GENERAL TRANSPORT SYSTEM
FOUNDATION

Inventing a General Transport System

ACRONYM: **GTSTEC**

Abstract

Today's transport suffers from inherent shortcomings due to friction dependence in the core technology and fragmentation in the service functionality. We propose a novel General Transport System (GTS), where a magnetically levitated and propelled drivesled is the heart. GTS will revolutionize land surface transport, using an overhead guideway and suspended, self-driving multi-purpose cabins.

The cabins will move individually at reduced speed in urban areas, but may also platoon, reaching a capacity close to that of a subway. Over long distances, consecutive platooning enables speeds up to 240 km/h. Switching will also be performed using a new magnetic technology without moving parts. This proposal is for development-research concerning the necessary new components and sub-systems. We will also describe the benefits of GTS in a broad societal perspective.

Previous monorail systems have been criticized. Low capacity, the need for a new exclusive infrastructure and "weirdness", are common comments. GTS however, starting as just a supplement, has a platooning function that increases the capacity enormously. Urbanization and maintenance of old transport infrastructures demand ever increasing - immense investments. Implementing any new disruptive system will naturally meet resistance. The project will therefore address this and we believe that continuous information with feedback sensitivity will pave way for this Internet of Mobility.

Replacing the slippery wheels with magnetic propulsion and braking, is a prerequisite for exact platooning. The severely disregarded wear on both wheels and tracks, is replaced by magnetic levitation and switching. A standard GTS-drivesled will incorporate magnetic-lead-screw propulsion, hybrid electro-magnetic suspension, magnetic switching, technology for automated platooning at speed and coupling to the cabin.

Different types of cabins may be suspended from the drivesleds and may be designed for person and goods transport. On local suburban and urban journeys, the passenger flexibility of the car will be retained and the parking problem is eliminated, as each cabin transfers to the next user, or remote parking, when vacated. Cabins can easily accommodate passengers and their bicycles, prams, wheelchairs or luggage. GTS travel time over the full distance is reduced compared to cars or high-speed trains. All current transit systems and also frontier concepts demand modal shifts. GTS passengers, however, will travel the whole urban, interregional and long-distance journey without having to change vehicle.

The proposal is quite complex, engaging some 30 researchers in several countries. Advanced electric, magnetic and operational experiments together with laboratory test of a demonstrator and a full-scale mock-up cabin will be made as a unique design. Everything will be open to public review, both at site and on the net. Interdisciplinary studies will compare both Conventional Transport Systems (CTS) and frontier technologies with GTS.

The best way of grasping the GTS concept is (still) by viewing the video Bubbles and Beams, produced for SIKA, Swedish Institute for Transport and Communications Analyses, 2007-2008 (now Trafikanalys Authority):

http://www.youtube.com/watch?v=rtrB82YObXw

Section 1 **Technology of GTS**

Introduction

This proposal addresses the topic FETOPEN-01-2016- 2017: FET – Open research and innovation actions (RIA). A **General Transport System** (GTS) challenges Conventional Transport Systems (CTS) and other frontier proposals, not only on land, but also on short sea and air links. Providing a general functionality is essential, as opposed to fragmentation with multiple transfers. This great challenge is met in four major stages. The current proposal concerns only the first stage arriving at a Proof-of-Principles, see below:

Proof-of-Principles; Laboratory inventions; Introductory analyses; Communications; **2018-2021**
Proof-of-Concept; Prototype & Pilot guideway; Advanced inventions; Full functional analyses; Communications, Uppsala; Industrial partners; **2021-2024**
Small-scale pilot plants; Standard, License and Commercial structure; Communications; Uppsala, other locations; Transport operators; **2023-2025**
Large-scale pioneering experiences; Start of commercial exploitation; Communications; **2026-**

New great paradigms of transport have been introduced once or twice every century since the industrial revolution, steam propulsion, railways, automobiles, diesel engines, electric propulsion and air transport. Since the global jet plane network developed in the 1960's no groundbreaking new technology has developed, even though important but incremental changes have refined century old technologies. Technology of physical mobility is surprisingly stagnant while information technology is leaping forward rapidly.

We think a unique new transport technology may develop soon, and that the key lies in electro-magnetic propulsion, braking, switching and platooning offering a general functionality by platoonable cabins, without friction dependence and with on-demand service instead of fragmented service.

It may be harder to describe GTS than to actually develop it. For us in the consortium it is easy because we have been living with the developing concept for years and decades. For others blind spots may occur initially, because they are accustomed to conventional transport technology and functionality in everyday life, causing our unique solutions to seem impossible or obsolete. Thus our communication activities will be crucial for a successful realization.

Our concept is far-reaching, comprising collaboration between many technological inventions and physical design. The framework of the call (3M€) only permits perception in the human scale, logistics, ecological analyses, social behavior science and financial analyses to be introductory touched upon but fully developed in a second stage, see above.

Our GTS concept fulfils the requirements of "FET gatekeepers" in abundance. It is difficult to imagine a more revolutionary change in transport technology and function. Automated driving, electrification of cars and roads, or vacuum tube solutions, are in fact incremental in comparison with full-fledged GTS. CTS is outdated by its dependence on friction and fragmented service.

1.1 **Long-term vision, targeted breakthrough and specific objectives**

The long-term vision is a universally applicable transport system that includes local, regional and long-distance highspeed lines in one service. The same vehicle will transport from "door to door", without transfer, just like a car. The only way to compete seriously with the car is to admit its formidable advantage and emulate it.

Most proposals to develop ground transportation depend intransigently on wheels rolling on roads and railways. GTS employs electromagnetic levitated propulsion, free from wear of wheels and ground. Other advantages include freedom from conventional fragmentation of journeys and hazardous function of ground transportation.

A completely new infrastructure is needed, ousting ideas of new vehicles using roads and rails. Light cabins are suspended from drivesleds, running electromagnetically and platoonable at speed inside slender, elevated guideways. Platooning yields a capacity like a subway train, simultaneously allowing for velocities like a high-speed train. Cabins are automatically and seamlessly directed from many small stations through a network of local, regional and high-speed lines to other small stations. Travelers enter and exit comfortable at grade. All stations will be placed on sidetracks and booths will be organized in a fishbone structure next to the sidetrack. Like in all rail-systems vehicles and platforms have to be carefully compatible. Platforms can be placed at ground level but may then create barriers. Often staircases, lifts and escalators will be used to reach the station, or the ground. The area around the booths may often develop as local service centers.

The cabins have an optimum volume for both private and public travel (5-12 pax), with bicycles, prams, (electric) wheelchairs and all baggage. For long distance journeys, facilities like WC, kitchenette and beds may be fitted. Cabins may also be built for carrying small vehicles, goods on pallets and waste etc. or, alternatively, also be itself an electric vehicle on wheels (dual-mode), self-driving "the last miles". GTS is available, for all people any minute, hour, day or night, like "60/24/7", with no need of a driving license. Notably GTS enables great mobility for any disabled person. It uses only a small amount of electric energy, which may be harvested on or close to the guideway itself. GTS produces no exhaust fumes and very little noise (mainly from air compression at high speed; propulsion, braking, switching and propulsion are all performed by magnetic power, never by noisy friction dependence). Transport capacity is superior to most conventional modes. Furthermore the efficient travel times are much shorter for most journeys. In order to enable travelling at high speed without creating barriers, guideways, including suspended cabins, will normally be elevated 4,5 meters which is above the European standard for free road passages.

GTS releases ground for public ground space to be enjoyed for bicycling, meetings, play and recreation. GTS will endow towns and landscapes the functional beauty of a sustainable connectivity. This will partly compensate for the new visual intrusion. For the future success of GTS it is essential though, to show that the visual impact can be handled in all kind of environments. Like there are countless different ways to design a bridge, there will be so many ways to design beams, pillars and cabins. Our goal in this stage is to show some examples, pinpoint principles, restrictions, challenges and possibilities.

Our *targeted scientific breakthrough* is a **Proof-of-Principles** for fully automated, magnetically propelled, levitated and switched drivesleds. They are the technical heart of GTS. The drivesleds interact with both the elevated guideway and the cabins below. One of the fundamentally groundbreaking GTS features lies in its advanced control methods. Together they form an "Internet of mobility" or "Mobility as a Service" (MaaS) with both a physical and digital infrastructure for the modern age.

The required research is ambitious and challenging because:
A) the same technology must cope with speeds ranging from low (local) to high (interregional) without compromising safety and comfort, and **B)** dynamic platooning and separation at speed are safety critical manoeuvres.

The sum of these advanced, combined, and fully integrated attributes characterizes the Technology of Excellence in our project. This technology is absolutely needed if the general functionality of GTS shall be fulfilled.

The project has the following specific objectives to be achieved within the duration of the project:

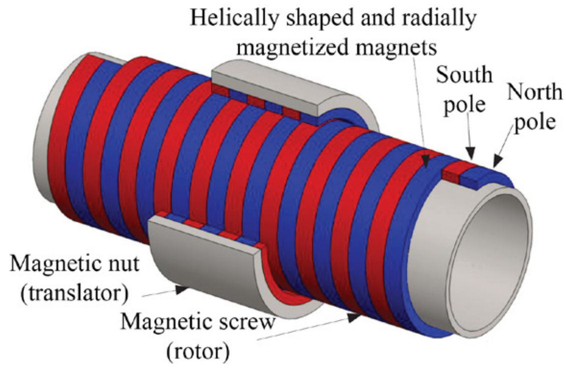
1. Develop the standard GTS drivesled;
2. Develop the GTS automation and control system;
3. Design the GTS cabins and guideway components;
4. Disseminate, exploit and communicate the findings.

See more on how to achieve these specific objects in 1.3 Research methodologies.

1.1.1 **Magnetic and other Core Technologies**

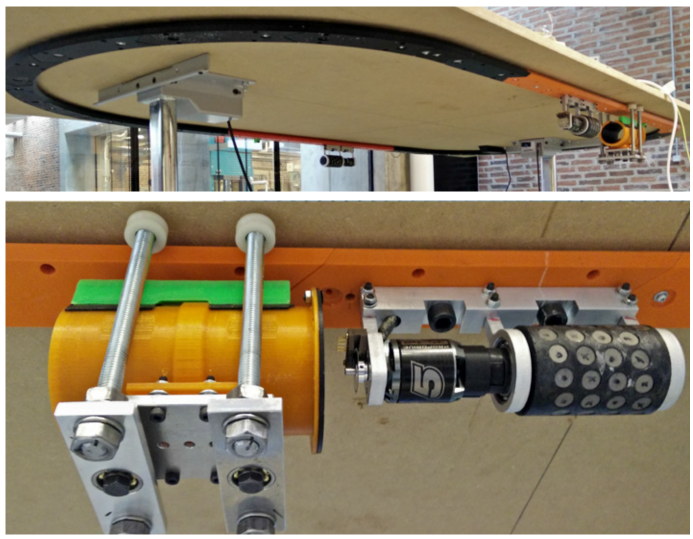
The known "Maglev" system using only electromagnets has proved to be a rather expensive, complicated technology (e.g.Transrapid). Alternatively electro-dynamically levitated vehicles require a rather high speed before they start to levitate (e.g. Japanese SC). The proposed hybrid electromagnetic suspension, or HEMS, will radically reduce costs in comparison with "Maglev".

Magnetically levitated systems have previously been too expensive for widespread use, due to the high cost of track, cumbersome mechanical switching, inflexible train sizes and small production scale. These hindrances will be overcome using new hybrid principles combining intelligent digital control systems with electromagnetic actuators.



The simple magnetic lead screw, Aalborg University

Magnetic propulsion and regenerative braking is preferred instead of friction dependent technologies. This result in reductions of maintenance, slip/slide wear, lubrication problems and mechanical fatigue. The main goal for the research is to evaluate different types and invent new types of technology for precisely controllable Linear Synchronous Magnetic propulsion (LSM). The challenge is to find a low-cost, high efficiency propulsion system, while avoiding a large electric power transmission to the moving drivesled. Initial calculations show that adapting the Magnetic Lead Screw (MLS) technology, developed at Aalborg University (AAU), reduces the mass of the propulsion system by a factor of 18, and the cost of it by a factor of five compared to current SOA Maglev systems. The combination of track design and intelligent control system are crucial challenges, as high electromagnetic power must be available for acceleration, braking and climbing.



Physical setup of GTS runway. Aalborg University

Magnetic levitation and guidance is well suited to GTS. It is silent, compact and light. By eliminating physical contact between vehicle and track, maintenance cost, noise and vibration are greatly reduced. GTS will research the use of Hybrid Electro-Magnetic Suspension (HEMS), using both electromagnets and permanent magnets. That yields low energy consumption. Initial calculations suggest that GTS will produce about nine times the lifting force for a similar cost of levitation system. Key challenges are safety, integration of levitation, guidance, propulsion and switching. That demands a robust and fault tolerant control of the drivesleds. Capabilities to withstand wind forces, and negotiate curves at flexible speeds, are crucial challenges.

Intelligent controlled **Magnetic switching** technology will be researched to achieve smart operational function, high level of safety and a low maintenance level. Such a switch cannot be blocked by frost or foreign objects in the same way that mechanical railway track switches can today. Magnetic forces will steer the vehicle either to the left or right, as selected, in divergences. Switches must be fail-safe and redundant. This method is new in contrast to the earlier "Maglev" that often switches the whole beam, which is a very slow process, precluding a high capacity of vehicles/hour. The reason for applying that type of switch is that the vehicles normally enclose the guideway rather than being enclosed by the guideway, as in GTS by drivesleds.

Magnetic platooning control of vehicles at speed will be researched, as this allows for both a high line capacity and a high velocity, with a small energy demand (normal trains also avoid large air-drag by combining cabins into a single train). Platooning and separating platoons at speed demands exact control of the relative position and speed of each vehicle.

Smart connection between the drivesled and the suspended cabins is also researched. This will control the cabins as they swing out in curves (similar to banking an aircraft, motorbike or a bicycle) enabling flexible vehicle speed in curves. The smart connection also allows the cabin to be lowered to ground level, using a built-in elevator.

Power supply will also be researched to determine suitable voltage and power ratings. Some tramways operate at 750 volts DC. This can be a starting point for local power supply blocks. The general power supply to the blocks must run with a much higher voltage though (e.g. 10-25 kV). Braking will be regenerative. Emergency UPS power supplies, positioned at key points will deliver sufficient power for essential functions during power outage.

System operation with individual vehicles, without platooning, is rather well known. High speed platooning operation, with no distance between the cabins, demands a quite new high-tech research challenge. High capacity and high-speed features, both enabled by platooning are factors that make GTS unique.

The **Physical design** of GTS in the human scale environment, poses new challenges in many perspectives. The design process includes technical and economic aspects as well as questions of adaption to the surrounding and the impact the design can have on future urban planning. It will be not only an efficient transport system but also a new architectural element employing advanced materials combining appropriate scale, with rhythm, texture etc. GTS being lightweight and neat, free from emissions, noise and vibrations, opens new possibilities for example building integration and multitask guideway constructions. The system may even be

Fig. 1.1.c Platooning on GTS high-speed line (Bubbles&Beams)

installed below ground, through or above buildings. The long-term vision is that GTS, properly designed, will be fully integrated in a future urban system and will make way for a more social use of public urban space than is possible with today's CTS. Spans may vary between 10 and more than 1000 meters. Transport of a bicycle, a pram, a wheel chair, a small vehicle or goods on pallet must be easy. Entrance and exit of a cabin should be possible in upright position. Cabins must have a lightweight and safe structure, designed with aerodynamic and vehicle dynamic properties in mind; special dual-mode cabins which also can be used as ordinary road-cars must adapt to the GTS standard. The construction of GTS will be adjusted to the Building Information Modelling (BIM) handbook.

1.2 Novelty, non-incrementality, plausibility and foundational character

GTS combines its technological breakthrough with a general functionality, a combination that other systems do not embrace.

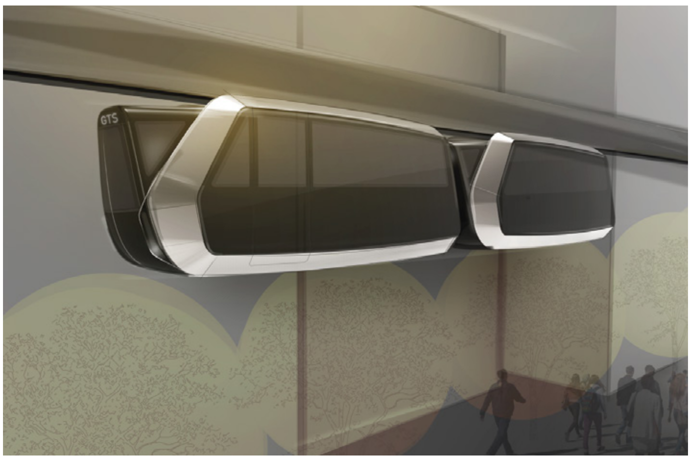
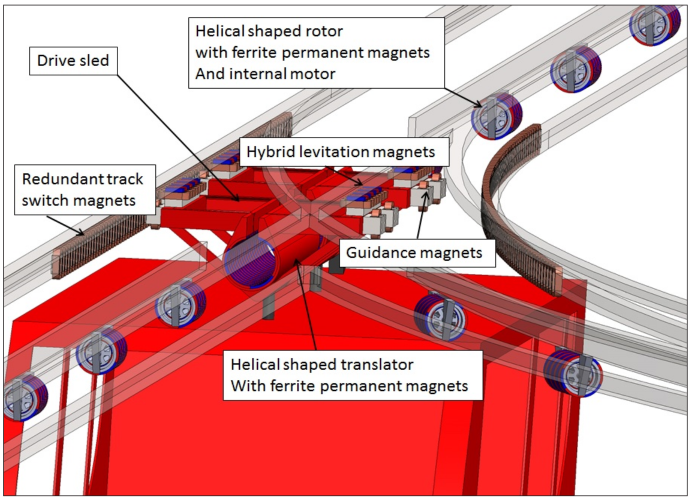


Fig.1.1.d Mirage, reflecting cabins (Yovinn, Axel Eriksson)

Attempting to improve CTS thousands of scientists and engineers all over the world are working on developing for example electronic control of logistics, new kinds of fuel, particle reducing materials in tyres and road surfaces, autonomous cars, PRT… each one addressing only part of the problem. GTS holistic approach however, using the most excellent technique throughout the entire system, presents a tremendous leap in the development of future transportation. So, GTS is **not** an **incremental change**, it is a **novelty**.

GTS provides a major disruption breakthrough from CTS by combining modern computer systems at all levels, from levitation and propulsion control to traffic logistics control, with new inventions in electromagnetic force production and new designs of high level track, releasing ground level area for the use of pedestrians, children and recreational purposes. The aim is to make a transport system where the passenger or goods on pallets are loaded at the point of departure and proceed, with no intermediate stops or changes, to the ultimate destination, be it a local, regional or interregional journey. Starting and stopping points will be provided in large numbers and in close proximity to each other for convenience.

The high risk, involved in researching the GTS system will be mitigated by investigating multiple methods of meeting the various challenges, using advanced electromagnetic computerized prototyping techniques such as Finite Element Method and Dynamic Simulations. The results will be compared using innovation practices such as SWOT tables to ensure that the best solutions are selected for manufacturing demonstrator laboratory models. In order to ensure success the project must make use of the close collaboration of many scientific disciplines, for example: Electromagnetics, power electronics, control engineering, mechanical engineering, material science, architecture and industrial design, to name but a few.



Exploded sketch of drivesled by Ass.prof. P O Rasmussen

Introduction of GTS is **plausible** because the request for breaking the detrimental effects of conventional transport is on the agenda in society. However, due to blind spots, to some extent caused by vested interests, financially strong decision-makers avoid the deeper analysis of reasons for the failings. Our site-partner, the municipality of Uppsala, like many other municipalities, understands this dilemma and they are open for trying a new path for technological and functional development, which makes GTS plausible.

As can be seen in table 1.2a below GTS differs from all other alternatives in five major aspects: **Magnetic switching, low land use, platooning, dual mode and service all times and distances in one combination**. Roads and high-speed trains require large areas of land, often in conflict with other purposes and needs. A mainly elevated structure avoids these problems. Technologies may prove successful and, together with the physical fact and hard-to-solve problems with autonomous vehicles, walking people and animals don´t run any risk of serious fatalities.

Table1.2a GTS compared to conventional and frontier alternatives

Type	**Technology**							**Function**	
	Power	**Auto-mation**	**Motor**	**Levitation**	**Switch/ Steering**	**Land use**	**Plato oning**	**Dual mode**	**Service */ ****
CTS									
Road/Car	Fuel	No	Rotating	Wheels	Wheels	High	No	No	Dr.license
Rail/Train	Direct electricity	Partly	Rotating	Wheels	Rail switch	Fair	Fixed	No	Timetable
Road/Bus	Fuel/Different	No	Rotating	Wheels	Wheels	Fair	No	No	Timetable
Frontier									
Electric car	Battery charging	No	Rotating	Wheels	Wheels	High	No	No	Dr.license
Self-drive car	Fuel or battery	Semi	Rotating	Wheels	Wheels	High	No	No	Dr.license
Driverless car	Fuel or battery	Full	Rotating	Wheels	Wheels	Fair	No	No	Developing
PRT	Direct electricity	Full	Rotating	Wheels	In vehicle	Low	No	No	Local
Skytran	Direct electricity	Full	Linear	Magn/dyn	Magnetic	Low	No	No	Low capacity
Hyperloop	Direct electricity	Full	Linear	Magnetic	? N/A	Low	? N/A	? N/A	Long distance
Transrapid	Direct electricity	Full	Linear	Magnetic	Rail switch	Fair	Fixed	No	Timetable
Cableway	Direct electricity	Full	Rotating	Wheels	No	Low	Cable	No	Local
El. cargo HW	Direct electricity	Semi	Rotating	Wheels	No	Fair	Semi	Yes	Developing
Bicycle	Pedal/electricity	No	Rotating	Thin wheel	Manual	Low	No	No	Local
GTS	**Direct electricity**	**Full**	**Linear**	**Magnetic**	**Magnetic**	**Low**	**Yes**	**Yes**	**All T&D**

* The most restrictive service function is indicated for CTS and Frontier; For GTS All Times and Distances (All T&D) are indicated.
** GTS Cabins and stations are exclusively designed for easily bringing your bicycle, pram or wheel-chair.

GTS is in an early stage and carries a high risk because of its visionary character. If, however, our exploration of untried magnetic technologies and combinations of technologies is successful, the foundation of a radically new and plausible technology will be laid. The approaches to meet FETOPEN characteristics are analyzed in table 1.2b below.

Table 1.2b **• FETOPEN characteristics**
GTS approaches

• Long-term vision GTS embraces a Proof-of-Principles of a proposed new general transport functionality having a very small ecological footprint on Earth. GTS offers the vision of a new future global standard for "door-to-door" service, opening aglobal market far beyond the present State-of-the-Art. GTS avoids friction between wheels and ground, and avoids fragmentation of transport as by CTS.
• Breakthrough **• Science and Technology target** The low cost magnetic core technology to be developed facilitates the general functionality of GTS. Other enabling technologies include traffic control software for safe automated operation of the whole system covering platooning and switch operation at high speed, traffic control and logistics.
• Foundational Once the Proof-of-Principles is presented a new line of technology is likely to emerge. The automotive, rail and infrastructure industry will then benefit as their production facilities may easily be restructured to support a GTS market expansion.
• Novelty A radically new transport system that offers the efficiency and capacity far beyond that of railways combined with the flexibility of road vehicle system is envisaged. This has never been researched before. The high speed, high capacity, railway type operation is achieved by coupling many small vehicles into platoons - at speed. In all, GTS is a unique novelty.
• High-risk It will be many years of pilot plant test and operation before all features of the system can achieve their final structure. But the peak of technological risk lies in this project; Specifically, platooning at speed is a severe challenge.
• Interdisciplinary The project concept has a highly interdisciplinary approach. It ranges from advanced technological and operational breakthroughs, exciting new physical design, and, in a second stage, new environmental traffic planning, passenger adaption, social and economic analyses; all these factors enable a research development exceeding incremental refinements within existing technologies. Interdisciplinarity is assured by the Interdisciplinary Working Board (IWB).

1.3 Research methodologies

The physical development and research will start with a mathematical phase using methods like the Finite Element Method (FEM) and Computational Fluid Dynamics (CFD). Prototypes in appropriate scales will then be built for experimental validation. The Proof-of-Principles is limited by the project economy. The proposal therefore only covers advancement through Technology Readiness Levels (TRL) 1-3. We start by basic principles observed and end with experimental proof of principles of the new technology in laboratory.

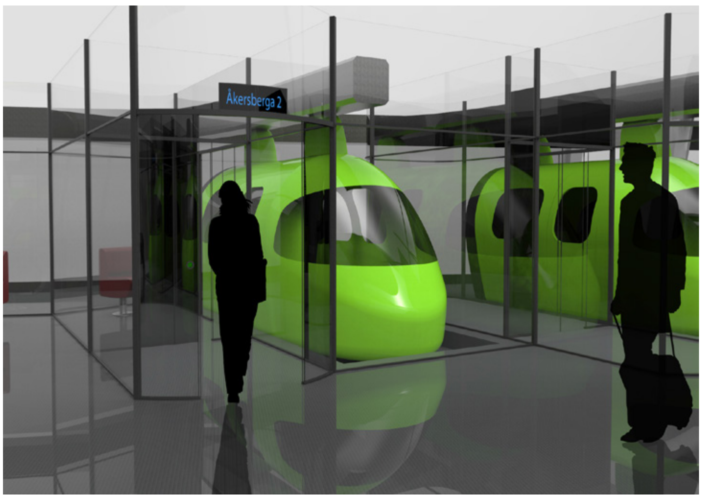
"Less than 30 years ago, few of us could imagine carrying a telephone, radio, TV, newspapers, books, music & maps in a tiny module in our pocket.

GTS aims for a similar revolution."

1.3.1 Social and gender issues

GTS is designed for multipurpose trips for all. Unpaid labour for the upkeep of a household with care for children, elderly, shopping etc. is poorly understood in ordinary public transport planning. This category however, stands for a quarter of all public transport use. Housekeepers without cars are often responsible for the majority of care work. GTS may here bridge inequity between genders and other social categories. GTS combines the efficiency of the car and public transport, and avoids their respective drawbacks. As an example, trip-chaining is made easy by GTS as there are no constraining schedules. It is also much easier to load a bicycle, a pram or a wheelchair on board a GTS cabin than on a bus, train or car. It is often unnecessary to own a car or to have a driving license to obtain free mobility.

Ref. **http://ec.europa.eu/research/science-society/gendered-innovations/index_en.cfm**
(Rethinking Concepts and ...).



Terminal study by design student Joakim Gustafsson

Table 1.3a Overall research approaches, methodologies and relevance to specific objectives (see also 1.1)

Work Package	Methodologies	Specific objectives	Indicators of success
1. Management, Coordination & Communications (MCC) Interdisciplinary Working Board (IWB)	Normal administrative procedures and coordination between all work packages and tasks; Two-way communication activities; Interdisciplinary conferences by the lead participants aiming at strong guidance to the single task works;	Objective 4 Disseminate, exploit and communicate the findings.	Efficient coordination, Impressive communications amongst people and concerned leaders
2. Electro Magnetic Research (ERC) 3. Converter & Control Research (CCR) 4. Demonstrator (DEM)	Standard methods for laboratory exploration; Performance specifications, conceptual analysis, selection of technologies using SWOT analysis; fullscale design concepts, scaled down model for lab. demonstration, manufacture scale model for lab. testing and validation; reflections for a complete system;	Objective 1 Develop the standard drivesled.	Propulsion actuator fulfills performance spec. (e.g. torque); Levitation actuator fulfills perform. spec. (e.g. levitated mass); Guidance actuator fulfills perf. spec. (e.g. at max. deviation); Switching actuators fulfills perf. spec. (e.g. at specified speed);
		Objective 2 Develop the automation & control system.	Emergency brake fulfills safety spec. (e.g. max. travel distance after emergency); Communication among different drivesleds fulfills perf. spec. at max. speeds (e.g. communication time); Control system fulfills perf. spec. (e.g. travel comfort).
5. Physical Design, Construction and Visualization (PCV)	Architectural and engineering methods; Creation of a sustainable standard structure for beams, pillars, pylons, longer spans etc; optimization of standard cabin sections; design of devices joining cabins, drivesled-cabin-hooks etc in accordance with the BIM Handbook (see 1.1.1); Visualization of urban and landscape intrusion using drawings and perspectives;	Objective 3 Design the cabins & guideway components.	Calculations showing affordability and sustainability; Communications by visual means with all social strata will show the grade of GTS acceptance

1.4 Interdisciplinary nature – and general functionality

It is difficult to envisage a completely different order, in which all sorts of shortcomings in transportation of today are swept away.

Fragmentation of journeys would come to an end just like it has done in information technology. We call this a general functionality. The GTS concept differs from other frontier technologies in transportation by this interdisciplinary unification.

The main parts of GTS comprise the infrastructure, the drivesled, the cabin and various auxilliary systems like the control system, the electric supply system, the station structures, service functions and physical design etc. Within each of these parts there are many interdisciplinary links. For example, the drivesled is not only a controlled electromagnetic device; it must also be seen as a vehicle where safety is of prime importance. The communication between the drivesled, the cabin, the guideway and other vehicles is a formidable task. The communication interfaces and networks must be specified at an early stage of the project. The mechanical and electrical interfaces must also be specified early.

The guideway must not only be strong enough, it must be beautiful and corrosion resistant. Just to mention a few points. Taken together it is hard to imagine projects with a higher interdisciplinary nature striving for a general functionality.

Our project will have a special supervision of the complex interdisciplinary effort by the Interdisciplinary Working Board (IWB), consisting of all lead partners, including leaders in the second stage.

Section 2 **Impact**

If successful, the project comprises the following results, compatible with the specific objectives explained in section 1 (note “feasible” below means also economical):

1. Magnetic and other unique core technologies are demonstrated and shown to be feasible;
2. A unique operation including platooning is demonstrated and shown feasible using simulation software;
3. A unique infrastructure with strength and design, compatible with modern, historical and natural environments, is visualised and shown feasible;
4. Cabin design is demonstrated and appreciated as both feasible and comfortable.

These results will be disseminated and exploited worldwide to support a breakthrough and leading to further development with support from EU, the GTS Foundation and Consortium, strategic partners and relevant companies.

2.1 Impact on technology, industry and society

The impact of GTS will be groundbreaking and indeed ground saving! GTS will reduce the ecological footprint of transport substantially and it has the potential to solve many conflicts between urban development and natural conservation. The GTS will mean preservation and enrichment of the environment, new spaces for safe playgrounds and parks, and fewer land barriers. GTS represents a disruptive outlook for the future. Its impact will be far-reaching. We can only point on a few strategic subjects where the impacts are overwhelming.

The core technology
Small-scale experiments at Aalborg University have already shown promising results. The proposed hybrid electromagnetic suspension (HEMS) will radically reduce costs in comparison with “Maglev” and it can also have an impact in many other engineering fields, like magnetic bearings.

The propulsion technology suggested is based on rotating magnets arranged to form a drive screw; Similar thoughts have been suggested by competitors (like Skytran) though less efficient in execution. This enables much energy to be stored locally along the track for use as cabins pass. Power is transferred to each section of the track resulting in minimum power handling, cheaper power transmission, better acceleration and improved gradient capacity. Such a propulsion system could even be used for trains or as launch systems for aircrafts.

The track switching technique implies that the drivesled is magnetically attracted to the left or right side in a bivalent way (never in between). Such a safe switching technique could find future applications, even in railways.

Platooning technology
The platooning technology is the most challenging. When - in conventional train technology - vehicles are a long distance from each other this is considered to be safe and when they are mechanically coupled close to each other it is also considered as safe. Compare two trains at a large distance and the wagons in a single train coupled together. Challenges arise when two vehicles are approaching each other or separating. An airplane fuelling in the air or a space module approaching the international space station are examples showing that this can be done. Platooning has been proposed for self-driving cars. Platooning offers both a much higher capacity (like pax per meter) and due to the reduced air friction at higher speed. Progress in the field of platooning gives large benefits also for road and rail traffic.

Goods transport
Major shippers and receivers of goods can have their own station on the GTS network. Shipments will be direct with no intermediate reloading or marshalling. Transport and handling damages are reduced. Inventory capital in shipment is reduced. Transport times are short and reliable, allowing just-in-time deliveries. Non-polluting and quiet operation allows GTS stations to be integrated in buildings near the point of use.

Environmental factors
GTS is acting in response to the Worldwide Climate goals, set out in the Paris Agreement. GTS is capable of dramatically reduce Europe’s dependence on imported oil and cut carbon emissions in transport by 60 percent by 2050 or even more. Key goals for 2050 relevant for GTS include:
• a 50 percent shift of medium distance passenger and freight journeys from road to rail and waterborne transport;
• the phasing-out of conventionally-fuelled cars in cities; and
• CO2-free city logistics in major urban centres by 2030.

EU transport policy has long focused on connectivity, especially for the functioning of the single market, and it remains of core importance. There is now a particular focus on bringing innovation into the long distance networks.

Beside this EU Policy, the EU-adopted sustainable development agenda, including 17 goals, and the global agreement on climate, GTS delivers a considerable contribution to goal 03 health, 07 sustainble energy, 08 sustainable economical growth, 09 innovative infrastructure, 11 sustainable city development and 15 sustainable ecosystems.

A Strategic Environmental Assessment (SEA) will be undertaken to validate the impact GTS has on these aspects. We will also estimate the impacts of GTS on the economy, society and human wellbeing following the requirements of the 2016 Paris Agreement on climate change and the EU policies as described above. Finally we will develop descriptions how and to what extent GTS complies with the Paris Climate Agreement. When considering the final impact of GTS we will take into consideration how GTS performs in the zero ambition, which we want to achieve:

- Zero casualties, zero emissions, zero fossil energy usage and zero congestion.

Door-to-door travel time Stockholm suburb - Göteborg suburb
High-speed rail will save relatively little time and it is very uneconomical. GTS would be both faster door-to-door and cheaper to build. Apart from that, GTS would have a much wider use and larger development potential. A most wanted high-speed railway between the major nuclei in Sweden, Stockholm and Göteborg, has recently been turned down to the modest top-speed 250 km/h. Now, the top-speed does not tell you what the true speed is when the journey in fact is fragmented by adjusting to timetables, changes at stations, waiting, and, in case of traveling by air, security. Comparing alternatives for average starting and ending points in Stockholm and Göteborg shows how GTS by its local and closer access, has the shortest, seamless travel time by all possible options. See fig. 2.1a.

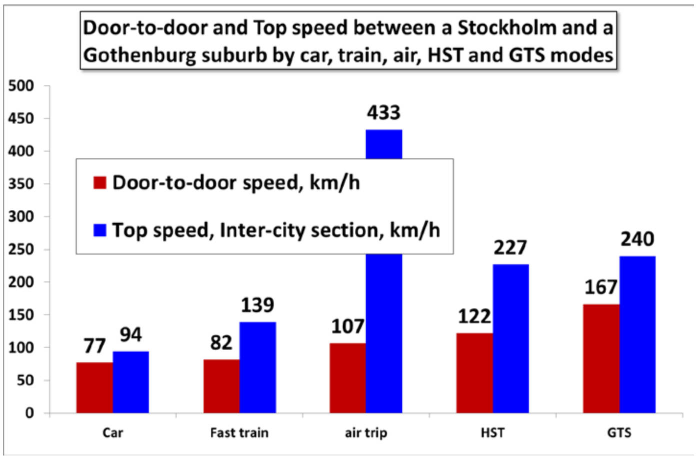


Fig. 2.1a Effective door-to-door travel time with different travel modes (G. Tegnér/Transek)

Investment analysis Stockholm suburb - Göteborg suburb
The total capital costs for HST is estimated to 10,700 M€, while the GTS estimate amounts to 6,800 M€, or only 64 percent of the HST capital cost. Our GTS cost estimate is based on 20 years of experience from previous PRT technologies, adjusted to the proposed GTS standard, speed and capacity. However, both the HST and especially the GTS estimate are surrounded by substantial uncertainties, which would be substantially reduced by this project.

GTS performs at a higher average door-to-door speed, as showed above. Applying travel demand elasticity with respect to the perceived total travel time, the GTS system is estimated to yield at least 15 percent more trips. This is an obvious under-estimation as we have not (so far) considered the higher level of comfort by GTS and its seamless travel compared to the HST journey with its waiting and transferring times.

Key facts about HST and GTS	HST	GTS	GTS/HST
Total Capital costs, M€	10 700	6 800	64%
Capital cost per track-km M€	24	14	60%
Total Annual Capital cost, M€	310	220	71%
Total Annual Operating cost, M€	280	110	39%
Total Annual Costs, M€	590	330	56%
Total Annual Costs/track-km, M€	1,30	0,69	53%
Annual passengers, million	4,5	5,16	115%
Annual cost per passenger, €	129	63	49%

Fig. 2.1b Investment analysis of HST and GTS (G. Tegnér/Transek)

Uppsala South - a constructive pilot and pioneering example
At Stockholm-Arlanda international airport and Uppsala, podcars and GTS have been discussed and demonstrated repeatedly over the last decades. Uppsala municipality has recently adopted a comprehensive master plan for the target year 2050+ with a five-nuclei-structure. Two of the five nuclei are on the southern latitude of the rectangular structure and from the south-eastern nucleus, Bergsbrunna, it is 25 km to Arlanda (32 km from Uppsala City). Bergsbrunna would be an optimal location for a new train station on the railway line Uppsala-Arlanda-Stockholm. This is obviously a catchment area to the airport, but also to the greater Stockholm region, so the municipality plan to develop the southern link, "Uppsala South", possibly a pioneering GTS link between Bergsbrunna and the southwestern nucleus Gottsunda-Ultuna, a suburb with both an immigrants character and the University of Life Science. "Uppsala South" does not exist as a motor artery today and politicians want to keep that environmentally friendly character; it crosses a sensitive nature reserve along the Fyris river why a mobility artery should be constructed in the most environmentally protective way. GTS is perhaps an optimal alternative. See fig. 2.1c. A GTS double-track along Uppsala South would be 6.3 km with 7 stations.

With careful choice of design GTS may also be a starting point for a GTS system in Uppsala with its five nuclei plan. The design must then allow for change of technology within the basic structure, if GTS would not develop in a favourable way.

Fig. 2.1c Uppsala South, municipal and, partly, GTSTEC alternative

A pilot test track can be planned over Fyris river, 1500 meters, 10 cabins and drivesleds, 2 stations, Ultuna and Nåntuna, and a laboratory workshop with surveillance and control station. Crossing the Fyris river requires a cablestayed span of 360 meters, and 20 meters free height over the river for sailing ships, between pylons, two tracks and, on top of the beams, one 5 meter wide lane for walking and bicycling in both directions. See fig. 2.1d.

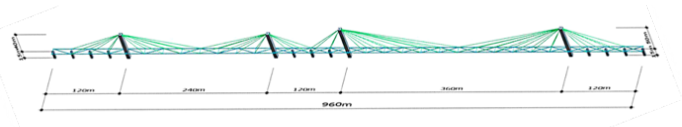


Fig.2.1d Fyris river bridge, a calculated span for GTS and Bike&Walk (AyCrete Design)

Preliminary costs

A pilot track between Ultuna and Nåntuna 1.5 km with 2 stations, 1 service station and 10 cabins&drivesleds is estimated to cost 23 M€ (G. Tegnér, Transek) and the bridge like in fig. 2.1d would cost 9-12 M€ (AyCrete).

A pioneering track between Gottsunda and Bergsbrunna 6.3 km with 7 stations, 1 depot and 60 cabins&drivesled is estimated to cost 64 M€ (G. Tegnér , Transek). If the pilot track has been erected the cost can probably be reduced by around 20 M€. The bridge like in fig. 2.1d would cost the same as for the pilot track. This corresponds to 10 M€ per track-km. A comparison with eight recent LRT (Light Rail Transit) cost studies in great Swedish cities show an average investment cost of 36 M€ per track-km. Thus the LRT is 3.6 times more expensive than the estimated GTS cost per track-km (G. Tegnér, Transek).

Failing success

It is reasonable to believe that the project will have a strong impact if it succeeds, but even if it fails. The Swedish Standards Institute would be willing to help establish a GTS standard as soon as a specific trade sector emerges. Simultaneously we may also have an opposition who may fear a disruptive technology.

Many companies have shown interest in GTS but they have feared the disruptive momentum, simply to elevate from the road, and melt private and public transport together. When we can show positive proof of GTS principles the outlook will be obvious for acceptance and even eagerness to join in to the “magnetic super-path”..

2.2 Impact on future leadership

Just proving that a new paradigm of thinking is possible within the transport sector, will have a deep impact on the leadership throughout the European Union. The proud European culture of major transport inventions, has laid dormant for a hundred years. New, radical ideas about transport might come alive again, both in academy and in society. The consortium consists of a group of highly experienced scholars in societal, technological and transport sciences. All partners are aware of the need for a sound generation shift soon and within the project. Younger research fellows and postgraduates will be assigned.

2.3 Measures for achieving impact

a) Plan for dissemination and exploitation of results

Introductory, concurrent and concluding conferences will be arranged for disseminating the ideas and results. We will also take part in relevant international conferences on transport and magnetics. Contributions will also be made to respected international scientific journals. The GTS homepage (upgraded with Office 365/ Sharepoint Portal Login) will be used for presentation of the on-going project parts. FAQ’s will be answered in lists on-line, news releases and articles will be published by the consortium and also individually by all scientists in their respective domains. The project will have Facebook, Youtube and Linked-in profiles. See further under c. Supporting semester and master thesis projects will raise student awareness, and involve the younger generation.

b) Open research data and organisational measures

The GTS Foundation will be reinforced by new capital and several new board members. A standard development and licensing structure will be prepared. A consortium agreement will be signed to manage key knowledge, IPR and data. The strategy for knowledge management and protection of the GTS Core technology is to leave it open, and establish a Standard & Licensing Structure (SLS) that will support the market exploitation in the most favorable fashion. Research data will thus be spread openly to prevent hostile patent applications. The GTS Consortium AB will be ready to administer and develop the GTS standard, and to collate and preserve data as commissioned by the GTS Foundation. The SLS under GTS Consortium AB will be the holder and curator of all relevant data generated by the project. All partners in the GTS project consortium will be invited to form the GTS Consortium AB when the time is ripe. The four stages of development will be structured as conceptualized below:

Proof-of-Principles **<u>2018-2020</u>** 100% EU support GTS Consortium to be GTS Foundation	Proof-of-Concept prototype **<u>2019-2020</u>** 75% EU support 25% Private support GTS Consortium AB GTS Foundation
Small-scale pilot plants **<u>2020-2023</u>** 50% EU support 25% Government support 25% Private support GTS Consortium AB GTS Foundation, Licenser	Large-scale pioneering commercial exploitation **<u>2023-</u>** 90% private, 10% public; GTS Consortium AB, Standard & Licensing Structure (SLS); GTS Foundation, Licenser and Standard holder

c) Communication activities

Combining modern communication and physical experience

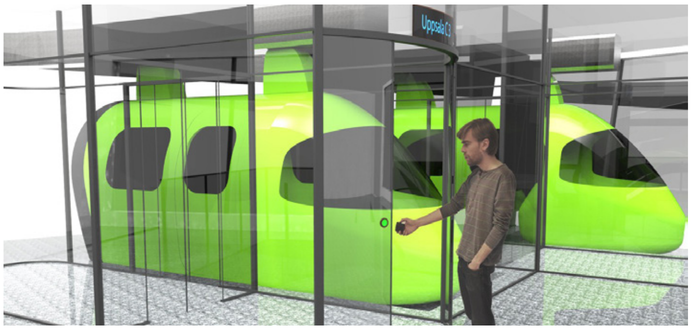
Promotion and implementation of GTS must be presented from a bottom up perspective. This is necessary to secure leverage by the interest of policy makers and businesses.

A full-scale mock-up cabin will be designed and produced to present the GTS to the public at large. Included in these communications will also be presentations on the newly developed propulsion, levitation, switching and platooning, i.e. the development of the drivesled. These presentations should also promote widespread understanding of the GTS revolutionary function in society.

A physical interactive exhibition will be constructed to provide a physical experience of GTS cabins, both exterior and interior. It will be open to the public at the GTS exhibition point on a daily basis. The exhibition point is planned to be located in Uppsala due to its pioneering status. The exhibition can be set up in other locations, as requested. Miniexhibits at well targeted libraries and other public spaces in main capitals or selected smaller places, might be a good aproach to meet people among the many curious but not always experts. These exhibits can also be hired by key persons acting as nodes, within relevant fields; students, business associations, tenant unions etc.

The visual impact must be shown and explained. Reuse and adaptations of existing infrastructure will be visualized. Public project information and research results, press releases, interviews with key researchers, and technical articles in more popular technical magazines will stream out from the project, reaching transport experts, architects, urban planners, decision makers and the like. Special promotion of master thesis will raise awareness in academia.

In order to reach an international public and wide participation, physical exhibition and traditional communication channels will be accompanied by an active presence not only live at well selected opportunities with open access at universities and other relevant fora, but also on the internet via an interactive web-portal and social media. The portal will provide relevant information and data to user groups such as landscape designers, architects, engineers and construction companies as well as game developers and simulator designers. This allows businesses and citizens to engage and design future transportation solutions with "real" information about the possibilities in GTS.



Internally, Sharepoint will be used by team members, with shared progress reports, document sharing etc. The management team will distribute newsletters with status, summary and prospects four times a year.

Section 3 **Implementation**

3.1 Work plan and intermediate targets

The project is divided into five work packages (wp) described below (and initially also under 1.3). Wp 1 has uniting obligations to all wp, including interdisciplinary coordination and communications (GTS Foundation). Unique core technologies will be developed at Aalborg University, Department of Energy Technology in close cooperation with Mondragon University, Department of Electronics Engineering. Their work is subdivided in three wp's with distinct different tasks. Wp 4 deals with demonstrating the GTS drive technology on a laboratory guideway. Wp 5 develops the construction and design of the beam structure and cabin standard (Bjerking AB and VinnEx Centre for ECO2 Vehicle Design, KTH, Stockholm).

Milestones are placed after 2, 4, 7 and 8 quarters. See fig.3.1a and table 3.2a. Settling the performance specifications of the technology will be the first milestone after six months. We arrive at the second milestone when the prototype demo is ready after one year. Nine months later we will arrive at the third milestone when construction and visualization of GTS and a full-scale design concept of the electro-magnetic technology can be presented. After two years all wp's except the demonstrator wp 4 DEM have delivered their preliminary results and will evaluate GTS at the fourth milestone, forecasting the final result that will be available following one year of testing the demonstrator. Final results will then be collected in the main GTSTEC report.

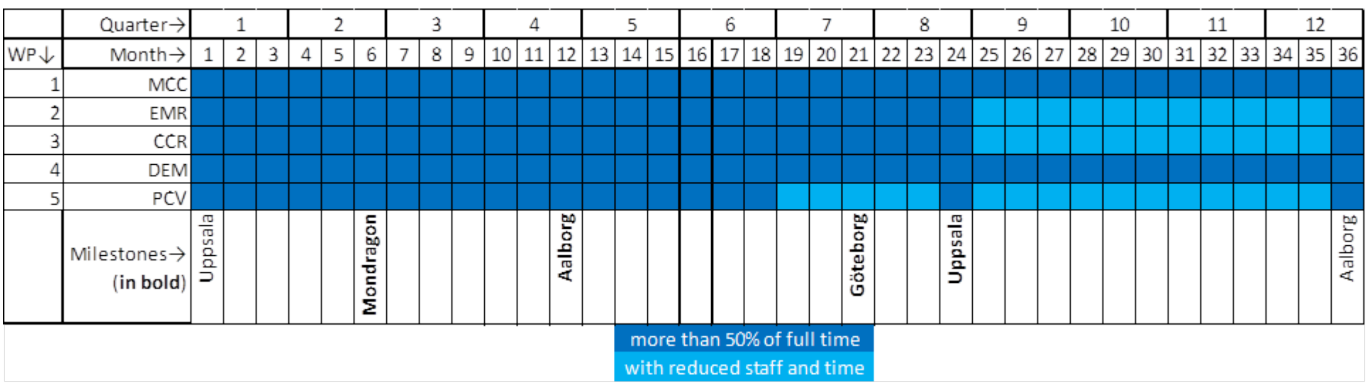


Fig.3.1a Timing of the different work packages, intermediate targets (milestones) and meetings

Table 3.1a Work package descriptions (~3 pages)

wp. nr, title	**1. Management, Coordination & Communication - MCC/IWB/COM**						Lead beneficiary	**GTS1**
participant nr	**1.01**	1.02	1.03	1.04-05	1.06-10	1.11-15	see table 3.4a	subcontr.1
short name	**GTS1**	GTS2	GTS3	GTS4-5	IWB6-10	COM11-15	GTS/IWB/COM	Yovinn et.al.
personmonths	**21**	9	12	6	1	28	8 * 0.125 = 1	Axel Eriksson
start month M1					end month M36			

Objectives: Conceptual leadership, comprehensive coordination, editing Proof-of Principles and final report (GTS);
Managerial and administrative efficiency, time keeping and accounting (GTS);
Interdisciplinary Working Board (IWB), members: wp lead participants and lead participants to be in stage 2;
Communication activities on the web and at exhibition at our location in Uppsala (COM).

Description of work
Task 1.1 Main coordination, visits on all locations, conceptual leadership and final reporting, future structure;
Task 1.2 Financial, administrative and HR management; periodical and final reports;
Task 1.3 Interdisciplinary connections by IWB analyses and decisions, quarterly meetings, digital and physical;
Task 1.4 Communication activities on a daily basis at exhibition, net and office location in Uppsala, quarterly reports;

Deliverables
1D1Webpage up and running, logo, M1
1dx Press releases on all major occasions
1dy Financial reports quarterly, Q1-Q12
1dz Communications reports quarterly, Q1-Q12
1D2 Intermediate coordination report, M12
1D3 Forecast final report,
Research findings & recommendations M24
1D4 Final report,
"Inventing a General Transport System", M36

wp. nr, title	**2. Electro-Magnetic Research - EMR**				Lead beneficiary		**AAU1**
participant nr	**2.02**	2.04-	3.01-3.03		1.01	1.02	1.07-10	1.11-15
short name	**AAU2**	AAU4-	MU1-MU3		GTS1	GTS2	IWB7-10	COM11-15
personmonths	**4**	36	22		0.5	1	0.5	0.5
start month 1				end month 36				

Objectives: Find cost effective and safe mechanisms for transporting the cabin under the beam. Specifications of the electromagnetic suspension, propulsion, and switching actuators are the first steps.
A radical new propulsion system based on lead screws will be investigated. A safe magnetic high-speed track switch mechanism and a levitation and guidance actuator will also be specified.

Role of Partners AAU is the leader of the WP, and carries out the design of the propulsion system based on the MLS technology (T2.2). MU affords the design of the magnetic switching system (T2.3) and the design of the magnetic levitation and guidance actuators (T2.4). Both partners take part in the definition of specifications (T2.1) and in the full-scale design concept (T2.5).

Description of work
Task 2.1 Agree on actuator performance specification; Vehicle mass, acceleration, deceleration, speed, wind effects, curvature and input from other work packages will dominate the design of all actuators and material.
Task 2.2 Radical new and cost effective and reliable propulsion and levitation actuator; Develop steady state analytic and finite element models of a novel linear electromagnetic propulsion and levitation actuator unit. Design a novel linear electromagnetic propulsion unit, using the magnetic lead screw (MLS) technology.
This is expected to result in a cost reduction to 1/5 of the cost of earlier technologies, combined with a mass reduction to 1/20. The MLS propulsion unit design is combined with a magnetic levitation unit and integrated with a contact-less current collector. The results will be valuable for other work packages.
Task 2.3 A safe magnetic switch mechanism enabling switching at high speed; Design of a safe magnetic switch mechanism enabling switching at high speed. It must apply sufficient force to always direct cabins safely on to the right track. The magnetic switch will eliminate problems with stones, fallen leaves and icing of mechanical switches.
Task 2.4 A cost effective electromagnetic levitation and guidance actuator. Develop dynamic models of the levitation actuator, which is also required to provide guidance. Guidance is closely related to the safe operation of the switching of task 3.3. The models developed will be used in task 3.2 to determine if the operation of cabins will be safe under the specified conditions included in task 3.1.
Task 2.5 A full-scale design concept of the propulsion, levitation, guidance and switching actuators. Use the combined results of tasks 2.2 to 2.5 compiling a full-scale design enabling CAPEX and OPEX estimations.

Deliverables 2D1 Initial performance specification M6;
2D2 Technical report on actuator models and design M15;
2D3 Technical report on track switch mechanism models and design M18;
2D4 Technical report on full scale design concept M22;
2D5 Preliminary Proof of Principles M23 (GTS2)

wp. nr, title	**3. Converter and Control Research - CCR**				Lead beneficiary		**MU1**
participant nr	**3.01**	2.03-	3.04-3.07	1.06	1.01	1.02	1.07-10	1.11-15
short name	**MU1**	AAU3-	MU4-MU7	IWB6	GTS1	GTS2	IWB7-10	COM11-15
personmonths	**3**	24	27	6	0.5	1	0.5	0.5
start month M1					end month M36			

Objectives: To find safe control systems for the electromagnetic levitation, propulsion, and switching. The control system should also allow for platooning and separation of cabins. The electromagnetic levitation should also allow for guidance sideways. The whole control system must be both cost-effective and control energy efficient.

Role of Partners MU is the leader of the WP and carries out the control systems for propulsion, levitation and magnetic track switching (T3.2, T3.3). AAU and MU collaborates in the definition of technical specifications (T3.1) and in the full-scale concept (T3.5). In addition, AAU develops the high-level controller defining the required sensors and communication net between different elements comprising the whole system (T3.5), and the platooning system (T3.4). IWB6 participates in the platooning system as well (T3.5).

Description of work

Task 3.1 Agree on sled system performance specification based input from other work packages. Specify the functions of a control system, develop and test its core elements for proof-of-principle.

Task 3.2 A propulsion and levitation actuator control system comprising controller and power converters; All control of the motion, levitation and guidance will be effected via controlled electric power converters. Models for a complete control system including converters will be built.

Task 3.3 A safe magnetic track switching system comprising controller and power converter enabling switching at high and low speeds. Models for a fail-safe system controlling the switching mechanism will be developed and simulated.

Task 3.4 A safe cost-effective platooning system comprising controller and power converter enabling very low high speed energy consumption due to minimal windage. Platooning of vehicles must control the distance and velocity to the cabin in front very precisely.

Task 3.5 Propulsion, braking and switching of drive sleds will be monitored from controllers activating rotors and magnets. Sensors for position and speed can be placed in guideways and/or in drive sleds and in the nose of cabins. Communications between drive sleds and controllers can be done via dedicated short range (DSRC) or e.g. 5G broadcast. Safety monitoring and emergency brake activation are critical functions. Vehicle platooning at speed is a high-risk design target as has already been demonstrated for road vehicles.

Task 3.6 A full-scale design concept of the propulsion, levitation, guidance and switching control systems. Using the combined results of tasks 4.2 to 4.5 to compile an initial full scale design concept to form input to other work packages and enable estimates to be made of the CAPEX and OPEX.

Deliverables 3D1 Initial performance specification M6; 3D2 Report on actuator controllers & design M24; 3D3 Report on track switch controller & design M24; 3D4 Report on full scale design concept M12

wp. nr, title	**4. Demonstrator - DEM**				Lead beneficiary		**AAU21/MU31**	
participant nr	**2.01**	2.04-	**3.01**	3.05-08	1.01	1.02	1.06-10	1.11-13
short name	**AAU1**	AAU4-	**MU1**	MU5-8	GTS1	GTS2	IWB6-10	COM11-13
personmonths	**1.5**	43	**1.5**	15	0.5	0.5	0.5	0.5
start month M1				end month M36				

Objectives: Specify, draw, & manufacture a small scale demonstrator laboratory prototype.

Role of Partners The total small-scale demonstrator will be assembled in Aalborg in order to test the overall system. A second partial demonstrator will be assembled in Mondragon in order to test the sub-components before they are integrated in the total demonstrator in Aalborg. MU will develop the controllers and power electronics devices for propulsion, levitation and guidance systems. AAU will build the rest of elements comprising both demonstrators.

Description of work

Task 4.1 Agree on Demonstrator performance specification, based on demonstrator site etc.

Task 4.2 Draw & design cabins, track, drive sled, controllers and converters. Using input from other work packages design, draw and compile a parts list for the demonstrator comprising a section of a scale model track with two operational cabins.

Task 4.3 Purchase components, parts and materials, and Manufacture Demonstrator. Purchase all materials. Efforts should be made to employ commercially available components to save costs and time.

Task 4.4 Assemble Demonstrator and Track. As parts become available, assemble the sub-systems, e.g. cabins, drive sleds, converters, controllers, track, etc.

Task 4.5 Test Demonstrator. Test the sub-components as they become available. Test the assembled demonstrator with individual cabin transport and platoon operation of two cabins.

Task 4.6 Demonstrator Show Demonstrate the scale model system to an invited audience. Make a video recording of the demonstrator in action. Make the video recording public on the Internet.

Task 4.7 Evaluation of Test Results Write a report of the test results with discussion and evaluation of the performance achieved compared to the specification.
Deliverables 4D1 Prototype laboratory scale model of a section of track with two operational cabins. M24; 4D2, 4D3 Technical report evaluating tests and performance of the demonstrator. M30, M36

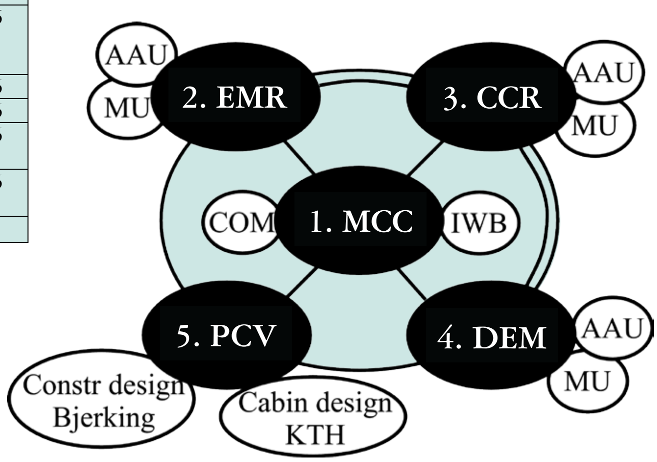
wp. nr, title	**5. Physical design, Construction &Visualization - PCV**						Lead beneficiaries		**BJE1, ECO11**	
participant nr	**4.01**	4.02-4	**5.01**	5.2-4	1.01	1.02	1.06-8	1.11-13	4.21-4.31	subcon.2
short name	**BJE1**	BJE2-	**ECO1**	ECO2-	GTS1	GTS2	IWB6-	COM11	AAU-MU	Lutfi Ay
personmonths	**4**	22	**3**	8	1.5	0.5	0.5	0.5	2 * 0.5	AyCrete
start month M1					end month M36					

Objectives: Advanced calculations for a unique, new, sustainable infrastructure. Design and architectural studies forms the physical impact of GTS in the human, urban and landscape scale. Cabin design.
Description of work **Task 5.1 Agree on a preliminary infrastructure performance specification.** Based on input from other wp's, summarizing standards and regulations (stability, vibrations, tolerances, fire, earthquake, real estate etc) to be observed/questioned and an initial creative attempt to describe for example the function and design principles of a small station. What services should it render considering the door-to-door chain of transportation for people, goods and waste? What impact will it have on the neighborhood? Students from the Royal Institute of Technology (KTH), Architecture and Urban Planning will be engaged. Selections from this session will be published on Internet. **Task 5.2 Infrastructure, strength and design, R&D** The general infrastructure consists of pillars/pylons and beams wherein the drive sled runs. The system to be created can be prefabricated and easily adapted to different situations, also integrated into buildings. The principles for mounting, maintenance and recycling must be established. Conventional materials such as steel and concrete will be used to start with. Advanced materials will also be scanned for comparison. Principles for foundation of pillars will be studied as well as optimal spans considering different situations. We plan for a close cooperation with the other workpackages solving challenges like switching, platooning, maintenance and robustness. Visualization of stops and guideways will be shown - and published on the Internet. Sub-contractor AyCrete, with advanced knowledge and experience of novel infrastructure design, in frequent cooperation with Bjerking, will support, producing calculations and CAD-sketches. Postgraduates from KTH will assist. Pilot sketches for Uppsala, natural protection area, GTS bridging Fyris river. **Task 5.3 Cabin design, optimization of volume and load, general functionality** Cabin design for GTS demands a strict standardized cross section due to the dependence on a fixed infrastructure. The total weight should not exceed 2,5 metric tons. Platooning will always be made possible. Cabins can be designed in many special ways, like dual mode cabins/cars (3-5 pax), public high capacity cabins (12 pax) etc. The issues of low weight, aerodynamic and vehicle dynamic properties will be addressed through simulations. This will determine materials used and shape. A standard cross section will be presented in drawings, models and visualization. Modelling and design support will be given by sub-contractor Yovinn with long experience of the art within automotive industry.
Deliverables 5D1 Initial performance specifications of guideway structure, M6; 5D2 Construction and visualization of GTS infra sketches, pilot sketches for Uppsala, M12; 5D3 Construction and design of GTS cabins, M12; 5D4 Construction & Visualization of GTS, M18; Report evaluation, listing challenges to encounter in the next step, M24.

Table 3.1b List of work packages

wp nr	Work Package, title and acronym	Lead P nr	Lead P acronym	Person Months	Start M	End M
1	Management, Coord. & Com. (MCC) Interdisciplinary Working Board (IWB) - Communications (COM)	1.01	GTS1	48 1 28	1	36
2	Electro-Magnetic Research (EMR)	2.02	AAU2	64.5	1	36
3	Converter & Control Research (CCR)	3.01	MU1	62.5	1	36
4	Demonstrator (DEM)	2.01 3.01	AAU1/ MU1	63	1	36
5	Physical design, Construction and Visualization (PCV)	4.01 5.01	BJE1 ECO1	28 13	1	36
∑				309		

Fig.3.1b Interrelations between all work packages and partners



3.2 Management structure, milestones and procedures

The registered GTS Foundation (GTSF) is the main partner in the project consortium. The founders are the main carriers of the GTS concept. As main coordinator and technical coordinator they also support the research and innovation work in all work packages. A financial manager controls the economy, HR and administration. A mind map of interrelations between all work packages is presented in fig.3.1b. The consortium will collectively govern the project by means of a leadership, parallel to IWB. It will establish its office in Uppsala.

Six reporting occasions will be arranged and four will be coordinated with the milestones. They will also include external presentations. Two internal meetings are scheduled. The first two milestones are crucial for alleviating highrisks whereas the two latter milestones open the road for the final proof and presentation. See Fig. 3.1a and Table 3.2a. Probable risks are listed in Table 3.2b.

GTSF is a non-profit organization but it may own shares or other properties to a limited extent. After a successful project GTSF invites all partners in the project, building firms, cabin manufacturers, electric equipment manufacturers etc to form the GTS Consortium AB (GTSC). GTSC builds the first pilot and pioneering tracks and may continue building in order to develop skills and experience, parallel to competing license-holding industries.

GTSF collects license fees from GTS producing companies and operative fees from GTS licensed operators. This future business structure will secure the independence of GTSF as licenser and standard-holder. GTSF also buys licences from other inventors and incorporates them into the GTS standard when applicable.

3.3 Relevance of experience in the consortium

The GTS Consortium has been created after years of searching for the right partners. We are now a collection of university research departments, skilled consultants and specific sub-contractors (SME) with special knowledge for creating, inventing, analyzing, synthesizing and visualizing our proposal (see sec. 4). Also, all partners have an open mind that makes our mission possible to accomplish; this is a necessary gate value for bringing our project to a happy end. All lead partners have accepted a Letter of Intent. In all we are around 30 researchers, inventors, engineers, architects, economists and analysts, including the 2 sub-contractors. 1 out of 5 lead participants are women. Roughly 12 participants are under 30 years, more than 10 are between 30 and 60, and 7 are over 60. See also section 4.

Table 3.1c List of Deliverables (D)

D. nr	Deliverable name	Lead P	Type	Diss.	Deliv.
1D1	Launching website and logo	GTS1	DEC	PU	M1
2D1	EMR Initial performance specification	AAU2	R	PU	M6
3D1	CCR Initial performance specification	MU1	R	PU	M6
4D1	Prototype laboratory scale model of..track..with two cabins	AAU1	DEM	PU	M12
5D1	Initial performance specification of guideway structure	BJE1	R	PU	M12
5D2	Construction and visualization of GTS infra sketches	BJE1	DEM	PU	M12
5D3	Construction and design of GTS cabins	ECO1	DEM	PU	M12
1D2	Intermediate coordination report	GTS1	R	PU	M12
2D2	Technical report on actuator models and design	MU1	R	PU	M15
2D3	Technical report on track switch mechanism models & design	MU1	R	PU	M18
5D4	Construction and visualization of GTS	BJE1	DEM	PU	M18
2D4	Full scale design concept	AAU2	R	PU	M22
4D2	Techn. report evaluating tests & performance of demonstrator	AAU1	DEM	PU	M23
2D5	Preliminary Proof of Principles	GTS2	R	PU	M23
3D2	Technical report on actuator controllers and design	MU1	R	PU	M24
3D3	Technical report on track switch controller and design	MU1	R	PU	M24
3D4	Technical report on full scale design concept	AAU1	R	PU	M24
1D3	Preliminary final report, research findings & recommendations	GTS1	R	PU	M24
5D5	Report evaluation listing challenges to encounter in next stage	BJE1	R	PU	M24
4D2	Techn. report evaluating tests & performance of demonstrator	AAU1	R	PU	M30
4D3	Techn. report evaluating tests & performance of demonstrator	AAU1	R	PU	M36
1D4	Final report "Inventing a General Transport System"	GTS1		PU	M36

Table 3.2b Critical risks of implementation

Description of risks	WP	Proposed risk-mitigation measures
a) The core technology does not develop as expected; power performance are too weak. b) The demonstrator does not fill the proposed requirements. c) The approaches proposed in wp2 and 3 aint enough precise for integration in wp4.	2, 3, 4	a) The reasons can be avoided by adjustments of specifications and early selection of alternatives (by SWOT analyses). b) V model design method is used in development. Its basis is verification and validation of each phase before passing to next. It reduces uncertainties in demonstration, as models have been tested previously (- also applied in automotive development). c) WP leaders take actions to ensure an effective information flow between WPs to risk mitigation
Infra-construction causes severe problems with strength, maintenance or cost.	5	The reasons can be avoided by adjustments of specifications.
Human perception values the design and environmental effects difficult to accept.	COM 5	Communications must be sharper as to the full social, aesthetic and environmental improvements.
Key staff may unexpectedly be lost	1	The leadership has back-ups
Works slow down for various reasons	1	The coordinators take actions
Vested interests perform hostile	1	The leadership takes actions
Major faults can't be prevented or avoided	1	The leadership proposes closure of the project

3.4 Appropriate allocation and justification of resources

Table 3.4a Summary of staff effort

Workpackage /Staff	wp1 MCC	wp2 EMR	wp3 CCR	wp4 DEM	wp5 PCV	∑ pm
1.01 GTS1	**21**	**0.5**	**0.5**	**0.5**	**1.5**	**24**
1.02 GTS2	9	1	1	0.5	0.5	12
1.03 GTS3	12					12
1.04-GTS4-	6					6
1.06-IWB6-	1	0.5	6.5	0.5	0.5	9
1.11-COM11-	28	0.5	0.5	0.5	0.5	30
2.02 AAU2	**0.125**	**5**				**5.125**
2.04-AAU4-	0.125	35				35.125
3.01 MU1-	0.125	22				22.125
2.03- AAU3-			24			24
3.01 MU1	**0.125**		**3**			**3.125**
3.04-7-MU4-7			27			27
2.01 AAU1	**0.125**			**4.5**	**0.5**	**5.125**
2.04- AAU4-				40		40
3.01 MU1	**0.125**			**1,5**	**0.5**	**2.125**
3.05-8 MU5-8				15		15
4.01BJE1	**0.125**				**4**	**4.125**
4.02 BJE2-					22	22
5.11ECO1	**0.125**				**3**	**3.125**
5.02-ECO2-					8	8
∑	78	64.5	62.5	63	41	309

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Table 3.4b 'Other direct cost' items (travel, equipment, other goods and services)

Workpack.	**Cost €**	**Justification**
wp 1 MCC, GTS Foundation, main coordination, communications, MCC, IWB, COM		
Travel	36 000	6 meetings x 2p. + 6 travels by main coordinator; 24 x 2000€
Equipment	20 000	Computers, server, smartphones, network, furniture, on short-term rental basis if possible
	200 000	Cabin full-scale mock-up, publicly accessible at exhibition Subcontractor Yovinn AB, Göteborg
Other goods and services	145 000	Central office in Uppsala, rent acc. to local market cost, for public communication, exhibition & work on short term rental basis; printing service, webpage service, conference costs
Total	401 000	
wp's 2 EMR, 3 CCR & 4 DEM Aalborg University, Department of Energy Technology (AAU), and Mondragon University, Department of Electronics Engineering (MU); Core technologies		
Travel	72 000	AAU + MU: Travels, 2 x 6 meetings x 3 p. x 2000€/meeting, 36 000€ each AAU & MU
Equipment	160 000 10 000	AAU: base structure 11000, HEMS demo 22000, MLS demo 22000, guidance 22000, software, control, sensors and verification 22000, material 30000, guideway 31000. MU: small scale material, 10000 (3 controllers dSPACE1104, fr.year 2).
Other goods and services	12 000 57 000	AAU + MU: General consultants, auditors etc. 12000€, 6000€ each AAU & MU MU: Material to build elements for the functional subsystems demonstrator: 3 power devices 15000€, track structure 5000€, magnetic switch 5000€, propulsion/levitation/ guidance device 20000€, flux SW license leasing, 3 years * 4000€/year: 12000€
Total	**311 000**	**AAU 202 000€ and MU 109 000€**
wp 5 PCV, subcontractor 2, AyCrete, Lufi Ay		
Construction	106 000	GTS pillars, pylons and guide-way, calculations & drawings