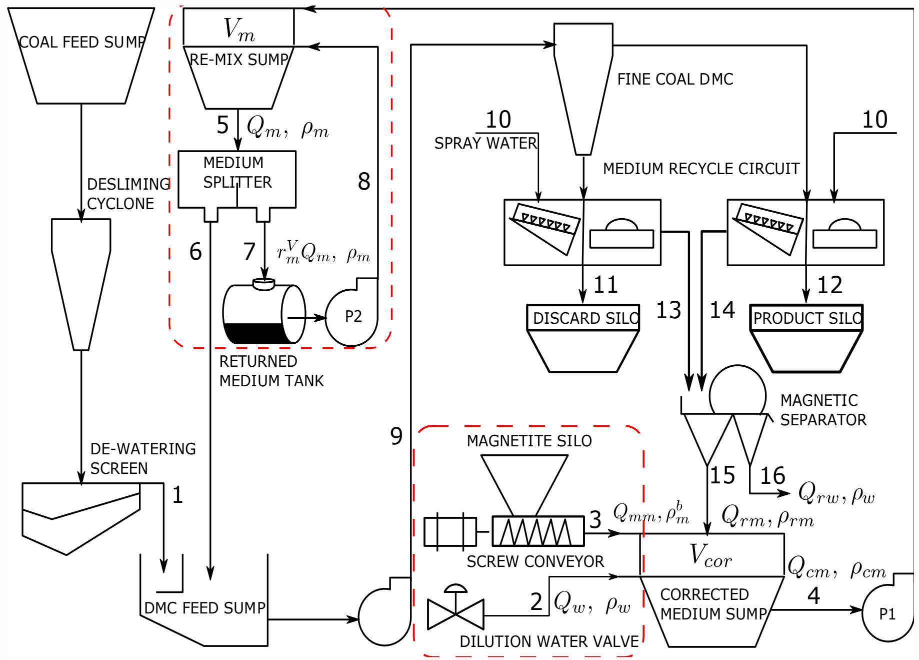
- Conveyor belts
- Pumping systems
- Crushers

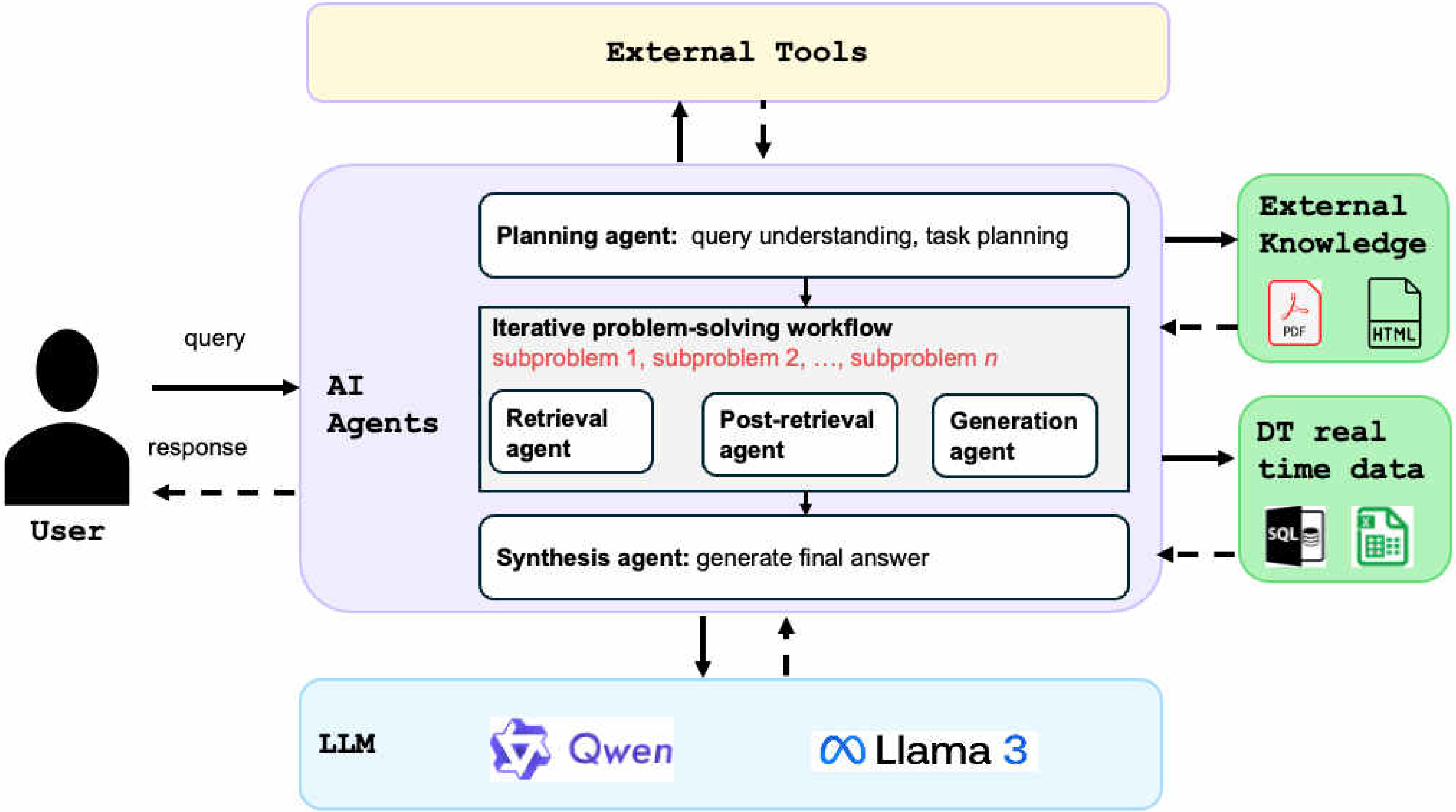




- Rock winders
- Coal washing cyclones
- Ventilation systems
- Heavy haul trains

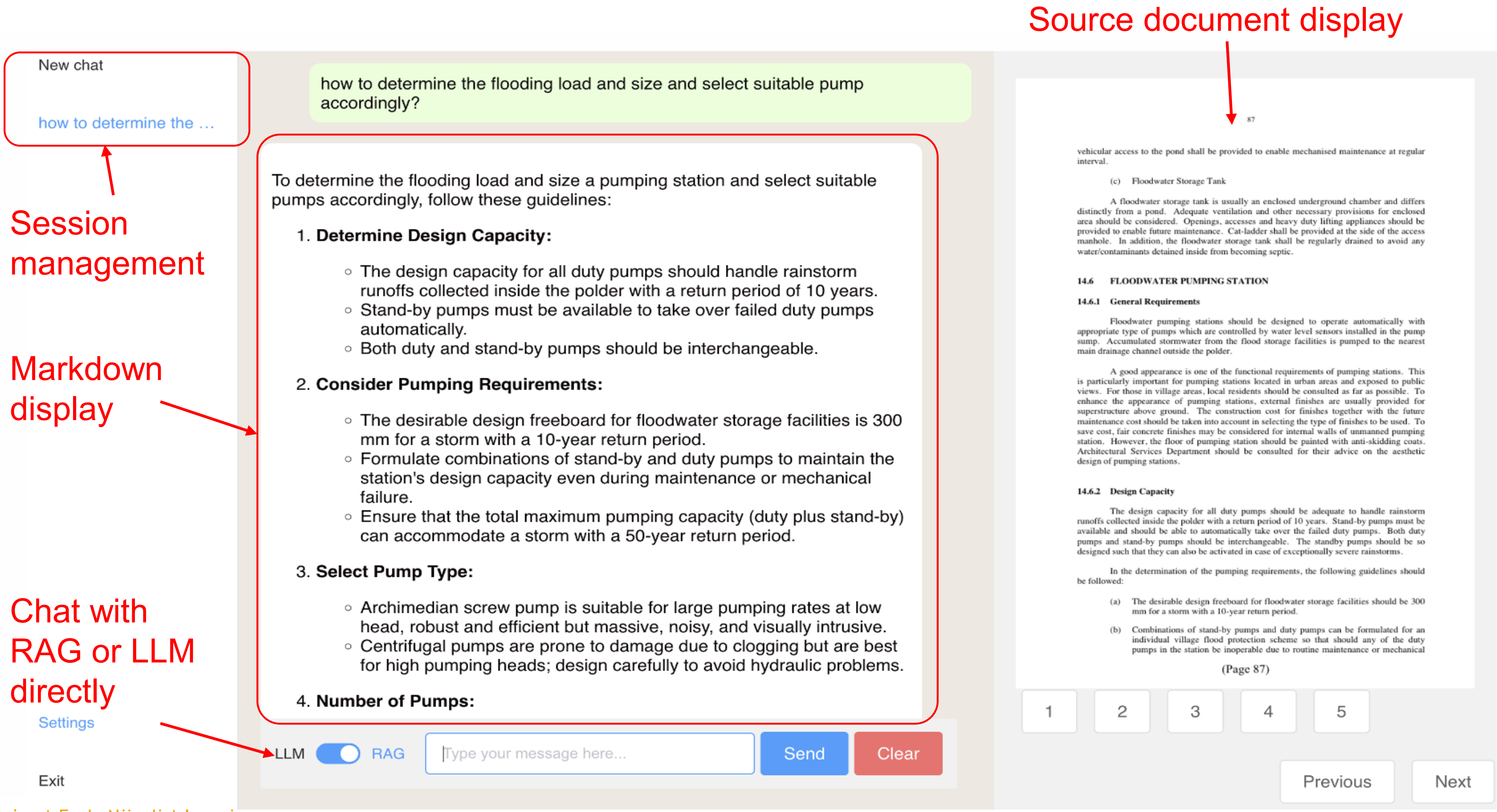
Process digitalization, optimization & control

Integration with large language models



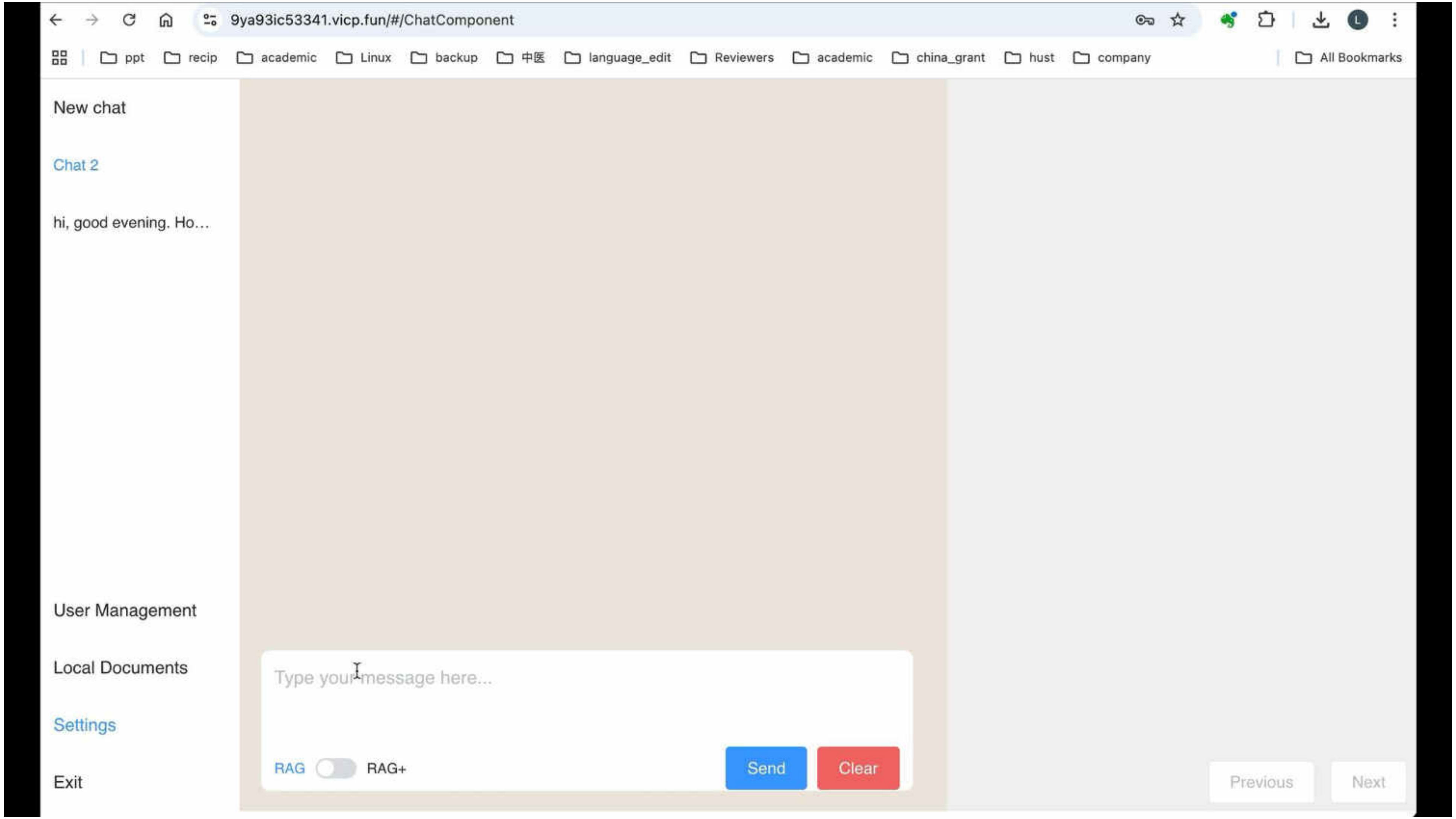
Process digitalization, optimization & control

Integration with large language models



Process digitalization, optimization & control

Integration with large language models



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Thank you
Enkosi
Dankie

Photo by Stefan Els

Any Questions?

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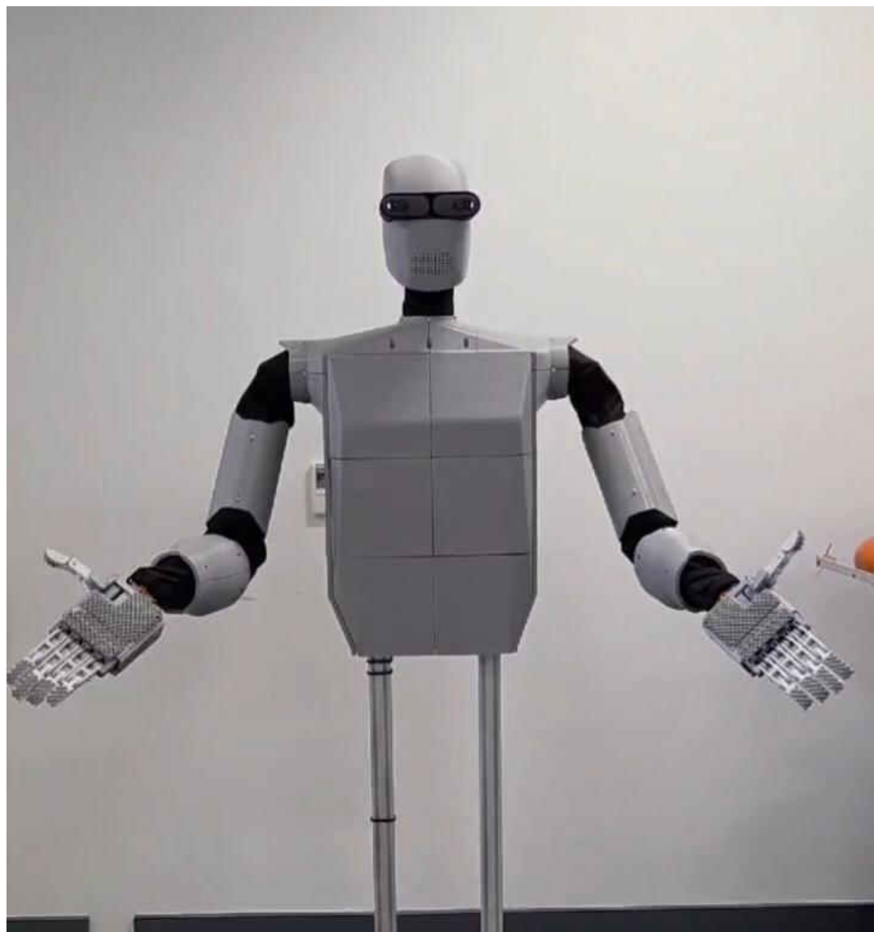
Questions?



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