UPDATE ON MAGNET AND PEOPLE TRANSPORT VEHICLES AND LOGISTICS SIMULATION STUDY

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Fraunhofer IML

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- Dimensions, capacity and storage
- Motorization and drive
- Autonomous driving capabilities

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- New scenario and parameters
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3 Magnet transport vehicle (additional topic)
- Challenge: Offset of booster ring
- Spreader beam and gripper concept

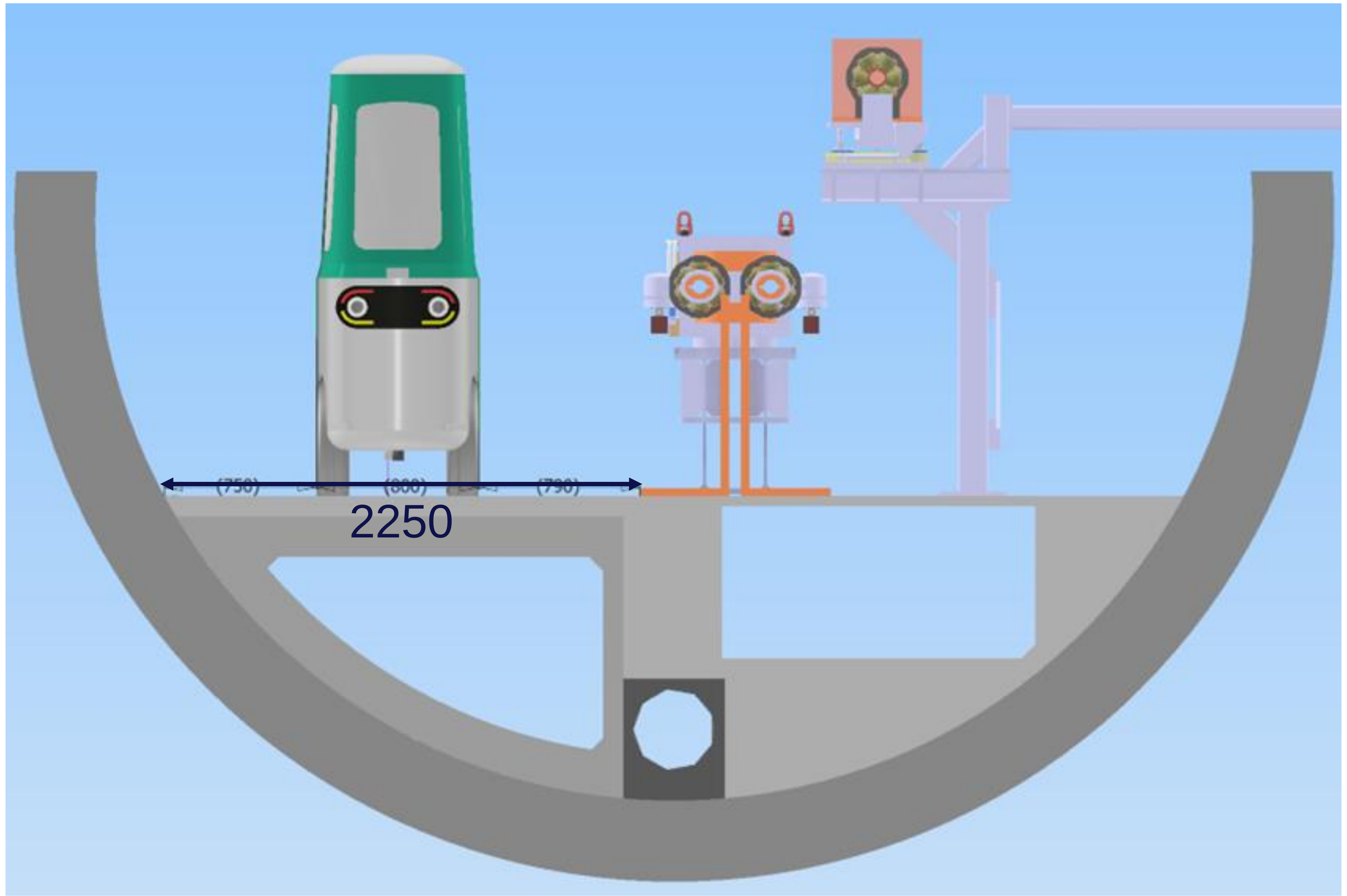
1 PEOPLE TRANSPORT VEHICLE

2 LOGISTICS SIMULATION STUDY

3 MAGNET TRANSPORT VEHICLE
ADDITIONAL TOPIC

Requirements for vehicle

- Capacity for up to 6 passengers with luggage
- Available width in tunnel: 2,25 m
- Vehicle slim enough to allow encountering traffic and bypassing of other vehicles
- Fully autonomous driving
- Symmetrical in both directions for bidirectional driving
- Electrical vehicle to avoid emissions in tunnel
- Closed vehicle to drive through smoke if necessary

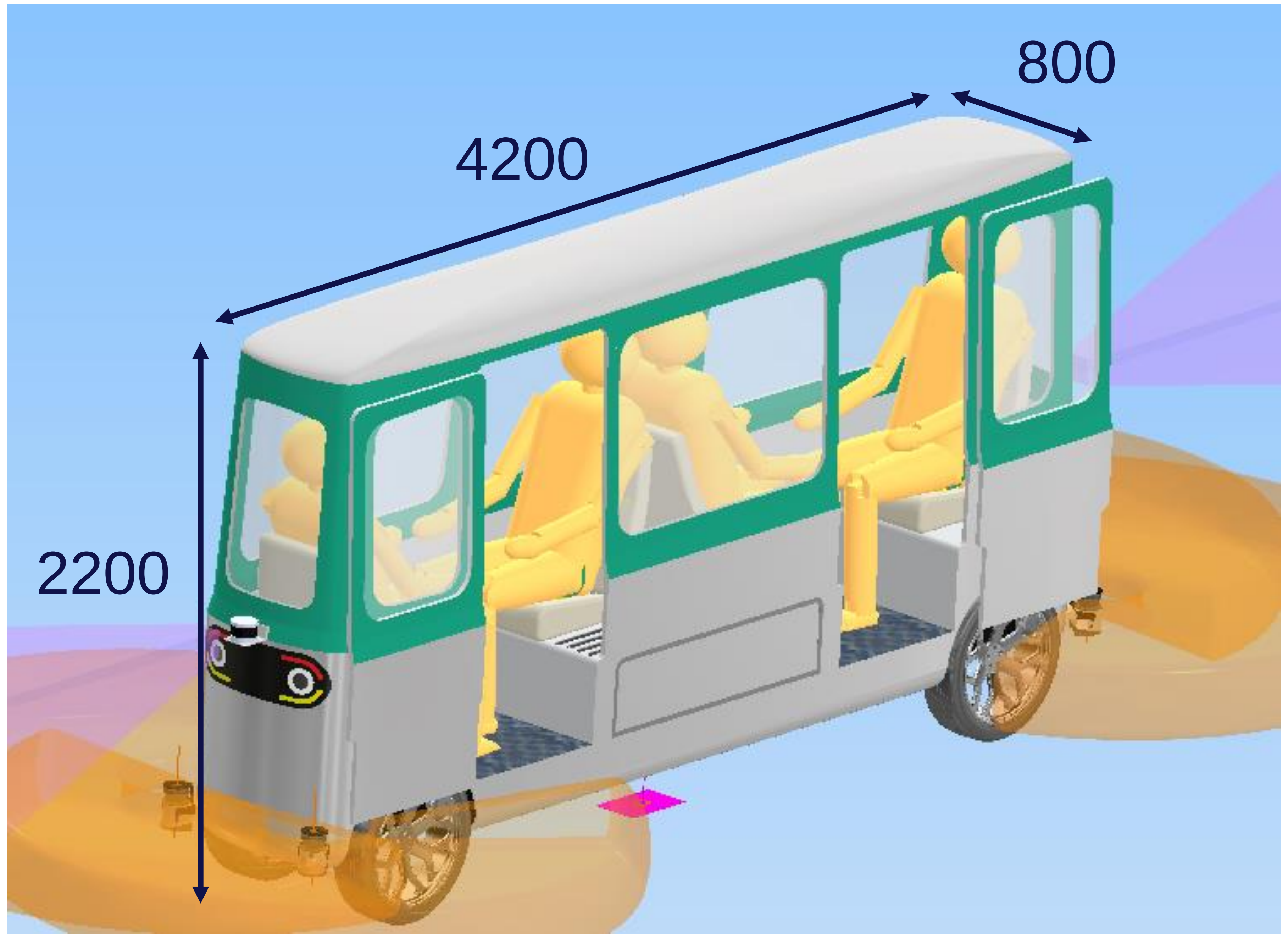


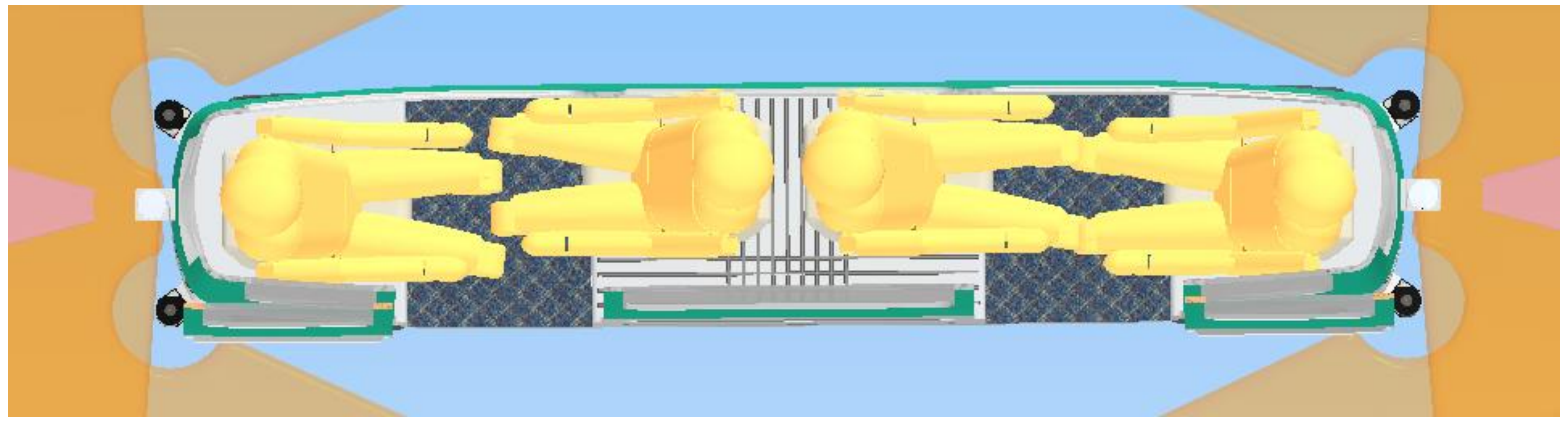
Dimensions, capacity and storage

- 80 cm width makes it possible to pass other vehicles in the 2,25 m wide tunnel
- Room for error per vehicle: (225cm - 2*80cm) / 2 = 32,5 cm
  → narrow but manageable with automated driving
- Cabin with windows to be able to drive through smoke in case of evacuation
- Sliding doors for maximum comfort and minimal usage of space
- Capacity of 4 passengers and additional space for luggage

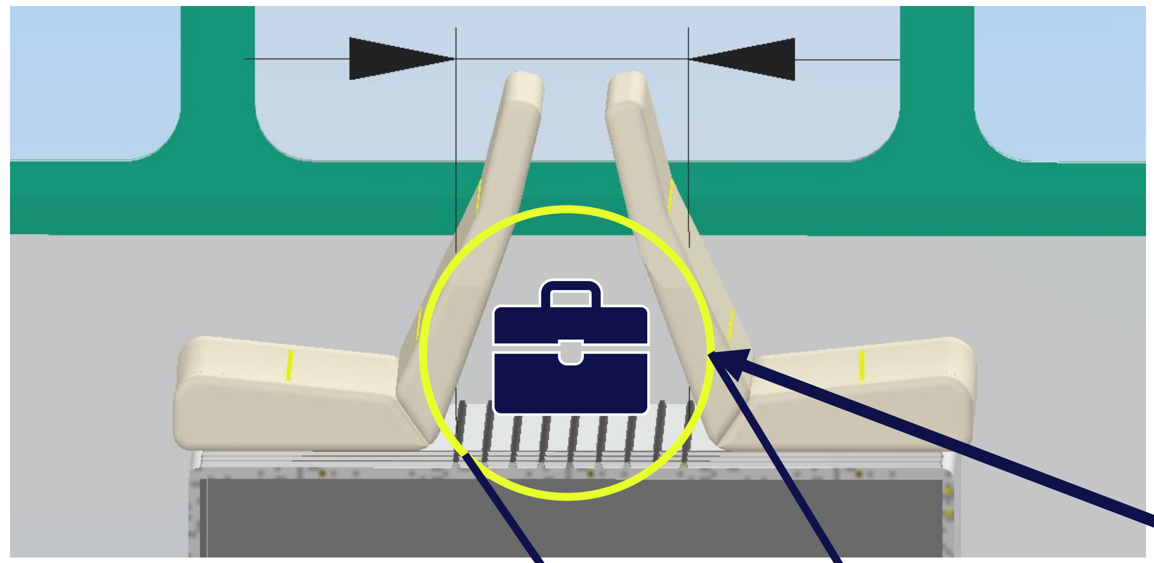
Notes:

- Capacity of 6 people would have cost manoeuvrability and the ability to pass other vehicles
- Hight of people in figure is 192 cm (exceed the 95th percentile)

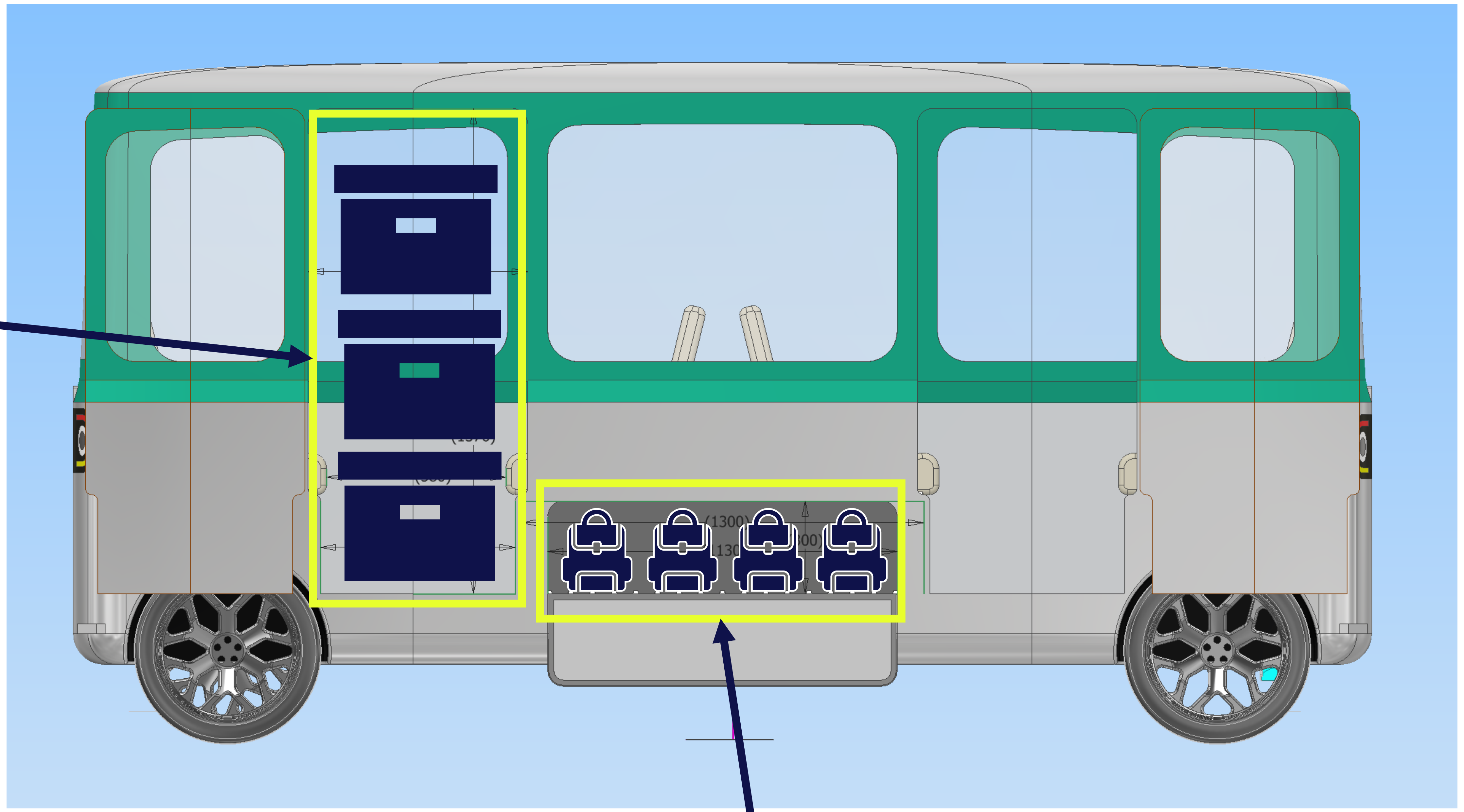




Dimensions, capacity and storage

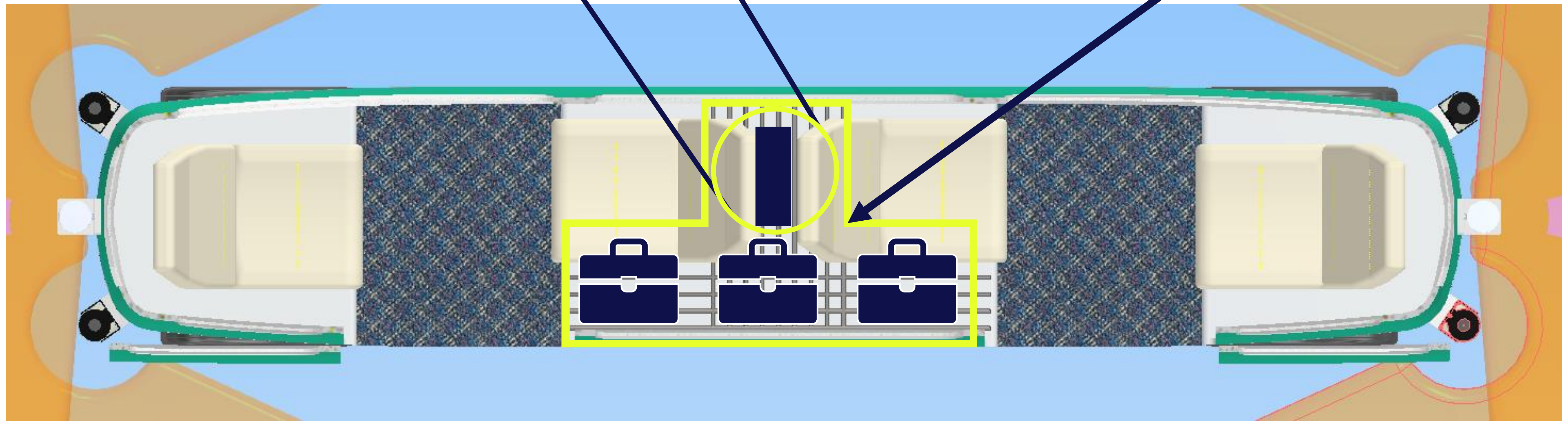


- Larger cargo can be transported in the cabin instead of two passengers
- Max size: 580x700x1500 mm^3



- Max size: 408x522 mm^2

- Space for small luggage (briefcase size)
- Inside the cabin
- Max size: 238x1300 mm^2



- Space for 4 pieces of hand luggage (standard airplane size)
- Accessible through flap from outside
- Max size: 1130x760x300 mm^3

Motorization and drive

- Defined maximum speed: 30 km/h
- Fully loaded vehicle weight: 1500 kg
- Both axels are steerable 17°

- Expected necessary power ≈ 15 kW
  → 4 wheel hub motors ≈ 16 – 24 kW

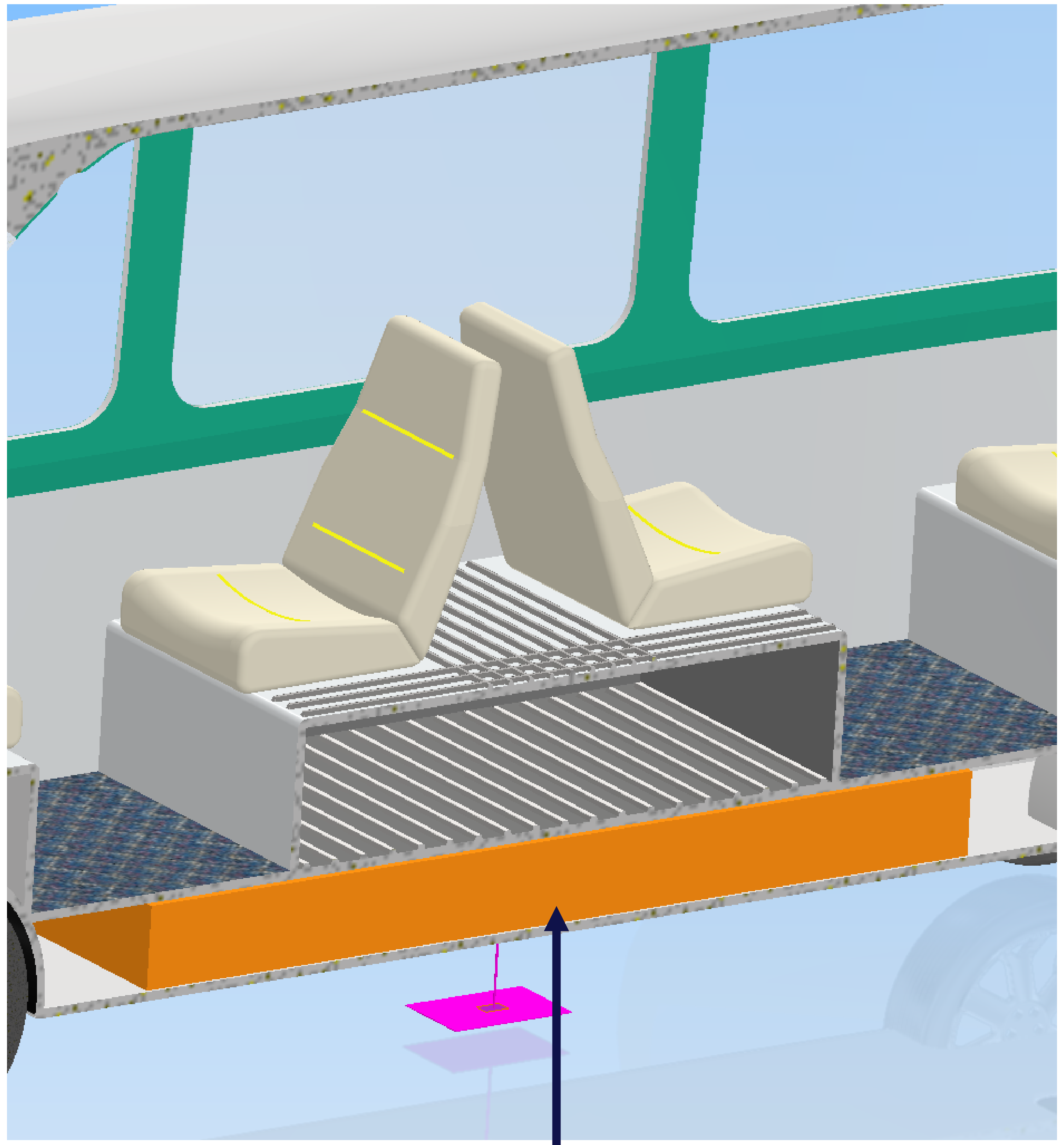
- 216l batterie ≈ 48 kWh
- Expected energy consumption << 20 kWh / 100 km
  → expected range 150-200 km

- Batterie technology will improve in future and must be further analysed

- Challenge tilting speed: 24 km/h
- No sudden maximum change of direction at high speed when fully loaded → implement in software
- Following the tunnel radius in regular operation at full speed is possible

Source: https://www.pinterest.de/pin/470907704781127446/

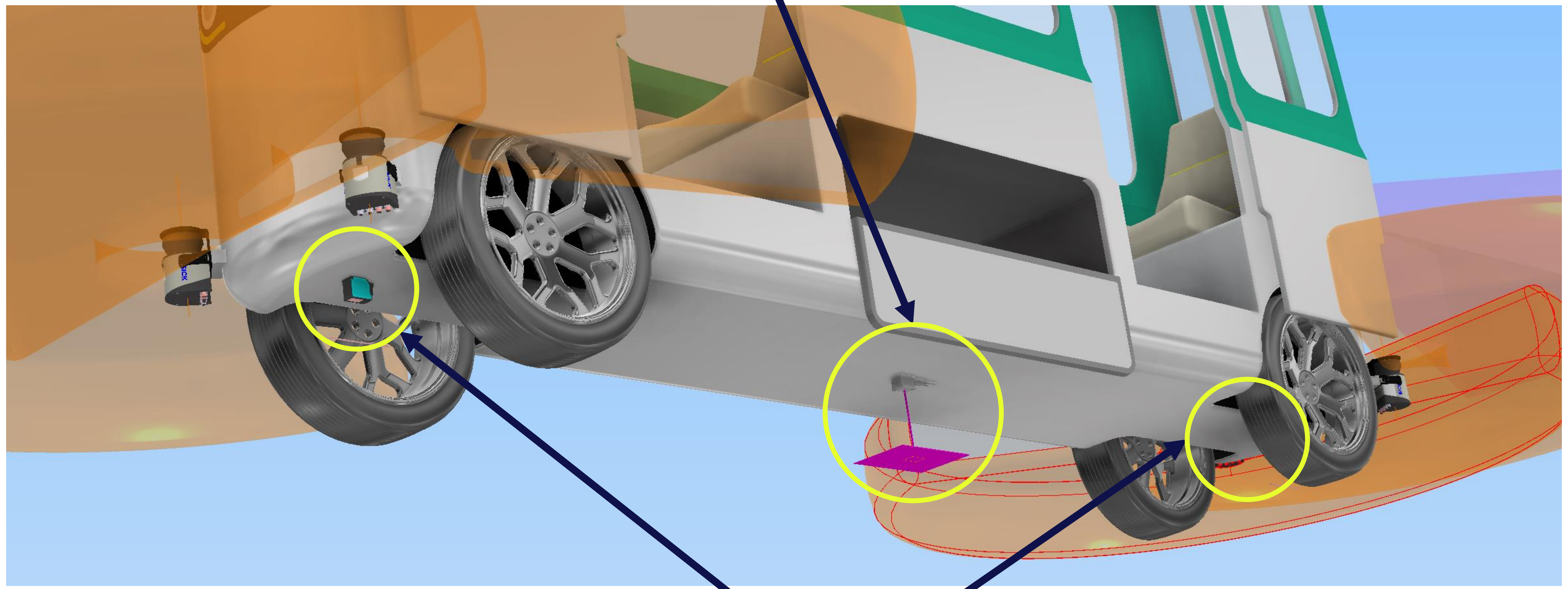
- Power of current wheel hub motors ≈ 4 – 6 kW



- Space for battery: 2000x180x600 mm^3 = 216l
- Current batteries energy content ≈ 225 Wh/l

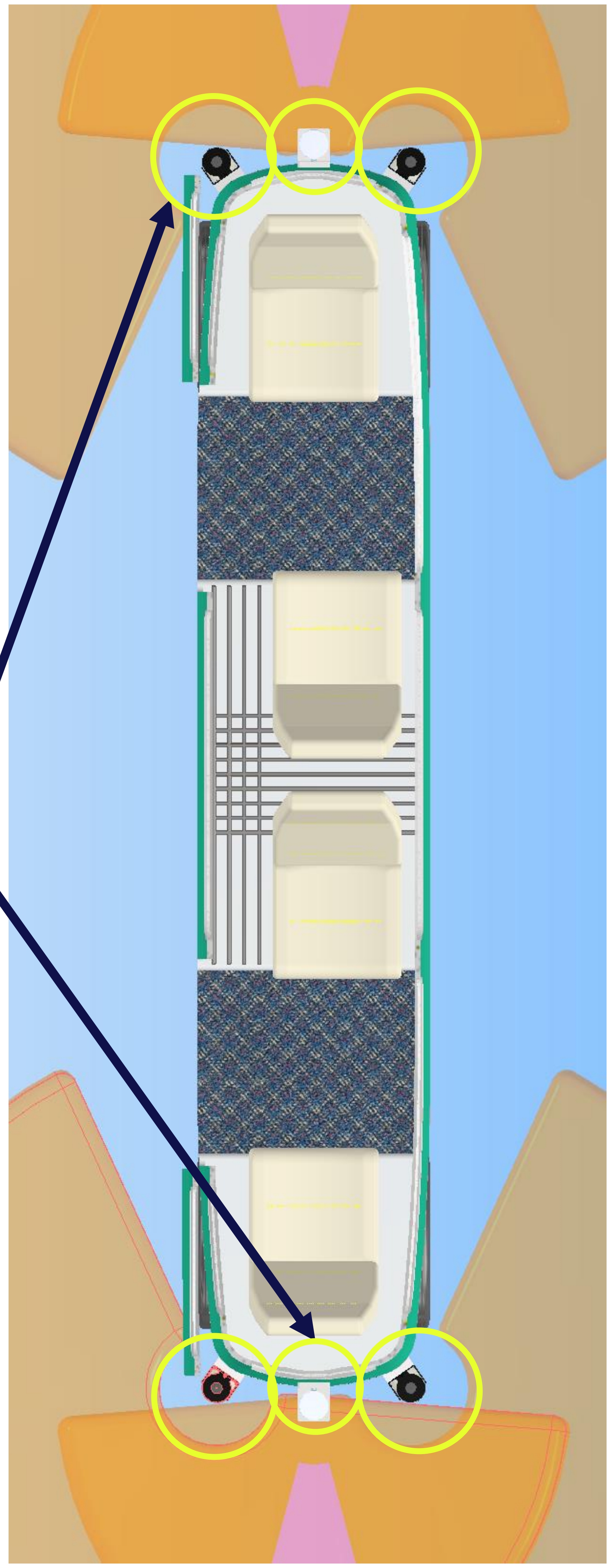
Autonomous driving capabilities

- Sensor to read barcode on the ground for localization of vehicle
- Between two codes odometry is used to determine the position



- Sensors at front and back detect line on floor that guides the vehicle

- LIDAR scanners at front and back to detect objects or people
- 2 short range sensors (20 m) per direction at the edges
- 1 long range sensor (100 m) per direction in the middle
- Sensors are also used for objects hanging from the ceiling
- 3D scanner on the roof is an additional option if the LIDAR sensors aren't sufficient
- Sensors that can handle smoke are available (e.g. infrared, radar)



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ADDITIONAL TOPIC

New scenario

Assumptions

4 experimental shafts for lowering dipoles
4 technical shafts for lowering girders

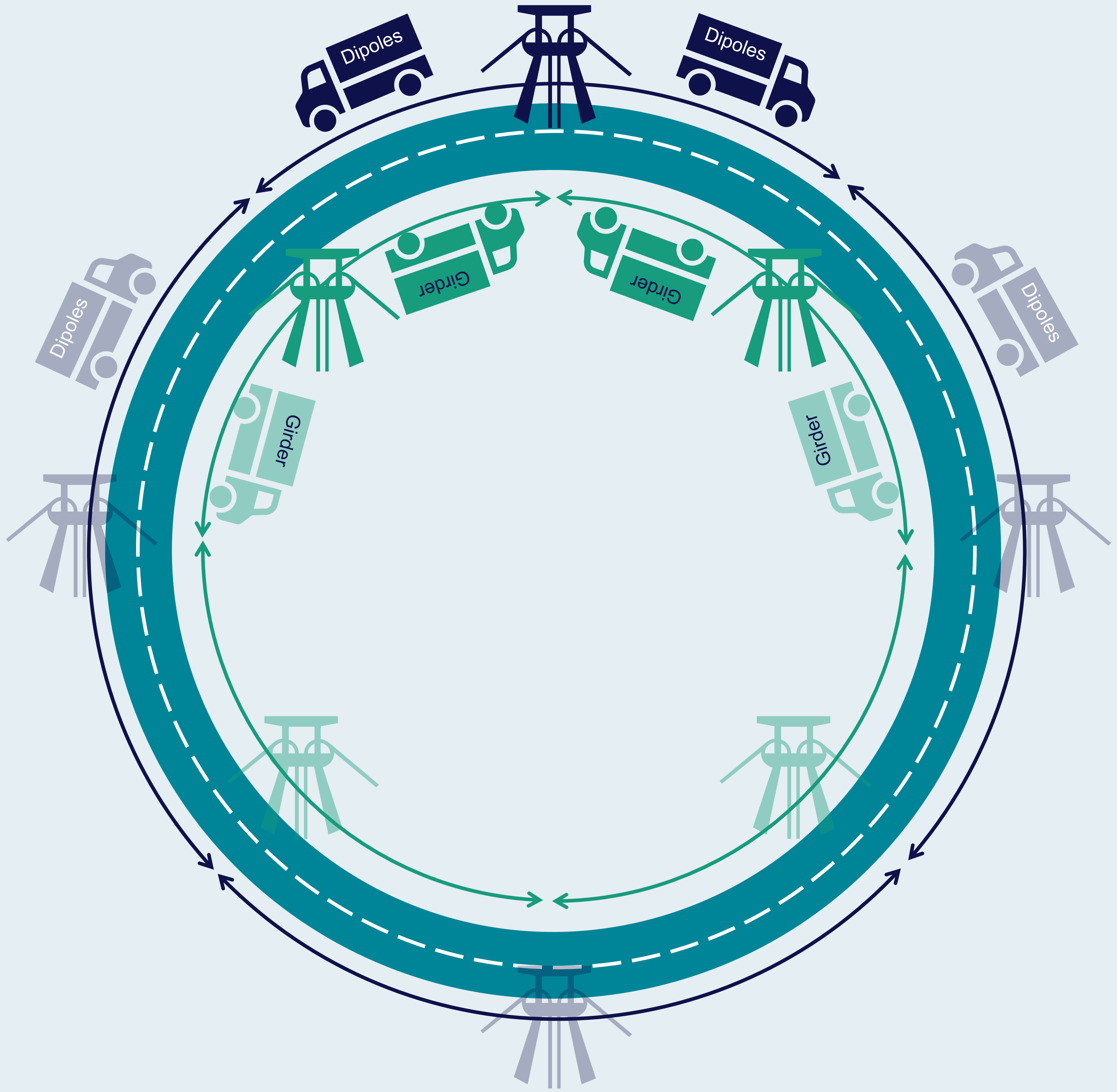
Simulation only covers magnets so far, further materials may be considered in future experiments

Limited availability of the crane at experimental shafts (50%)

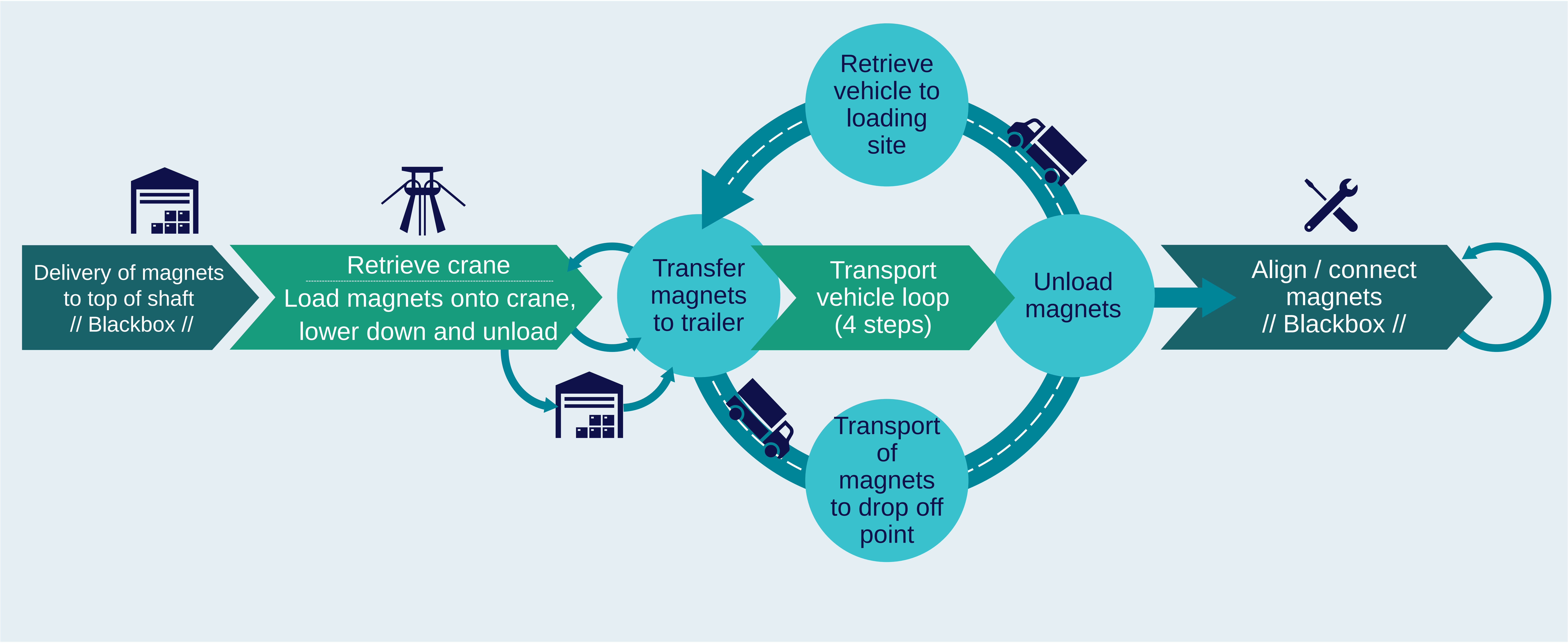
Connecting and aligning magnets is excluded for now and may be considered in future experiments

The traffic of each shaft will be influenced by traffic from adjacent shafts

Simulation is based on average parameters (e.g., crane cycle time), individual shafts may be considered in future experiments



Process for the simulation study



Parameters for the simulation study

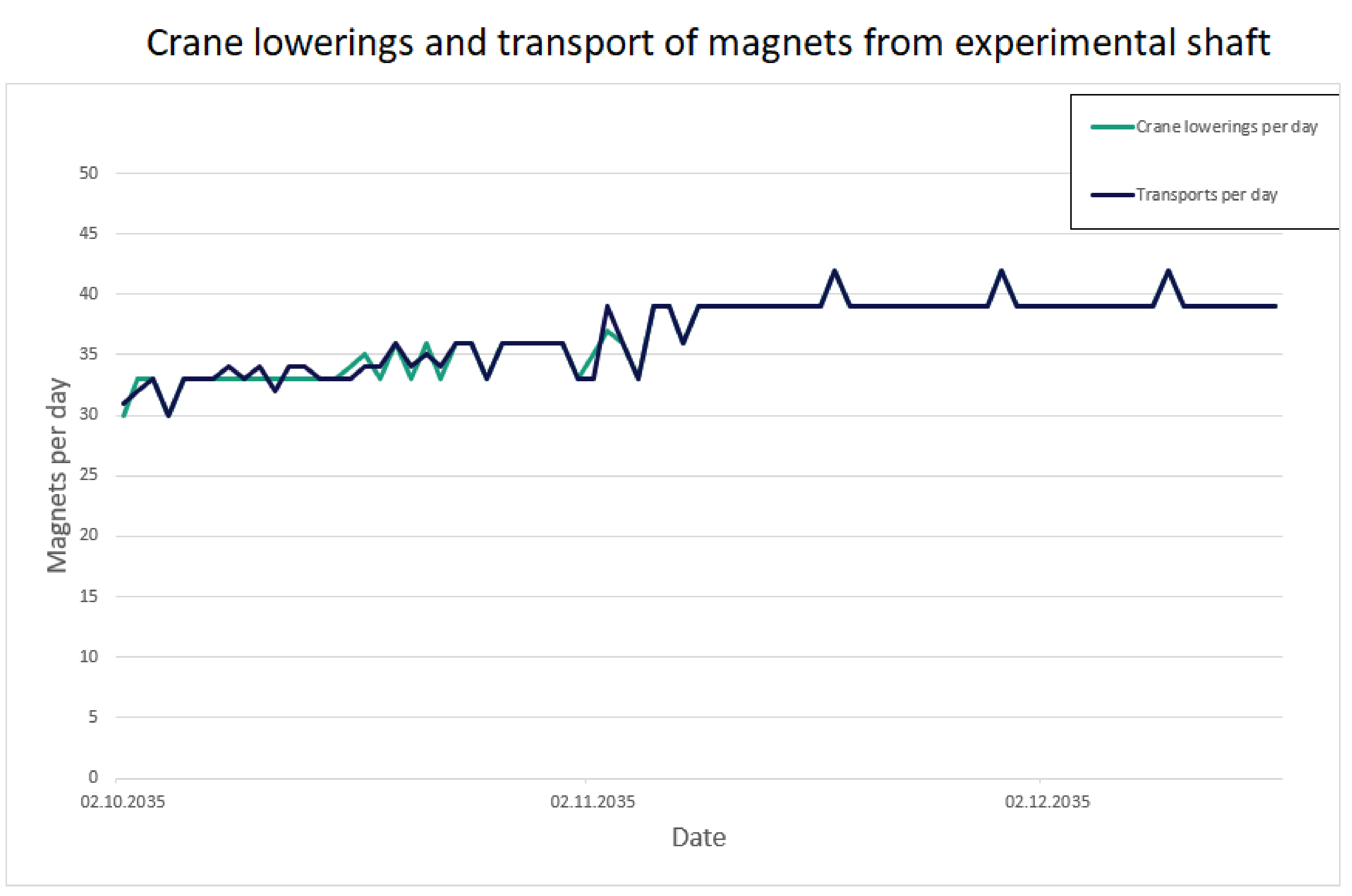
Parameter	Value	Information maturity
Length of tunnel	91200 m	Given by CERN
Enlargements for transport passing	One on each sector	Given by CERN
No. of magnets overall	17352	Given by CERN
Load crane, lower down, unload and retrieve crane	55 min	Rough guess by CERN
Magnet transfer time from crane to vehicle	25 min	Rough guess by IML / CERN
Unloading time vehicle	23 min	Estimate by IML
Vehicle driving velocity loaded	10 km/h	Estimate by IML / design value
Vehicle driving velocity unloaded	20 km/h	Estimate by IML / design value
Underground buffer capacity for magnets at shaft	3 transport units	Rough guess by CERN / IML
No. of shafts for magnet transport	4 experimental for dipoles + 4 technical for girders	Given by CERN
Availability of crane at technical shaft	100 %	Given by CERN
Availability of crane at experimental shaft	50 %	Given by CERN
No. of vehicles operating per shaft	2	Result value

Results

Experimental shaft for dipoles

- Transport time net working hours: 1872 h
  → in workdays with 1x8 h shift / day: 234 days
  → in workdays with 2x8 h shift / day: 117 days

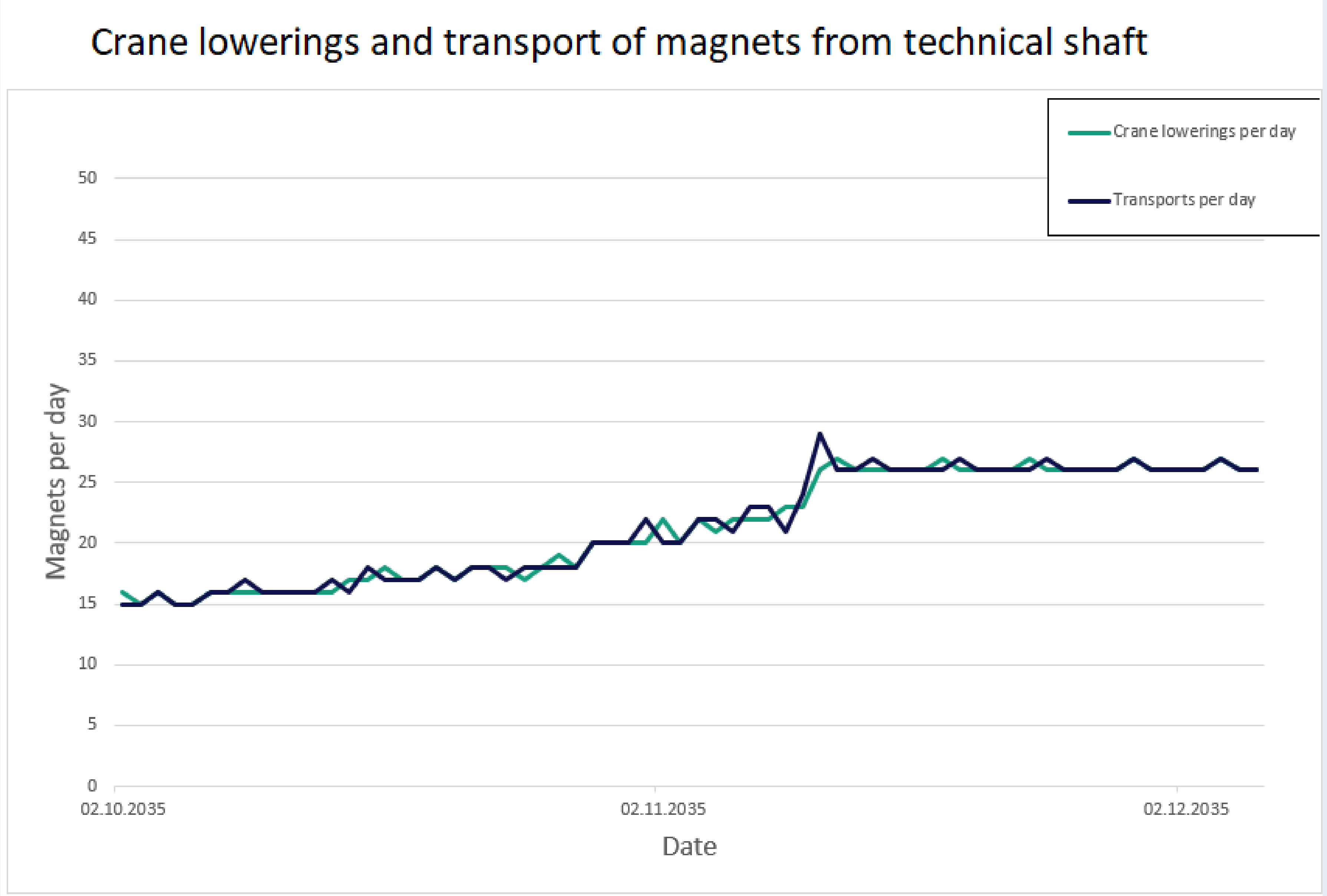
- Avg. magnets transported per day: 37 dipoles



Technical shaft for girders

- Transport time net working hours: 1608 h
  → in workdays with 1x8 h shift / day: 201 days
  → in workdays with 2x8 h shift / day: 100,5 days

- Avg. magnets transported per day: 22 girders



Further experiments

Next potential steps for exploration (non-exhaustive list)

- Include mature information on magnet alignment and connection
- Add transport of further material (technical infrastructure etc.) to simulation
- Fine tune parameters and do further experiments with different parameters (in general)

- Conduct experiments with individual parameters for each shaft configuration in the schedule
- Check how crane failure affects the overall duration
- Review the importance of the underground buffer with different crane times

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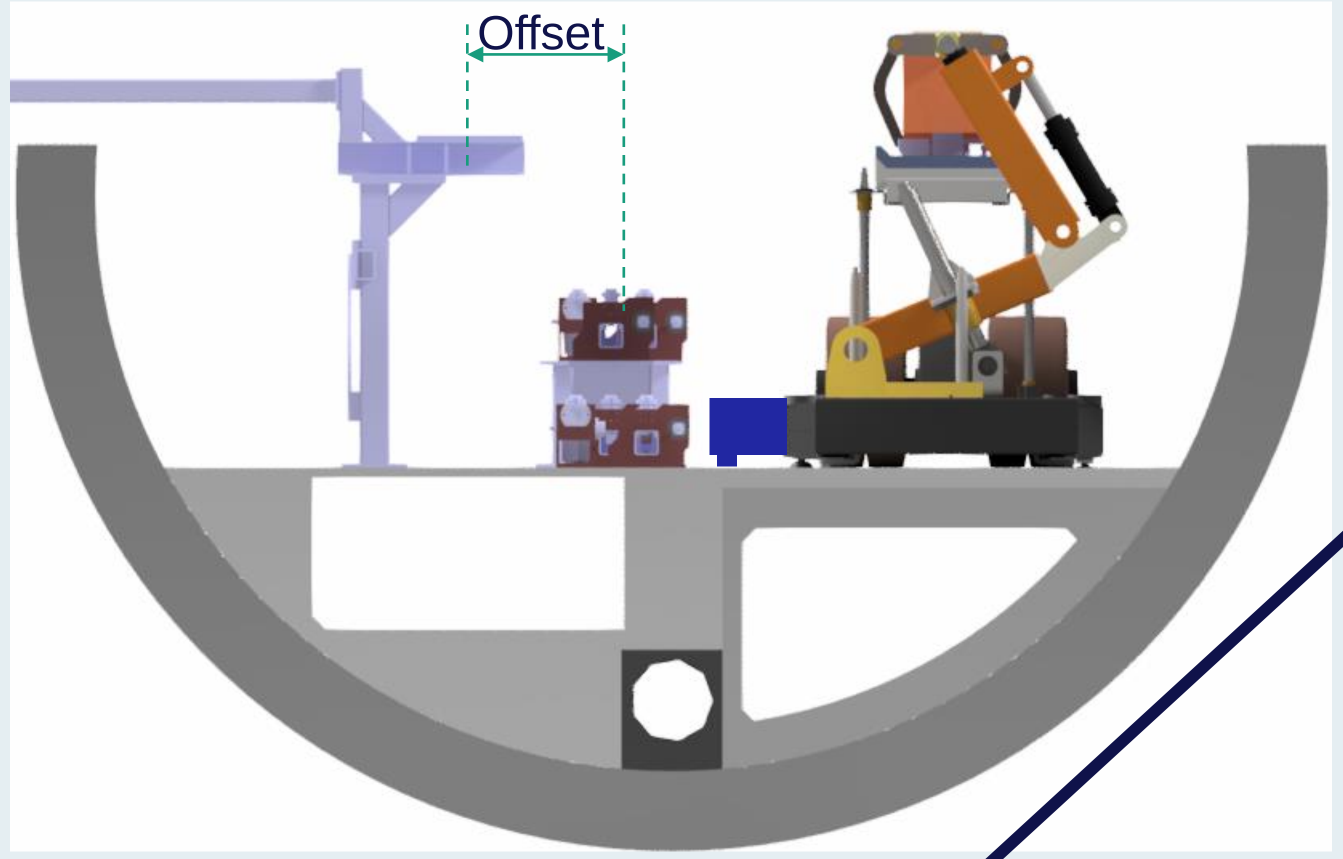
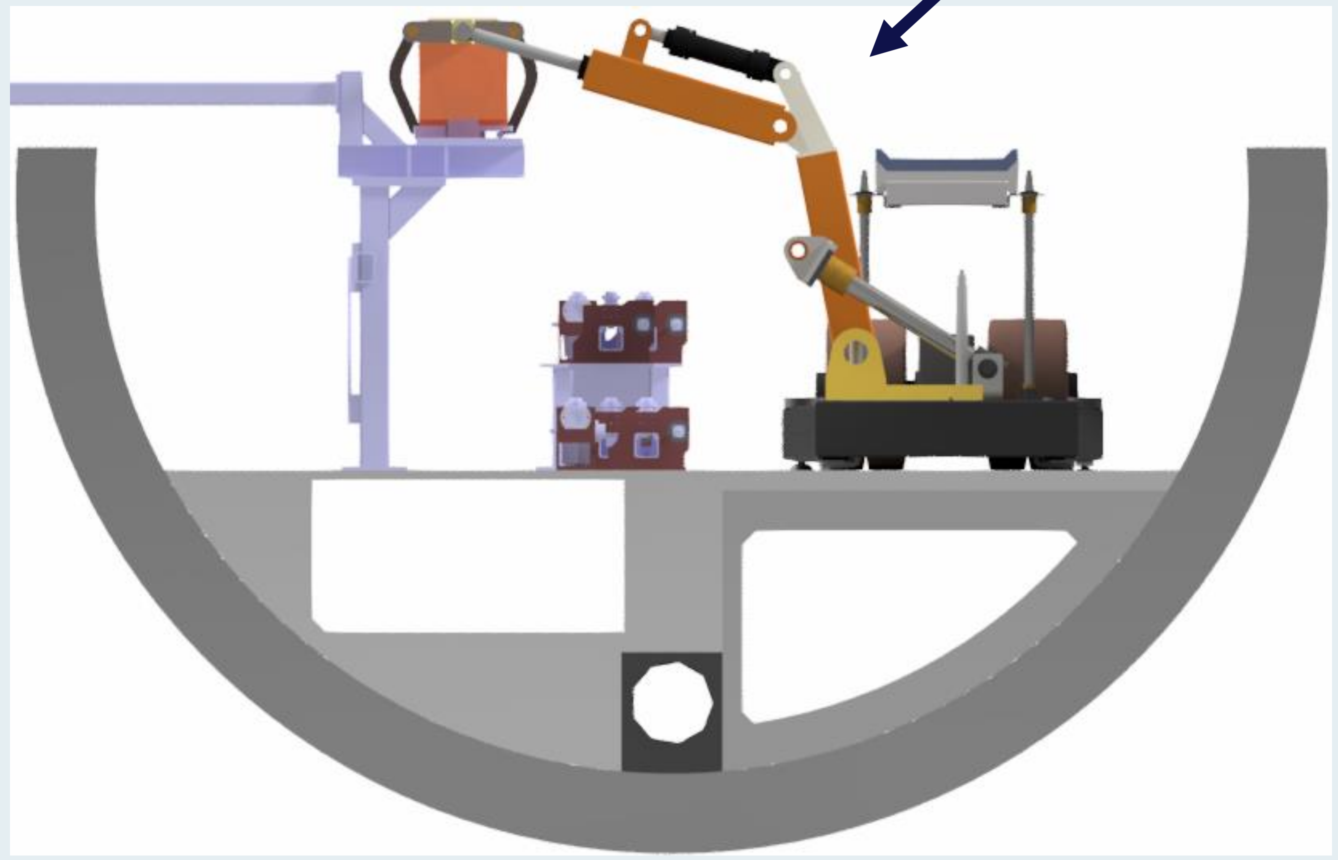
ADDITIONAL TOPIC

Challenge: Offset of booster ring

Placing of booster ring elements



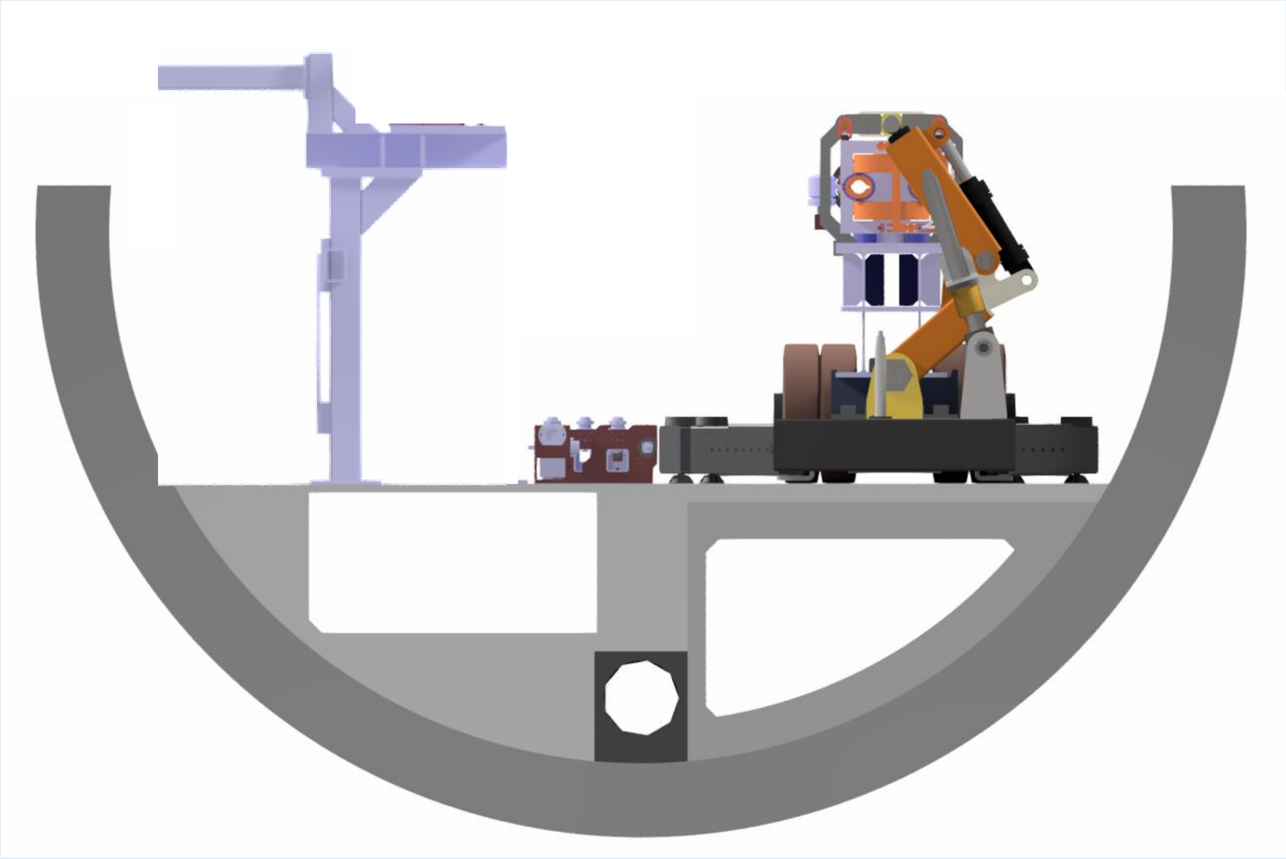


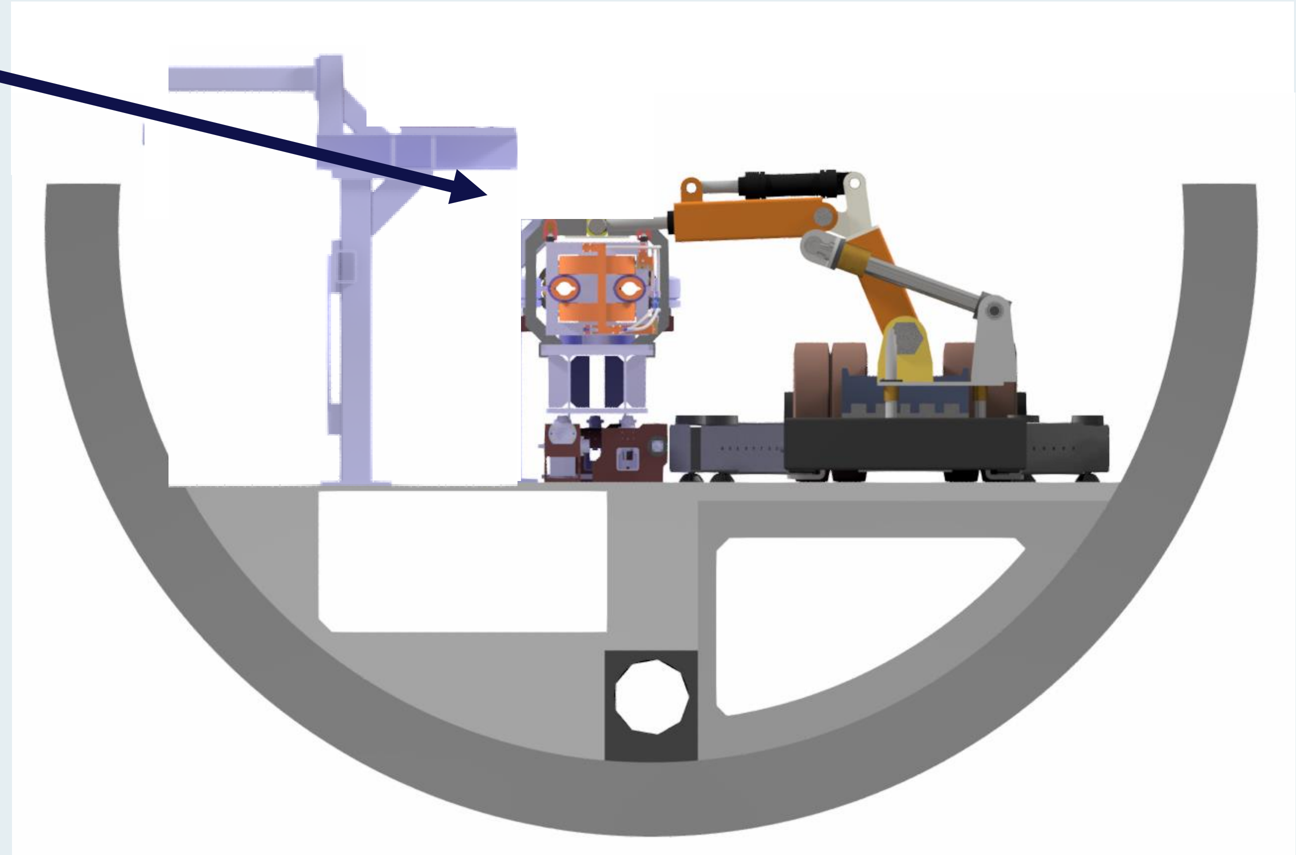
- Transport vehicle can realize an offset and reach over the collider ring to place elements of the booster ring on the instalment racks
- Offset cannot be too large, because reach is limited

- Also, offset cannot be too little, otherwise there might be space problems when placing the elements of the collider ring

- Offset must be double checked before freezing the design of the vehicle and the position of the instalment racks

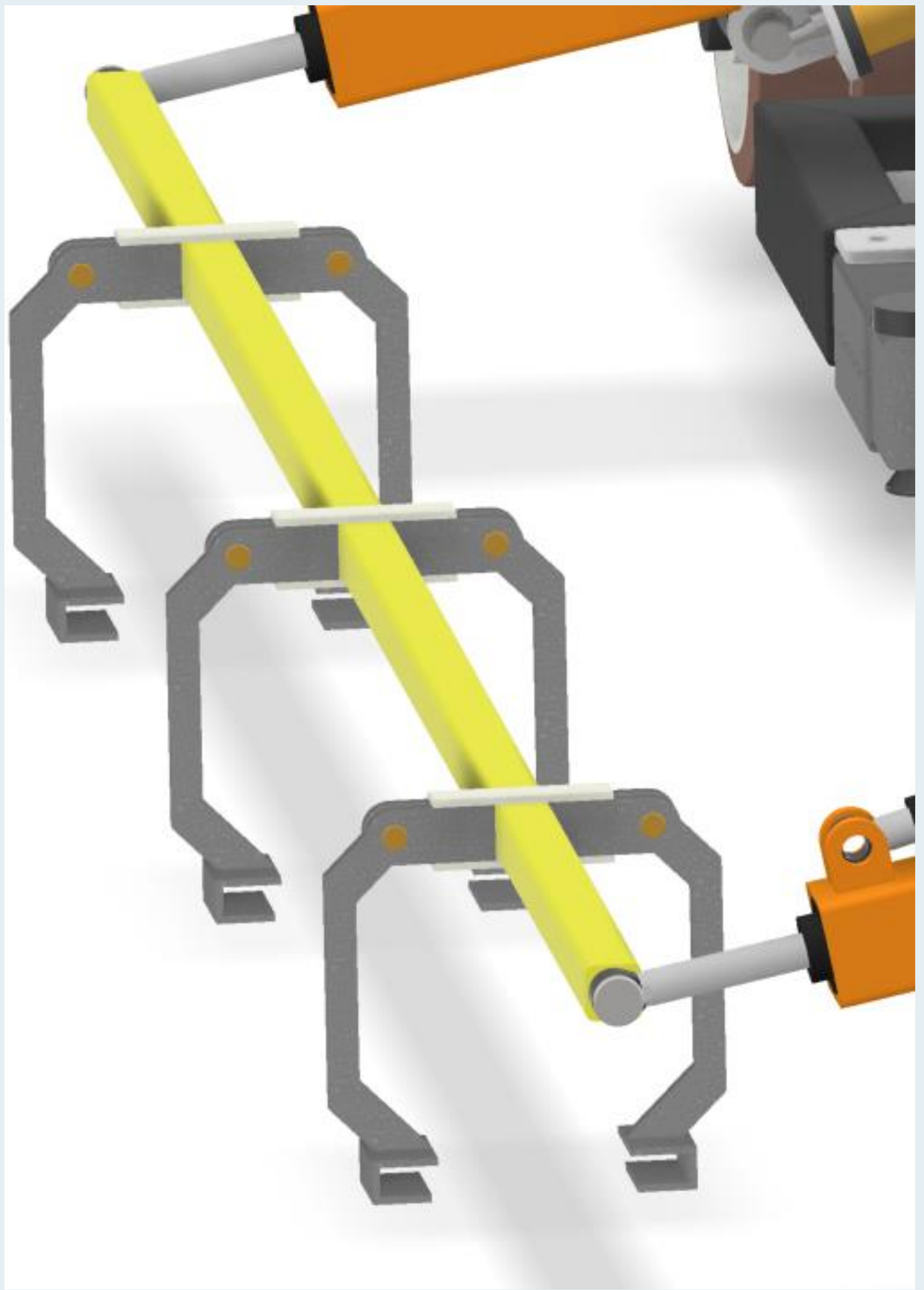
Placing of collider ring girder





Spreader beam and gripper concept

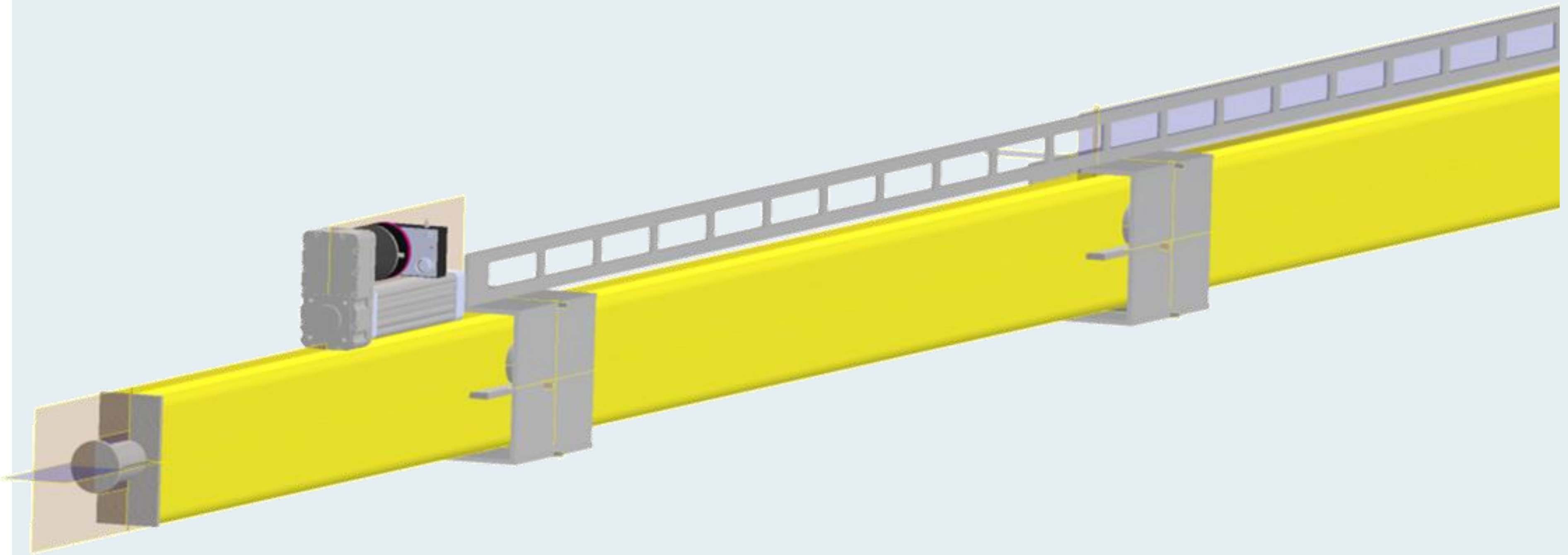
Spreader beam with gripper for collider steel girder

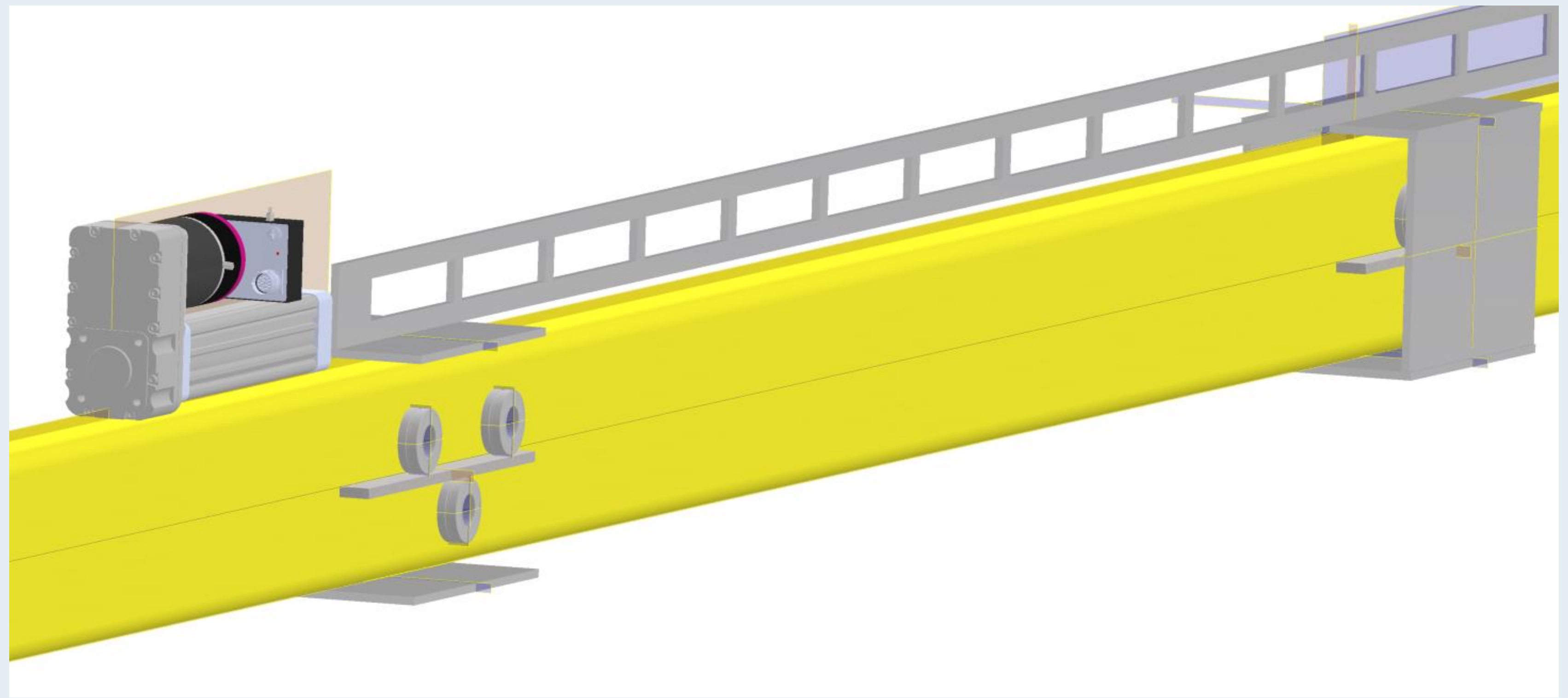


- Spreader beam with multiple points of contact is used for all elements to get even distribution of weight
- There are different versions of the spreader beam (length and gripping / connecting system) to fit the different transport elements → next slide

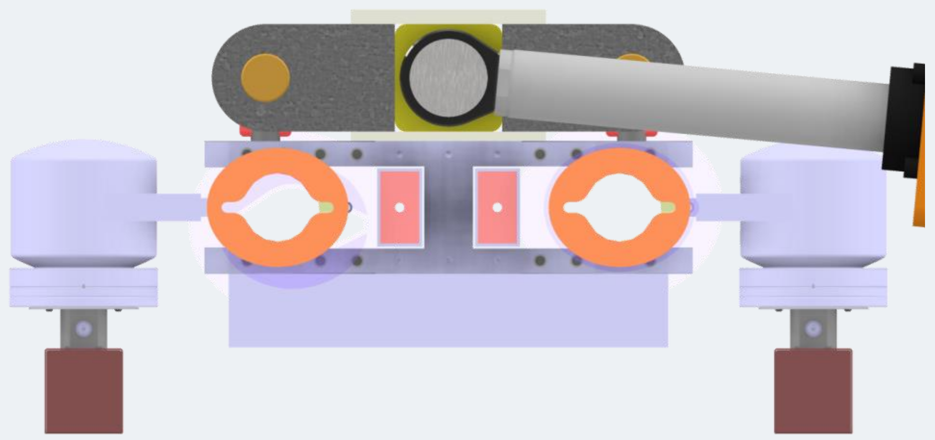
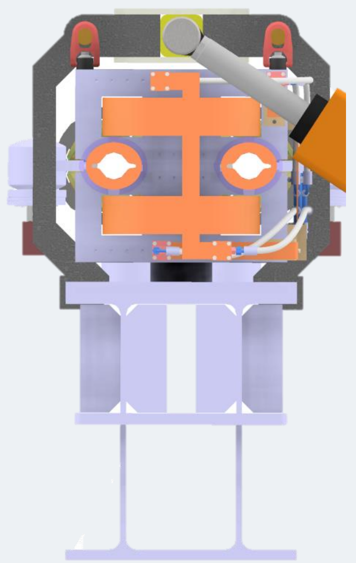
- Spreader beam has linear bearings and an electric motor to do lateral fine adjustments to the position of the transported element before placing it → vehicle does not have to do the fine adjustment by driving forwards or backwards

Spreader beam with lateral bearings to fine adjustment of position





Spreader beam and gripper concept

System type for magnet handling	Connector (structure / passive)	Gripper (mechanic / active)	Connector / gripper (magnetic, pneumatic, …)
Pro	▪ good for automatization ▪ reliable in case of electric shut down ▪ No moving parts / motors in connector	▪ no elements integrated in magnets / small effort in design of steel girder for position of gripping process	▪ no elements integrated in magnets / small effort in design of steel girder for position of gripping process
Contra	▪ Connecting parts must be designed into magnets / girders	▪ automatization of fixing and loosening the gripper at the magnet ▪ Not as reliable in case of electric shutdown as connector ▪ Moving parts and motors for gripping	▪ high amount of energy (electric for magnetic force or for vacuum technology) ▪ not reliable in case of electric shutdown ▪ No positioning in connection between gripper and structure
Example	Connector system for dipoles using bolts on dipole to lock in 	Gripper system for collider ring girder with magnets 	

Thank you for your attention

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