

# The SemiMaglev Urbanaut™ – A New Total Monorail Concept

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**Keywords:** Bogies, LIM, Monorail, SemiMaglev, Urbanaut.

## Abstract

The SemiMaglev Urbanaut™ technology represents a new innovative, unique, energy-efficient high-capacity total monorail passenger transportation and light freight concept, incorporating all aspects of monorail technology, including vehicles, guideways at surface and elevated, stations, and simple switching. The technology applies vertical levitation forces that vary from 0 – 100% depending on economics and application. Load wheels are partially applied to conserve energy when the vehicle is stationary as is in a station, in the maintenance area, etc. The aerodynamic shaped vehicles, powered by LIM or in-wheel electromagnetic motors, ride on top of a narrow 1.0 meter wide runway at surface, in tunnels, on bridge decks, or on prefabricated elevated guideways. The Urbanaut® technology does not envelope a massive beam way like most other monorails in operation today, so has unlimited flexibility. A uniquely shaped magnetic guide rail, ideal for maglev, is installed in the center of the runway and interacts with electromagnets in the vehicle to provide combined lift, guidance and stability with easy switching of guideways.

## 1 Introduction



Figure 1

The Urbanaut® is a light weight, independent, innovative medium-to-high speed Semi or Full maglev transportation system applicable in medians of highways and in densely populated areas, communities and recreation areas where space, pollution and other environmental restrictions do not permit conventional wide-guideway transportation systems. It is adaptable to high, medium and low speed depending on a project's route planning, capacity and economics. The Urbanaut® system has boundless flexibility in planning and application in transportation technology [16].

The SemiMaglev Urbanaut™ Monorail is a trade name of The Urbanaut® Company, Inc. There are numerous issued patents and patents pending worldwide on all aspects of the technology, including one issued in China. The concept is unique in several respects and is **the only monorail in which a smaller vehicle operating on a smaller guideway can be seamlessly integrated with and switched onto a larger higher capacity system** [3][18][19].

By applying the simpler new SemiMaglev Urbanaut™ total monorail technology, with its small vehicle and guideway, **the high cost of conventional construction of massive maglev guideways** [2][4][9] **and vehicles can be reduced considerably**. The safety and stability of the Urbanaut® system has been determined by extensive engineering studies and large scale model testing of vehicles and guideways.

## 2 New Technology

### 2.1 Basic Principle of the SemiMaglev Urbanaut™

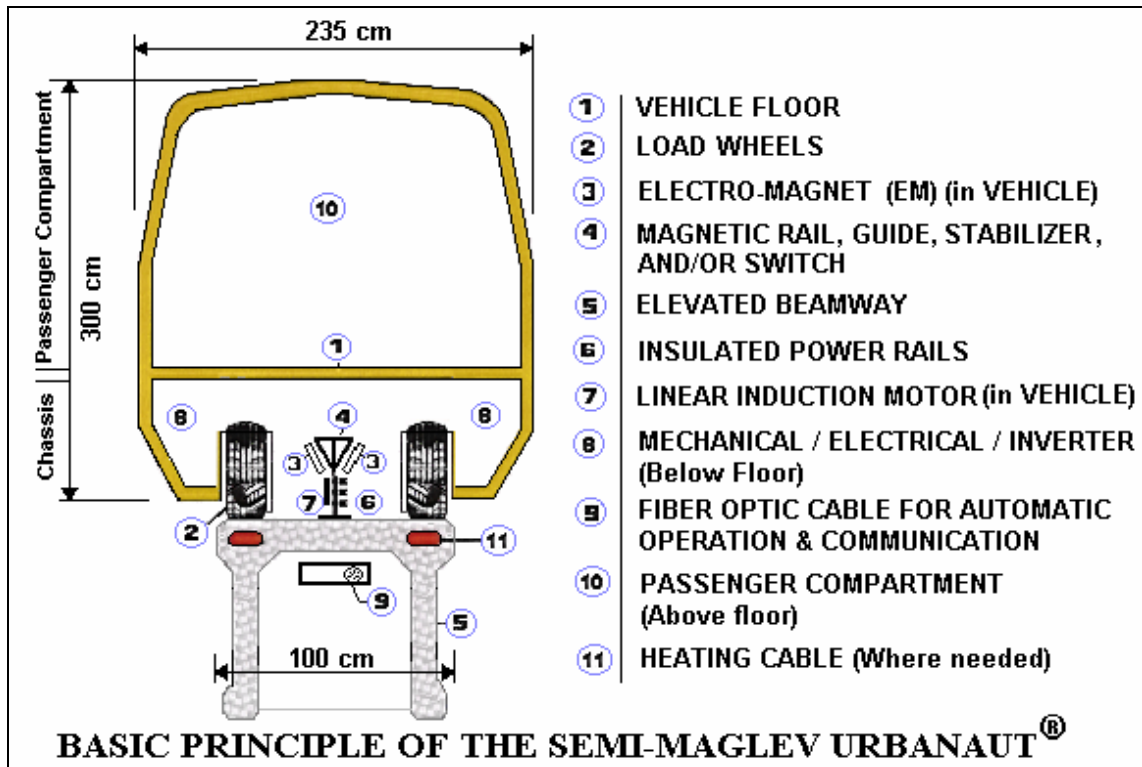


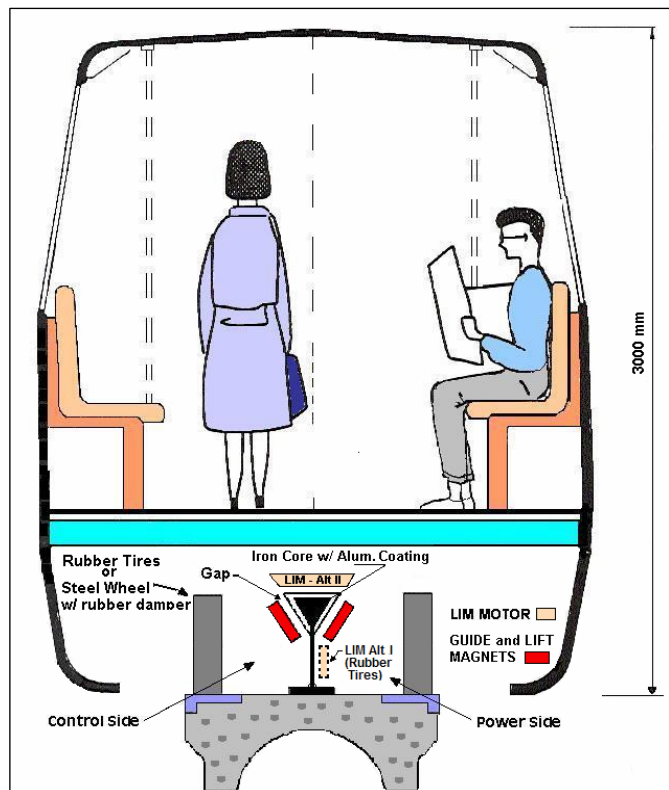
Figure 2

The SemiMaglev Urbanaut™ system is not dependent on a massive enveloping beam way as other monorails, but utilizes a narrow runway which can be on an elevated beamway, a slab at surface or subsurface. No parts of the vehicle will extend below the top surface. Electric automatic light weight maglev vehicles that ride on top of the runway are guided and held in place by a **single center magnetic rail**, which also serves as a simple switch for guiding vehicles from one guideway to another. The magnetic rail makes the system ideal for maglev at low, medium and high speed applications. The technology is adaptable to semi-maglev or full maglev concepts, depending on application and economics [18].

### 2.2 Dynamic Stability of the Vehicle

Ideal for maglev, a center magnetic rail with a uniquely shaped head (Fig. 3) dynamically guides and stabilizes the vehicle against excessive wind and centrifugal lateral forces. The guide rail head configuration locks the vehicle to the guideway and derailment is virtually impossible. Patents issued allow for different shapes of the head for emergency guide wheels or electromagnetic air cushion guidance and lifts.

Figure 3



### 3 SemiMaglev Urbanaut™ Vehicle Bogies

#### 3.1 Comparison of Conventional Rubber Tire and SemiMaglev Urbanaut™ Vehicles



Figure 4

Figure 4 is a photo of a typical Single Urbanaut® vehicle illustrating size and shape of 2 types of compact bogies:

- 1) A rubber tire wheel bogie in front (at left) and
- 2) A SemiMaglev Urbanaut™ bogie, in the rear (at right) on an elevated guideway.

The basic difference between the 2 bogies is that for the SemiMaglev bogie the inclined guide wheels are replaced with electromagnets that maintain an air gap with the inclined faces of the guide rail. The photos are of large scale operational test models with in-wheel lightweight EM (electromagnetic) or LIM (linear induction motor) propulsion bogies. The tests show superb stability, exceptional low aerodynamic and frictional resistance.

#### 3.2 SemiMaglev Urbanaut™ Bogie Components (See Figure 5)

A SemiMaglev Urbanaut™ vehicle has 2 confined maglev bogies, located in the front and rear ends of the vehicle. The 2 bogies are the most important components (the “**brains**”) of the vehicle, and also, by far, the most complicated portion of the vehicle. Special pockets in the chassis have been designed and engineered for easy installation, service, and removal of the bogies. **The bogies are the link** between the concrete runway and vehicle body above it. The SemiMaglev Urbanaut™ primary bogie components and functions are as follows;

**3.2.1 Load Wheels to Preserve Energy – SemiMaglev Technology.** The 2 bogie load wheels can be partially loaded for safety, to save energy and to simplify operation. While the vehicle is at stations, in service, during switching, etc., there is no vertical levitation energy used. Weight from the load wheels is transferred from the vehicle bogie frame to the concrete runway below.

**3.2.1 Combined Guidance and Lift by EMs.** All lateral forces such as centrifugal forces and wind acting on the vehicle are transferred to the center guide rail. The guide rail is anchored to the structural guideway below. Air cushioned electromagnets (EMS) in the vehicle (one pair in front and one pair behind the two load wheels) interact with the magnetic guide rail, and steer the vehicle along the guideway; they are angled approx. 30° and are of the attractive magnetic force type, acting against the center guide rail, and create **combined guidance and lift of the vehicle**.

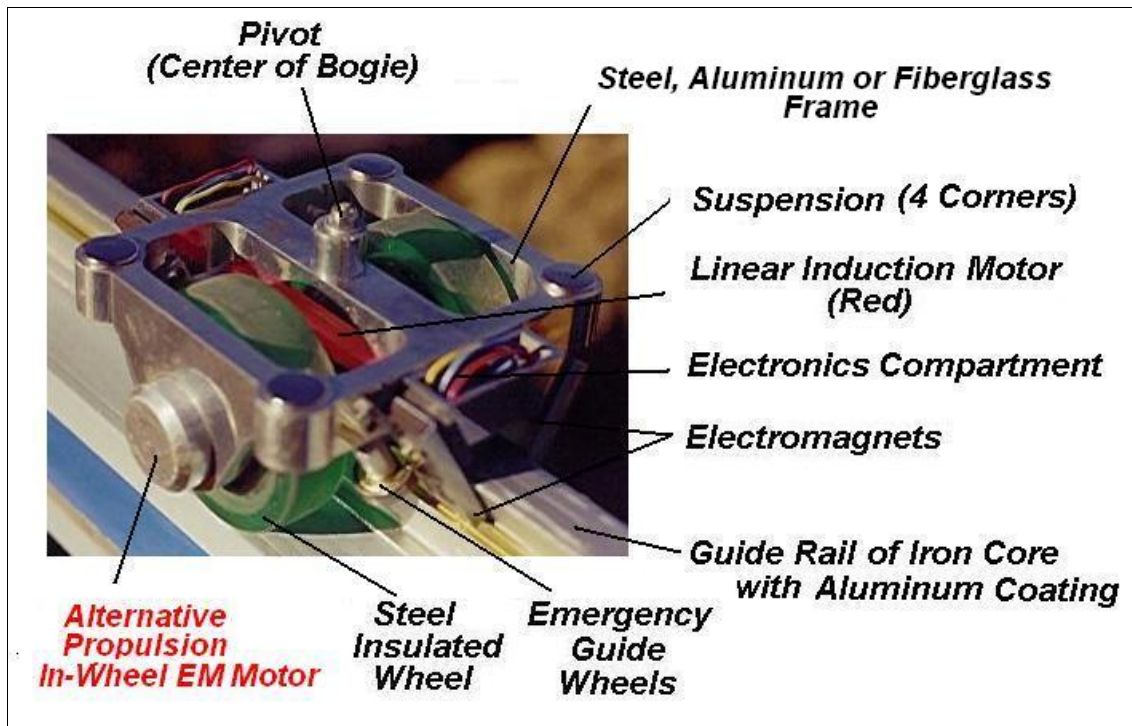


Figure 5 SemiMaglev Urbanaut™ Bogie Components

### 3.3 Types of EM Bogie Propulsion Systems

The bogie has been engineered and designed for 2 alternative types of propulsion systems [14][18]:

#### 3.3.1. Alternative I: Application of Linear Induction Motor (LIM) Propulsion

The SemiMaglev Urbanaut™ is unique to the Urbanaut® Monorail only, and is a considerably simpler concept than a full maglev system. This alternative utilizes an electromagnetic linear induction motor (LIM) propulsion system, which in principle, is well known and is used in light rail transportation currently.

The Urbanaut® (LIM) version consists of two primary components:

- 1) The **Primary Coil Stator** (Moving component installed in the vehicle) is the LIM, which is basically an ordinary rotary electromagnetic motor that has been opened, rolled out and flattened in shape. The LIM motor is part of the SemiMaglev Urbanaut™ Bogie.
- 2) The **Secondary Conductor** (Stationary component) is the magnetic reaction guide rail. The guide rail which is part of the guideway is made of magnetic iron, with the top surface and 2 vertical sides of the rail coated with a 5 mm thick aluminum or copper plating, which serves as an electrical conductant. This is a very simple technical and practical arrangement for a vehicle that is locked to a monorail guideway.

The interaction between the two components (the moving and stationary) takes place across a small air gap less than 10 mm. There are no mechanical frictional contacts, no axle, and no gear, which are its major advantages of an LIM.

Electric power to the primary stator (PS) in the vehicle is provided by an outside source, which can be contact power rails along the guide rail or a non-contact source.

The LIM together with an inverter represents a propulsion system that ensures propulsion, acceleration, deceleration, braking, stopping and operational control of the vehicle. While ordinary LIMs used in rail transportation apply steel wheels to maintain the air gap, the SemiMaglev Urbanaut™ utilizes an EM magnetic guidance concept, where a constant gap along the inclined faces of the guide rail is maintained by the EM current through an active controller.

## Maglev Interaction between EM and Magnetic Guide Rail

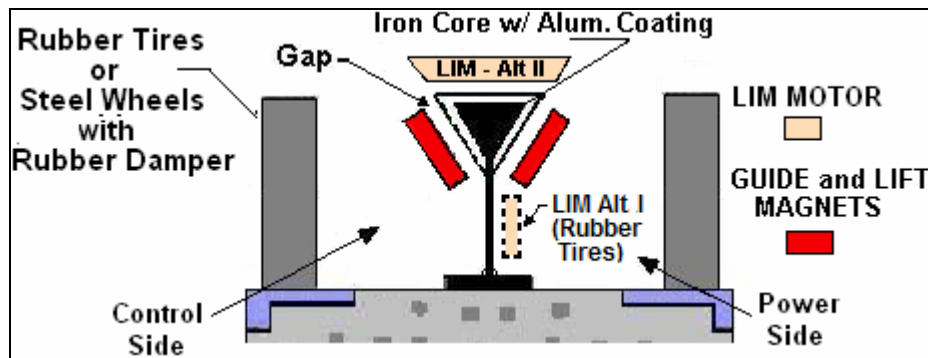


Figure 6

There are several potential locations of the LIM motor unit in the bogie.

### 1. LIM Interaction with Top of Guide Rail – Applying Insulated Steel Load Wheels

For high speeds, 2 insulated partially loaded steel wheels are applied for variable speeds up to 224 km/hr when station stops are 4 miles apart. The LIM unit is attached to the underside of the longitudinal cross brace of the bogie, interacting magnetically with the top portion of the guide rail. In this alternative location a Maglev Linear Induction Motor (MLIM) is applied. This MLIM has a repulsive force approximately 135% of the propulsion force which will reduce the demand for levitation energy [14].

### 2. LIM Interaction with Vertical Web of Guideway Applying Rubber Tire Load Wheels [13]

This alternative applies air cushion rubber tires which, during partial weighting of the load wheels, may slightly deflect. The LIM is located in the vehicle so it faces the vertical web of the magnetic rail. The surface of the web has a 5 m/m aluminum or copper coating for electrical conductance.

#### Advantages of LIM:

1. Can be custom made to shape and size
2. Traction is not by adhesion
3. Vehicle can climb steeper grades
4. Needs no wheels, no gear, no axle
5. No mechanical links

### 3.3.2. Alternative II - In-wheel electromagnetic (EM) motor for rubber tire traction, for speeds up to 100 km/hr

EMs with an air gap are applied to guide and partially lift the vehicle. An in-wheel powerful electromagnetic motor provides propulsion with direct traction on the wheel hub. Load wheels have brakes, but no axles and no gears [11][18].

A bogie can have one or two EM motors depending on vehicle size and power requirements. For example, in a 3-car train the propulsion will be by 4 motors, 2 on each of the bogies within the outer ends of the front and rear cars.

The in-wheel EM propulsion alternative is a simplified SemiMaglev Urbanaut™ concept adaptable to vehicle speeds up to 100 km/hr. It implies traction between the rubber tire and the runway at all times and an EM air-cushion guidance.

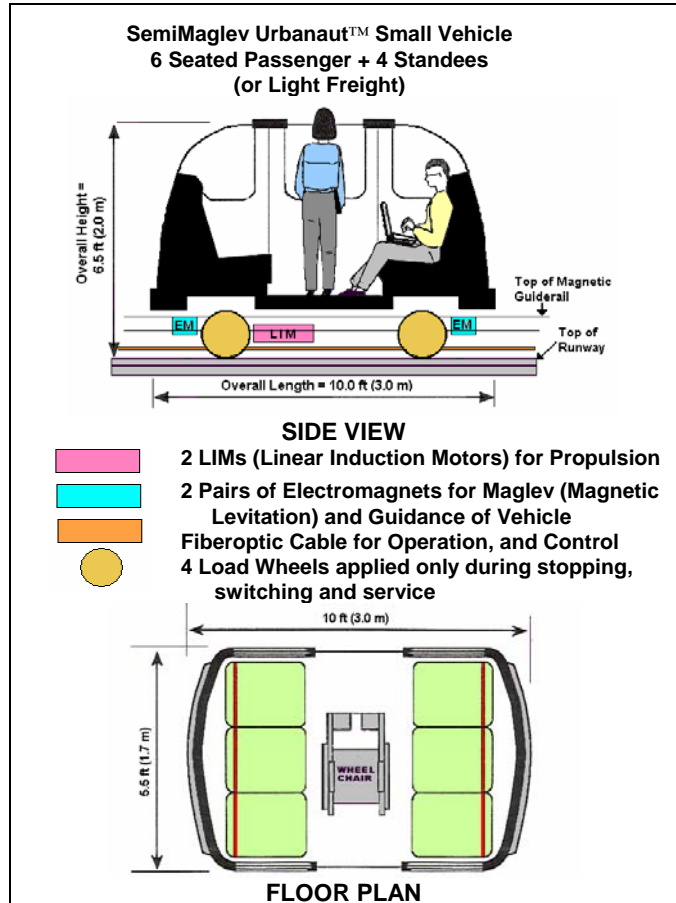
## 4 Vehicle Sizes and Trains

Three different scales (Full, Intermediate, and Small) of the SemiMaglev Urbanaut™ have been designed, engineered and model tested.

### 4.1 Urbanaut® PRT Vehicle - Small Size

The low-profile PRT (Personal Rapid Transit) version features vehicles that can seat 10 passengers or 6 passengers plus a wheel chair. The Low Profile vehicle is unique since the vehicle height from floor to ceiling is less than the average passenger's height. A central sliding or overhead doorway on each side of the vehicle covers half the cross section of the vehicle [18].

Figure 7



### 4.2 Single Vehicle – Intermediate Size

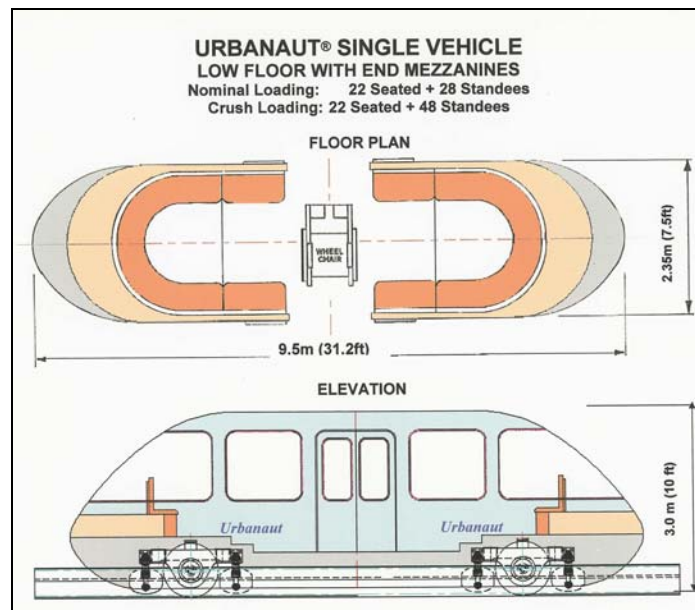


Figure 8

#### 4.3 3-Car Train at Surface – Intermediate to High Speed

##### SemiMaglev Urbanaut™ 3-Car Bullet Nose Train – Intermediate Size

Max. Nominal Loading: 62 Seated + 72 Standees

Max. Crush Loading: 62 Seated + 102 Standees



Figure 9 3-Car Train = 80 ft (24.3m)

#### 4.4 6-Car High Capacity Trains on Dual Elevated Guideway



Figure 10

The SemiMaglev Urbanaut™ "Full Scale" System is applicable to trunk lines and as commuter vehicles and for potential large volumes of passenger traffic per hour. It can be made for high speed and slightly longer distances between stops [21].

Full scale Urbanaut® trains of 6 cars with a length of 55 meters (180 ft) has the potential carrying capacity of 40,000 passengers per hour (seated + standees).

## 5 Guideways and Stations

### 5.1 Prefabricated Portable Guideway Components

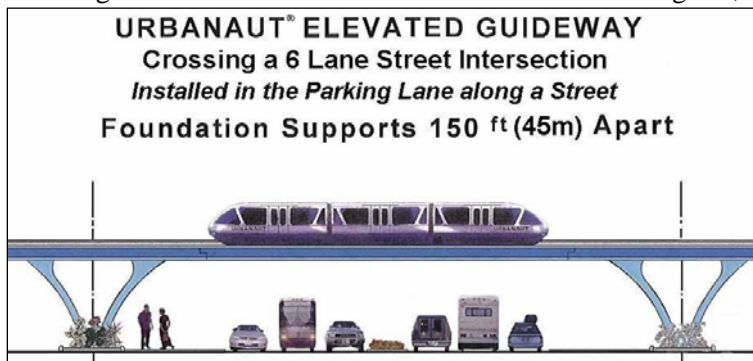
At surface and subsurface only a 1.0 meter wide concrete runway slab is required compared to 2.5 to 3.0 meters for normal non-stabilized maglev vehicles. The elevated guideway is a standardized prefabricated system of basically 2 components, a column-to-beam unit and a drop-in center beam [20].

Several types of elevated, lightweight, pre-manufactured guideways have been engineered by Urbanaut® which can be located off-street, having no interference with existing auto traffic. One type consists of two elements; a curved Y-shaped column-to-beam and a center drop-in beam. These two elements allow for free spans of 45 meters between foundations which can bridge a large, busy street intersection. This system allows for flexibility in a network route design in that it can be easily expanded, removed or relocated if need be.



Figure 11

The attractive elevated curved Y-shaped column-to-beam triangular units have a unique structural advantage which makes the elements more slender and lighter, leading to a lower construction cost.



Longer beam spans will reduce the number of foundations needed and interference with underground utilities and will have less environmental impact on the community.

Figure 12

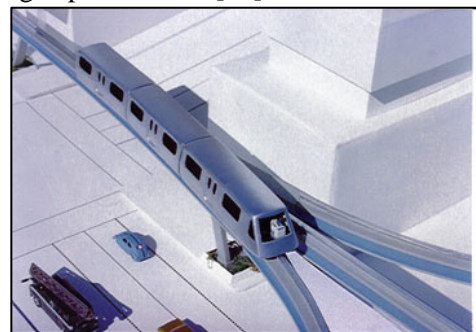
An alternative is an inexpensive guideway assembled with portable lightweight components utilizing

vertical hollow columns and a beam way of composite or steel materials with a concrete running slab on top. Heating cables are installed in the runway for regions with cold climates to prevent surface icing.

### 5.2 Switching of Guideways

Urbanaut® has 3 different simple switches, depending on application: **1.** An on-board switch for at slow speed; **2.** A swivel switch for 2 guideways crossing each other; and **3. A flexible high speed switch.**

The central magnetic rail can also be made into a lightweight high speed switch [18], which is flexed by automatic operation to route the vehicle from one guideway to another. This allows the Urbanaut to be used in a network configuration so that larger areas in a community can be served and the vehicles can be utilized more efficiently. **It is possible to switch vehicles from a smaller guideway onto a larger one.** This has application where smaller, independent single guideway Urbanaut® "circulators", extending from a trunk line into a high density community, will interact continuously with passenger movement to and from, avoiding large, expensive parking lots at the stations. Figure 13





### 5.3 Stations Adapted to Planned Route Layouts

Monorail stations are a significant part of monorail systems. Efficient stations serve to enhance passenger entry and exit of the monorail vehicles and trains. For a dual guideway, the station must be designed and engineered for maximum capacity for 2 trains simultaneously loading/unloading plus emergency unloading in case escalators and stairs fail to expedite passenger exiting to the surface below. Urbanaut® has several versions of stations depending on application and service of passengers and vehicles [16]. Where practical and economically feasible, an Urbanaut® station can be built into a multistory building

Figure 14

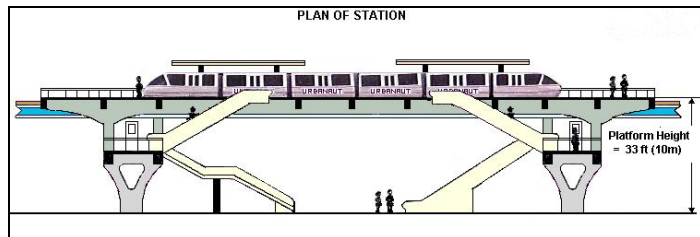
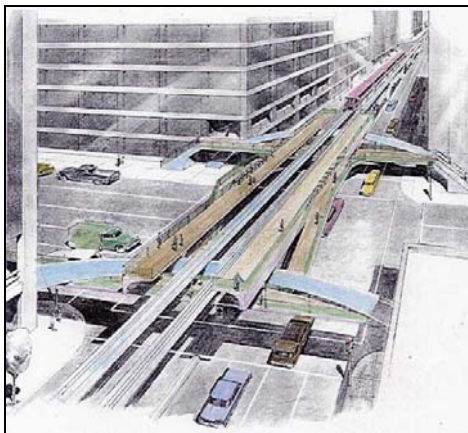
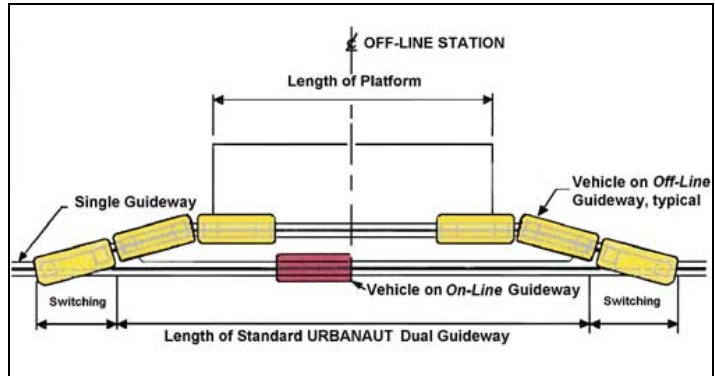


Figure 15

Figures 14 and 15. High Capacity Elevated Urbanaut® Intersection Stations are special stations designed and engineered for unobstructed free flowing surface traffic in both directions below. Such a station has the flexibility for passengers to enter and exit any of the 4 street corners.

An Off-Line Urbanaut® Station shown has dual uses. A) It can load and unload passengers on an Off-Line guideway platform while vehicles are moving by on the On-Line guideway. B) By means of simple Urbanaut® switching provided by the uniquely shaped magnetic rail several parallel off-line guideways can be added to a station for storage and servicing of vehicles [18].

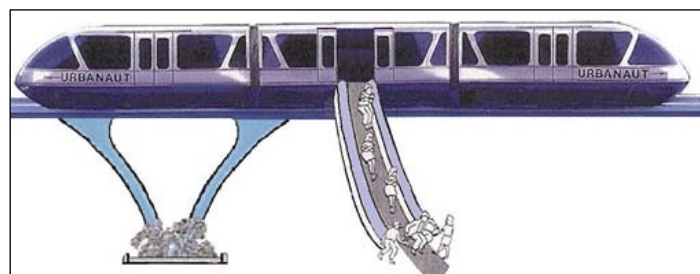
Figure 16



### 5.4 Passenger Safety and Evacuation

Figure 17

The Urbanaut systems will be fully automated (no drivers) with central control from facilities adjacent to the guideways. Security personnel, by means of audio-visual communication, would view the vehicles inside at all times, during unloading and loading as well as while traveling on the guideway. Laser beams on-board the vehicle will control any irregularities or emergencies on the guideway and bring the vehicle to a stop if needed. Special vehicle escape devices are provided in case of emergency evacuation from elevated guideways.



## 6 Project Sample and Costs of SemiMaglev Urbanaut™ (U.S.A.)

The SemiMaglev Urbanaut™'s central magnetic rail which enables simple and fast switching allows for the versatility of using a single, smaller, environmentally friendly guideway to feed a larger high capacity trunk line, thus creating a versatile transportation network serving larger areas of the community. The SemiMaglev Urbanaut™ is the only monorail system that allows this exchange. Such an example is the 160 km (100 miles) long Puget Sound Regional Master Plan (PSRMM) [15], a large scale monorail layout that has the potential to move up to 500,000 passengers daily in Washington State, USA.

An Urbanaut® elevated, surface or subsurface single or dual line right-of-way loop "Circulator" (See Figure 19) can be applied to the distribution of people within urban communities, industry, shopping centers, ports, parks, university and school campuses, sports activities and recreational areas. Such a guide way concept is expandable and can be connected to other loops or guide ways in the future if needed. Several "circulator" loops can be integrated, with transfer from one to another possible.

During high capacity demand periods, vehicles (trains) will be operated continuously around the loop, programmed for maximum service. When there are few passengers, such as at night, the excess vehicles can be docked and/or serviced away from the guideway in an off-line station area.

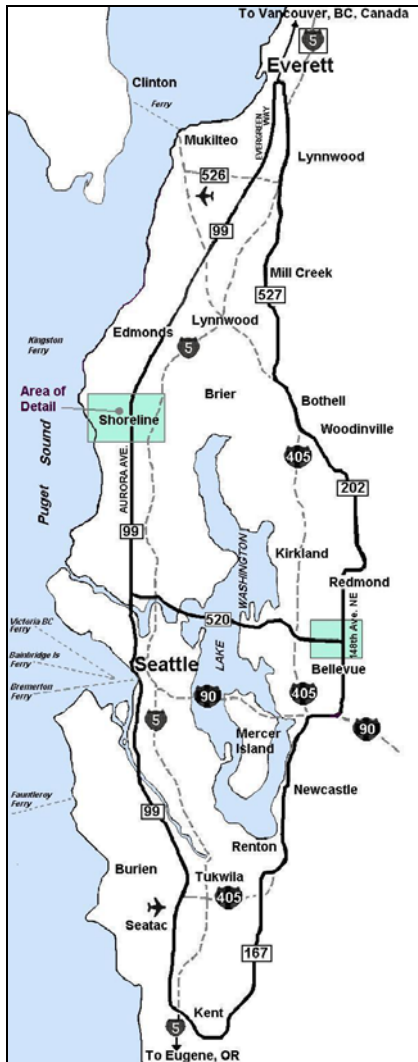


Figure 18

### SemiMaglev Urbanaut™ Circulator

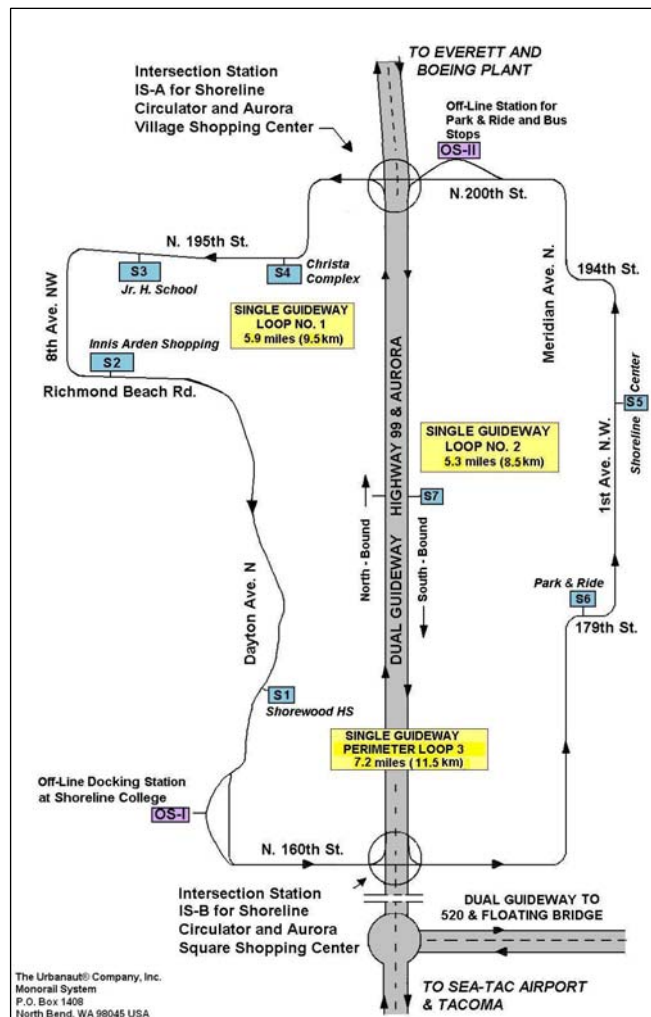


Figure 19 Area of Detail

## 6.1 Cost of High Capacity Master Plan [21]

### Puget Sound Regional SemiMaglev Urbanaut™ Monorail Master Plan Location: Washington State, U.S.A

#### TECHNICAL DATA

- 1) 100 miles (160KM) of Elevated and Surface Urbanaut® Dual Guideway
- 2) 50 high capacity stations, 2500 passenger design loading, spaced 2 miles apart
- 3) Trains each capable of carrying up to 1000 passengers
- 4) Daily potential moving capacity: 500,000 passengers
- 5) Maximum speed of trains = 128 km/hr (80 mph) for train stops every station
- 6) Maximum potential speed = 185 km/hr (115 mph) for train stops every second station
- 7) 2 Maintenance facilities
- 8) Apply SemiMaglev Urbanaut™ monorail technology

#### COST ESTIMATE OF 3 STAGES OF CONSTRUCTION

Stage I	West Side:	Everett to Seatac With 20 stations	= 64 km (40 miles)	US\$2.6 billion
Stage II	East Side:	Seatac – Kent – Everett With 25 stations	= 80 km (50 miles)	US\$3.0 billion
Stage III	Central Connector:	Highway 99 across 520 Bridge With 5 stations	= 16 km (10 miles)	US\$0.6 billion
	Total	100 miles of Urbanaut® dual guideway With 50 stations		US\$6.2 billion

Cost Estimate does not include:

- 1) Updating the 520 Floating Bridge
- 2) Any underground (tunneling)
- 3) Major utility relocation
- 4) Cost of surface and aerial right of way (to be donated by state and local government)
- 5) Financing of capital  
(Revenue and other income may pay for operation, part or all of installation over a 15 year period) (Example: existing Seattle Monorail)

## 6.2 SemiMaglev Urbanaut™ in Median of Freeway

Figure 20



An inexpensive high speed SemiMaglev Urbanaut™ constructed on a 1.0 meter wide slab in the median of a freeway can favorably compete with autos, thus reducing the congestion and gridlock on the freeway, and provide a relaxed, stress less ride and a much shorter traveling time at reasonable cost [21].

There are numerous such application sites along freeways in the USA and abroad. Such an inexpensive high speed SemiMaglev Urbanaut™ as a back-bone system can have passenger transfers to slower speed SemiMaglev Urbanaut™ Circulators or distribution networks serving high density communities and cities. As part of a comprehensive regional transportation plan, applying the same technology throughout has numerous practical and economical advantages. It becomes more efficient, has greater capacity and is a less costly

alternative than complicated tunnel diversions and expensive, massive, outdated steel wheel-steel rail concepts.

It should be noted that the speed of 225 km/hr (140 mph) is the upper limit on our freeways in the U.S. because of the limited right-of-way curvatures. Ultra high speed maglev systems also require very large radial curves, which would require additional right-of-way along freeways, substantially increasing costs.

## 6.3 Speed/Time Curve for High Speed SemiMaglev Urbanaut™

For a SemiMaglev Urbanaut™, a potential speed of, for example, 225 km/hr (140 mph) can be reached at relatively low operational cost. However, because of longer acceleration and deceleration distances, the spacing between stops will have to be considerably longer (Figure 21). Such an Urbanaut® could be suitable for application between cities, high density centers and airports. The high speed, inexpensive SemiMaglev Urbanaut™ could, for example, travel from Vancouver BC, Canada to Eugene, Oregon, USA, a distance of 690 km in approximately 4 hours with stops in 10 cities. This is half the time an auto would take driving nonstop with no freeway congestion.

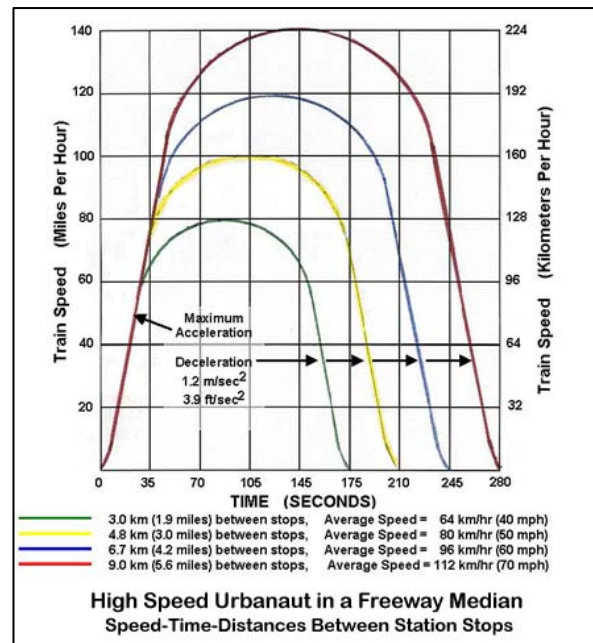
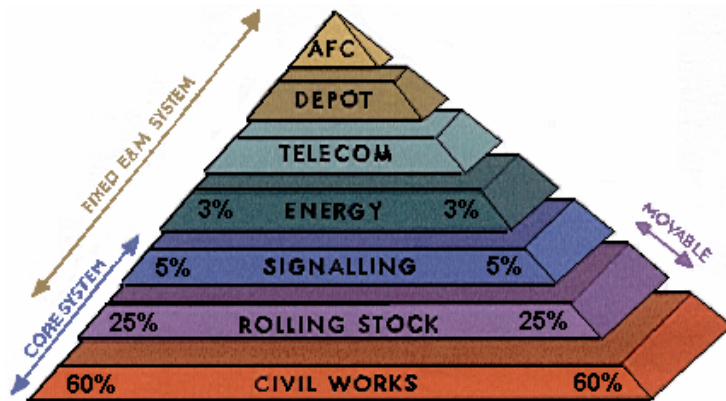


Figure 21

## 7. Distribution of Cost for the SemiMaglev Urbanaut™



### Description of Element

- **Civil Works:** Guideway, Stations, Switches, Maintenance Buildings
- **Rolling Stock:** Trains and special vehicles
- **Signaling:** Train Control System (TCS) and other controls
- **Energy:** Energy supply
- **Telecom:** Communication
- **Depot equipment and control center**
- **AFC:** Automated fare collection system

In the SemiMaglev Urbanaut™, the Core System, representing 85% of costs, embraces

1. The Civil Works (Elevated Guideway)
2. The Rolling Stock
3. Signaling (Automatic control)

The Fixed E&M (Electrical & Mechanical) integrates with the Civil Works [12]

Figure 22

Cost of a monorail project is quite involved and varies with the passenger capacity of the system, the location, the geography and the route layout of the monorail guideway, along with the station location and sizes, service and maintenance facilities, switching and total environmental impact on the community. Urbanaut® has the flexibility to integrate future expansion or deletion, which could reduce planning and construction cost.

The graphical cost illustration [7] shown in Figure 23 is specific to the Urbanaut® technology. While the "Cost of Depot" is a relatively small item for the Urbanaut®, it is very large for the straddle-beam type monorails, which require a very large land area with complicated equipment to move the inseparable massive beam ways with the trains on top.

The height of the Urbanaut® is 40% to 60% less than the straddle-beam type monorails built in the USA and Japan because the Urbanaut® technology is not dependent on a beam way like most other monorails. This means the much lighter vehicle and guideway can be constructed for considerably less cost.

A cost comparison by an independent consultant suggests costs may be only 50% of the Alweg type technology because of Urbanaut®'s many features discussed above [16].

Urbanaut® has the potential capacity of 20 freeway lanes at 10% of the cost.

## 8 Summary - Economical and Practical Advantages of a SemiMaglev Urbanaut™ Compared with Other Transit

The SemiMaglev Urbanaut™ monorail technology is substantially different from conventional straddle-beam type monorails [1] and steel wheel –light rail systems [8] and proposes to solve many of the problems encountered by them. It has been designed so that it does not have to straddle the beam way, but rides on top of a runway and is guided by a central magnetic rail. It has much more flexibility, is much smaller and lighter in weight and considerably less costly to install and operate.

### 8.1 Comparison of Relative Energy Demand

The energy cost to propel a vehicle is directly related to the weight and size of the vehicle. A heavier, more massive, vehicle will require more energy. A Comparison of Energy Demand shows the SemiMaglev Urbanaut™ will use only 60% of the energy per passenger as the straddle type rubber tire monorails.

Force = mass (acceleration) or ( $F=ma$ )

A more massive vehicle will require more energy.

A straddle-beam type monorail with a large number of contact tires has considerable more mechanical friction. Such a monorail vehicle also has a larger cross section and less aerodynamic shape than the smaller aerodynamic bullet-nose-shaped SemiMaglev Urbanaut™ .

	New York Transit	Alweg / Hitachi/ Bombardier	SemiMaglev Urbanaut™
Aerodynamic Drag	1.3	1.0	0.60
Mechanical Friction	1.5	1.0	0.65
Ac-De-celeration	1.4	1.0	0.60

### 8.2 Operation and Maintenance (O & M)

The installation and operation of an Urbanaut® maintenance facility may cost only one-tenth of a straddle beam type monorail which needs a very large area and dozens of complicated mechanical switches for arranging and moving vehicles on the bulky beamways. The Urbanaut® center magnetic guide rail is removed within the maintenance area and the vehicles can be stored parallel to each other either by manpower or by using a custom small pallet lift for a three-car or longer train.

### 8.3 Advantages in Switching

The concept of the **small central magnetic rail** allows for far more flexible and efficient methods of switching and is more versatile for urban network applications as opposed to the current monorails' back and forth (shuttle) or continuous loop applications which have no practical nor economical switching capabilities.

### 8.4 Advantages of Steeper Climbing Capabilities

The SemiMaglev Urbanaut™ is environmentally friendly and adjusts to the landscape. The SemiMaglev Urbanaut™ powered by a **non-contact LIM** can climb considerably steeper grades than light rail, where adhesion between steel wheels and rails is limited to grades of 3 to 4%. Light rail therefore frequently has to construct deep cuts and tunnels, while the SemiMaglev Urbanaut™ can adapt to steeper grades up to 12%, adjusting more closely to the landscape, avoiding expensive tunnels and deep, damaging expensive cuts for rights-of-way through existing residential communities.

### 8.5 Advantages in Sharp Turn Radius and Steep Climbs

The SemiMaglev Urbanaut™ has a small turning radius of 38 m (125 feet) allowing for sharp curves at 90° street intersections (Figure 23).

Both the large turning radius required and the inability to climb steep hills are **major problems for the straddle-beam type monorails and steel light rail** in many cities and urban areas.

Shown is a vehicle at a station built into a multistory building.



Figure 23

### 8.6 Noise Impact

The SemiMaglev Urbanaut™ is virtually noiseless with its aerodynamic shape and no surface friction. The old conventional steel-wheel/steel-rail (light rail) concept is very noisy, and has much greater visual and street disruption impacts, has less flexibility and costs are 3 times greater than the Urbanaut®.

### 8.7 Advantages in Size

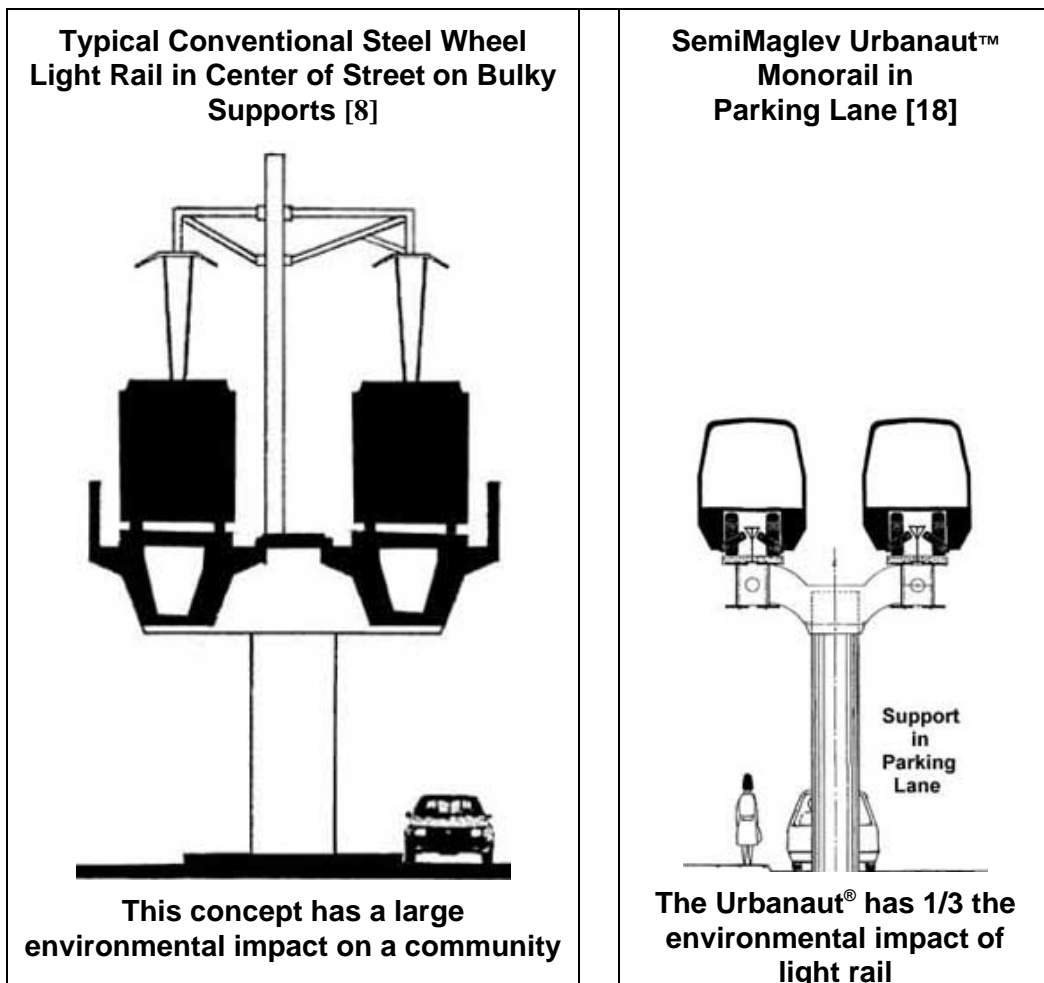
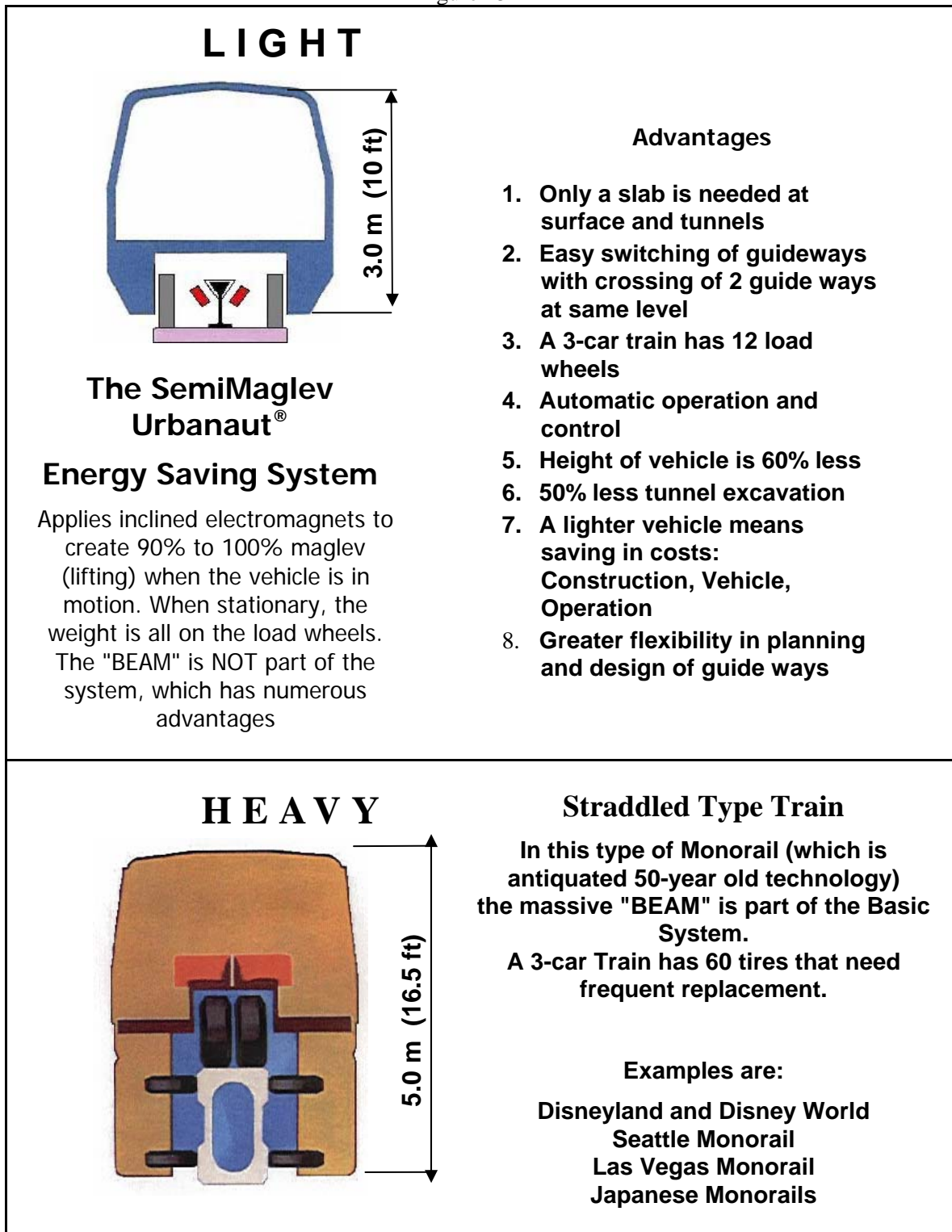


Figure 24

8.8 Energy and Cost Advantages

Figure 25





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