MARS
Mobile Agricultural Robot Swarms

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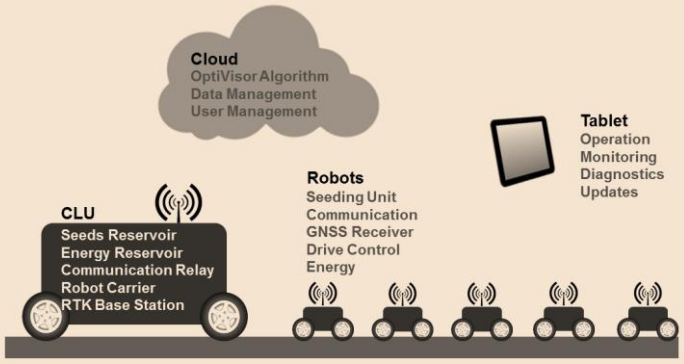

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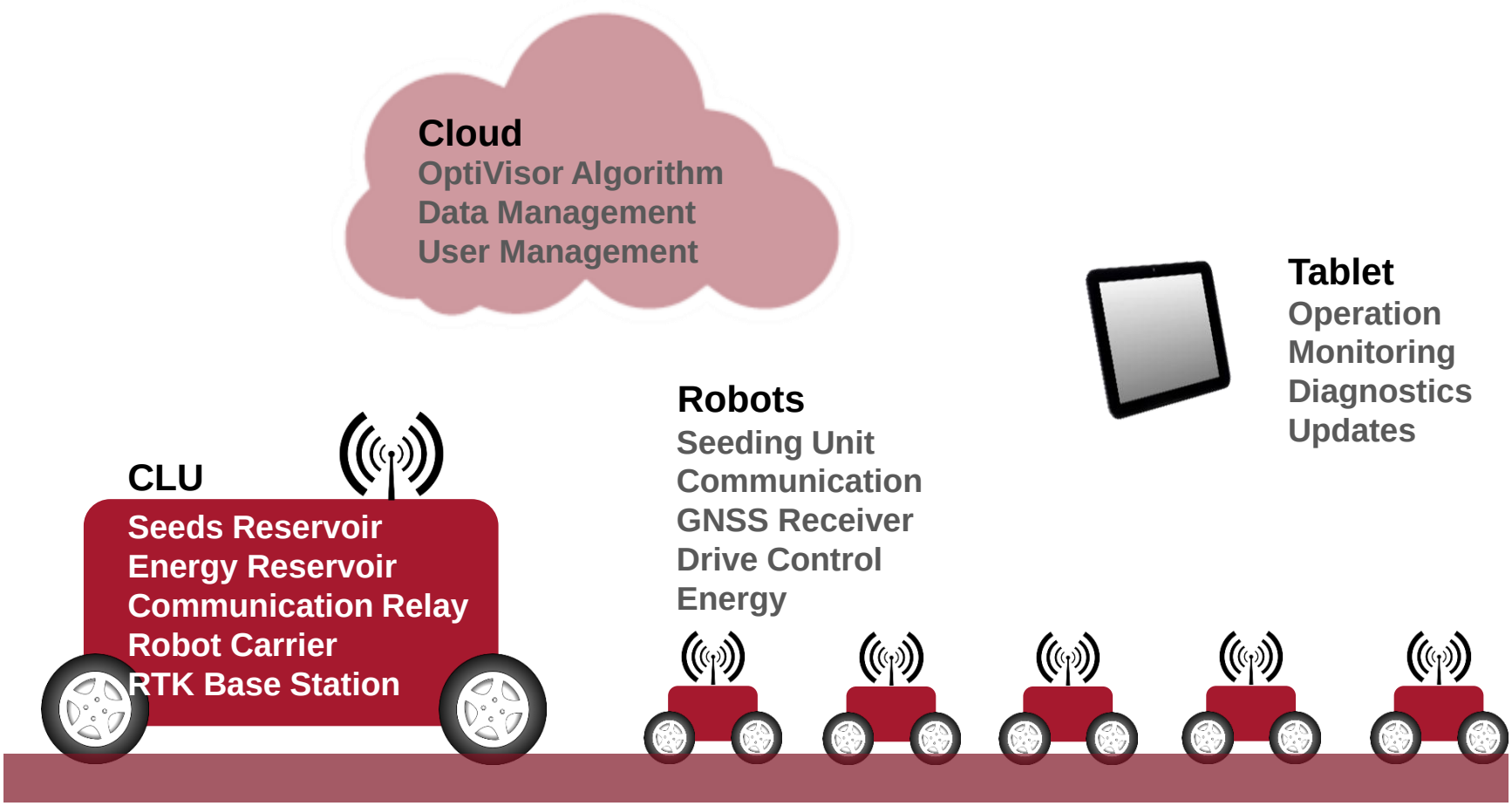
MARS – Mobile Agricultural Robot Swarms

- **Objective:** Small and stream-lined robot team.
- **Purpose:** Seeding corn.
- **Idea:** Simplification.
- **Means:** Lightweight and small.
  Minimized use of on-board Sensors.
  Little individual Intelligence.
  Robust Hardware.

MARS Concept



MARS Concept

- **CLU (Central Logistic Unit)**
  The CLU acts as base station for the robots, where they can refill seeds and energy. It also serves as communication relay to ease communication between robot and cloud. It enables high precision positioning and navigation by providing a RTK correction signal.
- **Robots**
  The robots preform the actual task of seeding corn, documenting the precise position of each planted seed and following the path determined by the OptiVisor.
- **Cloud**
  The cloud hosts the OptiVisor and takes care of data and user management. The OptiVisor represents the centralized intelligence and comprises two different modes, planning and working mode. It takes care of path/task planning and monitoring the current status of the system.
- **Tablet**
  The Tablet serves as HMI to the end-user (e.g. farmer). The HMI shows all necessary informations, like working progress, position of robots and planted seeds and CLU status. It also servers for planning the desired seeding task.

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Cloud

- **OptiVisor**
  The OptiVisor represents the centralized intelligence of the overall system. The planning mode allows user inputs concerning field data, seed pattern and other paramters (e.g. available robots). Based on these inputs the OptiVisor calculates the optimum seed positions and paths for each robot. During the seeding the OptiVisor switches to working mode. It communicates with each robot (sending waypoints, receiving seed positions) and monitors the status of the CLU and the robots. The OptiVisor is also capable of error handling (e.g. robot breakdown).
- **Data Management**
  The cloud stores and handles all data, which is necessary for planning and documenting the seeding task.
- **User Management**
  As different user could communicate with the OptiVisor and access data, a user management system is necessary.

OptiVisor: Concept

Planning Mode
Seed pattern
Seed position
Path pre-planning

Working Mode
Supervising
Event handling
Path re-planning
Communication

Module 1
Seed pattern
Seed position

Module 2
Path planning

Module 3
Supervising
Event-Handling

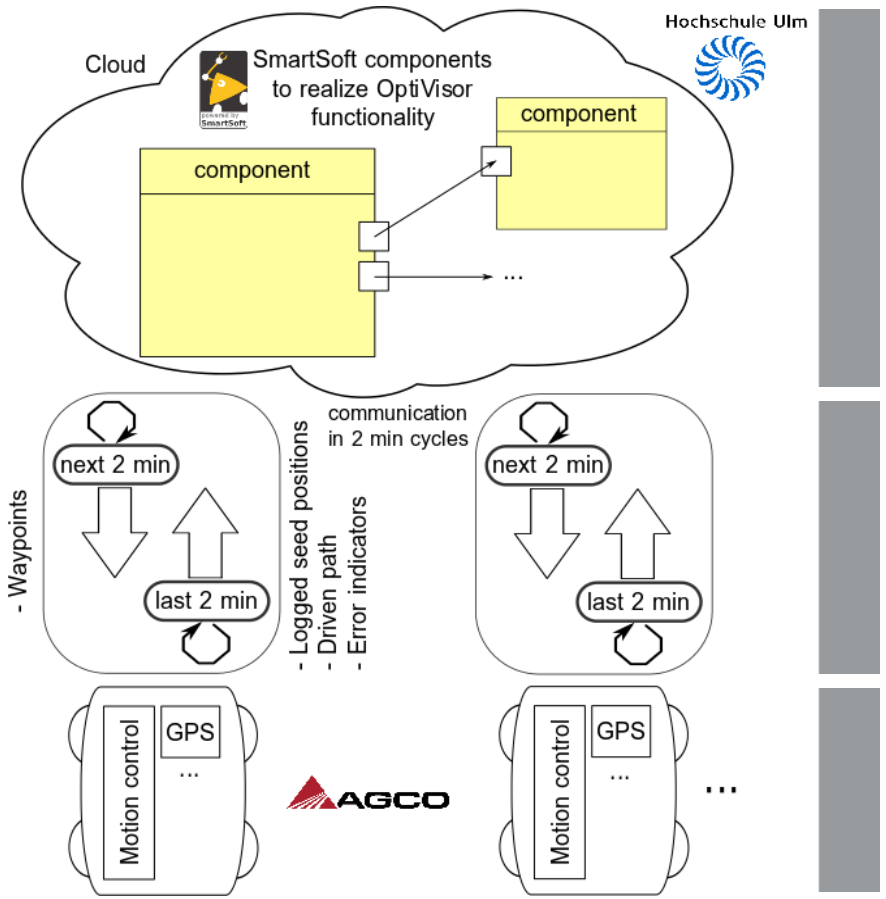
Module 4
Communication

OptiVisor-Robot Interaction

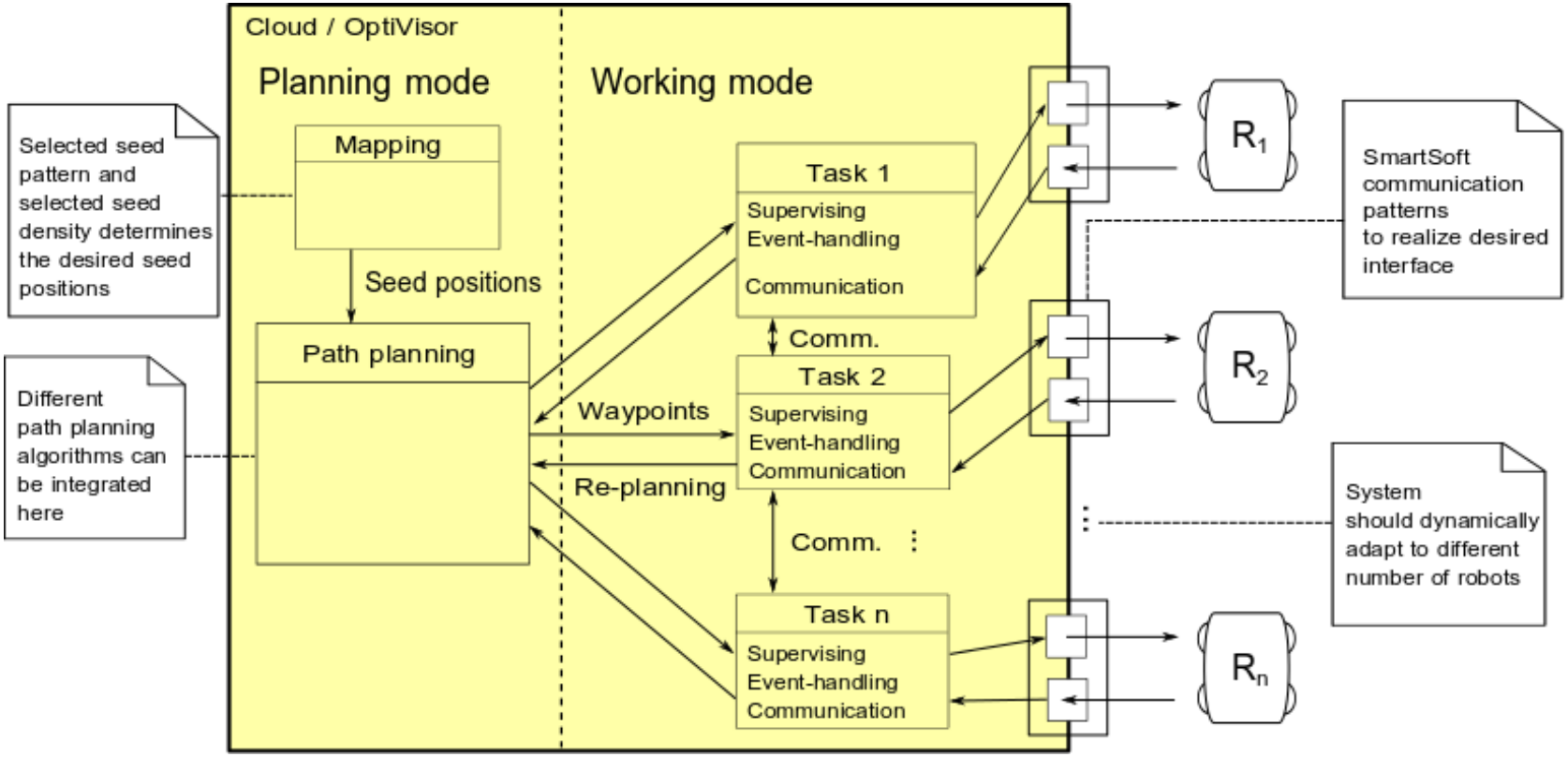
Cloud
Host for OptiVisor
Data Management
User Management

Communication OptiVisor-Robots
Receive data from robots (e.g. seed position, driven path, errors)
Send data to robots (next waypoints)

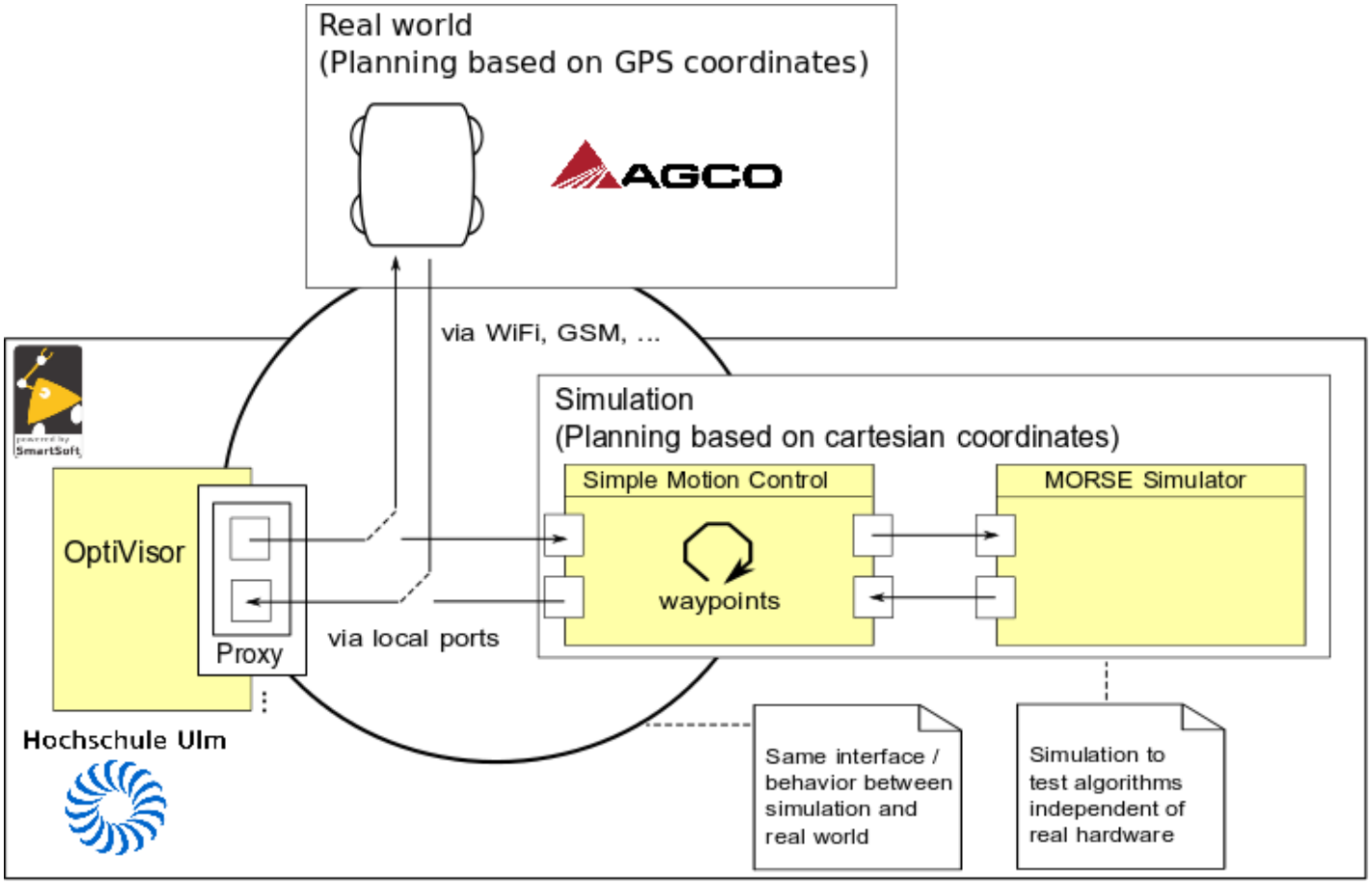
Robots
React according to received data (GPS)
Send data to cloud



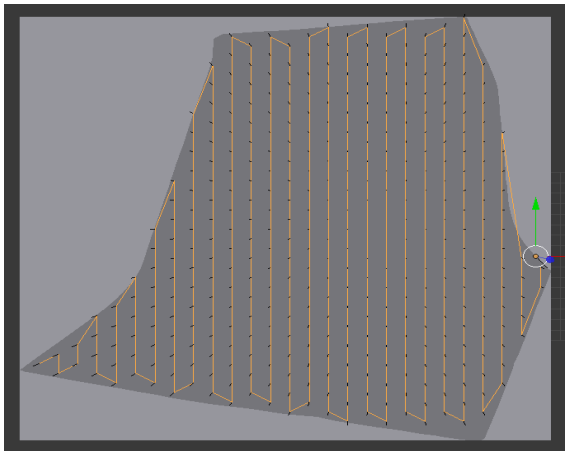
OptiVisor: SmartSoft realization

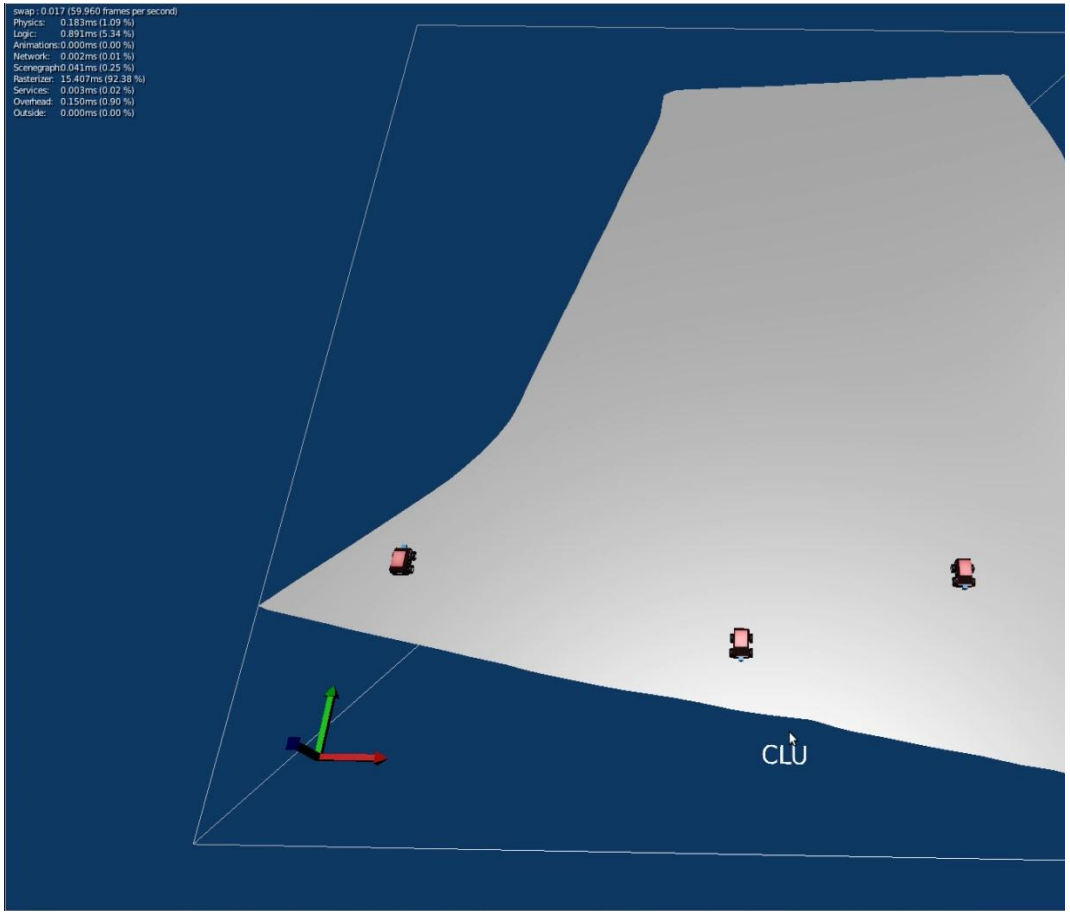


OptiVisor: Simulated and Real World Interface



OptiVisor Impressions





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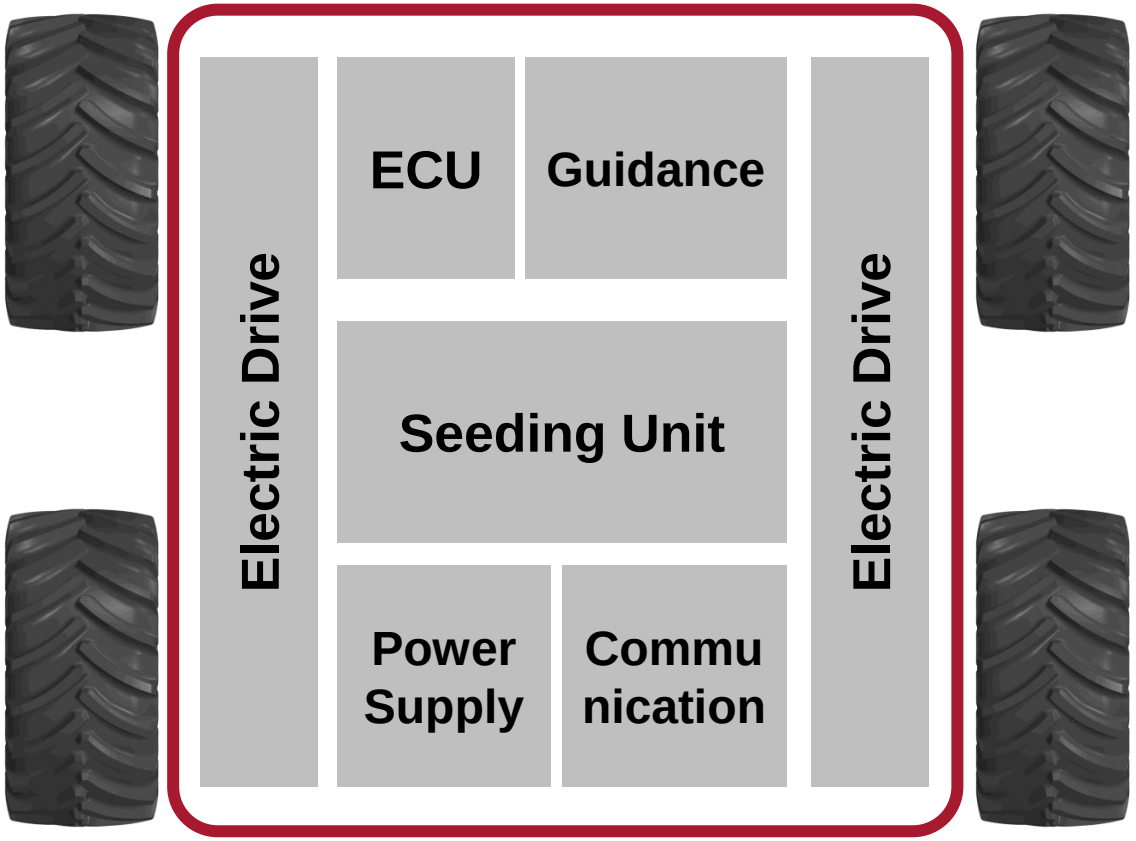
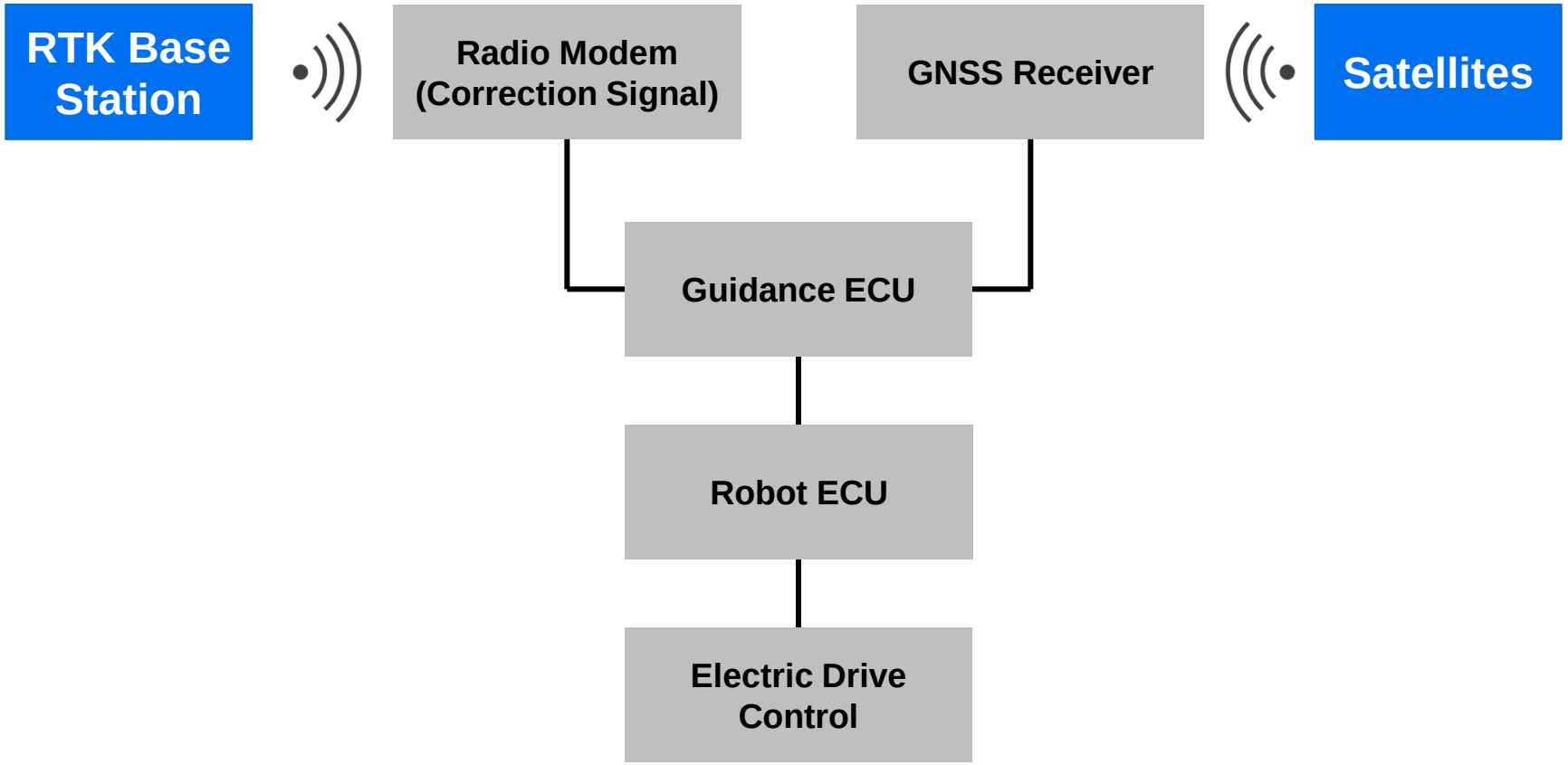
Robot Concept



Robot Concept

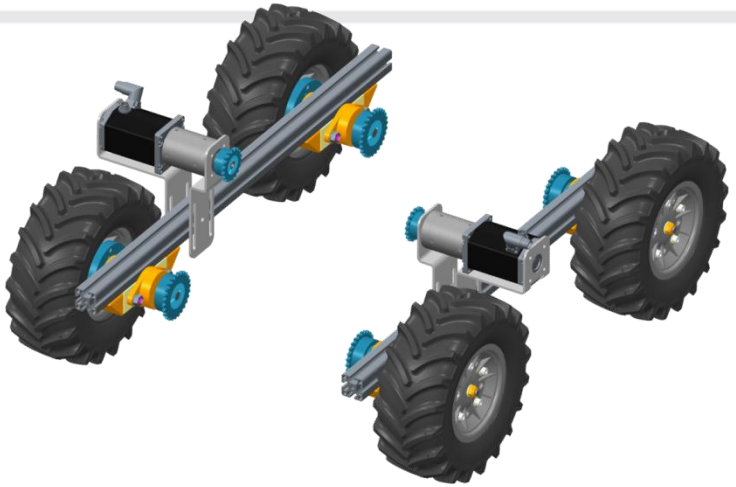
- **ECU (Electronic Control Unit)**
  The ECU controls the electric drive and the seeding unit. It communicates with the guidance unit and the communication device.
- **Guidance**
  The guidance unit receives position signals and computes the precise position of the robot. It also computes the necessary action of the steering system according to the next waypoint.
- **Seeding Unit**
  This is the mechanical core component of the robot. It puts the seed in the ground and is capable of recording the precise position of the planted seed.
- **Electric Drive**
  The electrice drive powers the wheels of the robot.
- **Communication**
  The communication device connects the robot to the outside world. It sends and receives data from the Cloud/OptiVisor.
- **Power Supply**
  The power supply provides energy for all electric components. It consists of a high-performance rechargeable battery pack, implemented in a quick-change system.

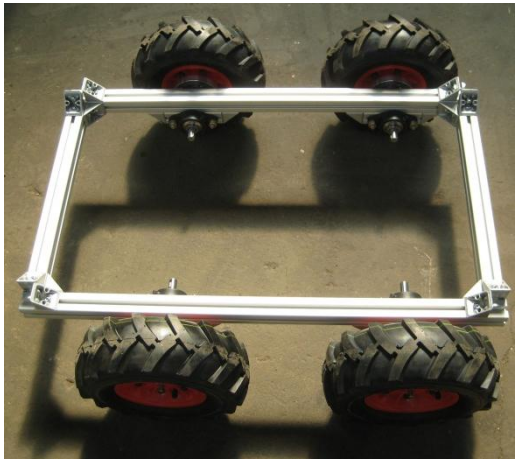
Robot: Guidance Concept



Robot: Drive Concept

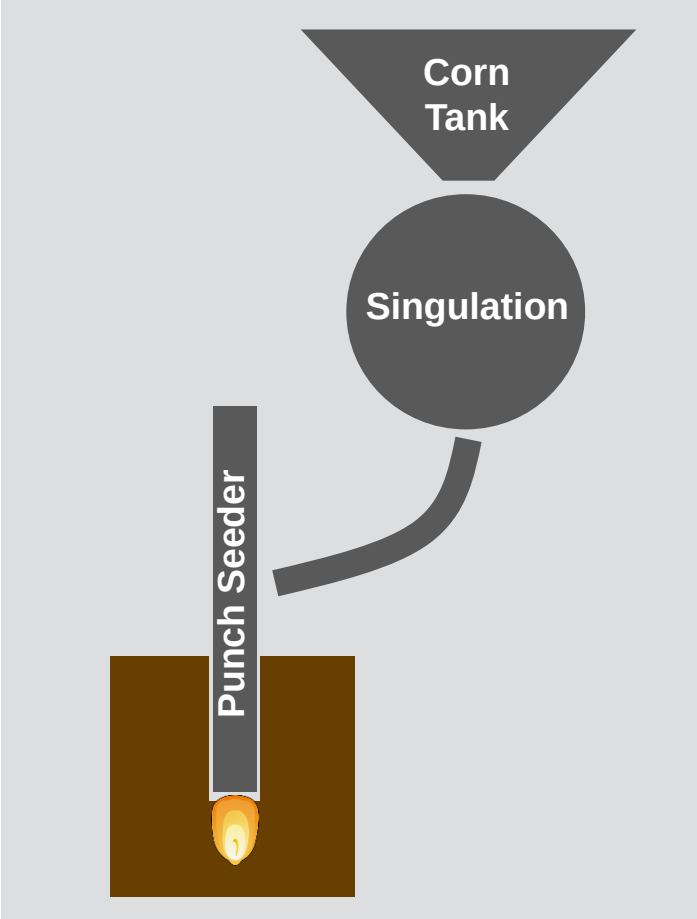
- Skid steering
- Electric motors
- Four-wheel drive
- One motor per side or integrated motors (each wheel)
- Recording of basic data: Speed, Torque
- Driving speed: ~ 3 kph





Robot: Seeding Unit Concept

- **Principle: Punch Seeding**
- **Corn Singulation**
- **Seed handling**
- **One electric motor**
- **Synchronized with robot‘s movement**
- **Capable of precise position control (relevant for seed position recording)**
- **Seeding while robot is moving at constant speed**
- **Seeding frequency: ~ 3 seeds/second**



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Central Logistic Unit

- **Robot Carrier**
  The CLU serves as robot carrier for transportation.
- **Seeds and Energy Reservoir**
  As robots are small and lightweight, they can only carry a certain amount of seeds and battery weight. To refill their seed and energy storage, robots return to the CLU.
- **Communication Relay**
  Regarding the possible technologies for establishing a reliable communication between robot and cloud, it could be necessary for the CLU to act as a relay station. For example, the CLU could communicate with the cloud by a gsm connection while the communication between robot and CLU ist established by a wifi signal.
- **RTK Base Station**
  A high precision positioning system is needed for an accurate documentation of seed positions and for navigation purposes. At the moment this can only be provided by RTK GPS Systems. The CLU carries the RTK base station which provides the correction signal.

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Tablet

- **Operation**
  The user can interact with the OptiVisor if needed. For example, the user can start or stop the seeding task. He can also plan the task by switching to the OptiVisor‘s planning mode. While the robots are seeding, no real-time interaction between user and OptiVisor is needed.
- **Monitoring**
  The HMI shows the current status of the overall system. The user can also select a certain robot or the CLU to gain more details.
- **Diagnostics**
  If the HMI reports an error or malfunction of robots or the CLU, the user can perform remote diagnostics.
- **Updates**
  It is possible to send software updates or updates concerning the current seeding task.

Impressions

First Field Tests and Assembly

OptiVisor Development