GACP 161-067
GA-C25498

CONCEPTUAL DESIGN STUDY FOR THE ELECTRIC CARGO CONVEYOR (ECCO) SYSTEM

Final Report

Prepared for
The Port of Los Angeles
San Pedro, CA

In support of
Agreement No. E-6304
GA Project 20132

Submitted by
GENERAL ATOMICS

27 October 2006

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Distribution Statement

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GENERAL ATOMICS

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EXECUTIVE SUMMARY

This executive summary provides the results of a study performed by General Atomics (GA) under sponsorship of the Port of Los Angeles, to evaluate the feasibility of a maglev cargo system.

The maglev network envisioned by the Port of Los Angeles depicts a system, which connects the terminals to the intermodal transportation center leading to the terminus of the Alameda corridor. The ICTF is the distribution center for long distance trucking and also the gateway to the Alameda corridor, which distributes cargo by rail from the port to locations within the country. A maglev network operating within the Port of Los Angeles, removes from the roads over one million truck trips per year, just between Terminal Island and the ICTF.

Maglev network envisioned by the Port of Los Angeles to support the green expansion of capacity

Guidelines provided by the Port of Los Angeles for this study include:

- Container trips per day 5,000 (2,500 per direction)
- Container size Up to 40-ft
- Container weight 30,480 kg (67,200 lb)
- Operation hours 24 hours per day
- Alignment length 7.5 km (4.7 miles) Terminal Island to SCIG

Maglev is not new; it has been developed for passenger service over the past 30 years and recently deployed for commercial revenue service in both China and Japan. Even though freight transportation requirements, in terms of weight capacity and throughput, are different than those for passenger service, the components of maglev technology can be readily adapted to handle freight.

One of the innovations being developed by the GA team is a totally passive permanent magnet, large-air-gap maglev system, which results in lighter vehicles, reduced energy consumption, and more streamlined, less costly guideway structures. We have developed this technology over the past several years under the sponsorship of the Federal Transit Administration (FTA), the Pennsylvania Department of Transportation (PennDOT) and private industry funding. This permanent magnet approach for Maglev was originally invented by the Department of Energy (DOE) Lawrence Livermore National Laboratory (LLNL) and is being further developed for deployment by GA under a license agreement with LLNL.

In September 2004, we completed development of a 400-ft-long test track located at GA in San Diego, California, and are presently in the process of perfecting the system controls and optimizing components to improve performance and reduce costs.

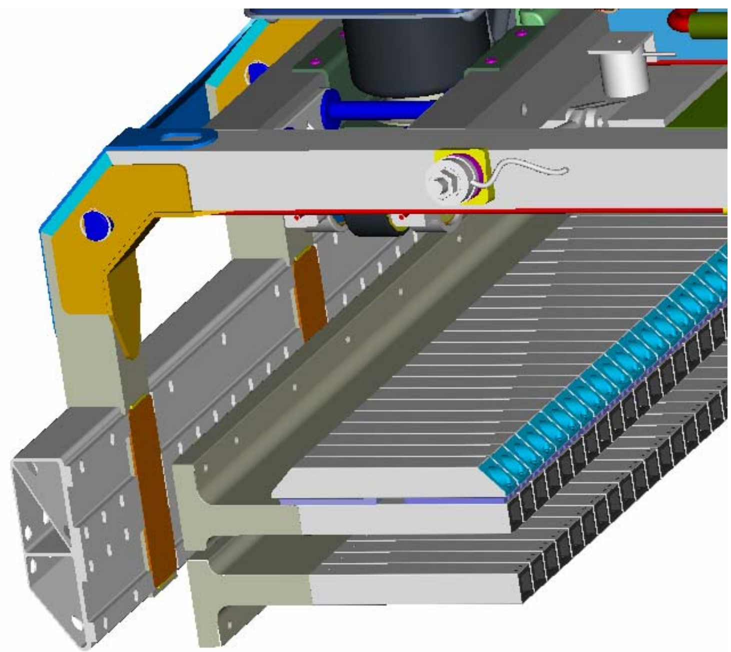
Based on extrapolation of the engineering and development conducted to date for passenger maglev, we have performed conceptual engineering of the maglev cargo system. Our studies indicate that it is readily feasible to design, build, and economically operate a maglev system to carry cargo that will meet the guidelines required by the Port of Los Angeles.

We have named this system the Electric Cargo Conveyor (ECCO) system.

System capabilities allow a high volume, expandable throughput.

KEY SYSTEM PARAMETERS	
System Parameter	**Value**
Throughput Capacity	2,500 containers per day per direction
Weather	All-weather operation
Levitation	Permanent magnet Halbach array, passive
Propulsion	Linear synchronous motor (LSM)
Operation	Fully automatic train control (driverless)

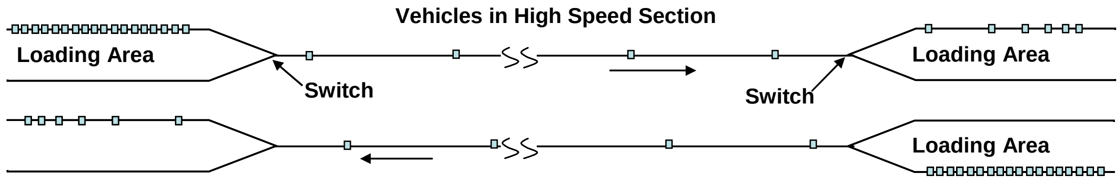
KEY SYSTEM PARAMETERS (CONT'D)	
System Parameter	**Value**
Safety	Automatic control, wraparound feature of the design, and restricted access to elevated guideway
Speed, maximum operational	145 km/hr (90 mph)
Vehicle size	13.7-m (45-ft) long x 2.6-m (9-ft) wide
Grade, operating capability	10%
Turn radius, design minimum	100 m (328 ft)
Size of vehicle (container capacity)	40 ft, 67,400 lb



Magnets used for levitation and propulsion are robust, off-the-shelf components

Neodymium-iron-boron rare earth permanent magnets are used for levitation, propulsion, and guidance. These magnets are commercially available and currently being used in computer hard-drives and electric motors including hybrid automobiles. They are robust and can withstand long-term operating environment requirements. The operational levitation height is 1.0 in., which alleviates tight construction tolerances.

The system architecture is arranged to shuttle cargo vehicles back and forth through high-speed sections connected with dual-loading/unloading spurs. This arrangement, coupled with 20-sec headway between vehicles in transit and 2-min dwell time for loading and unloading, meets the 5,000 container trips per day requirement. The system is driverless, using automatic train control. It is also energy-efficient, and uses regenerative braking during deceleration.



The system architecture can handle 5,000 container trips per day using safety-certified train control systems

Single vehicles with single-stacked containers are used to allow maximum mobility for the container while minimizing structural loads and propulsion power requirements.

To demonstrate this capability, under separate GA internal discretionary funding, we mounted a single TEU (20-ft) cargo container on our existing urban maglev test chassis making it the world's first cargo maglev test vehicle as shown below. We successfully tested the system up to 22 mph (speed limited due to relatively short length of the test). While this system is presently not optimized for cargo, the system performed very well.

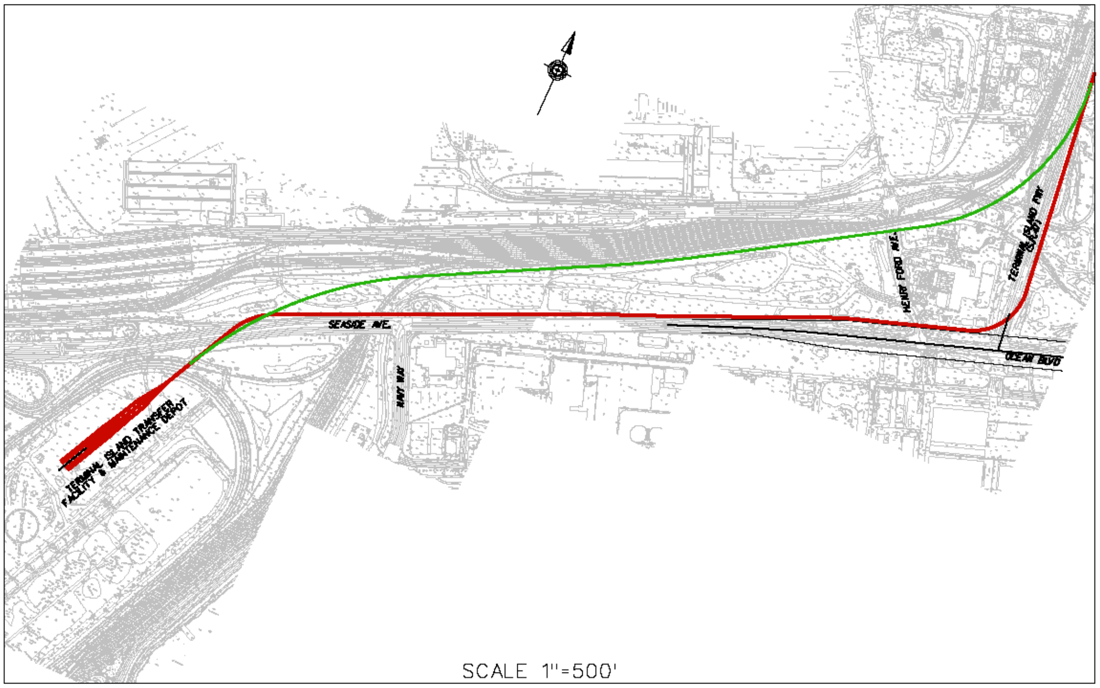
World's first cargo maglev system, the Electric Cargo Conveyor (ECCO) undergoes testing at the GA test track in San Diego, California

As part of this feasibility study, we worked with staff at the Port of Los Angeles to investigate potential alignments from Terminal Island to the Southern California International Gateway (SCIG). Two alignments, each approximately 5 miles long were studied (depicted as green and red). The green alignment appears to be preferred since it is the shortest and allows the largest turn radius to provide greater average speed and container throughput. Our studies indicate that either alignment infrastructure can be built within the existing space using conventional civil construction methods with minimal, if any, building facility impacts.

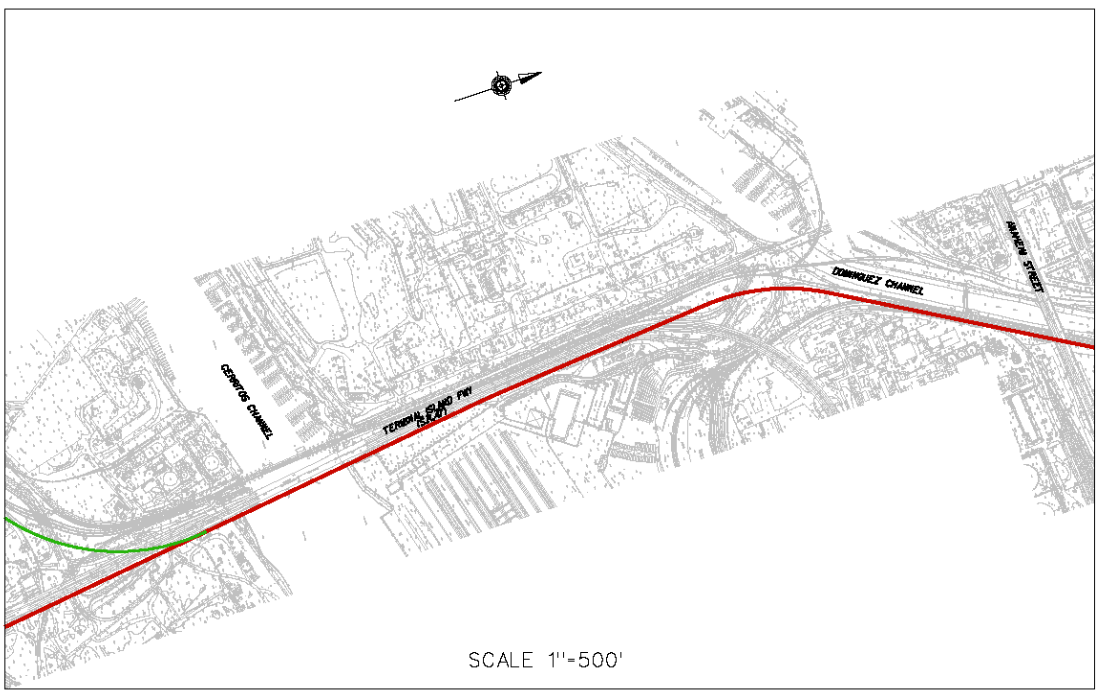
Both of the alignments studied will be located within the right-of-way owned by the Port of Los Angeles, Port of Long Beach, Caltrans (Route 47), railroads (owned by the ports), and some private properties.

Alignments studied connects Terminal Island with the SCIG facility

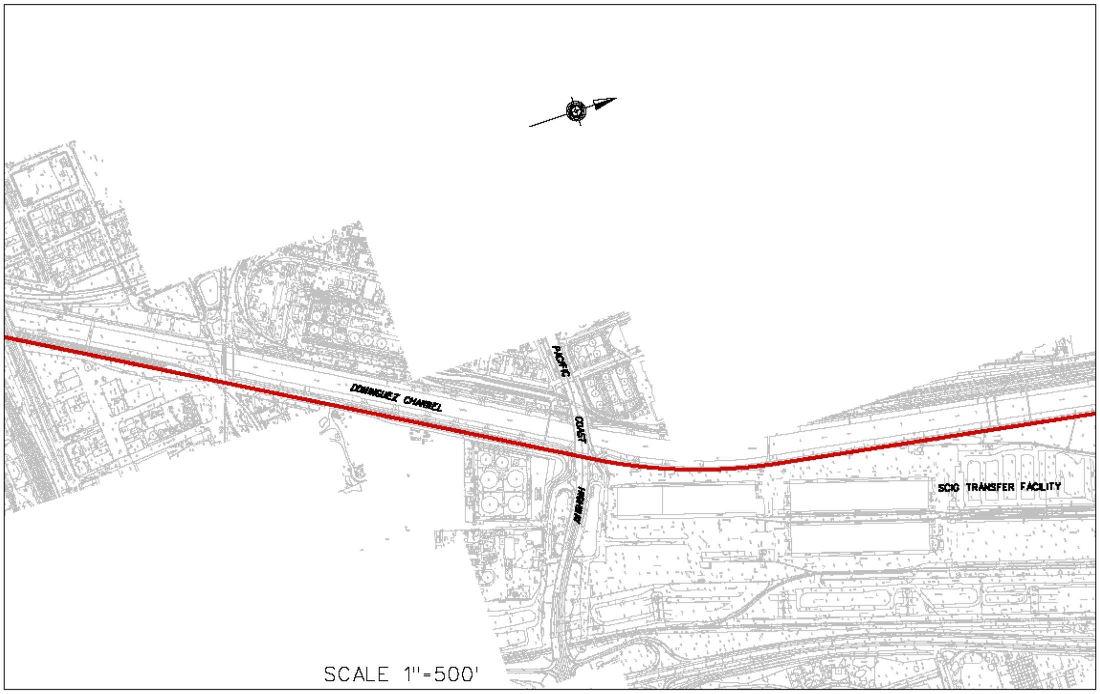
Two alignments were investigated: the baseline (red), and the preferred (green) alignment, which is shorter, and faster.

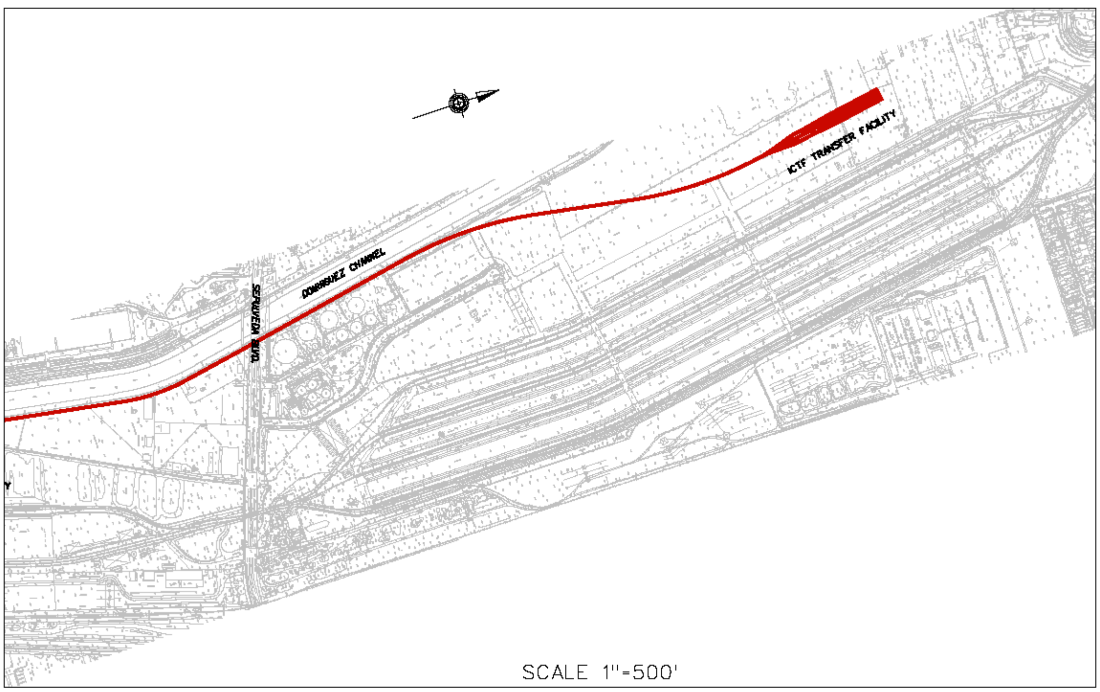


SEASIDE AVE.
NAVY WAY
HENRY FORD AVE.
TERMINAL ISLAND FWY
OCEAN BLVD
TERMINAL ISLAND TRANSFER FACILITY & MAINTENANCE DEPOT
SCALE 1"=500'



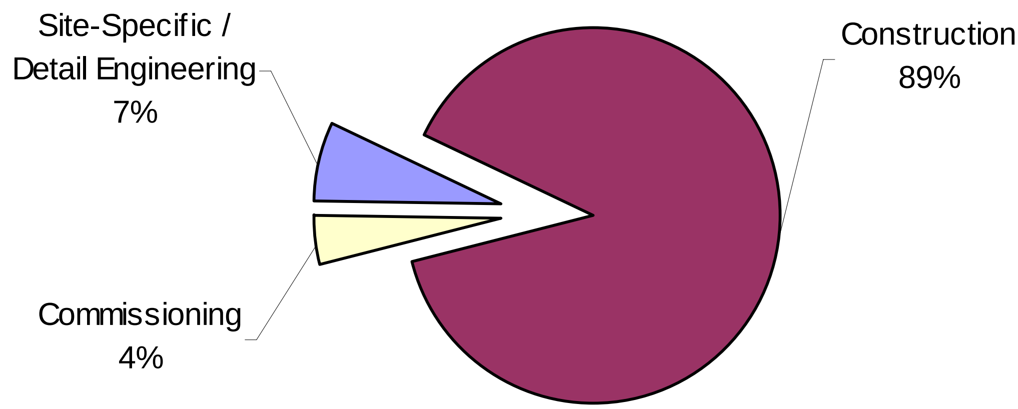
CERRITOS CHANNEL
TERMINAL ISLAND FWY
DOMINGUEZ CHANNEL
ANAHEIM STREET
SCALE 1"=500'


DOMINGUEZ CHANNEL
PACIFIC
COAST
HIGHWAY
SCIG TRANSFER FACILITY
SCALE 1"=500'

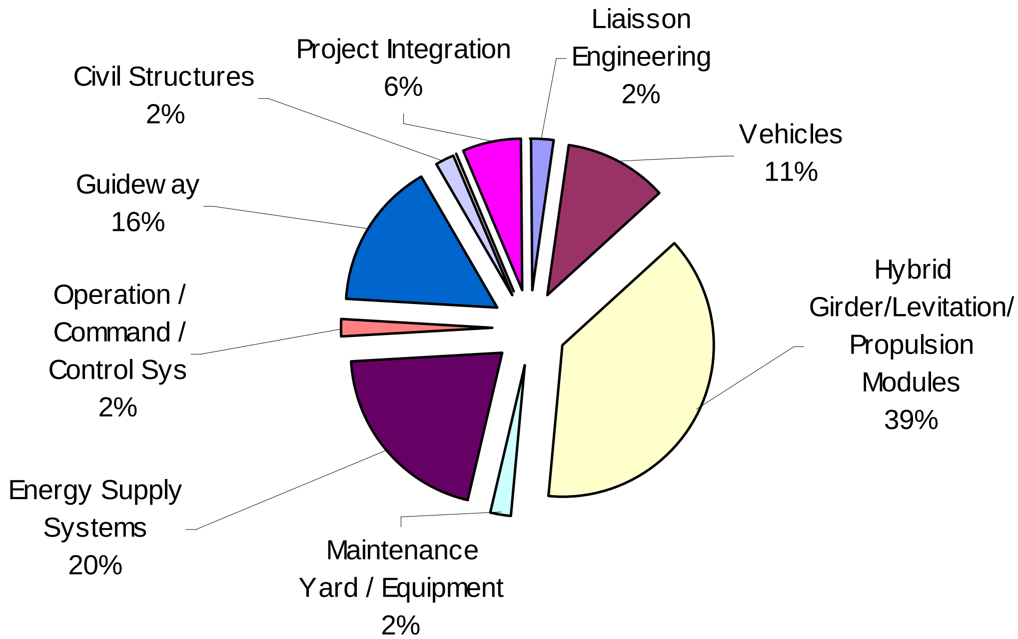

DOMINGUEZ CHANNEL
SEPULVEDA BLVD.
ICTF TRANSFER FACILITY
SCALE 1"=500'

Our cost studies indicate that maglev will be very cost competitive with highway transportation while offering all-electric operation with many environmental and efficiency benefits. Another key advantage of the system over conventional wheeled rail systems is its quiet operation, eliminating the need to go underground for noise abatement. This benefit greatly reduces construction cost and schedule. Operation and maintenance costs are also greatly reduced since the system is levitated contact-free, resulting in reduced maintenance and life-cycle cost.

Our budgetary cost estimate for the 4.7-mile maglev system from the port to the intermodal transfer facility, including engineering, construction and commissioning (excluding cargo handling equipment) is $575M (expressed in 2006 dollars). Please note that this budgetary estimate is for planning purposes only and does not constitute an offer.

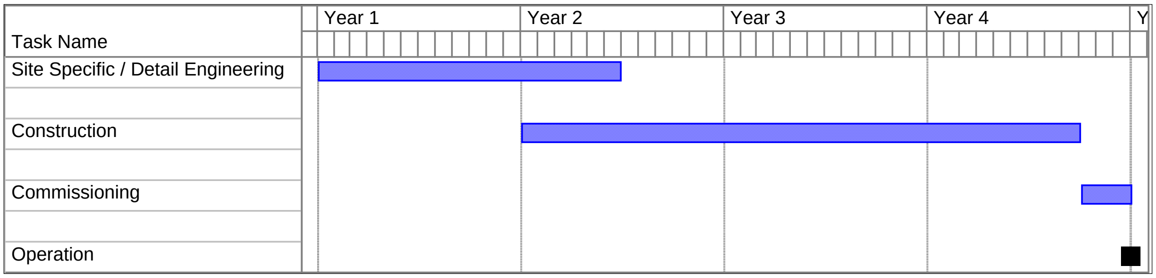


Budgetary cost breakdown – system



Budgetary cost breakdown – construction

An initial 4.7-mile long segment, providing a vital link from the port to the intermodal transfer facility would require about 4 years to design, construct, and commission. Future expansion could be accomplished at a much faster pace.



First 4.7-mile system can be operational in 4 years

BUDGETARY CASH FLOW

	Year 1	Year 2	Year 3	Year 4	Total
Site-Specific / Detail Engineering	$ 28,251,300	$ 12,107,700			$ 40,359,000
Construction		$ 153,044,700	$ 255,074,500	$ 102,029,800	$ 510,149,000
Total Engineering & Construction	**$ 28,251,300**	**$ 165,152,400**	**$ 255,074,500**	**$ 102,029,800**	**$ 550,508,000**
Commissioning				$ 24,070,000	$ 24,070,000
Total	**$ 28,251,300**	**$ 165,152,400**	**$ 255,074,500**	**$ 126,099,800**	**$ 574,578,000**

Annual operating and maintenance costs are projected to be ~$13M. This includes control communication and system operation, electrical energy, and maintenance parts and labor. For reference, the cost of electricity for this system to make one-way 4.7-mile trip is less than $4 at current electric rates.

Additional benefits of the maglev system include:

- Dedicated movement of freight with a very high throughput, which will greatly reduce traffic congestion
- Freight movement that is safe and efficient on grade-separated, elevated guideway structure, greatly improving efficiency
- All-electric propulsion that eliminates local sources of emissions and reduces emissions overall
- Quiet operation since it is contact-free, which furthermore greatly reduces maintenance costs
- Steep-grade capability in all-weather conditions, allowing the guideway to be routed where it best serves the need

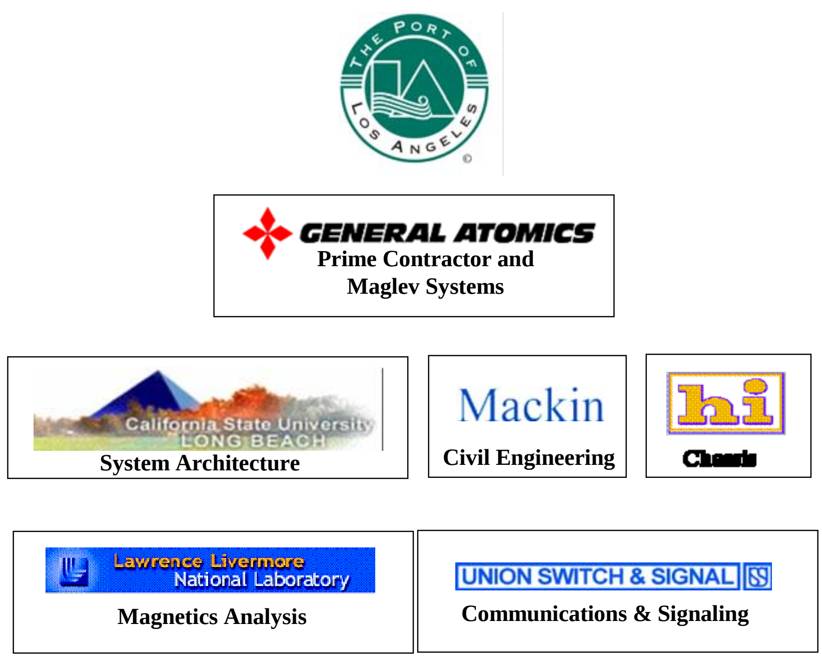
The overall conclusions of the study:

1. Maglev technology is feasible and can be implemented with proven components
2. The alignment is feasible for a high throughput system within the Port of Los Angeles complex
3. The complete 4.7-mile system connecting Terminal Island with the SCI complex facility budgetary cost estimate is ~$575M and includes channel/highway crossings, vehicles, power systems, switches, and system ends (without cargo handling equipment)
4. The detail engineering, construction, and commissioning schedule is 4 years, assuming full funding, and environmental approvals performed in parallel
5. Annual O&M costs are projected to be ~$13M

The next steps in moving forward on the project are to perform detailed site-specific engineering of the system, including the development of procurement and manufacturing plans. We envision that environmental and right-of-way planning activities would start in parallel.

We are very enthusiastic about the potential of contributing maglev technology to the Port of Los Angeles' future expansion plans. Our team is committed to working with the Port of Los Angeles to make the ECCO system a reality.

Maglev technology is a 21st century solution that could help optimize the effectiveness of intermodal transfer facilities for ports to reduce pollution and congestion, and increase the capacity of ports to meet the projected growth of our nation in the 21st century.



ECCO study team organization encompasses core technologies

1. INTRODUCTION

The General Atomics (GA) team takes great pleasure in submitting this final report to the Port of Los Angeles to evaluate the application of the urban maglev technology to moving cargo. We believe the proposed approach is responsive to the vision of the Port of Los Angeles as it looks toward expansion of its facilities in moving cargo efficiently and cleanly. The overall goal of this project was to develop preliminary design, cost, and schedule for a maglev cargo conveyor system from Terminal Island to the Southern California International Gateway (SCIG) Transfer facility, 4.7 miles away. The alignment studied is a result of a future maglev network developed by the Port of Los Angeles, as shown in Fig. 1-1. The alignment studied is shown in red. The goal of the system is to be capable of transporting 2,500 containers per direction per day (5,000 total container trips).

The tasks undertaken in this study include:

1. Identification of the alignment, and development of a preliminary alignment-specific operational requirements document.
2. Conceptual design of the maglev system components, including the vehicles, guideway, power systems, and communication and signaling.
3. A rough-order-of-magnitude (ROM) cost for the construction, operation, and maintenance of the system, including needed development activities.
4. An overall project schedule, including needed development activities, leading to construction, and commissioning of the demonstration system.

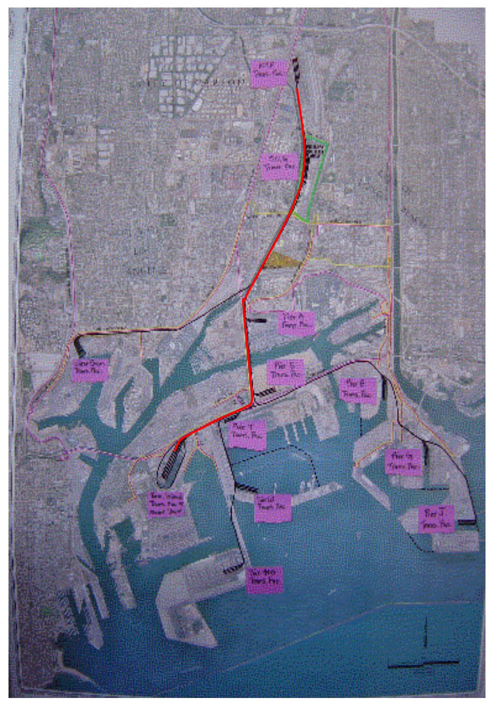


Fig. 1-1. Potential cargo maglev network

The study was performed using, as a basis, the GA maglev test track located in San Diego, California. The test track is 400 ft in length, with a full-scale test chassis currently undergoing extensive testing, as shown in Fig. 1-2. Since we have an operating maglev system, this provides a credible basis for making performance and cost projections. Our approach to developing the system design was to first develop a requirements document for the cargo system, including the alignment and performance parameters. This document then formed the basis for scaling the component designs to the maglev cargo conveyor system.

Fig. 1-2. GA maglev vehicle testing at the test track in San Diego, California

Our overall finding is that the technology is particularly well-suited to accommodate the high throughput required for the Port of Los Angeles. The system is completely automated and can accommodate multiple vehicles at a time, with headways of about 20 sec. It is inherently safe due to the wraparound structure on the vehicle (cannot be derailed), and the fact that only the track around each vehicle is powered (collision between vehicles cannot occur). In addition, there is no third rail for power pickup, which greatly improves the safety of the system during the cargo loading and unloading operations. The system has a peak speed of 90 mph (85 mph average) on a completely elevated dual-track guideway, with 18 vehicles operating on a single track at any given time. The loading/unloading ends of the system are configured at-grade to more easily accommodate overhead gantry handling of the cargo containers as they are transferred to trucks.

In the following pages, we discuss the overall plan, describe the technical characteristics of the system components, and provide the schedule and budgetary cost estimates. In addition, Appendix A contains the completed requirements document and Appendix B provides a description of the team. Appendix C provides GA's response to questions from the Port of Los Angeles on our draft technical report. We believe that this plan will provide the basis for future detailed engineering and construction of the proposed system. In light of the clean and efficient electric technology used to move cargo, we have decided to name this system the Electric Cargo Conveyor (ECCO) system.

1.1 PLANNED ALIGNMENT

The ECCO system alignment extends from the Terminal Island Transfer Facility and Maintenance Depot at the location of the ACCED Coke Storage Facility, to the SCIG and ICTP Transfer Facility, a distance of 4.7 miles.

Red Horizontal Alignment. The red alignment (refer to Figs. 1-3 through 1-6) begins at the Coke Facility, extends 1,700 ft in a northerly direction across the railroad and Seaside Avenue (Route 47), parallels Ocean Boulevard (Route 47), on its north side for 5,500 ft, crosses the Terminal Island Freeway (Route 47), and then parallels the Terminal Island Freeway for 6,500 ft on the east side of the freeway (crossing local streets, Route 47 ramps, the Cerritos Channel, the Terminal Island Freeway (Route 47, second crossing) and associated ramps in the vicinity of the railroad crossing (truss bridge) over the Dominguez Channel. The alignment then parallels, and is located on the east side of the railroad, for 3,400 ft, crossing Anaheim Street; after Anaheim Street, the alignment parallels the Dominguez Channel for 9,600 ft (the alignment will be located on the east side of the service road adjacent to the channel) crossing Pacific Coast Highway and Sepulveda Boulevard, prior to the final 3,500 ft to the Loading/Unloading Station.

The alignment meets all requirements document provisions, with a radius of 500 ft over Seaside Avenue and a minimum radius of 400 ft over the intersection of Ocean Boulevard and the Terminal Island Freeway Crossing – the minimum acceptable turning radius is 328 ft in accordance with the requirements document. The alignment incorporates 10 additional horizontal curves with ascending radii of 1,400 ft, 1,500 ft, 2,900 (3) 3,800 ft, 5,700 ft (2), and 11,000 ft (2) to achieve the route described above. Several alternatives were identified which would increase the minimum horizontal radius to 1,400 ft. The green alignment is discussed below. Alternatives would be considered in subsequent project phases.

Refinement From Port of Los Angeles Study Alignment. The red alignment section, which parallels Seaside Avenue/Ocean Boulevard (Route 47), was placed on the north side of Route 47, rather than the south side as indicated in the study alignment provided by the Port of Los Angeles. Available information, including mapping and Caltrans plans for the widening of Route 47 between Henry Ford Avenue and the Terminal Island Freeway, indicated potential interferences with several buildings and future Pier T Secondary Gate facilities.

In addition, the widening of Route 47 requires a very long structure (240 to 300 ft) to carry the guideway from the south side of Ocean Boulevard to the east side of the Terminal Island Freeway. Intermediate supports cannot be placed within the Route 47 limits.

Green Alternative Alignment. The green alternative alignment (refer to Figs. 1-3 and 1-4) begins just north of the railroad tracks near the Coke Facility, extends in a northerly direction across Seaside Avenue, parallels the railroad yard (adjacent to New Dock Street) on the south side of the tracks, and crosses the Terminal Island Freeway south of the Cerritos Channel.

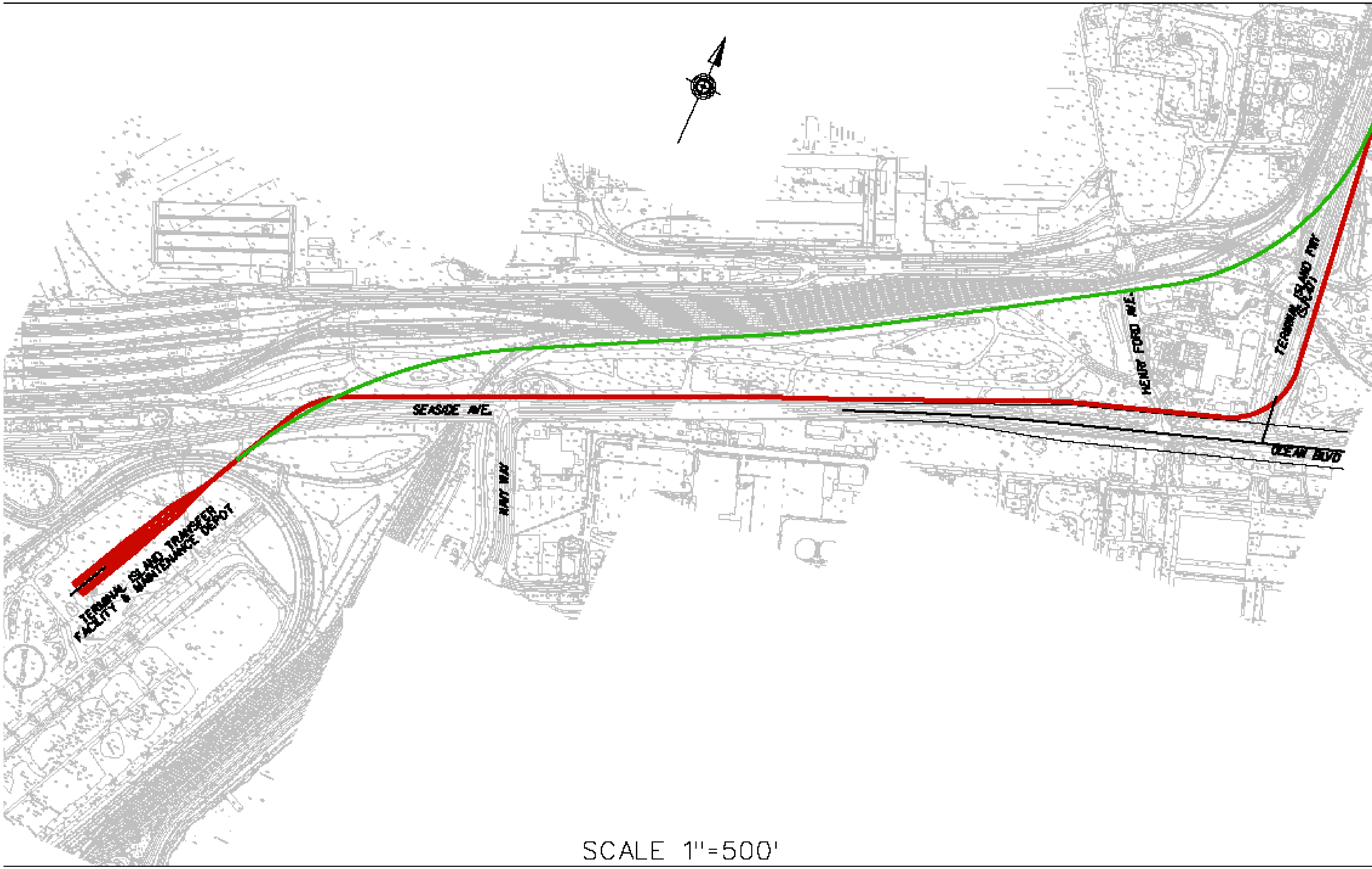


Fig. 1-3. ECCO system alignment

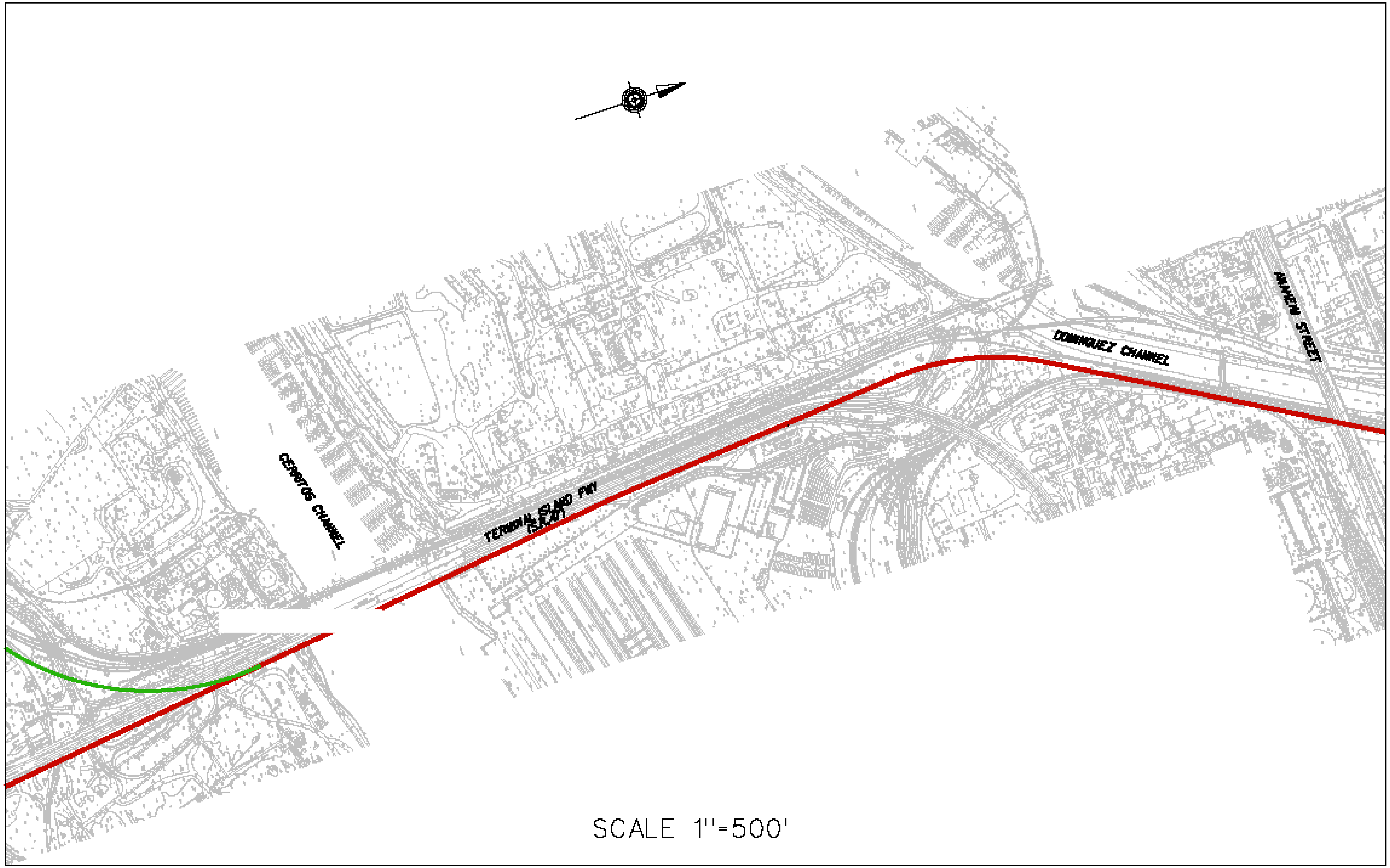


Fig. 1-4. ECCO system alignment

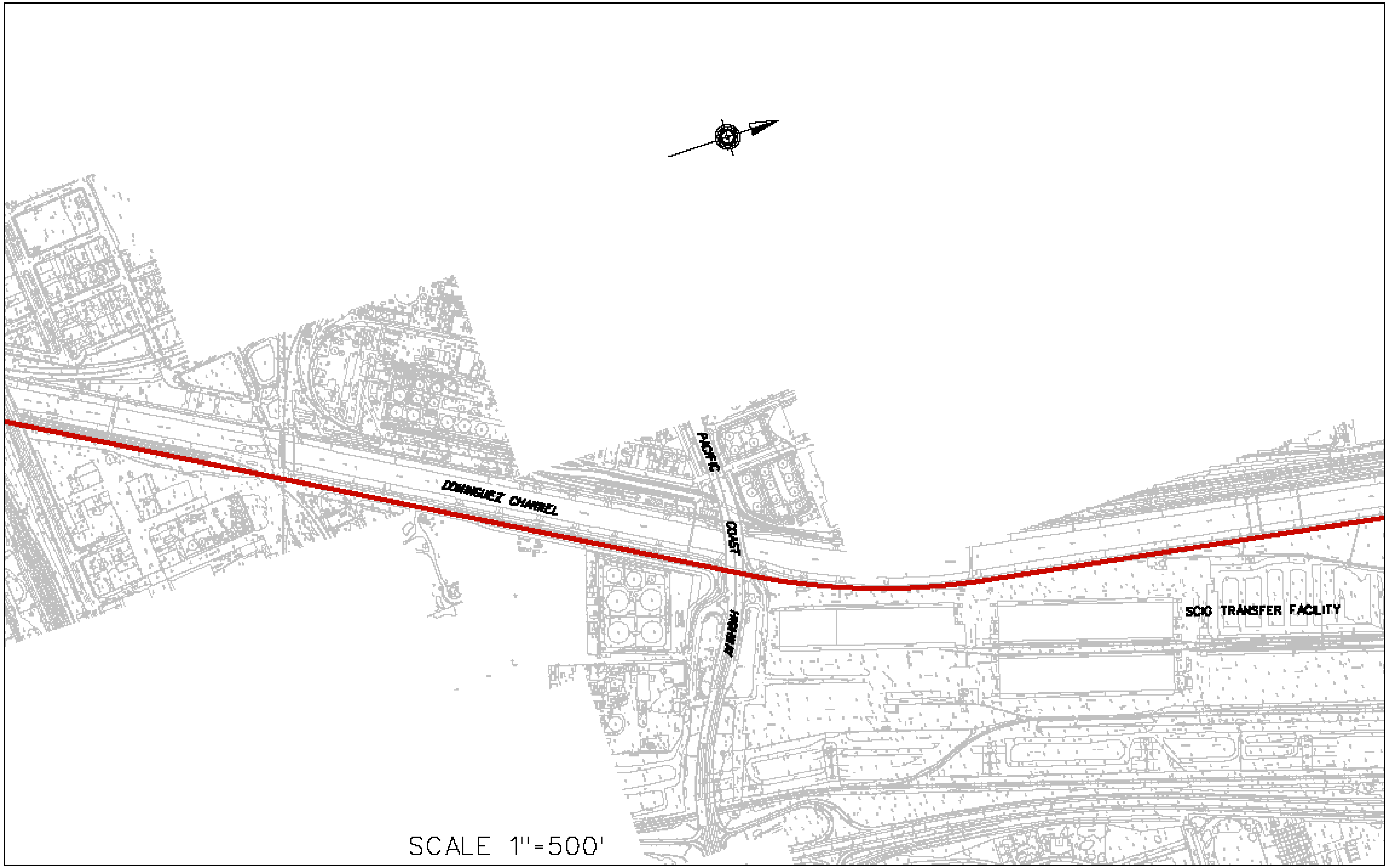


Fig. 1-5. ECCO system alignment

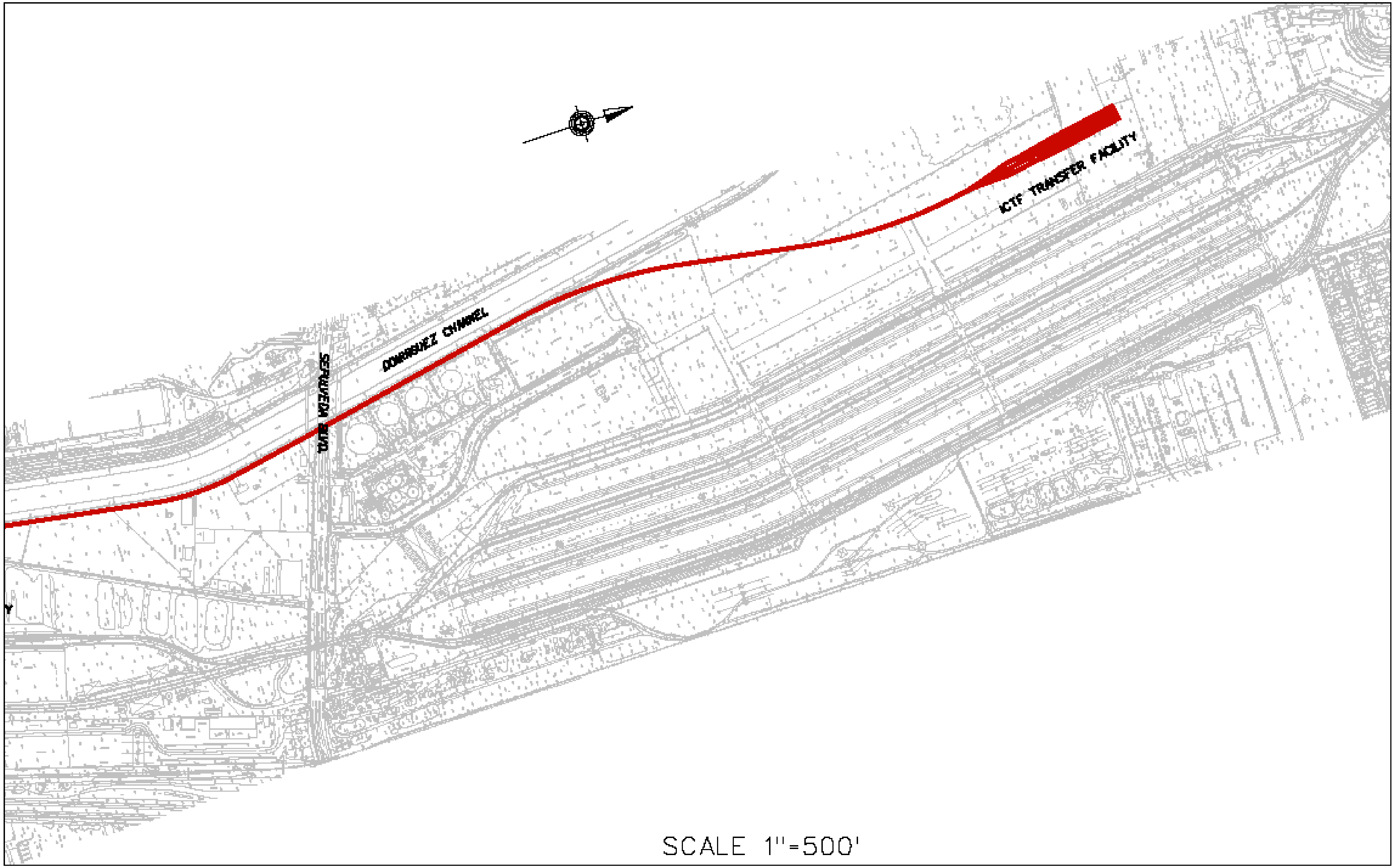


Fig. 1-6. ECCO system alignment

Further Refinement From the Red Horizontal Alignment and Port of Los Angeles Study Alignment. The green alternative alignment, which parallels the railroad yard adjacent to New Dock Street, avoids the Port of Los Angeles Study Alignment difficulties (interferences with several buildings and future gate facilities, along with the long span over the Ocean Boulevard/Terminal Island Freeway intersection) as well as replaces the 500-ft and 400-ft red alignment radii with 2,500-ft and 1,500-ft radii, respectively.

The overall minimum radius of the combined green/red alignment increases from 400 ft over the Ocean Boulevard/Terminal Island Freeway intersection to 1400 ft just south of Sepulveda Boulevard. The larger minimum radius significantly increases the average maglev vehicle speed, and thereby increases the throughput of the containers.

In addition, green/red alignment length is about 700 ft (2%) shorter than the red alignment alone.

Vertical Alignment. The vertical alignment is generally located 30 ft above existing ground. The profile elevation is increased where required to provide clearance over railroad tracks, various crossings of Route 47 and associated ramps, Cerritos Channel, and Anaheim Street. The controlling locations are the Cerritos Channel and Anaheim Street.

With the exception of the crossing of the Cerritos Channel and Anaheim Street, the alignment is nearly level (varying from –0.4% to +0.4%) and is located on tangent. The alignment will be level at the port loading/unloading stations. At the crossing of the Cerritos Channel and Freeway Ramps north and south of the channel, vertical curves, with maximum 1.17% and -1.06% grades, are utilized to provide required vertical clearance over the channel [58 ft over mean lower low water (MLLW)], and the Terminal Island Freeway Ramps (16.5 ft). Anaheim Street is the controlling vertical elevation (highest point) on the alignment. A vertical curve, with +2.28% and –1.64% grades, is required to provide the required 16.5-ft clearance over Anaheim Street.

The maximum grade on the alignment is 2.28% (significantly less than 10% maximum grade indicated in the requirements document). This is due to the relatively flat topography at the site, with the exception of man-made features such as Anaheim Street. The minimum vertical radius is 6000 ft, greater than the minimum requirement of 3,281 ft. Level grades are provided at the port loading/unloading stations and maintenance facilities. A 16.5-ft vertical clearance is provided over all roadways, ramps, and streets, and a 24.5-ft clearance is provided over railroad tracks. A 10-ft horizontal clearance will be provided from the centerline of railroads to the face of guideway piers.

1.2 PROJECT SCHEDULE

The overall project schedule is shown in Fig. 1-7.

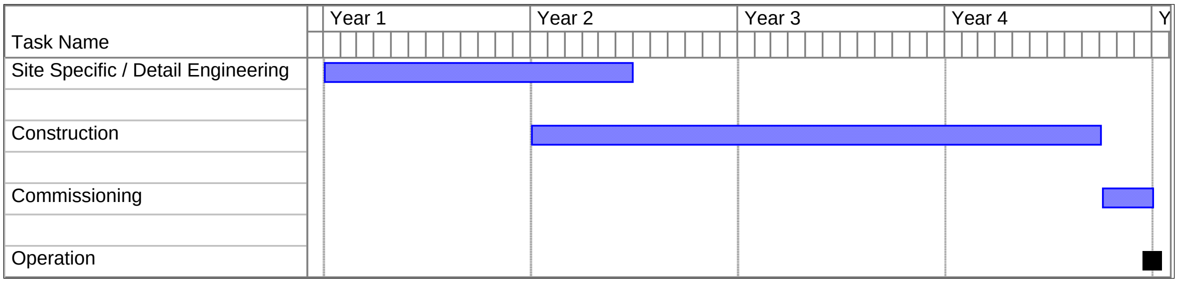


Fig. 1-7. ECCO system schedule

The critical schedule activities envisioned for engineering and construction are covered in three key phases:

I. **Site-Specific/Detail Engineering.** Key activities in this phase include engineering of all components, development of system requirements, development of work breakdown structure (WBS), and development of a detailed, time-phased cost and schedule for integrated factory testing, construction, and commissioning. This is followed by completion of drawing and procurement packages for all components.

II. **Construction.** During the construction phase, the guideway sections, cargo-handling ends, switches, 72 vehicles, and all power systems will be fabricated.

III. **Commissioning.** Upon completion, commissioning of the system would commence. Commissioning would include safety planning, failure modes and effects analysis (FMEA), test planning, component acceptance testing, system acceptance testing, training, and project integration.

1.3 COST SUMMARY

The basic costing methodology is to use the existing test track, and scale its performance for cargo on an alignment that connects Terminal Island with the SCIG facility, a distance of 4.7 miles. The costs are in 2006 dollars, and include detail engineering, construction, and commissioning (excluding cargo handling equipment). The overall system includes a double-track guideway, switches for the cargo handling areas at Terminal Island and the SCIG facility, 72 vehicles, all power systems, communication/control/signaling systems, as well as channel and highway crossings. Table 1-1 provides a summary of the overall capital costs. The annual operation and maintenance (O&M) costs are estimated to be ~$13M, and include costs associated with O&M personnel, energy consumption, and materials. Please note that this budgetary estimate is for planning purposes only and does not constitute an offer.

TABLE 1-1
BUDGETARY ESTIMATE FOR ECCO SYSTEM

Site-Specific / Detail Engineering	$ 40,359,000
Construction	$ 510,149,000
Total Engineering & Construction	$ 550,508,000
Commissioning	$ 24,070,000
Total	$ 574,578,000

2. KEY SYSTEM PERFORMANCE PARAMETERS PROPOSED FOR THE ECCO SYSTEM

Table 2-1 lists key parameters that apply to the site-specific design, construction, and operation of the Electric Cargo Conveyor (ECCO) system. ECCO is based on a totally passive permanent-magnet, large-air-gap maglev system, which results in lighter vehicles, reduced energy consumption, and more streamlined, less costly guideway structures. A linear synchronous motor (LSM) housed in the guideway provides propulsion. The system uses neodymium iron boron permanent magnets placed in a configuration called a Halbach array. This yields a very high lift-to-drag ratio and leads to an efficient levitation and propulsion system. One of its most significant attributes is its quiet, all-electric, environmentally friendly operation. The system can maneuver tight turns, climb steep grades, has low maintenance costs due to fewer moving parts, and is reliable in all-weather conditions.

TABLE 2-1
KEY SYSTEM PARAMETERS

System Parameter	Value
Throughput capacity	2,500 containers per day per direction
Weather	All-weather operation
Levitation	Permanent magnet Halbach array, passive
Propulsion	Linear synchronous motor (LSM)
Operation	Fully automatic train control (driverless)
Safety	Automatic control, wraparound feature of the design, and restricted access to elevated guideway
Speed, maximum operational	145 km/hr (90 mph)
Vehicle size	13.7-m (45-ft) long x 2.6-m (9-ft) wide
Grade, operating capability	10%
Turn radius, design minimum	100 m (328 ft)
Size of vehicle (container capacity)	40 ft, 67,400 lb

3. DESCRIPTION OF PROPOSED SYSTEM

This section describes the proposed Electric Cargo Conveyor (ECCO) system.

3.1 SYSTEM ARCHITECTURE

The description of the ECCO system has been organized by work breakdown structure (WBS). Figure 3-1 provides the WBS structure and displays all major elements of the project design.

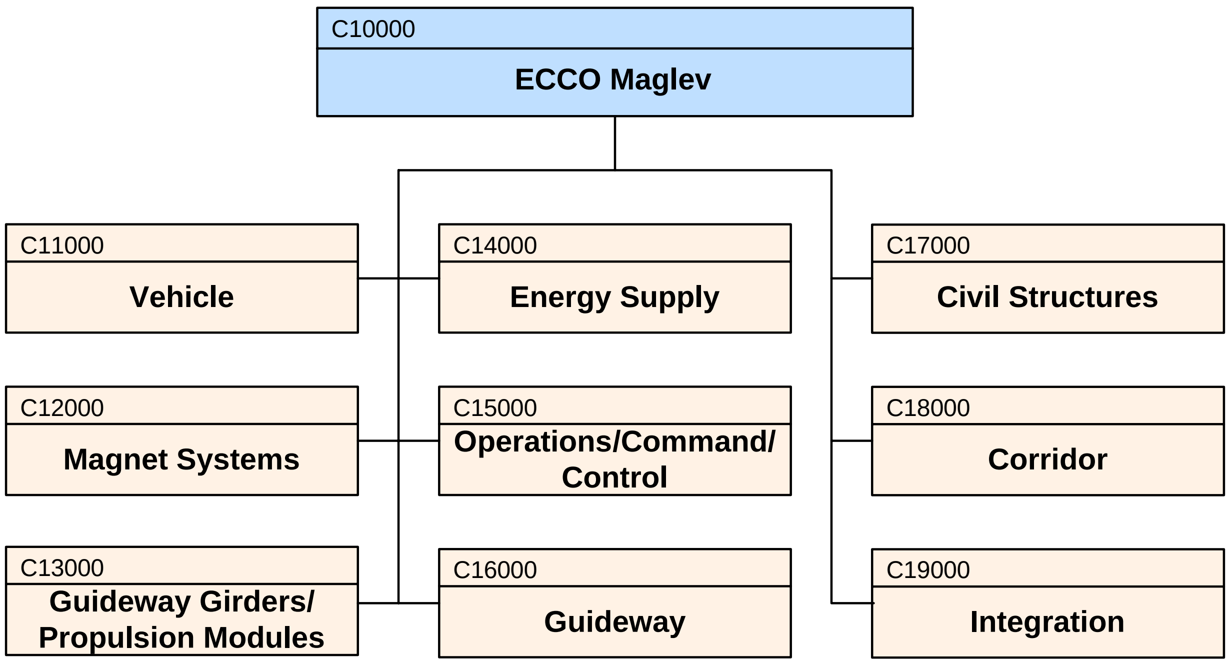


Fig. 3-1. ECCO WBS structure

The objective of constructing an ECCO from the central port area to the Southern California International Gateway (SCIG) is to eliminate 5,000 container truck trips per day on roads near neighborhoods and schools. This conveyor utilizes nonpolluting magnetic levitation technology. The planned route runs approximately 4.7 miles from the SCIG, to the Port of Los Angeles, along an alignment that parallels the Terminal Island Freeway, and runs west along Ocean Boulevard as shown in Fig. 3-2. While conveyor systems are typically envisioned as moving in one direction, the nature of port container traffic requires both inbound and outbound container moves, inferring (1) a bidirectional conveyor, or (2) a continuous loop. A bidirectional ECCO container architecture has been selected to ensure minimum space requirements at the conveyor terminals.

To move 5,000 containers per day along the ECCO guideway requires optimal use of the high-speed portion of the guideway. Optimal use requires that all carriages mounted on the guideway flow from one terminal to the other, one direction at a time. Since the terminals of a bidirectional system are inherently “last in, first out” arrangements, the time required to unload and load the last carriage to arrive at a terminal will idle the high-speed portion of the guideway for that period. A switched bifurcation at each terminus allows for the first half of the carriages arriving at a terminal to move to one spur for unloading and loading and the last half to move to the other. By the time the last half arrive, the first half have been loaded and are ready to immediately proceed along the high-speed guideway to the other terminal, thus eliminating idle time on the high-speed guideway.

Fig. 3-2. Projected alignment and system architecture of ECCO

Analysis of this architecture, using headway time between carriages, guideway switch times, and container processing times at the terminals has produced a design that meets the 5,000 containers per day requirement. The design uses two parallel high-speed guideways, each with 36 carriages. Guideways are terminated with two switched spurs to accommodate the loading and unloading of 18 carriages. Two guideways have the added benefits of system redundancy and the potential for system expansion to a continuous loop architecture.

A realistic operating scenario for the ECCO system would have truck drayage of containers from the Port of Los Angeles terminals to the unload/load spurs of the ECCO system. The arrival of containers will vary from hour to hour and day to day, while the ECCO conveyor operation will be continuous. An effective unload/load process, coupled with a container storage magazine, would connect the somewhat random truck arrival to the steady conveyor operation and avoid truck queues at the ECCO terminal. A similar process at the SCIG, couples the continuous conveyor to a rail spur requiring the unloading/loading of an entire, stationary long-haul train segment. While top-loaders could be used, the potential of extending the automated operation of the ECCO to the unload/load process, and the necessity of a container magazine infers the use of a straddle crane-based system as shown in Fig. 3-3.

Fig. 3-3. Top-loader (left) and straddle crane (right)

Such a system would consist of four (4) rolling straddle cranes in tandem, running the length of two adjacent ECCO spurs—one from each high-speed guideway. Analysis of the selected ECCO design shows a 6.7-min unload/load process at the front of each spur and an 18-min unload/load time at the back of the spur. The four straddle cranes (one for the first 3 carriages, one for the next 4, one for the next 5, and one for the last 6) are in-line rail-mounted to simultaneously unload/load the 18 ECCO carriages on the spur. By coordinating the two high-speed guideways, only one spur at a time in the straddle crane formation will require unloading/loading. Figure 3-4 shows a cross section of the tandem straddle crane system.

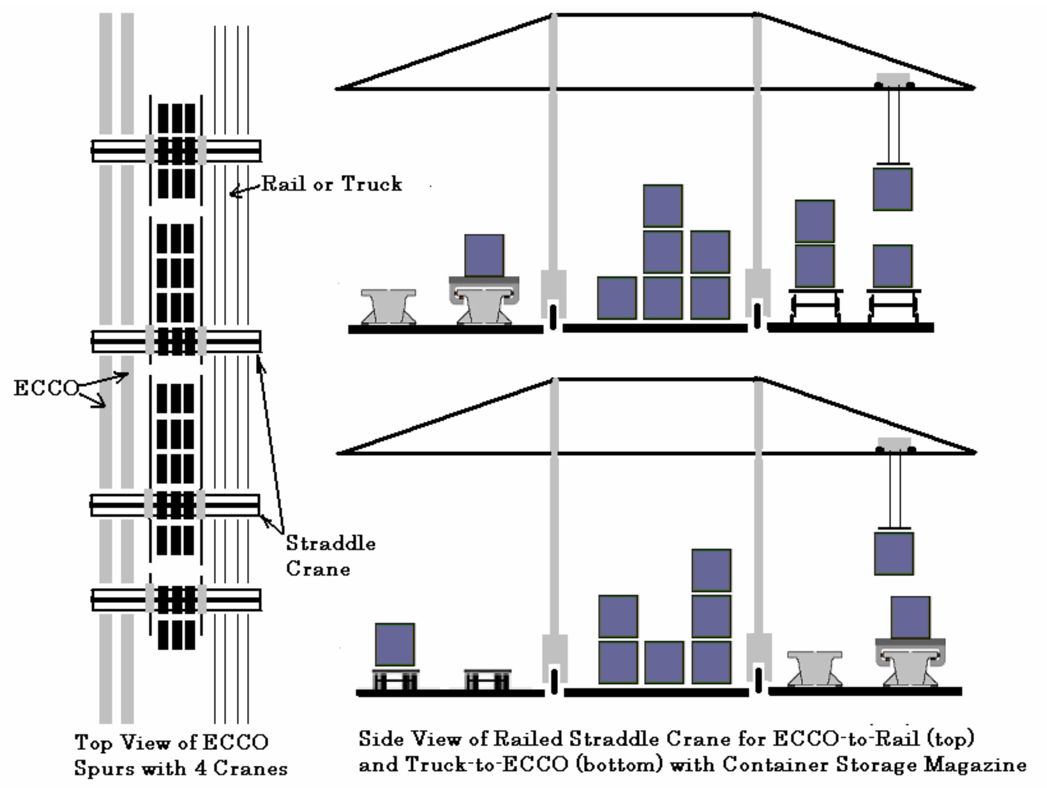


Fig. 3-4. Top and side views of ECCO unload/load

While current straddle crane/work crew operational data indicates that this ECCO system unload/load process will produce the required 5,000 container moves per day, automation of the cranes and enhancements to the proposed system architecture will likely improve system throughput.

3.2 VEHICLE (WBS D11000)

A conceptual design of a container carrier vehicle (chassis) has been developed, which uses the existing maglev test chassis and its load carrying capabilities as the basis for design extrapolations. Figure 3-5 shows the existing urban maglev chassis.

Fig. 3-5. Existing levitation propulsion arrangement of the urban maglev chassis

The chassis concept development for container transportation has to consider the basic load requirements. The maximum permissible weight of a standard 40-ft container is 30,408 kg (67,200 lb). The required magnet mass for both the levitation and propulsion system is approximately 10,000 kg (22,000 lb) and the chassis support structure is estimated to be around 8,000 kg (~18,000 lb).

The total conservative weight distribution estimates of the system are as follows:

Payload	33 tons
Levitation propulsion	10 tons
Chassis structure	9 tons
	52 tons (~115,000 lb)

The structural components will be made of nonmagnetic materials such as aluminum, stainless steel, fiberglass, or a combination of these materials.

The dimensional requirements for the container carrier vehicle (CCV) are set by the dimensions of the 40-ft (2-TEU) container:

Length	12.18 m (40 ft)
Width	2.44 m (8 ft)
Height	290 m (9.5 ft)

The selected footprint dimensions are:

Length	12.5 m (41 ft)
Width	3.0 m (9.84 ft)

We have developed the basic chassis structure by scaling the existing chassis to accommodate the increased loading seen by the cargo maglev chassis. The basic resulting chassis structure and associated deflections in the magnet components (magnified 100 times) are seen in Figs. 3-6 and 3-7, respectively. The cargo container is inherently rigid in the longitudinal direction; therefore, the driving loads for the carrier vehicle design are those acting on the wraparound components (magnet support structures and reaction rails) and generate transverse bending moments, which the structural design must accommodate.

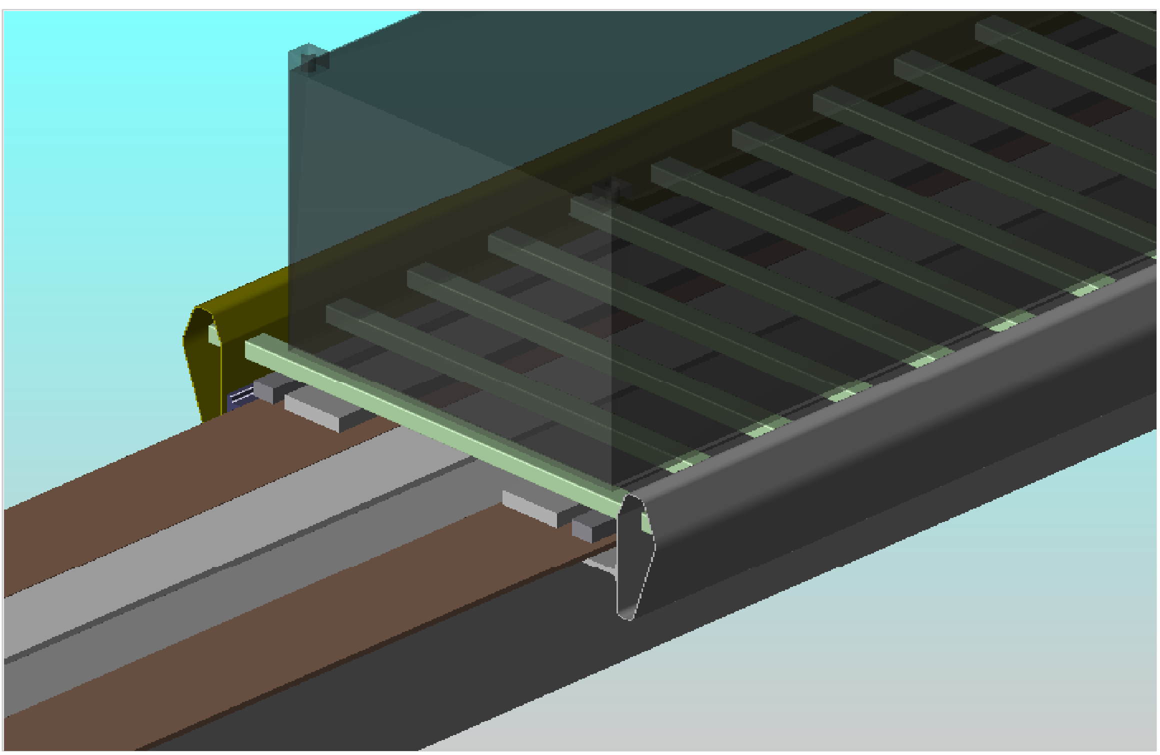


Fig. 3-6. Chassis with container load (front view)

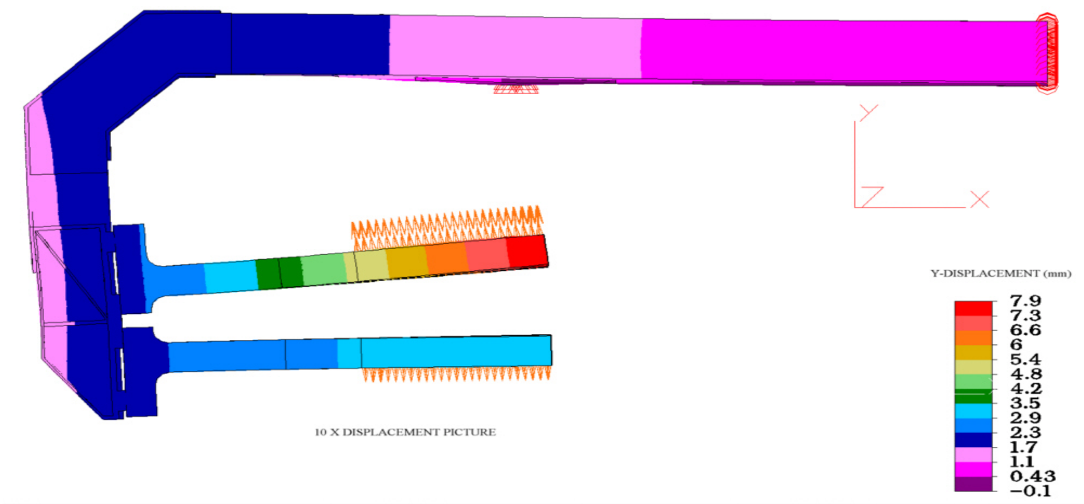


Fig. 3-7. Characteristic deformation of a double sided levitation array

Figures 3-8 through 3-10 show different views of the vehicle and cargo container. Preliminary calculations indicate that the design can accommodate the required loads.

To maintain reasonable physical levitation gap between the arrays and the levitation rails, and an efficient gap between the drive magnet arrays and the LSM, the permissible displacement had to be limited to 2 mm.

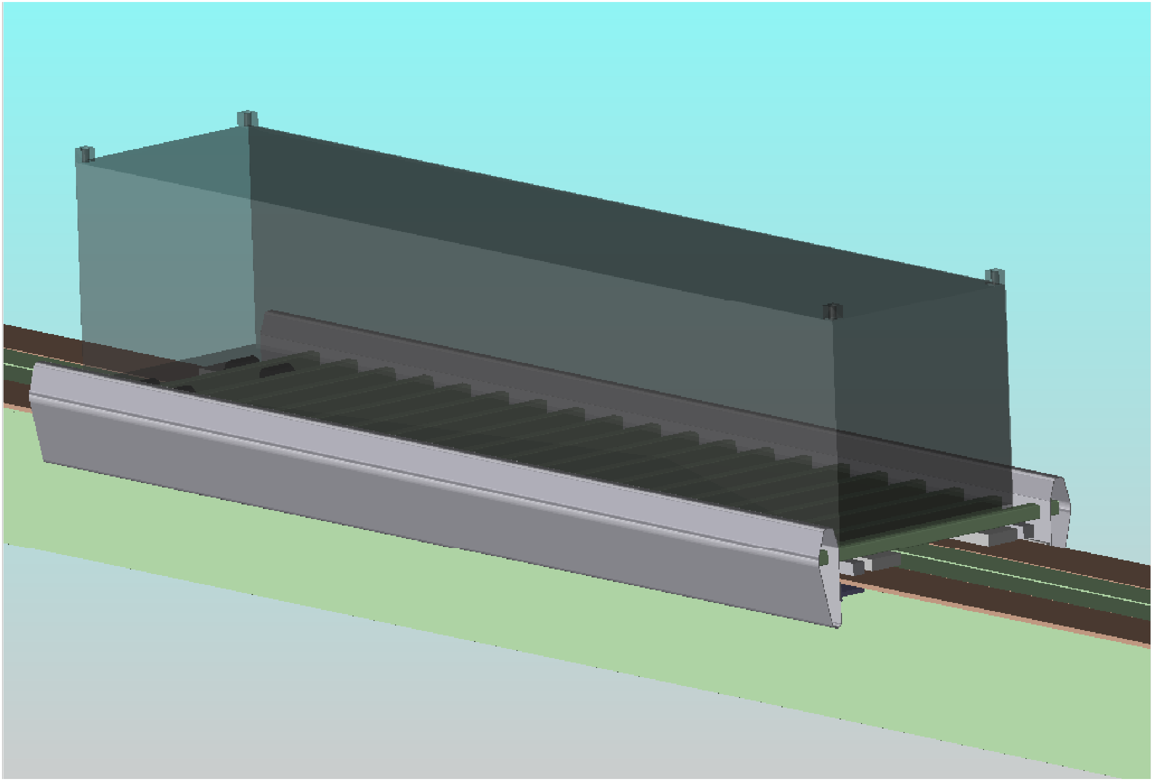


Fig. 3-8. Container carrier vehicle on the guideway, top view (the container is shown transparent)

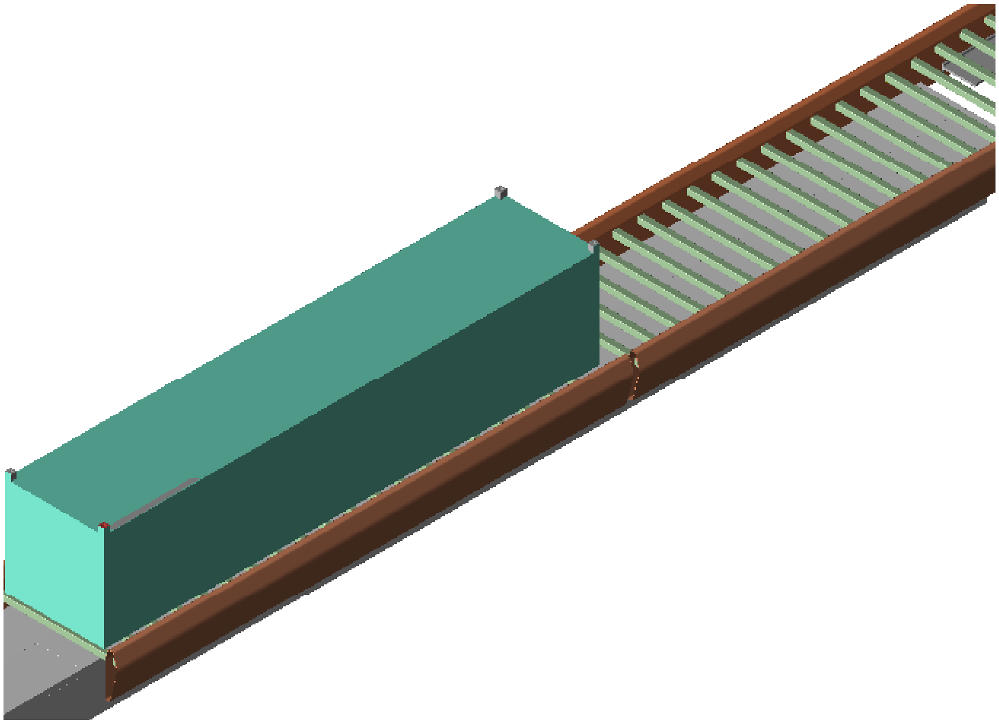


Fig. 3-9. Top view of two vehicles, one with a container and the second one unloaded

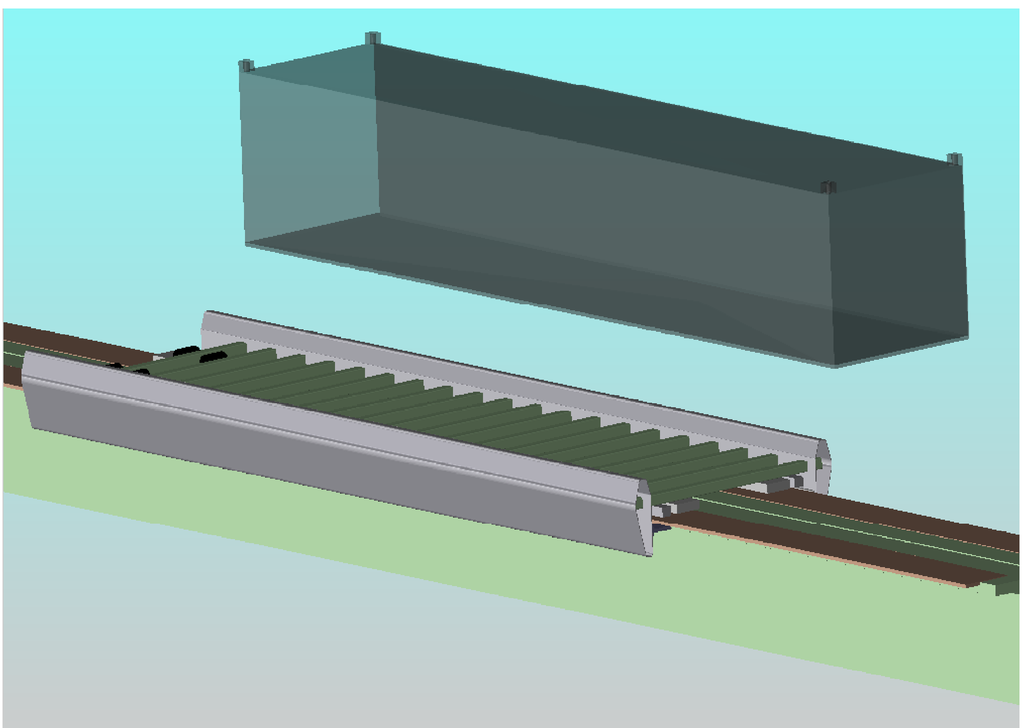


Fig. 3-10. Container carrier vehicle being loaded

3.3 MAGNET SYSTEMS (WBS D12000)

3.3.1 Mechanical Configuration

The ECCO system hovers above the guideway, supported, aligned, and propelled by magnetic forces, with no physical contact. This noncontact feature eliminates friction, providing a smooth, quiet ride. With the absence of contact friction, component wear is virtually eliminated, resulting in an efficient system with significantly reduced maintenance costs as compared with wheeled systems.

The magnet systems include the design and fabrication of the ECCO magnet modules. The system is inherently safe with its wraparound design and the passive and stable levitation/guidance system provided by permanent magnet arrays, as shown in Fig. 3-11.

The ECCO includes guidance/propulsion system magnets and levitation system magnets. These magnets are designed to be packaged as assemblies for integration with the vehicle chassis.

One benefit of the ECCO is in the simplicity and efficiency of the design. The system is passive. Achieving levitation requires no control systems to maintain system stability. Further, the system uses permanent magnets, which are more efficient in their size-to-field-strength ratio than electromagnets and require no power systems to operate. This yields a system that is much less complicated, less expensive, and more widely adaptable than other maglev systems.

Permanent magnets in a configuration called a Halbach array provide increased magnetic field strength for levitation, guidance, and propulsion. Originally conceived for particle accelerators and named after inventor Klaus Halbach, Halbach arrays concentrate the magnetic field on the active side, while canceling it on the opposite side. This magnet arrangement, along with other design features of the ECCO system, results in very low magnetic fields in the passenger compartment, below the track, and at stations. In fact, the fields are lower than other transportation systems that use conventional electric motors, without the need for magnetic shielding.

Permanent magnets are used widely in the commercial industry. For example, the average computer system (PC, printer, monitor) contains over 40 magnetic components. The number increases as more peripherals are added, such as a second CD-ROM drive, DVD drive, or a scanner or laser-jet printer. Also, large quantities of permanent magnets are produced each year for adjustable speed drives, stepper motors, and starters.

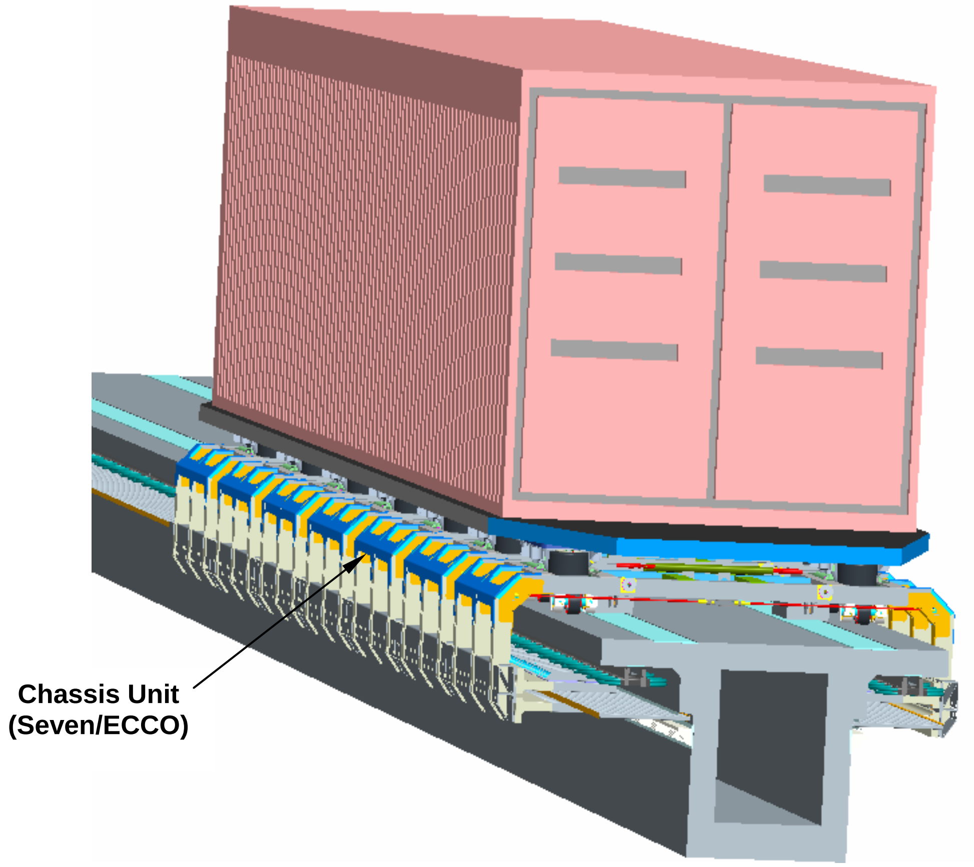


Fig. 3-11. ECCO levitated on guideway (top figure); test chassis unit on the test track at GA (lower figure); each ECCO has seven chassis units

Figure 3-12 shows a cross section of the magnet system assembly. There are arrays consisting of magnet blocks with nominally a 1.97-in. (50-mm)-square cross section and a height of 1.57 in. (40 mm), and arrays consisting of 1.97-in. (50-mm) cubes. The two kinds of arrays are built in a similar fashion and differ only in height. The arrays with 1.57-in. (40-mm)-high blocks are installed in the lower magnet module supports.

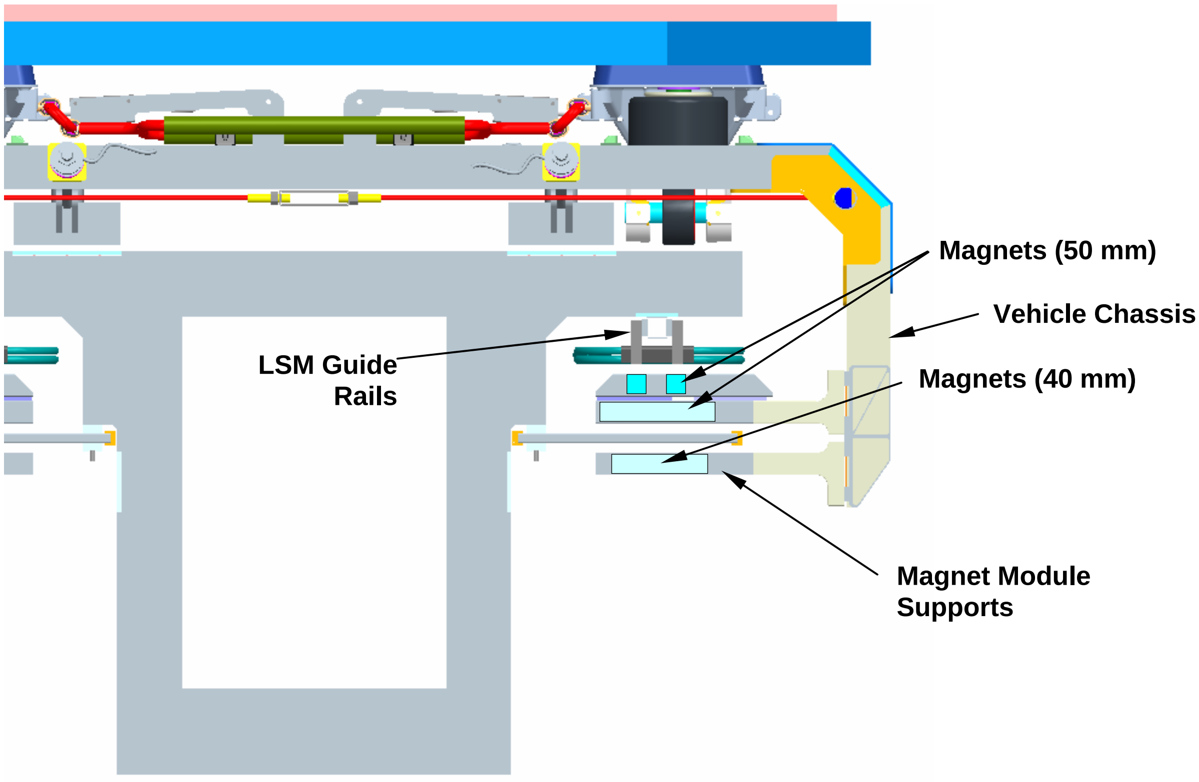


Fig. 3-12. Cross section of magnet system assembly

The magnet blocks consist of neodymium-iron-boron (NdFeB) rare-earth permanent magnets. The magnet blocks are subdivided into subassemblies and loaded into the magnet module supports, as shown in Fig. 3-13. The top set of magnet blocks interact with the LSM to provide guidance and propulsion. This arrangement, combined with the LSM rails, provides the

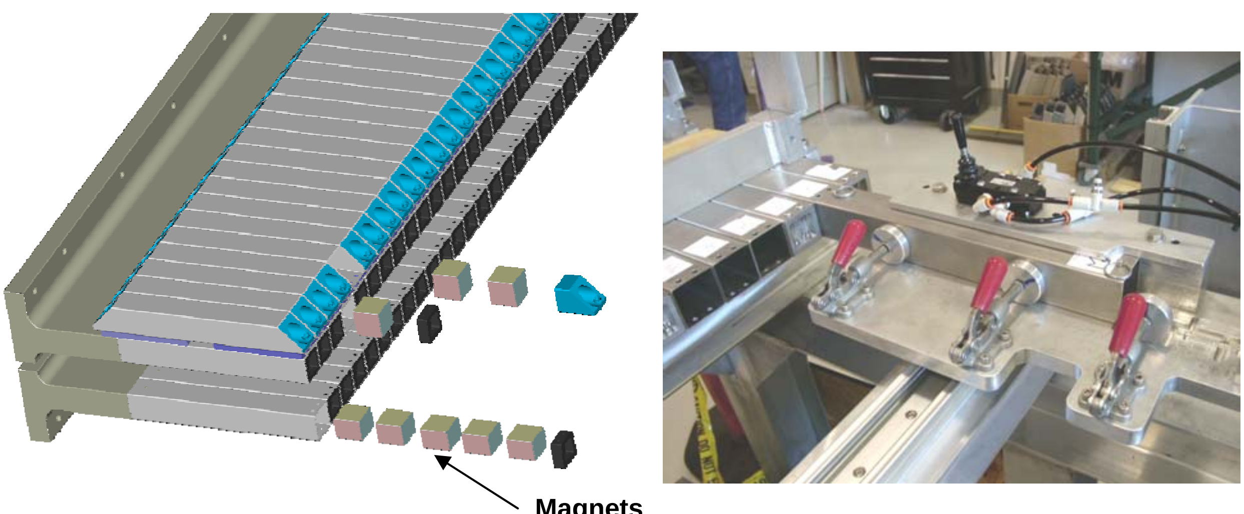


Fig. 3-13. Magnet inserted into magnet module supports

passive guidance force for the ECCO. The middle and lower sets of magnets provide levitation. In each subassembly, the magnet blocks are placed with their magnetization vectors in the same direction and in an enclosed container. Along the length of the Halbach array, the magnetization vectors rotate in steps of 45 degrees per magnet container subassembly. This rotation of the magnetization vectors provides the Halbach effect, as discussed above, that concentrates the magnetic field lines to increase the lift forces.

To complete the assembly of the Halbach arrays, the magnet modules are then mounted to the chassis supports with removable fasteners, as shown in Fig. 3-14.

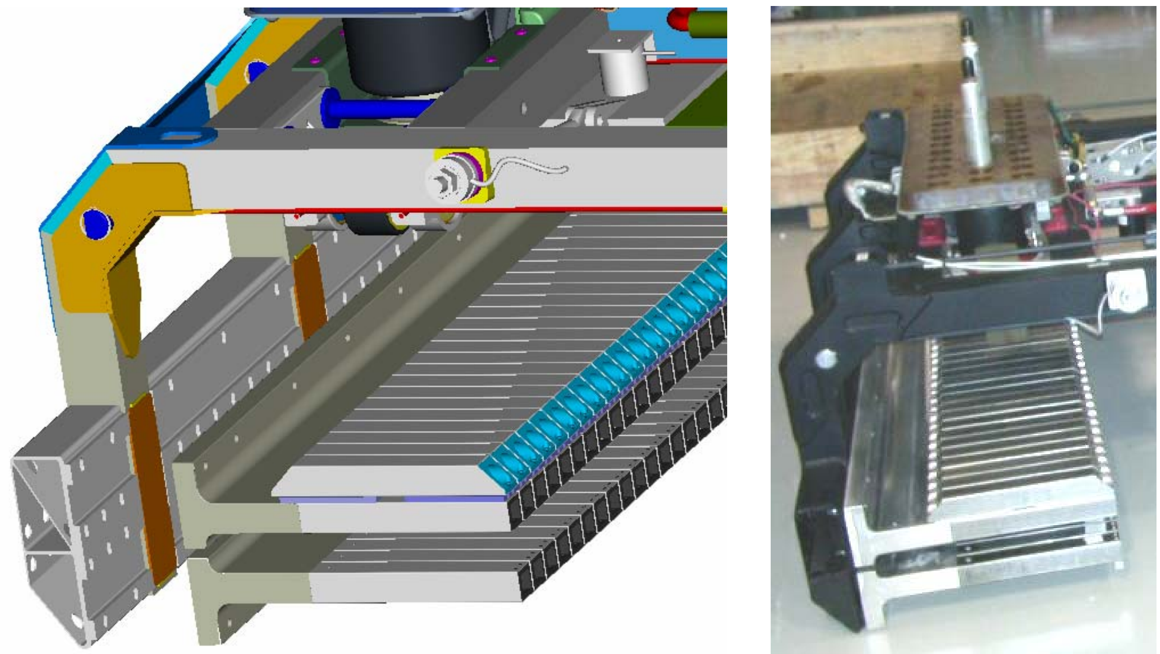


Fig. 3-14. Magnet assembly to vehicle chassis

3.3.2 Magnetic Performance

A magnetic levitation and LSM drive system for container transporters, has been configured and analyzed specifically for the demands of a cargo maglev system. The approach is based on combining elements of the GA maglev test track system that has been built and demonstrated. The analyses were performed using computer codes that have been benchmarked against experiments. Several special requirements of container transport by maglev (ones not encountered in passenger transport) were addressed. These include adaptation of the maglev system to be able to handle, with high energy efficiency, very heavy loads when leaving the port, while also being able to accommodate, when returning empty to the port, to operation at much reduced weights. It was found that not only could these new requirements be met, but that drag-related losses at operating speeds could be reduced below those of steel-wheel-steel-rail freight transport systems. Thus, it represents potentially an energy-efficient transport system for heavy freight.

When the transporter is in motion at speeds above a low lift-off speed (comparable to walking speeds) the moving periodic field of the Halbach arrays on the transporter induces strong currents in track. These induced currents interact back on the magnetic field of the Halbach arrays to produce the levitating force. Using the high-field permanent-magnet material, Neodymium-Iron-Boron (now in large-scale production for use in computer hard-drives and in electric motors), the levitation forces that can be generated are large – tens of metric tonnes per square meter of magnet array. While no energy is required to maintain the magnetic fields, there will always be some resistive losses in the conductors that make up the track. These losses then appear as an electromagnetically induced drag force that must be overcome by the drive system of the transporter. Care in the design of the track and of the magnet system can reduce this drag power at operating speeds to values far below that of rubber-tired systems and even below that of steel-wheel-on-steel-rail systems.

Computer codes developed at Lawrence Livermore National Laboratory (LLNL) using the Mathematica® platform were used to predict magnetic performance. Using the codes the parameters of the system, such as the wavelengths and sizes of the Halbach arrays, the operating gaps, etc., were varied so as to achieve operational characteristics that would meet the requirements posed earlier. It was found that all of the requirements could be met, for both the loaded and the unloaded states of the transporter cars. The results of these calculations are presented in Figs. 3-15 through 3-19.

The proposed maglev system must operate efficiently at speeds of ~90 miles per hour. Thus, in addition to minimizing the drag forces of electrodynamic origin, aerodynamic losses should also be made as low as is feasible. In the Davis formula, the aerodynamic drag coefficient is taken to 0.8, corresponding to the value appropriate to an ordinary freight car. For the dedicated transporter cars of the maglev system it has been assumed that streamlining fairings will be located fore and aft of the containers. Therefore, consistent with tabulated values for streamlined cars, a drag coefficient of 0.2 has been assumed for the transporters.

The first comparison plots, Fig. 3-15, show two computed drag power curves: (a) the Davis formula, as evaluated for a loaded car (upper curve), and (b) the maglev car, loaded, and augmented with streamlined fairings on the transporter (lower curve).

As shown in Fig. 3-15, at all speeds above about 20 m/sec (45 mph) the maglev system has a lower drag power than that predicted by the Davis formula for a freight car with steel wheels operating on steel rails.

A similar set of curves, shown in Fig. 3-16, was also calculated for the unloaded condition.

As the curves show, in the unloaded condition the maglev system drag power is below the Davis curve for all speeds above approximately 15 m/sec (33 mph), and is less than one-fourth of the Davis value at operating speeds of 40 to 45 m/sec (90 to 100 mph).

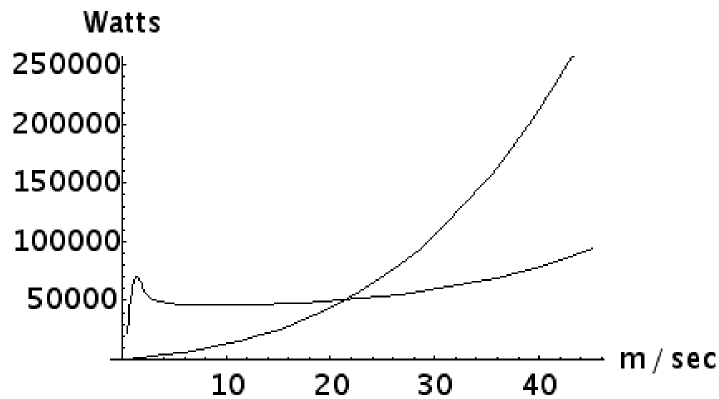


Fig. 3-15. Drag power comparison between the Davis formula for freight cars and the maglev system with bias magnets and streamlined fairings (both for loaded cars)

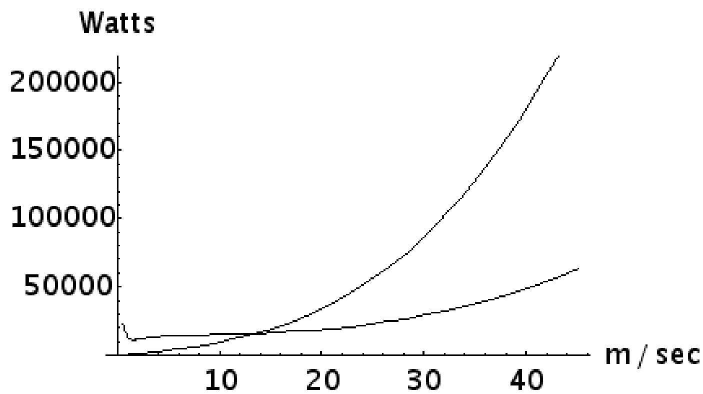


Fig. 3-16. Drag power comparison between the Davis formula for freight cars and the maglev system with bias magnets and streamlined fairings (both for unloaded cars)

To make direct comparisons between the mechanical frictional drag of the steel-wheel-steel-rail system with the electrodynamic drag of the maglev system, comparison curves were also calculated without the aerodynamic loss terms. Figure 3-17 shows such curves for the case of a loaded transporter.

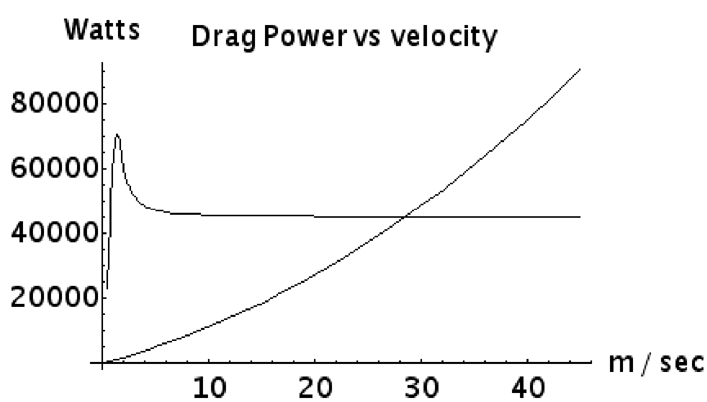


Fig. 3-17. Drag power comparison between the Davis formula and the maglev system with bias magnets (both curves are for loaded cars, but do not include aerodynamic drag)

These curves show that at operating speeds the drag losses of electrodynamic origin of the maglev system are about one-half the mechanical friction losses predicted by the Davis formula without its aerodynamic loss term. At low speeds, however, the maglev drag losses are greater than those of a steel-wheel system, and this fact must be taken into account in designing the LSM drive system to insure that the cars are accelerated up to operating speed at a reasonable rate. To take an example, at an acceleration rate of 0.1 g the transporter would come up to an operating speed of 40 m/sec (90 mph) in a distance of about 800 m, or less than 10% of the 4.7-mile-long alignment. The energy input required to accelerate the transporter to operating speed would then be largely recovered through the planned use of regenerative braking at the end of the run.

Finally, we present the calculated variations in the levitation gap as the transporter lifts off and is then accelerated toward its operating speed. Figure 3-18 illustrates this lift-off process for the loaded transporter. Note the low lift-off speed of about 1.75 m/sec (3.9 mph).

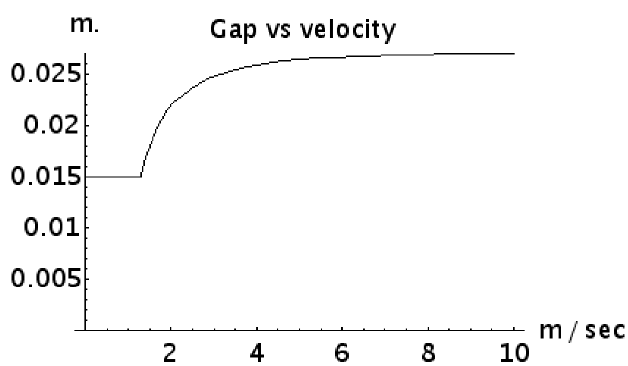


Fig. 3-18. Plot of computed levitation gap vs. velocity for a loaded transporter

One of the requirements proposed is that the change in levitation gap between the loaded and unloaded condition should be small, a centimeter or two at most. Figure 3-19 shows a plot of the gap vs. velocity for an unloaded transporter. In the unloaded case shown, the levitation gap is only about 1 cm larger than the gap in the loaded condition, and the lift-off speed has dropped to about 0.7 m/sec (1.6 mph – a slow walking speed).

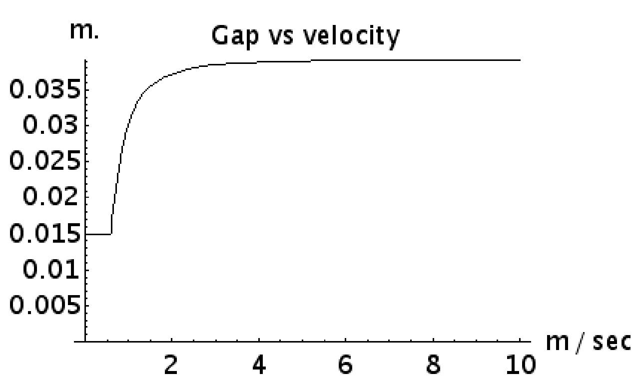


Fig. 3-19. Plot of computed levitation gap vs. velocity for an unloaded transporter

3.4 GUIDEWAY GIRDERS/PROPULSION MODULES (WBS D13000)

The guideway/levitation modules include the levitation track, LSM propulsion coils, and associated support structure. These module designs will be interfaced with the energy supply systems designer for integration with the propulsion system design.

As illustrated in Fig. 3-20, the guideway module assembly consists of a girder with a top deck (1) and box beam (2) cast monolithic into a form using steel fiber reinforced concrete (SFRC) hybrid concrete. Inlaid into the top deck are two steel plates (3), which interface with the parking brake backup emergency system. This top deck carries both the LSM assemblies (4) and provides the landing surface for the station wheels. The box beam includes features that provide the clamping support for the track assemblies (5) and the LSM assemblies.

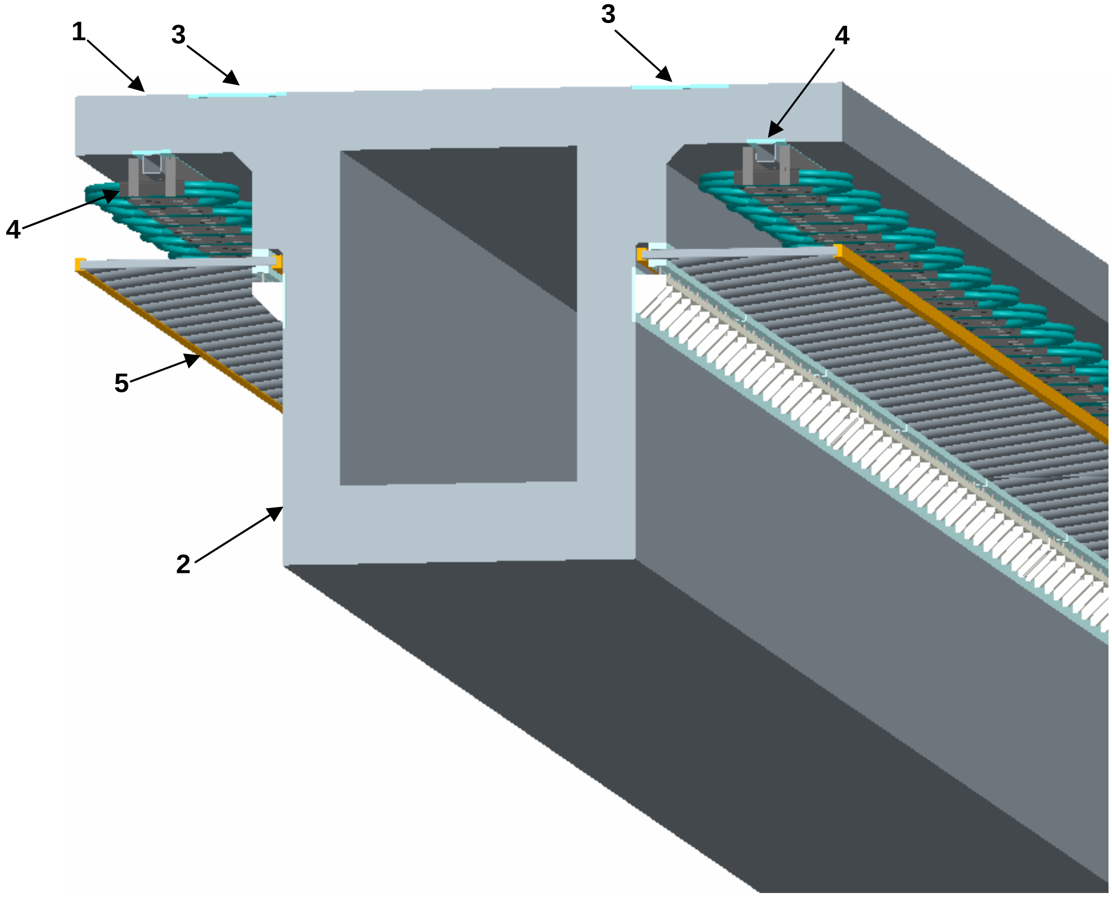


Fig. 3-20. Guideway girder-levitation modules

These interface features are positioned and accurately aligned in the beam's mold, prior to pouring the concrete. The interface features are integrated into the beam with studs that are welded to the plates providing a solid anchor to the concrete. After final curing, the result is an integrated module, which provides the accurate interfaces required for the ECCO system and the structural features of a box beam girder, all combined into a small efficient package.

A key feature of the guideway girders is the SFRC. GA originally developed SFRC over a decade ago under contract with the U.S. Air Force. In early 2004, GA and San Diego State University further optimized the mix design with excellent results (U.S. patent pending). Strength, durability, and low cost of concrete structures can be achieved with SFRC. These structures are constructed without the use of conventional reinforcing steel bars. SFRC is ultrahigh-strength concrete with unique properties, including high flexural and shear strength. It is also strong in compression, durable, and has high impact resistance. Structures can be either precast or poured in place.

The high flexural strength is achieved with the use of laboratory-configured steel fibers (Fig. 3-21) that provide effective bonding. This high bond strength results in micro-stitching of small cracks, thus significantly limiting crack propagation under loading. As compared to conventional reinforced concrete (RC) with solid reinforcing bars, cracking in SFRC is inhibited by the multiple steel fibers that prevent further crack propagation.

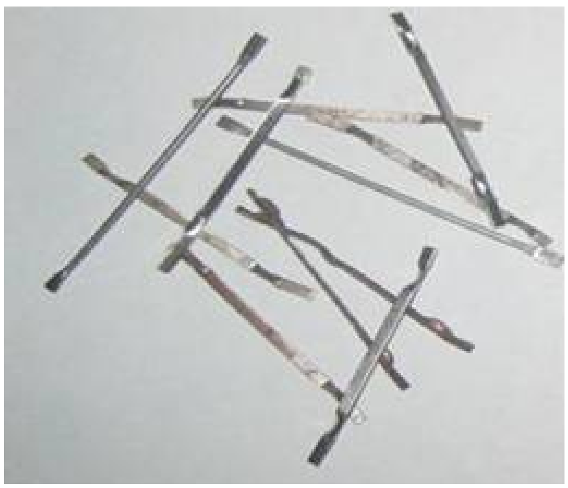


Fig. 3-21. Fibers in the SFRC concrete

Table 3-1 shows the actual test results of Ultimate compressive, flexural, and first crack stresses after 7-day and 28-day curing of test samples with calculated working stress allowables. The SFRC flexural working stress allowable for the beam design is about four times that of the similar allowable for the conventional RC with f'_c = 34.5 MPa (5000 psi).

The levitation track assembly, which are attach to the guideway girders, are either a series of conductive rungs shorted with copper bars at each end or a series of thin slotted conductive sheets.

As the levitation Halbach arrays move above and below the track, electric currents are induced in the track. The interaction of these currents with the magnetic fields generates the lift forces.

TABLE 3-1
SFRC FLEXURAL AND COMPRESSIVE STRESSES

Type of Stress	Ult Stress MPa (psi)	Std Dev MPa (psi)	SFRC Allowable Working Stress* MPa (psi)	RC Allowable Working Stress** MPa (psi)
First crack flexural f'_b, f_b	13.8 (2001)	1.2 (172)	5.7 (823)	—
7-day wet cure flexural f'_b, f_b	18.1 (2618)	0.7 (101)	7.8 (1133)	—
28- day dry cure flexural f'_b, f_b	19.4 (2818)	0.9 (125)	8.4 (1212)	2.0 (290)
28-day Compressive f'_c, f_c	85.5 (12,391)	2.5 (368)	37.3 (5410)	15.5 (2250)

*Allowable Stress (Working Stress Design) = 0.45(Ultimate – Std Dev) per Uniform Building Code (Ref 8.3)

**Calculated per ACI Handbook SP-3 (Ref 8.4) with loading on the similar RC samples with f'_c = 34.5 MPa (5000 psi)

The propulsion system consists of propulsion magnets located on the vehicle, the LSM windings on the guideway, and propulsion power supply system on the wayside. The propulsion thrust is generated by the LSM from the interaction between induced traveling field in the windings and the magnetic field created by the propulsion magnets. The speed of the ECCO is controlled by varying the frequency of the current provided to the LSM (which directly controls the speed of the traveling field).

3.5 ENERGY SUPPLY SYSTEMS (WBS D14000)

This section presents an overview of the energy supply systems required for the Port of Los Angeles. The main function is to provide power to the guideway for propulsion and to the cargo handling area at the ends of the track. The peak power requirement for operation of a single chassis is estimated to be 1 megawatt (MW) when it is loaded to a maximum cargo weight of 67,200 lb. The peak power requirement occurs during acceleration (0.16 g maximum). Each track has 18 vehicles running at any given time. Hence, the peak power draw is estimated by taking into account the total number of vehicles undergoing acceleration (deceleration), the number of vehicles cruising, and the number of vehicles moving in the low speed section. The power per vehicle required during 90 mph cruise is estimated to be ~750 kW. This is a conservative value based on the existing test track performance; it is possible to further optimize the energy consumption as discussed in the magnetic performance section (Section 3.3.2). However, for the purposes of this study, we decided to use the conservative values for power consumption. The power requirement/vehicle at the low speed ends is ~50 kW; and the peak power during acceleration is ~1 MW. Hence, the total power draw is estimated as:

2 tracks × [(2 vehicles in acceleration mode) × 1 MW + (10 vehicles in cruise mode × 0.75 MW + (18 vehicles in handling area) × 0.05 MW] = 20.8 MW

The power inverters used to power the track propulsion motors are housed in any convenient location (e.g., maintenance facility, or along the track) near the stations. This provides a protected, controlled environment for the power equipment and easy access for maintenance.

The variable frequency drive (VFD), or inverter, is used to change the dc input voltage to an ac output voltage (and current) of desired magnitude and frequency. The propulsion block inverters are based on insulated gated bipolar transistor (IGBT) power electronics as shown in Fig. 3-22. This system is identical to the drives being used on the urban maglev test track in San Diego, California, as well as the EMALS system being tested in Lakehurst, New Jersey, for the Navy. They are designed and built by GA, specifically for high-power, high-reliability applications. The propulsion block architecture can be designed to provide regeneration and dynamic braking capabilities.

Fig. 3-22. Insulated gated bipolar transistor (IGBT)-based inverter module and urban maglev test track electrical room

For flexible high throughput operation and improved efficiency, the propulsion system in the high-speed zone will be powered by 13 inverters per track. Each inverter is connected to three (3) propulsion blocks. Each block is 200-m long. To ensure safe braking distance between vehicles, the separation between vehicles is maintained at 800 m. Power is provided to the LSM propulsion block only as the vehicle approaches and passes over that specific LSM propulsion block. The low speed zone needs to be capable of handling 18 vehicles, which can be accomplished with 9 inverters; these inverters can handle both tracks, since the load/unload cycles can be staggered between tracks 1 and 2.

The round-trip energy consumption of a single vehicle (fully loaded) is estimated to be 94 kWh (assuming 80% efficiency). Total daily energy consumption for 2,500 round trips is 2.3×10^5 kWh. At a cost for electricity of 0.08 $/kWh, the daily cost is ~$17K and the cost of a one-way trip is projected to be less than $4.

3.6 OPERATION, COMMAND, AND CONTROL SYSTEMS (WBS D15000)

The purpose of this activity is to provide a conceptual design and a rough-order-of-magnitude (ROM) price for the control and communications system on a maglev freight transportation system for the Port of Los Angeles. The proposed system uses magnetic levitation technology to move vehicles carrying intermodal shipping containers from a yard-like marshalling area at the dock to a similar configuration about five miles away at which the containers are loaded to trains. The objective of the system is to reduce pollution and economically limit traffic congestion in the area, but yet allow for further expansion of port operations.

The overall transportation network is illustrated in Fig. 3-23. Two independent transportation Guideways will support the cargo containers per direction requirements of the system.

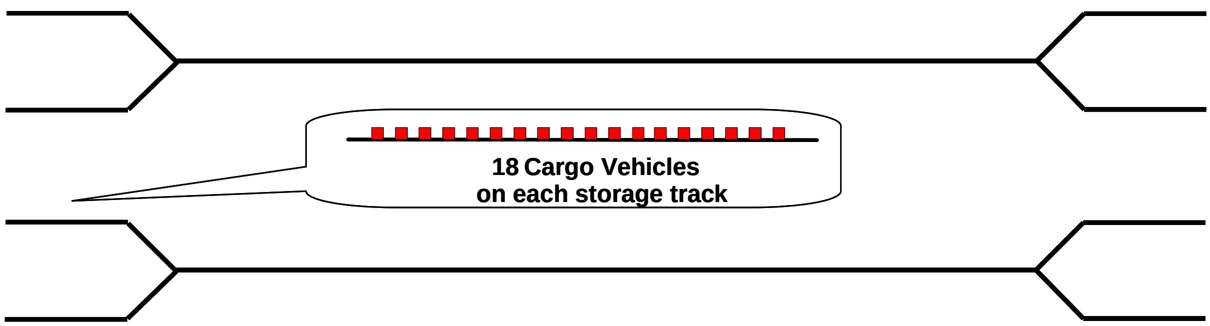


Fig. 3-23. Guideway diagram: two independent transportation systems

The communication at the command system will consist of two independent systems that monitor the cargo vehicles traversing each transportation complex.

The high-speed portion of the system is the ~4.7 miles of the planned network. Each cargo vehicle storage track would permit 18 vehicles to be loaded and unloaded in these areas. Two independent transportation systems would be employed to control the flow of cargo containers.

Train Control

The Union Switch and Signal (US&S) patented Micro Block architecture (Patent No. 5398894: Virtual block control system for railway vehicle) is used to implement a means of train control for the system.

A virtual block system is provided in which a section of track is represented by multiple virtual track circuits. Each virtual block is held in the memory of the office CAD computer-aided dispatching (CAD) and is geography the same as the LSM segment feed by an inverter. Communication between wayside and each cargo vehicle is established throughout the transportation system.

The cargo vehicle carborne equipment determines its position within the transportation system by using differential global positioning system (DGPS) information relative to its movement within the transportation system. The actual position within the transportation system is transmitted from each vehicle to the central control equipment.

The CAD system converts the actual position of each cargo vehicle within the transportation system to a virtual track circuit occupancy indication.

The CAD system keeps track of the status of the virtual blocks (occupied or unoccupied). If the operating rule is violated, CAD commands the inverters to shut down and issues an emergency brake request to each cargo vehicle. This is shown in Fig. 3-24.

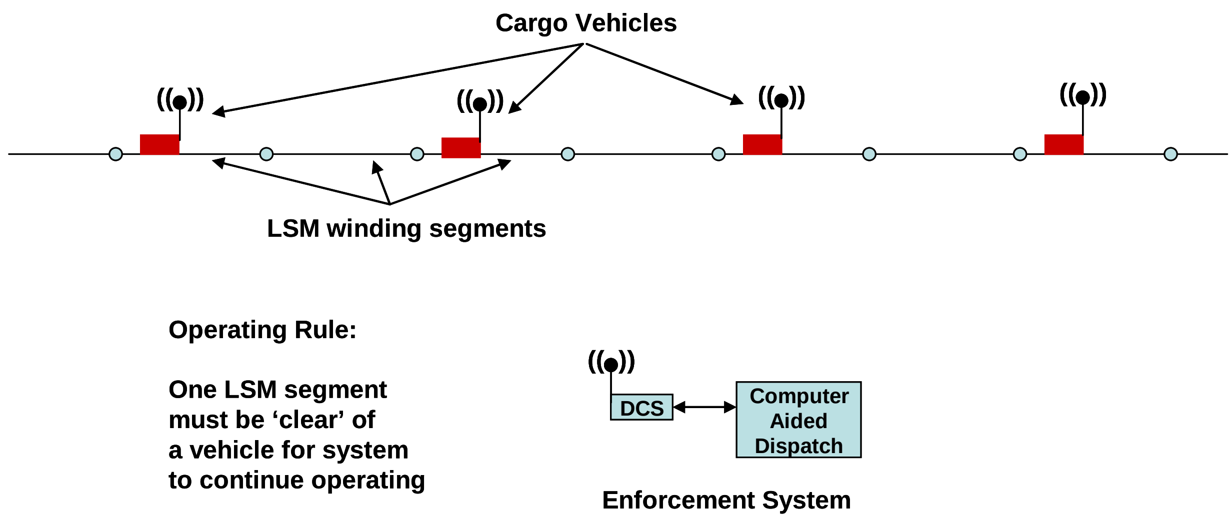


Fig. 3-24. Basic communication architecture for multiple vehicles

An apparatus for control of all the cargo vehicles on the transportation system comprises:

- A digital communication system (DCS) which communicates between each cargo vehicle and the CAD system
- Cargo vehicle equipment that determines its location on the guideway
- Cargo vehicle equipment that determines its speed on the guideway
- A CAD system that determines via the position of each cargo vehicle if the operating rule is true
- Logic that determines if the operating rule is not true, and commands are sent to each inverter through the GA network inverter control to shut down and each cargo vehicle to apply emergency braking

US&S will provide the cargo vehicle carborne equipment, as well as signaling and communications.

System Architecture

The total system will consist of two independent transportation systems. One of these two systems is illustrated in Fig. 3-25. The red device represents the applicable software control device. The command and control system interfaces with the inverters via a simple command that indicates a "go or no go" to the software control device.

Figure 3-25 illustrates the devices that would be employed for one of the two independent transportation systems. Both of the two independent transportation systems are operated independently with two command and control systems.

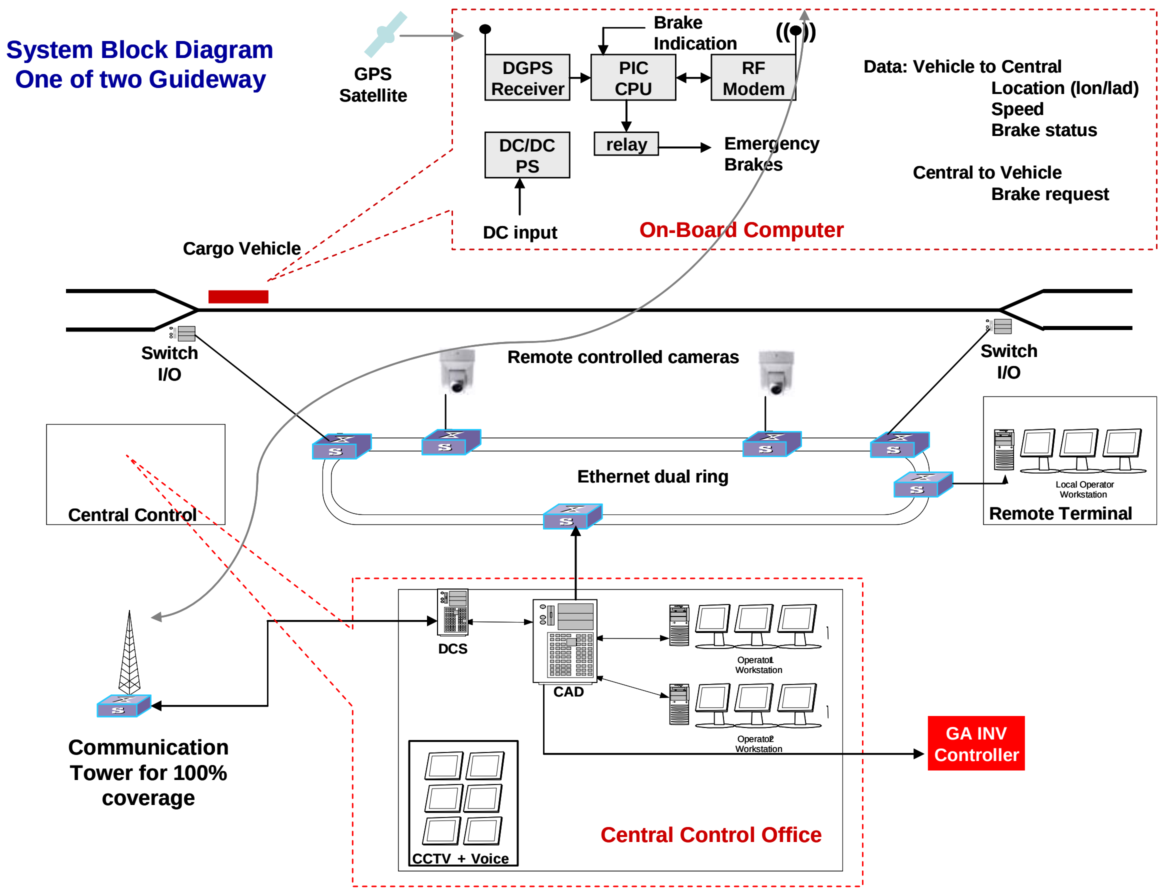


Fig. 3-25. System interfaces

In Fig. 3-25, an interface exists between the CAD system and the inverter controller.

The CAD system will be primarily a display system, but having the ability to make requests to the inverter controller system.

Communications between wayside devices is via one, redundant, self healing switches, dual ring Ethernet system.

The control of the guideway switches is from the CAD via the wayside switch input/output (I/O) devices. Both controls and indications are processed through these wayside switch I/O devices.

Hardware Deployment

Hardware will be provided for a central office and one remote office. Each office will have two workstations, of which one will normally be an on-line spare. The remote offices will be at either terminal.

There will be a pair of application servers in the central office (redundancy), as well as a small database cluster. There will be data replication to one of the remotes, which can act as a disaster recovery site in the event the central office is lost.

Visual observation of the entire transportation system is via the closed-circuit television (CCTV) system. The CCTV system employs remote controlled cameras with a monitor system using software to detect intrusion on the guideway.

Dispatch System Requirements

The CAD system provides the following functions:

1. Initiate movement of all or part of the fleet out of a yard and across the system. This may be a dispatcher request or an indication that a button in the storage platforms has been pressed. The CAD system will provide an interface for the dispatcher to lock out a remote initiation.
2. Block a yard track that is out of service. The dispatcher can select a yard track to block, and the system displays a form for entry of a reason code and expected duration. Upon commitment, the block is stored in persistent storage.
3. Select switch positions based on a traffic pattern, or allow the operator to request patterns from vital equipment. If the vital equipment does not implement traffic patterns, the CAD system will deal with this function.
4. Support display of:
   a. Vehicle location on a track display. Vehicles in the storage tracks will/may be counted rather than displayed by identifier.
   b. Block energization status.
   c. Switch position.
   d. Vehicle loaded/unloaded status received from each cargo vehicle onboard device.
5. The CAD system will support web-based viewing of the track display states.
6. The CAD system will keep an event log in the relational database.

7. The CAD system will provide event record extraction and replay of events on the track display. CCTV control will be a commercial-off-the-shelf (COTS) product provided by US&S. There will not be any integration with the CAD system.

Voice radio will be a COTS product provided by US&S. There will not be any integration with the CAD system.

Architecture

The CAD system will be provided by US&S.

1. US&S will provide the track display and support the web browser interface.
2. US&S will provide the code to support the peer to peer protocol.
3. The event logging and retrieval software will be provided by US&S as well as a playback function.
4. US&S will provide tasks to implement traffic patterns and request switch position and traffic flow initiation.
5. There will be an interface to the automatic train protection (ATP)/CAD will receive status messages from the ATP and send them on to the safety server.

Tasks for the CAS system

1. Requirements analysis and specification
2. Interface control documentation
3. Data creation and management
4. Project management and administration
5. Minor changes to human machine interface
6. Web-base interface
7. Peer to peer interface
8. Adapt playback
9. Data radio interface to cargo vehicles
10. Traffic control pattern management software
11. Hardware design and installation
12. Workstations, Oracle databases, servers, office networking gear
13. Quality assurance
14. Configuration management
15. Supervision
16. Testing
17. Training and documentation

The DCS computer controls the communications to each vehicle. The interface between the CAD and DCS is a serial link. The RF link describes the serial radio link between these two systems.

RF Link

Each maglev vehicle will communicate with the DCS over a half-duplex radio frequency (RF) link. The DCS will monitor the location and speed of each vehicle and will enforce proper separation between vehicles through control of the onboard braking system as well as the wayside inverters that feed each guideway section.

The RF link will consist of a network of 900 MHz spread spectrum radio modems in a point-to-multipoint configuration as shown in Fig. 3-26.

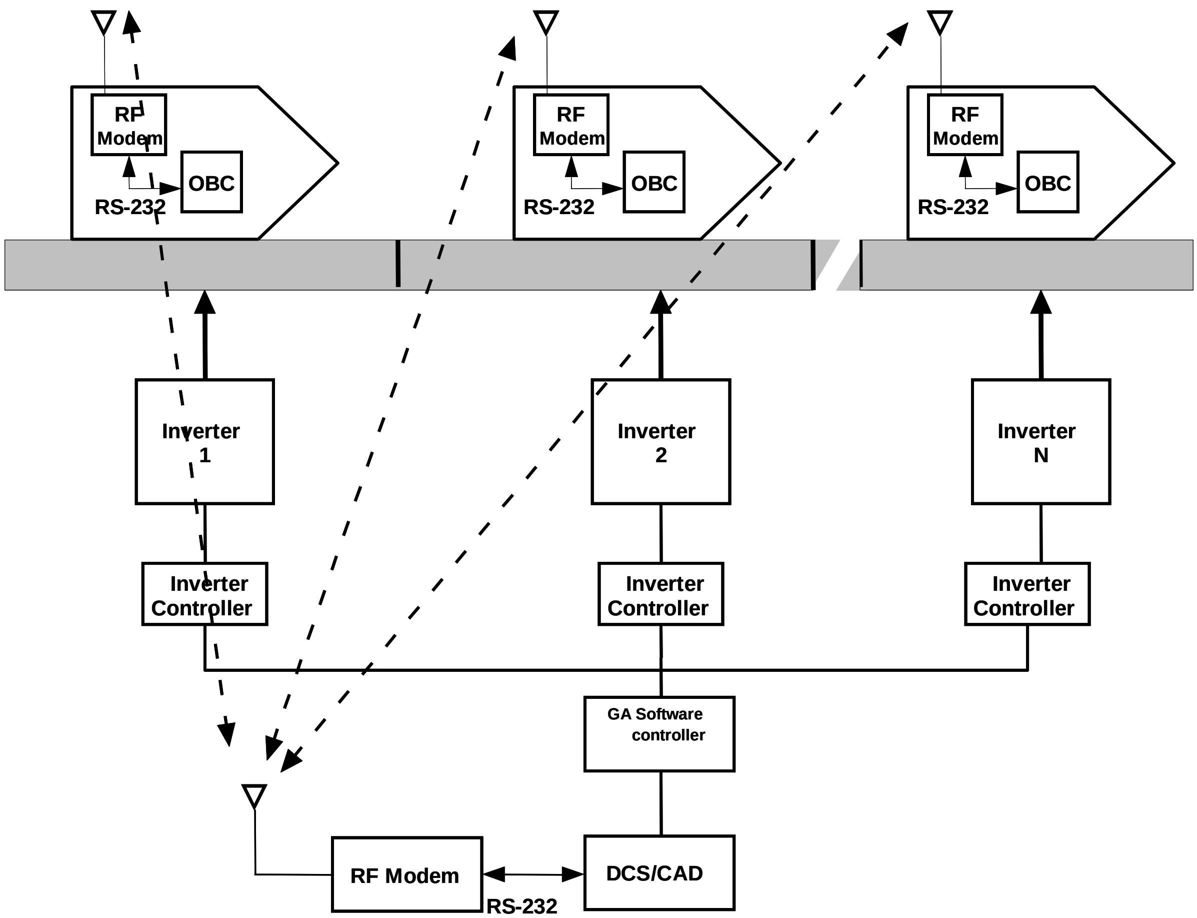


Fig. 3-26. Communication via RF link

The RF modems shown operate in the 900 MHz ISM band, and are thus license-free. At a maximum power output of 1 W each, the line-of-sight (LOS) range is up to 40 miles with a high-gain antenna. Security of the RF data is ensured through the use of 256 bit Advanced Encryption Standard (AES) encryption.

The RF modems will be configured to operate in “polling mode” where the base (DCS) unit will sequentially send out a message to each unique vehicle address. After each message is sent, that particular vehicle will respond by sending the following data back to the DCS:

- Speed
- Location (lon/lad)
- Vehicle brake status

Once all vehicles have been queried, the DCS/CAD/OSS will issue RUN/STOP commands to inverters as required to maintain safe separation distance between vehicles. The CAD/DCS will also broadcast a brake activation command to affected vehicles over the RF link.

Cargo Vehicle Device

Figure 3-27 to the right is a block diagram of the cargo vehicle’s onboard computer subsystem.

The primary function of the cargo vehicle’s onboard computer subsystem is to determine its position on the guideway via DGPS and radio back to central control its location.

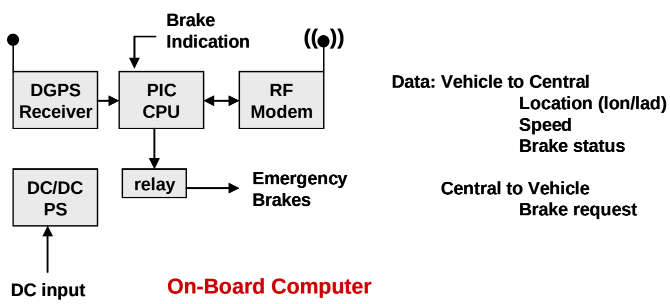


Fig. 3-27. Cargo vehicle computer system

Also the cargo vehicle’s onboard computer subsystem is interfaced to the cargo vehicle’s emergency brakes. Central control can request a brake application via the CAD/vehicle’s data radio system.

The onboard device interfaces to the cargo vehicle’s emergency braking devices via relay contacts.

The PIC CPU contains the logic necessary to transmit the cargo vehicle’s location, speed and brake status to central control. The PIC CPU also will request a brake application via an interface relay via commands received from central control.

Surveillance (CCTV) of the Transportation System

Continuous video surveillance will be maintained at each storage platform. There are eight platforms for each independent system. Multiple color video cameras will be installed, cameras will cover each storage platform and cameras will cover the switch areas. The cameras will be located so that the entire platform can be viewed clearly and the switching area can be seen clearly. The video signals from each storage platform will be transmitted to the central office over one strand of single-mode fiber.

To view the high speed guideway, a camera may be located every 500 ft. Approximately 122 cameras will be employed to monitor both cargo transportation systems.

The base-band signals, from the surveillance cameras, will be channelized. That is, each camera output signal will be translated to a standard TV broadcast channel. The standard TV channel will be different for each camera. The channelized video signals are combined to form a single broad-band signal that is converted to an optical signal for transmission to the central office.

Guideway Intrusion

There are several technologies that can be employed to detect intrusion. These technologies use sensors that include: radar, laser, ultrasonic, microwave, video-motion, and perimeter fence with sensors.

We have selected the video-motion sensors to be used for guideway intrusion. This technology was selected because of the 122 CCTV cameras employed in our architecture.

There are several companies that have experience implementing this type of technology. One company is GVI Solutions. GVI Solutions recently introduced a Mass Transit Intelligent Video System (MTIVS). Developed from the GVI TRAK platform, it can be deployed at airports, buildings, stadiums, nuclear and chemical plants, ports, and other critical infrastructure facilities. The MTIVS system continuously monitors multiple cameras with fully automatic pan, tilt, and zoom (PTZ) operation to identify and track unauthorized activity.

MTIVS utilizes sophisticated algorithms to automatically and continuously monitor, scan, evaluate record and display video inputs from multiple cameras in a single command and control center to instantly alert so that an active response can prevent a tragedy from occurring.

Another company is ClearView Communications Limited. Their cost-effective system records all video inputs and automatically displays and alerts security personnel to respond. Instead of hundreds of screens to watch at the command center, intelligent displays highlight types of critical threats.

Video Cameras

Each platform camera will have PTZ capability; in addition these cameras will have several preset positions that will be remotely activated in specific emergency situations.

Motorized Zoom Lens

The camera lens planned for use in the surveillance system will have 1/3-in. format with an auto iris feature. The lens will be motorized for zoom operation. The zoom range will be selected on an individual application by application basis, the available range selections are 6x, 10x, 15x and 20x.

Pan, Tilt Apparatus

The pan/tilt apparatus planned for the color video cameras used on the maglev cargo system will be designed for outdoor use; they will be weatherproof and corrosion resistant. The pan/tilts will be mounted in such a way that they will be vandal resistant.

Pan, Tilt, Zoom Transmission System

A separate transmission link will be used to control the PTZ functions. The link will consist of multiple dual-fiber modems. The dual fibers offer path redundancy by forming self-healing ring architecture. Two of the modems will be terminal modems and the remaining modems will be add/drop types.

The signal distribution unit located in the central office provides the PTZ signal for distribution. The signal is transmitted in daisy chain fashion to all platforms. The signals are addressed so that each camera in the system only receives messages that contain the correct camera address.

Receiver/Driver Unit

The receiver/driver unit is the control data decoder for the pan/tilt units and the zoom lenses. The receiver/driver unit decodes the data signals transmitted by the signal distribution unit located in the central office. The decoded messages are converted into specific control codes that activate the remote equipment. The receiver/driver unit contains low voltage dc lens drivers for focus, zoom and iris speed adjustment. The unit also provides a fused output for the pan/tilt motors. The receiver/driver unit also provides pre-positions settings for the cameras and the thumb wheel derived codes for the local cameras. The pre-position settings have a 10-bit accuracy.

Video Transmission System

The video signals generated by the cameras located at the storage platforms will be transmitted to the central office over one strand of single-mode fiber. The signals will be channelized. That is, they will each be modulated onto a different TV channel so that each camera may be viewed on a different TV channel. The resultant group of channelized signals is presented to the input of a combiner. The entire group of signals is combined or mixed so that they appear as a single broadband signal at the combiner output. The combined signal is connected to an optical transmitter (Fig. 3-28).

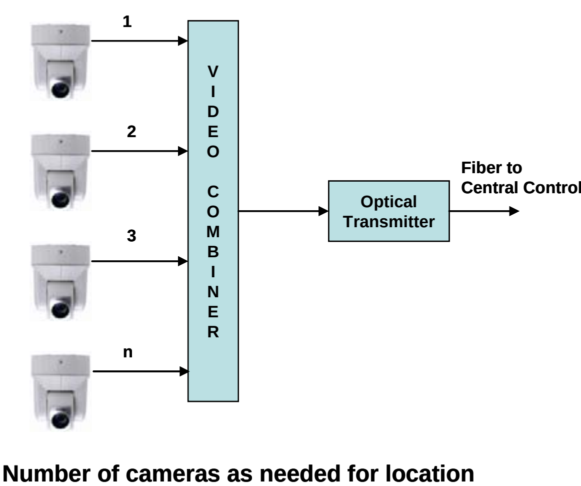


Fig. 3-28. Surveillance system

The combined signal is converted from electrical to optical form before it is transmitted over the single mode fiber that is connected to the output of the optical transmitter.

The opposite electrical conversions are performed at the central office, the receiving end of the fiber. The fiber is connected to the input of an optical receiver where the optical signal is converted to a broadband electrical signal that contains all of the camera signals from a particular station. The electrical signal from the output of the optical receiver is connected to a splitter where the broadband signal appears at multiple outputs. Each output of the splitter is connected to a demodulator circuit. Each of the demodulators is tuned to the same TV channel as the modulator located at the opposite end of the fiber. The output of each demodulator contains the base band signal for the camera to which the modulator/demodulator is tuned.

Video Switching Matrix

The video-switching matrix will be equipped initially for 122 cameras and 48 monitors. It will be designed so it can expand to 256 cameras and 64 monitors, by adding modules. The switch can be controlled from up to 32 keyboards and has an alarm handling capability of 1024. The matrix can switch any camera output to any monitor. A 48-character, on-screen display of time and date, camera ID, monitor number, and an icon to identify controllable cameras is available. Since there are 122 active cameras and only 48 monitors available, the rich selection of available display-timing functions will be used extensively as will the alarm operated monitor selection capability. The switch has available a wide array of amenities to make operation easier and enhance the security function.

Wall of Monitors

For each transportation system, the camera images will be viewed on 24 monitors, the monitors will be arranged on a wall that is 4-ft wide by 6-ft high (Fig. 3-29). The display units will be 21-in. flat screen color video monitors. The display wall will be located for easy viewing by the operator.

Fig. 3-29. Operation control center monitors

3.7 GUIDEWAY (WBS D16000)

The guideway will be elevated to provide clearance over all underpass highways, streets, ramps, and railroads, and port facilities, and to avoid interference with port facilities and disruption of services.

Guideway Section. A dual-guideway section will be utilized throughout the alignment, with the exception of single-guideway sections at spur locations. Refer to Fig.3-30 for typical guideway section.

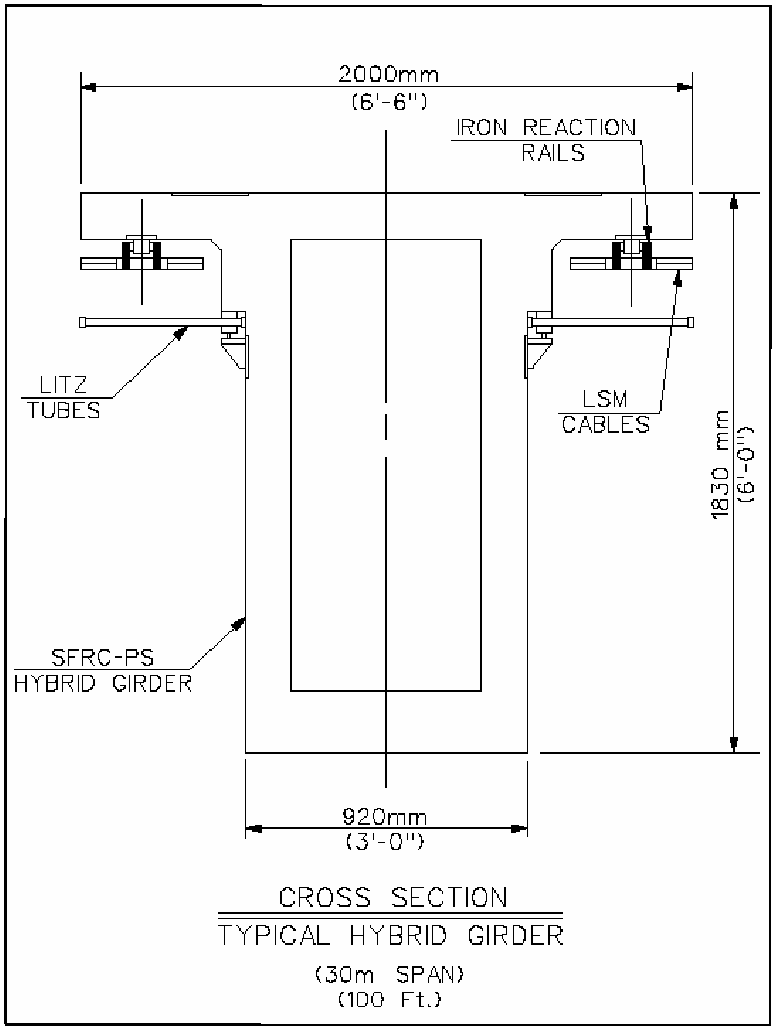


Fig. 3-30. Typical guideway section

Guideway Structure. Guideway beams/girders will be composed of hybrid concrete girders. These girders will consist high strength concrete and steel fibers that provide high-strength sections capable of efficiently carrying the heavy dead load and live loads required for port operations. Generally, guideway sections will be pre-cast, delivered to the site, and erected in place. This greatly facilitates and advances the completion of construction. Utilization of precast sections also minimizes interruption to port operations. Standard cast in place sections would require significantly greater time to construct. Crossings over Route 47 and the Cerritos Channel will require long spans (170 ft to 250 ft). At these locations, pre-cast sections will not be feasible and either segmental concrete or steel structures are anticipated. During subsequent phases, detailed analysis will be conducted to determine the most cost efficient method of design/construction, pre-cast and segmental combination, or all segmental.

Guideway Piers. (Refer to Fig. 3-31) – Typically, T-shaped piers will be utilized to support either the dual guideway or single guideways. The pier will consist of a top-T-section similar to numerous highway bridge structures. The pier will be supported by a single-shaft concrete caisson. The depth will be dictated by geotechnical conditions and design loads. Single-shaft concrete caisson will be used instead of conventional foundations founded on multiple caissons or piles, providing a significant advantage. The single-shaft caissons can be constructed quickly, with minimal right-of-way or facility impacts, and with minimal vibration and disruption to port activities. Caissons will be cast in place; pier sections will be either pre-cast or cast in place – detailed analysis will be conducted in future phases. Cantilever (L-shaped piers) will be utilized where horizontal clearance is an issue, such as sections of guideway adjacent to buildings or port facilities.

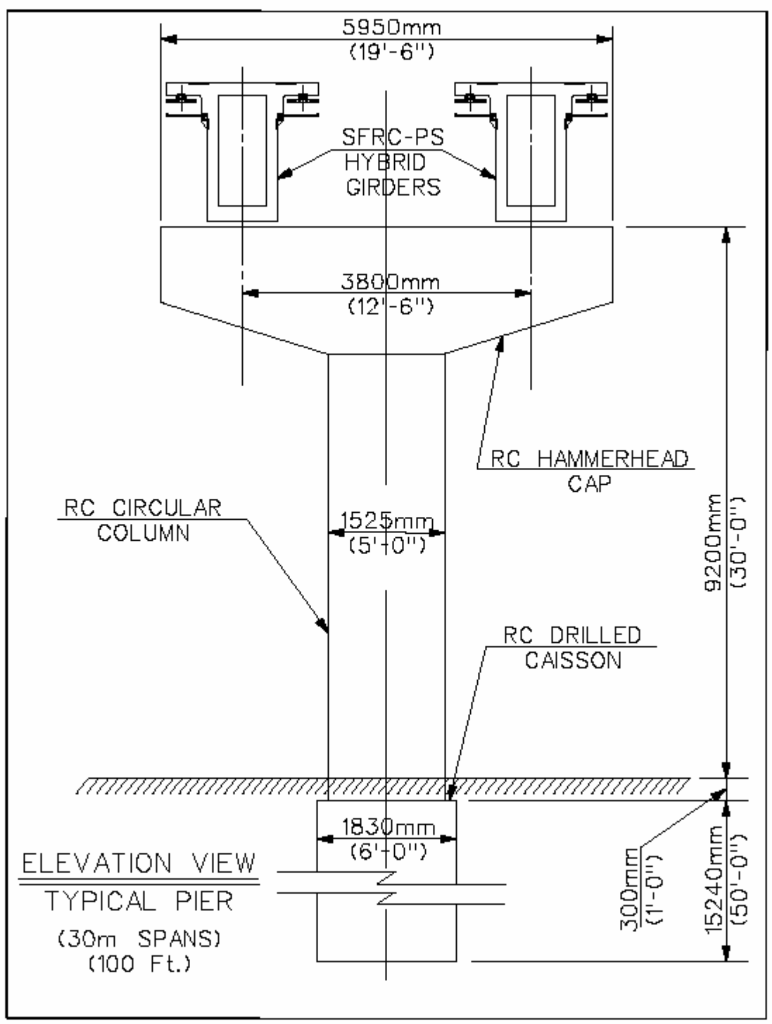


Fig. 3-31. Typical guideway piers

Design Loads. Design loads will consist of the guideway dead load, the vehicle load – 115,000 lb fully loaded, plus wind and seismic loads. All structures will be designed to meet ACI-358.1 Analysis and Design of Reinforced and Prestressed Concrete Guideway Structures, current Port of Los Angeles, City of Los Angeles, and City of Long Beach requirements, and Caltrans seismic design requirements.

Span Lengths. Typical span lengths range between 80 to 120 ft, with the predominant span length 100 ft; longer spans are required at highway, railroad and channel crossings. Maximum spans vary from 155 to 240 ft (over the Cerritos Channel). Total length of highway, railroad, and channel crossing structures requiring spans greater than 120 ft is 4,720 ft. These structures, as indicated above, will require either segmental concrete construction or steel box girder construction.

Cerritos Channel. The crossing of the Cerritos Channel requires a five span, 880-ft structure, with a maximum span of 240 ft, which is similar to the adjacent highway crossing.

Terminal Island Freeway. A three span, 550-ft structure with a maximum span of 225 ft, will be required to across the Terminal Island Freeway, north of the Cerritos Channel. Due to roadway ramp geometry, cross-girder bents will be required to support the guideway, rather than standard T-piers. (Individual T-piers would conflict with existing ramps.)

Pier Height. The typical pier height will be 22 ft above existing grade, corresponding to the minimum 30-ft alignment height. Maximum pier heights, in the vicinity of the Cerritos Channel and Anaheim Street will be approximately 55 to 74 ft (max. alignment elevations in these areas are 63 and 82 ft above existing ground).

3.8 CIVIL STRUCTURES (WBS D17000)

Civil structures will consist of the Maglev Maintenance/Control Facility, and Port Loading/ Unloading Stations. Loading/Unloading Stations will be required for any type of automated systems employed to transfer cargo/containers. The cost of these facilities is not included in the cost estimate for a maglev system.

Maintenance/Control Facility. Maintenance/Control Facility – This facility will provide space for the repair and maintenance of maglev vehicles, and the storage of related parts and tools. Maintenance/repair facilities will be located on the second floor of the building. The facility will house the vehicle communication and control center, including monitoring facilities for security, plus offices for communication, control and security personnel. These facilities will be provided the first floor of the building.

The building will be situated at a location agreeable to the Port of Los Angeles and easily accessible to the maglev system. Preliminarily, we suggest that it be located at the Loading/Unloading Station at Terminal Island.

3.9 CORRIDOR (WBS D18000)

As indicated by the port engineering staff, the Port of Los Angeles will resolve all right-of-way issues and acquire all right-of-way. Therefore, right-of-way costs are not included in the cost estimate.

Detailed right-of-way information was not provided for this study, and we have no detailed knowledge of property ownership. The following is a summary of potential issues:

Port of Long Beach. Significant areas of the alignment are located within right-of-way owned by the Port of Long Beach. Agreement will need to be obtained to utilize their right-of-way.

Caltrans. Portions of the alignment are located within right-of-way owned by Caltrans – adjacent to route 47 (Seaside Avenue, Ocean Boulevard, Terminal Island Freeway) and ramps. Discussions will need to be conducted with Caltrans regarding placement of the guideway within their right-of-way (if this is not acceptable, minor realignment may be required at some locations, major realignment may be required at the location of ramps to the Terminal Island Freeway).

Railroad. As indicated by the port engineering staff, the Port of Los Angeles and Port of Long Beach own all railroads, with operation by Union Pacific (UP) and Burlington Northern Santa Fe (BNSF). Areas of the alignment from approximately 1500 ft south of the Anaheim Street to 1500 ft north of Anaheim Street, occupy railroad right-of-way (or adjacent property owners right-of-way).

Property Not Under Control of the Port. At some locations, but primarily the section of the alignment that parallels Seaside Avenue and Ocean Boulevard, the alignment may occupy property not controlled by the Port of Los Angeles, particularly between Henry Ford Avenue and the Terminal Island Freeway.

Impacts to Existing Facilities. Impacts to existing facilities will be minimal – all piers required for guideway construction will be placed to avoid permanent impacts to Port Facilities, Caltrans, local streets, railroads, and existing buildings. The entire guideway can be constructed without permanent impacts to existing facilities. Electrical and Communication and Signaling components will be carried by the guideway – minor impacts are anticipated due to electrical supply.

Construction Impacts. Existing ground and terrain will be disturbed by construction activities – all disturbances will be restored upon completion of construction. We anticipate no disturbance or relocation of existing Port facilities during construction with the exception of utilities.

Utility Impacts. Existing utilities in the vicinity may be impacted by the construction; however, the location of the alignment and flexibility of pier placement will minimize utility impacts. Complete utility coordination and location will be conducted in subsequent phases of the project.

3.10 INTEGRATION (WBS D19000)

Program management, administration, quality assurance, and systems engineering tasks are performed under this WBS.

4. BUDGETARY COST ESTIMATE

A rigorous approach using a detailed work breakdown structure (WBS) was used to generate this budgetary cost estimate. Please note that this budgetary cost estimate is for planning purposes only and does not constitute an offer. Team members were responsible for providing a grassroots estimate for the equipment and labor required in their area of responsibility. The estimate includes all nonrecurring capital costs associated with the engineering, construction, and commissioning of the project.

- **Site Specific/Detail Engineering** costs are those application engineering tasks associated with identifying specific requirements and interfaces of the system, and those engineering tasks associated with completing the engineering drawings and specifications for the Port of Los Angeles ECCO system.
- **Construction** costs include all purchased parts, fabricated hardware, components, assembly, and labor to construct, assemble, and install the complete Port of Los Angeles ECCO system (excluding cargo handling).
- **Commissioning** costs include those tasks needed to put the Port of Los Angeles ECCO system into service. These tasks include safety planning, failure modes and effects analysis (FMEA), test planning, component acceptance testing, system acceptance testing, training, the cost of energy, and project integration.

All cost estimates in this plan reflect unescalated 2006 dollars and include all business factors such as warranties, competitive profit margins, and so forth.

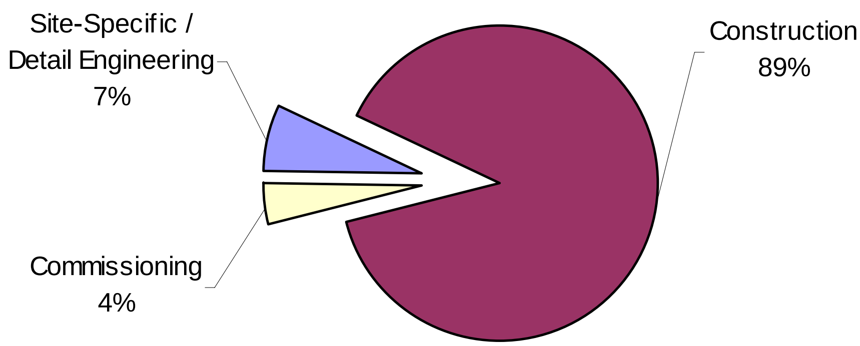
4.1 BUDGETARY COST ESTIMATE – PORT OF LOS ANGELES ECCO SYSTEM

Baseline ground rules and assumptions issued in preparing this estimate are as follows:

1. This budgetary estimate is for planning purposes only and does not constitute an offer
2. Constant, unescalated 2006 dollars, including all business factors such as warranties, competitive profit margins, and so forth
3. Right-of-way and environment impacts costs are not included
4. Channel and freeway crossings are included
5. The Port of Los Angeles ECCO system design concept is a close derivative of current passenger maglev concept
6. Site-specific/detail engineering is a 1.5-year activity
7. Construction is a 3-year activity
8. Commissioning occurs 3 months after completion of construction
9. Throughput – 2500 40-ft containers per direction/per year

10. Operation will be 24 hours a day/7 days a week
11. Length of project is 4.7 miles
12. Cargo handling equipment not included
13. Driverless operation
14. Single container maglev chassis (no consist)

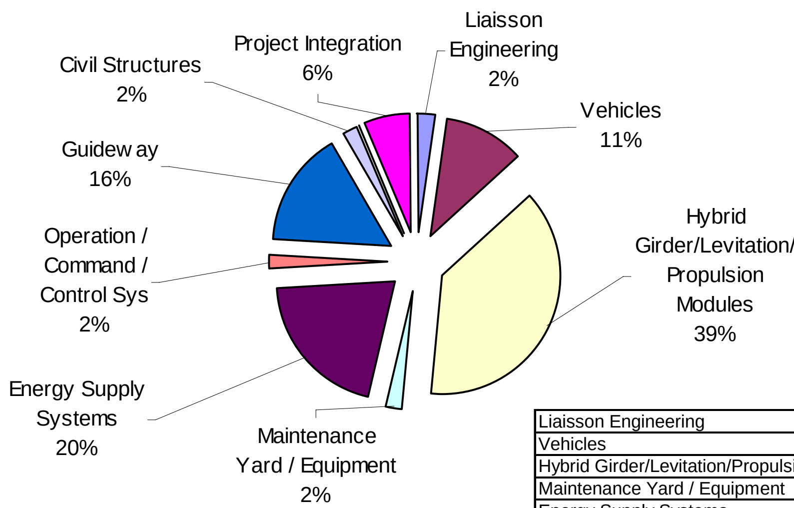
The total cost is depicted in Fig. 4-1.



Site-Specific / Detail Engineering	$ 40,359,000
Construction	$ 510,149,000
Total Engineering & Construction	$ 550,508,000
Commissioning	$ 24,070,000
Total	$ 574,578,000

Fig. 4-1. Cost summary

Because construction is the biggest driver, a further breakdown is provided in Fig. 4-2.



Liaisson Engineering	$ 12,500,000
Vehicles	$ 55,505,000
Hybrid Girder/Levitation/Propulsion Modules	$ 194,074,000
Maintenance Yard / Equipment	$ 11,234,000
Energy Supply Systems	$ 103,326,000
Operation / Command / Control Sys	$ 10,721,000
Guideway	$ 79,875,000
Civil Structures	$ 10,375,000
Right-of-Way / Corridor	$ -
Project Integration	$ 32,539,000
Total	$ 510,149,000

Fig. 4-2. Construction cost breakdown

4.2 FUNDING PROFILE

Table 4-1 presents the estimated funding profile.

TABLE 4-1
FUNDING PROFILE

	Year 1	Year 2	Year 3	Year 4	Total
Site-Specific / Detail Engineering	$ 28,251,300	$ 12,107,700			$ 40,359,000
Construction		$ 153,044,700	$ 255,074,500	$ 102,029,800	$ 510,149,000
Total Engineering & Construction	**$ 28,251,300**	**$ 165,152,400**	**$ 255,074,500**	**$ 102,029,800**	**$ 550,508,000**
Commissioning				$ 24,070,000	$ 24,070,000
Total	**$ 28,251,300**	**$ 165,152,400**	**$ 255,074,500**	**$ 126,099,800**	**$ 574,578,000**

4.3 OPERATING AND MAINTENANCE COSTS

To estimate the operating cost, we assumed that the system will be operated by a minimum staff of three people for 24 hours a day, seven days a week. Based on these assumptions, annual operating expenses are provided in Table 4-2.

Train operation requires one supervisor and one controls engineer located in the control room, and one security team member to provide for roving security watch of the system. Operations 24 hours a day and a 40-hour workweek result in a total operations staff of about 15 people. Additional staff is required for maintenance and emergency vehicle operation.

TABLE 4-2
ECCO-SYSTEM ANNUAL OPERATIONS COST ESTIMATE

Annual Operations Costs	Personnel	Salary & Benefits	Cost
Labor			
Control Center Operator	10	$ 60,000	$ 600,000
Security	5	$ 40,000	$ 200,000
Total Labor			**$ 800,000**
Non-Labor			
Enengy			$ 8,212,500
Management & Administration			$ 200,000
Total Annual Operations Costs			**$ 9,212,500**

With regard to maintenance, it is expected that staff of 19 people will work the day shift, performing routine maintenance and inspection of the system. Based on this assumption, annual maintenance costs are provided in Table 4-3.

TABLE 4-3
ECCO-SYSTEM ANNUAL MAINTENANCE COST ESTIMATE

Annual Maintenance Costs	Personnel	Salary & Benefits	Cost
Labor			
Vehicles	6	$ 90,000	$ 540,000
Electrical Systems	8	$ 90,000	$ 720,000
Guideway Inspection and Maintenance	5	$ 90,000	$ 450,000
Total Labor			**$ 1,710,000**
Non-Labor			
Spare Parts			$ 1,800,000
Total Annual Operations Costs			**$ 3,510,000**

Based on the above estimates, the annual operating and maintenance cost is estimated to be $12.7M per year.

5. SUMMARY

The General Atomics (GA) Electric Cargo Conveyor (ECCO) team is pleased to submit this final report evaluating the feasibility, cost, and schedule for the implementation of a cargo maglev system at the Port of Los Angeles. It represents our team's best effort to develop a plan that is responsive to the needs of the Port of Los Angeles as it looks ahead to expanding its cargo handling capabilities in an environmentally clean manner. Our approach has been structured to minimize deployment risk as well as the time to construct and commission the project. The overall conclusions of the study are:

1. Maglev technology is feasible and can be implemented with proven components.
2. The alignment is feasible for a high throughput system within the port.
3. The complete 4.7-mile system connecting Terminal Island with the SCIG facility will cost a total of ~$575M, and includes channel/highway crossings, vehicles, power systems, switches, and system ends (without cargo handling equipment).
4. The detail engineering, construction, and commissioning schedule is four years, assuming full funding, and environmental approvals performed in parallel.
5. Annual operation and maintenance (O&M) costs are expected to be ~$13M.

The next steps in moving forward on the project are to perform detailed site-specific engineering of the system, including the development of procurement and manufacturing plans. We envision that environmental and right-of-way planning activities would start in parallel.

We are very enthusiastic about the potential of maglev technology to contribute to the Port of Los Angeles' future expansion plans. Our team is committed to working with the Port of Los Angeles to make the ECCO system a reality.

APPENDIX A

GENERAL ATOMICS
ELECTRIC CARGO CONVEYOR (ECCO) SYSTEM
REQUIREMENTS DOCUMENT

20132S-OO-001

General Atomics
Electric Cargo Conveyor (ECCO) System

Requirements Document

Sponsored by:
The Port of Los Angeles
San Pedro, California

Submitted by:

General Atomics
PO Box 85608
San Diego, CA 92186-5608

Approved by:	**Function**
P. L. Jeter	**Chief Engineer**
H. Gurol	**Program Manager**

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GENERAL ATOMICS

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INTRODUCTION

This document establishes the requirements for the General Atomics Electric Cargo Conveyor (ECCO) System. The Requirements Document is organized into three parts (1) System Requirements, (2) Alignment Requirements (Site-Specific), and (3) System Concept Definition Requirements. Figure 1 shows the relationship between these three sets of requirements. The System and Alignment Requirements are independent sets of requirements which flow down to dictate the System Concept Definition Requirements.

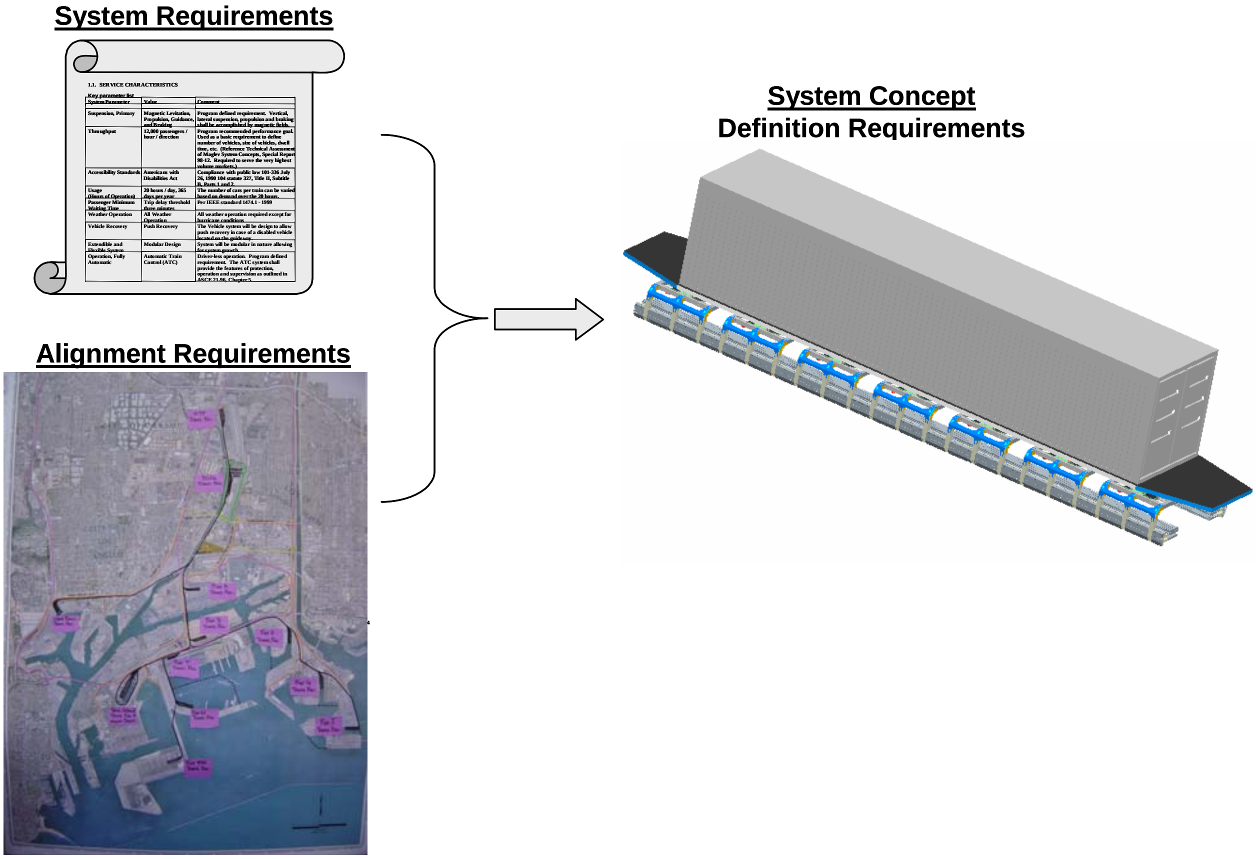

Figure 1. Requirements Relationship

The definition for these three requirement sections is as follows:

SYSTEM REQUIREMENTS – These are the top-level system requirements that apply to the design, construction, and operation of a maglev system. These requirements are generic and are intended to be universally applicable to the Electric Cargo Conveyor (ECCO) System, independent of either the system concept or the site-specific alignment constraints.

ALIGNMENT REQUIREMENTS (SITE-SPECIFIC) - Include the requirements that define the specifics of the guideway alignment. This set of requirements includes route characteristics, stations (number and layout), site-specific environmental requirements, and any other parameters needed to fully define the alignment.

SYSTEM CONCEPT DEFINITION REQUIREMENTS- Include the requirements for each of the major subsystems which make up the maglev system. These subsystems include: (1) vehicle, (2) guideway, (3) propulsion and power, (4) command, control, and communications, (5) cargo handling stations and maintenance facilities, and (6) security.

This Requirements Document shall provide the governing guidelines for the development of a System Concept Definition for the Electric Cargo Conveyor (ECCO) System. As such, this item will be a living document which will evolve and change as the development of the technology progresses. The rules and operating procedure for coordinating, documenting, and controlling the requirements along with both the physical and functional interfaces are defined in Appendix A. As a change to the Requirements Document is identified a Proposed Requirements Change Request will be completed and issued for review and approval. General Atomics, along with input from other applicable team members, will review the request and either recommend that the change request be rejected or incorporate the change into the Requirements Document. As the Requirement Document is revised, a revision number and revision date will be added to the document. The initial release of the document will be identified as Rev. "0" with each additional revision numbered in ascending order. Revision codes will be added to the document next to the change in the Parameter, Value or Comment column, as applicable. The codes are as follows:

Revision Code	Description	Example
*	Revised	*Revised Requirement *(Parameter, Value, or Comment)*
+	Added	$^{+}$New Requirement *(Parameter, Value, or Comment)*

APPLICABLE DOCUMENTS

The following documents (exact issue shown) form a part of this specification to the extent referenced herein. In the event of conflict between the documents referenced herein and the contents of this specification this requirement document will supercede.

Document	Description
AASHTO Publication HB-16	**American Association of State Highway and Transportation Officials, "Standard Specifications for Highway Bridges, 16th Edition (1996)**
AASHTO LRFD-US-2	**American Association of State Highway and Transportation Officials, Load-and-Resistance Factor Design philosophy, 2nd Edition (1998) along with 1999 and 2000 Interim specifications.**
ACGIH 1999	**"Threshold Limit Values (TLV) for Chemical Substances and Physical Agents and Biological Exposure Indices." American Conference of Governmental Industrial Hygienists. 1999.**
ACI Standard 358.1R-92	**American Concrete Institute (ACI), Analysis and Design of Reinforced Concrete Guideway Structures**
ANSI C37.20.2	**American National Standards Institute, Metal Clad and Station-Type Cubical Switchgear.**
ANSI C37.22	**American National Standards Institute, Mechanical Life - Preferred Ratings and Required Capabilities for Indoor AC Medium Voltage Switches used in Metal Enclosed Switchgear.**
ANSI C37.23	**American National Standards Institute, Busway Medium Voltage - Certification of momentary current testing, impulse testing and heat runs.**
ANSI C37.42, .44,.46 and .47	**American National Standards Institute, Fuses, Voltage and Construction requirements for Load Interrupter Switch (WLI).**
ANSI C37.57, C37.58 and NEMA SG5	**American National Standards Institute, Metal Enclosed Interrupter Switchgear Assemblies Conformance Test.**
ANSI C62.11/IEEE 32	**American National Standards Institute, Surge Protection - Metal-Oxide Surge Arrestors for AC Power Circuits.**
ANSI/IEEE C142 Green Book	**American National Standards Institute, Grounding Industrial and Commercial Power Systems.**
ANSI/IEEE C37.20.3	**American National Standards Institute, Construction of Metal Enclosed Interrupter Switchgear.**
ASCE 7-98	**American Society of Civil Engineers, "Minimum Design Loads for Building and Other Structures"**
ASTM B117	**Test Method of Salt Spray [Fog] Testing**
Caltrans BDS	**Caltrans Bridge Design Specifications**
FRA – Noise and Vibration Impact Assessment, 1998	**High-Speed Ground Transportation Noise and Vibration Impact Assessment, Final Draft, Federal Railroad Administration, December 1998.**
ICNIRP, 1990	**International Commission on Non-Ionizing Radiation Protection, Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields**

Document	Description
ICNIRP, 1994	International Commission on Non-Ionizing Radiation Protection (ICNIRP), Guidelines on Limits of Exposure to Static Magnetic Fields
ICNIRP, 1998	International Commission on Non-Ionizing Radiation Protection (ICNIRP), Guidelines for Limiting Exposure to Time Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)
IEEE 141 Red Book	Institute of Electrical and Electronics Engineers, Institute of Electrical and Electronic Engineers, INC., Recommended Practice for Power Distribution for Industrial Plants.
IEEE 1474.1 - 1999	Institute of Electrical and Electronics Engineers, Standard for Communications – Based Train Control (CBTC) Performance and Functional Requirements.
IEEE 242 BUFF Book	Institute of Electrical and Electronic Engineers, INC., Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems.
IEEE 519	Institute of Electrical and Electronic Engineers, Current Distortion limits for General Distribution Systems (120v through 69,000v)
IEEE Standard No. 100-1977	Institute of Electrical and Electronic Engineers, INC., Primary Unit Substations and Transformers.
IEEE Standard No. 1100-1999	Recommended Practice for Powering and Grounding Sensitive Electronic Equipment.
IESNA Lighting Handbook	Illuminating Engineering Society of North America, Lighting Handbook
IRPA, 1991	International Radiation Protection Association (IRPA). Guidelines on Protection Against Non- Ionizing radiation (NIR).
IRPA, 1994	International Radiation Protection Association (IRPA). Guidelines on Limits of Exposure to Static Magnetic Fields.
ISO 2041	International Organization for Standardization, Vibration and Shock - Vocabulary
ISO 2631	International Organization for Standardization, Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole Body Vibration
ISO 5805	International Organization for Standardization, Mechanical Vibration and Shock – Human Exposure - Vocabulary
NEMA Standard No. 201-1982	National Emergency Medicine Association, Primary Unit Substations and Transformers.
NFPA 70	National Fire Protection Association, INC., National Electric Code 1999 edition.
NFPA 130	National Fire Protection Association, INC., Standard for Fixed Guideway Transit System (Standard for rail fire-life safety)
NFPA 780	National Fire Protection Association, INC., Standard for the Installation of Lightning Protection Systems.
NPRM draft – August 30, 2000	Notice of Proposed Rule Making (NPRM) draft – August 30, 2000. Positive Train Control (PTC) working group recommendation.
Special Report No. 98-12	Technical Assessment of Maglev System Concepts, US Army Corps of Engineers, Cold Regions Research & Engineering Laboratory, Oct 98
TCRP Report No. 57	Transit Cooperative Research Program (TCRP) "Track Design Handbook for Light Rail Transit" by Parsons Brinckerhoff, Quade &

Document	**Description**
	Douglas, Inc. Herndon, VA
UBC/California Code title 24	**Uniform Building Code and California Code title 24 for Seismic zones 4, 3, 2A, 2B, 1 and 0).**
UCRL-MA-133867	**LLNL Environment, Safety, and Health manual, Volume II, Part 8: "Nonionizing Radiation and Fields (Electromagnetic Fields and Radiation with Frequencies Below 300 GHz)**
UL96A, 10th edition, 1994	**Underwriters Laboratory, Installation Requirements for Lighting Protection Systems**

1. SYSTEM REQUIREMENTS, PART ONE

The first part of this requirement document provides the general requirements that are generic ECCO system requirements. These requirements are independent of either a specific maglev system concept or a specific geographical location. These are the top-level system requirements that apply to the design, construction, and operation of a maglev system. These requirements are generic and are intended to be universally applicable to urban maglev, independent of either the system concept or the site-specific alignment constraints. This section separates these generic requirements into thirteen different categories, as follows.

1.1. SERVICE CHARACTERISTICS

Key parameter list

System Parameter	Value	Comment
Technology	Use Magnetic Fields for Suspension, Propulsion, Guidance, and Braking	Program defined requirement. The vehicle's suspension, propulsion and braking shall be accomplished by magnetic fields.
Throughput	2,500 containers per day, per direction (5,000 trip/day); 80% 40ft. & 20% 20ft. containers	Program recommended performance goal. Used as a basic requirement to define number of vehicles, size of vehicles, dwell time, etc.
Usage (Hours of Operation)	Up to 24 hour per day, 7 days a week	The number of cargo vehicles can vary based on peak demand
Containers per hour	156	
Weather Operation	All weather operation	All weather operation required except for hurricane and/or tornado conditions.
Vehicle Recovery	Push recovery	The vehicle system will be designed to allow push recovery in case of a disabled vehicle located on the guideway.
Extendible and Flexible System	Modular design	System will be modular in nature allowing for system growth.

System Parameter	Value	Comment
Operation, Fully Automatic	Fully automatic Train Control (ATC) per ASCE 21-96-Part 1, Chapter 5 (except as noted) for Driver-less operation	Driver-less operation. Program defined requirement. The ATC system shall provide the features of protection, operation and supervision as outlined in ASCE 21-96-Part 1, Chapter 5, except that Section 5.12, separation assurance shall be changed as follows: Separation assurance around the guideway. Separation assurance shall provide protection against rear-end collisions for following vehicles by maintaining a zone at the rear of each vehicle that continuously provides sufficient stopping distance for the following vehicle. This separation assurance shall be subjected to the safety risk assessment outlined in PTC Working Group Recommendation – Draft NPRM – August 30, 2000.

1.2. ACCELERATION/SPEED PERFORMANCE

Key parameter list

System Parameter	Value	Comment
Speed, Maximum Operational	145 km/h (90 mph)	Maximum speed for the ECCO system application. (Close station spacing, hills, and turn radius, minimize time spent at maximum speed).
Speed, Average	97 km/h (60 mph)	Based on acceleration and cruise speed profile.
Grade, Maximum capability	10% for a minimum of 460 m	Vehicle shall negotiate 10% grade at line speed (alignment operational speed up to 145 km/h) for a minimum of 460 meters.
Grade, Operating capability	7% at line speed with no degradation of performance	Vehicle shall negotiate 7% grade at line speed with no degradation of performance.
Acceleration, Max. Longitudinal, Vertical, & Lateral	0.16 g (1.6 m/s^2)	Value selected to prevent damage to breakable cargo.

System Parameter	Value	Comment
Jerk, Longitudinal, Vertical & Lateral	0.25 g/s	Value selected to prevent damage to breakable cargo. Jerk is the rate of change of acceleration (g's/s filtered at 0.3 Hz, or Jolt = peak to peak g's in 1 s)

1.3. BRAKING PERFORMANCE

Key parameter list

System Parameter	Value	Comment
Braking, Independent and Redundant	Dynamic brake Mechanical brake Emergency brake	Braking system shall be composed of three separate systems: a Dynamic brake; a mechanical brake and a fail-safe emergency brake
Braking, Deceleration	0.16 g (1.6 m/s^2)	Value selected to prevent damage to fragile cargo
Braking, Emergency	0.36 g (3.6 m/s^2)	Value selected based on vehicle operational safety.

1.4. NOISE CHARACTERISTICS

Key parameter list

System Parameter	Value	Comment
Noise Level - Outside 15.2 meters from guideway centerline	$\leq$ 72 dBA (Goal)	Noise levels to be determined in accordance with the High-Speed Ground Transportation Noise and Vibration Impact Assessment, Final Draft, Federal Railroad Administration, December 1998.

1.5. ALIGNMENT

Key parameter list

System Parameter	Value	Comment
Guideway	The guideway should be grade-separated for exclusive use, whenever necessary.	It should be designed to limit access to surface traffic, pedestrians or animals. Elevated guideway improves safety, allows use of existing right-of-way, minimizes impact on Urban environment, and minimizes construction cost and time. The guideway should be designed to the

System Parameter	Value	Comment
		AASHTO LRFD Bridge Design specification, 2nd edition, along with the 1999 and 2000 Interim specifications.
Turn Radius, Minimum	100 m (328 ft)	Based on 40-foot container vehicle geometry.
Crest Curvature, Minimum (Vertical Radius)	1000 m	1000m radius is currently used for LRT's.
Sag Curvature, Minimum (Vertical Radius)	1000 m	1000m radius currently used for LRT's.
Switching	Switching	Switches shall be provided for the end of alignments, cargo stations, merges on lines, diverges of lines, maintenance and storage facilities, off-line stations, and spur lines
Cargo Stations	Will meet the system operational requirements for loading and unloading cargo containers.	.

1.6. OPERATING ENVIRONMENT

Key parameter list

System Parameter	Value	Comment
Seismic	Peak Acceleration 0.6g to 0.7g	Caltrans Seismic Hazard Map 1996 Soil Classification D or E, deep caisson column supporting system. Use design guides of AASHTOSD Section 3 & 4 Caltrans ARS Curves & Hazard map.
Ambient Temperature and Humidity	Max. Operational temperature range of -32°C (-26°F) to 50°C (122°F). 95% non-condensing relative humidity at 30 ^{0}C (86 ^{0}F)	The system shall be designed to and capable of operating in, the applicable site environmental conditions.

System Parameter	Value	Comment
Wind	**<u>Operational threshold</u>** **≤ 50 km/h (~ 30 mph) operate at 100% capability** **<u>Vehicle safety threshold</u> ≤ 80 km/h (~ 50 mph) operational at reduced speed** **<u>Structural threshold</u>** **≤ 160 km/h (~ 100 mph) fully operational following wind condition**	**The wind threshold values are based on Technical Assessment of Maglev System Concepts, Special Report 98-12, Appendix B, paragraphs B.1 thru B.5 and Caltrans Bride Design Specification section 3.15. The wind speeds listed are an average over one hour in any direction. Operational threshold limits a peak gust to 75.6 km/h (47 mph) in any direction for vehicle speed up to 145 km/h (90 mph).**
Ice	**≤ 6 mm (0.25 inch)**	**Regular operation will heat guideway. Large gap EDS levitation systems are an advantage. The ice can build up to ½" during the 8 hours/day when the guideway is not in use. The thickness will be confirmed using ASCE 7-98.**
Snow	**≤ 300 mm (12 inch) / hr**	**Clearing during off-peak operation or via brushes attached to each vehicle. The snow can accumulate during the 6 hours/day when the guideway is not in use. The snow load will be confirmed using ASCE 7-98.**
Rain	**≤ 75 mm (3 inch) / hr**	**Proper drainage is required to prevent rain from accumulating on the guideway. Ponding can occur on the guideway with a v-shape top; it can't occur on the flat top guideway. The ponding load will be confirmed using ASCE 7-98.**
Lightning	**Compliance with IEEE Std. 1100**	**Protection shall be provided against lightning incidence in the area for those systems that are susceptible. For risk assessment procedures refer to NFPA 780.**
Salt Atmosphere	**System components and finishes to withstand salt fog atmosphere (5% NaCl by weight) up to 48 hours exposure and 48 hours drying without signs of corrosion**	**Reference standards for applicable urban coastal areas per ASTM B117 Test Method of Salt Spray [Fog] Testing**

1.7. ALLOWABLE MAGNETIC FIELDS

Key parameter list

System Parameter	Value	Comment
Static (DC) Magnetic Field, Public Allowable	**Permissible Exposure: 5 Gauss (G) (medical electronic wearers)**	**ACGIH, 1999, Threshold Limit Values (TLV). Public allowable is established based on persons with cardiac pacemakers and other implanted electronic devices.**
AC Time-Varying Magnetic Field, Public Allowable 1 Hz to 300 Hz	**Permissible Exposure: 1 G (medical electronic wearers) 600 G/Freq. (Hz) (for all other general public)**	**ACGIH, 1999, Threshold Limit Values (TLV). Public allowable is established based on persons with cardiac pacemakers and other implanted electronic devices.**
AC Electric Field, Public Allowable	**Permissible Exposure: 1 kV/m (medical electronic wearers) 5 kV/m (for all other general public)**	**ACGIH, 1999, Threshold Limit Values (TLV) and ICNIRP 1998. Public allowable is established based on persons with cardiac pacemakers and other implanted electronic devices.**
Static (DC) Magnetic Field, Whole Working Day (8 hrs), Occupational Allowable	**Permissible Exposure: 1 G (workers with cardiac pacemakers) 10 G at 60 Hz 600 G/f (to 300 Hz) 2 G (300 Hz – 30 kHz)**	**ACGIH, 1999, Threshold Limit Values (TLV).**
AC Electric Field, Whole Working Day (8 hrs), Occupational Allowable	**Permissible Exposure: 25 kV/m (up to 100 Hz) (2.5×10^6) / f V/m (100 Hz – 4 kHz) 625 V/m (4 – 30 kHz)**	**ACGIH, 1999, Threshold Limit Values (TLV). "f" equals frequency in Hz**
AC Magnetic Field Sub-Radio Frequency (SRF, 300 Hz - 30 kHz) Occupational Allowable	**Permissible Exposure: 2 Gauss 600/f (Gauss / Hz), 3000/f (Gauss / Hz) for arms and legs. 6000/f (Gauss / Hz) for hands and feet.**	**ACGIH, 1999, Threshold Limit Values (TLV).**

System Parameter	Value	Comment
AC Electric Field Sub-Radio Frequency (SRF, 300 Hz - 30 kHz) Occupational Allowable	Permissible Exposure: 2.5×10^6/f kV/m (100 Hz – 4 kHz) 625 kV/m (4-30 kHz)	ACGIH, 1999, Threshold Limit Values (TLV).

1.8. RELIABILITY, AVAILABILITY, MAINTAINABILITY AND SAFETY (RAMS)

Key parameter list

System Parameter	Value	Comment
Safety Risk Assessment	Meet system safety requirements in accordance with Draft NPRM	The Safety risk assessment shall be performed in accordance with Notice of Proposed Rule Making (NPRM) draft – August 30, 2000. Positive Vehicle Control (PTC) working group recommendation.
Safety Goal	<0.1 Incidents/million vehicle miles <0.1 Injuries/100 million vehicle miles Zero fatalities	The goal will be met by using automated train control and having a restricted access guideway. Zero fatalities over the system life exclude suicides, acts of God, and terrorism.
Maintainability Target	MTTR (First Level) < 30 min MTTR (Second Level) < 2 hours	MTTR stands for Mean Time to Restore service. MTTR (First Level) includes on-site diagnostics, replacement, testing and repair, excluding travel to site. MRRT (Second Level) for shop repair of a failed line replaceable unit. Reference IEEE Std 1474.1-1999 for CBTC equipment.
Availability Goal	> 99.99% - 24 hours/day, 365 days per year.	Program defined goal. Goal set to be competitive or superior to other systems. See Appendix C for description.

1.9. SECURITY

Key parameter list

System Parameter	Value	Comment
Security, Vehicle	**Create Security Plan. Audio and Visual Communications, , Guards etc.**	**Create a Vehicle Security Plan**
Security, Station	**Create Security Plan. Audio and Visual Communication, Lighting, Guards, Fencing, etc.**	**Create a Station Security Plan**

1.10. AESTHETICS

Key parameter list

System Parameter	Value	Comment
Aesthetics Philosophy	**Non-Intrusive Design and Construction**	**The guideway will be aesthetically pleasing to a large majority of the public, and will blend with and enhance the environment through which it passes. The primary measure of the term "aesthetically pleasing to the public" starts with the smallest guideway with the least cross-section. The design philosophy of the guideway will be to minimize impact on existing structures during construction, and to be sensitive to the architecture of the area under construction. Areas below the guideway will be visually enhanced if possible.**

1.11. SYSTEM LIFETIME

Key parameter list

System Parameter	Value	Comment
Life, System (Vehicle & Electrical/Electronic Systems)	**30 Years**	**Program recommended requirement. Life value defined for use with financial calculations. The 30-year life is consistent with IEEE Std. 1474.1-1999.**
Life, System (Civil Works)	**> 75 Years**	**Civil works items such as the guideway and station structures shall be designed for much longer life than the mechanical and electrical components of the system. The 75-year service life is consistent with that adopted by both AASHTO and ACI Std. 358.1R-92.**

2. ALIGNMENT REQUIREMENTS (SITE-SPECIFIC), PART TWO

The second part of this requirement document provides the requirements of a specific alignment. In our case, the specific alignment is designated the “Primary Alignment”. The alignment starts at the Terminal Island Transit Facility and end at the SCIG Transit Facility. A maintenance facility will be located at the Terminal Island Transit Facility. The total length of the alignment will be approximately 5 miles.

2.1.1 ROUTE KEY PARAMETERS

The following are a list of key route parameters.

Key parameter list

Alignment Parameter	Value	Comment
Route Length	5 miles	
Grade and Length, Maximum	Grade TBD Length TBD	
Elevation Change, Maximum	TBD	
Horizontal Curvature, Minimum — Crest Radius — Sag Radius	1000 m 1000 m	Centrifugal forces to be considered for bridge girder & column design (Caltrans Bridge Design Specification section 3.10)
Super Elevation, Maximum	9º cant angle	Based on stable vehicle lateral guidance and vehicle speed of 45 km/hour (28 mph) on a 100m radius.
Bridges, Number and Span Length of	TBD	

2.2 STATIONS

Key parameter list

Alignment Parameter	Value	Comment
Stations, Number of	Two	
Station Layout	TBD	
Transportation, Connection to Other Modes of	Trucks and Existing Rail.	

2.3. OPERATING ENVIRONMENT, SITE-SPECIFIC

Key parameter list

Alignment Parameter	Value	Comment
Seismic	Peak Acceleration 0.6g to 0.7g	Caltrans Seismic Hazard Map 1996 Soil Classification D or E, deep caisson column

Alignment Parameter	**Value**	**Comment**
		supporting system. Use design guides of AASHTOSD Section 3 & 4 Caltrans ARS Curves & Hazard map.
Ambient Temperature and Humidity	**Site temperature condition range over the last 50 years. 95% non-condensing relative humidity at 30 ^{0}C (86 ^{0}F)**	**Same as System Requirement. See Section 1.7**
Wind	**Operational threshold ≤ 50 km/h (~ 30 mph) operate at 100% capability Vehicle safety threshold ≤ 80 km/h (~ 50 mph) operational at reduced speed Structural threshold ≤ 160 km/h (~ 100 mph) fully operational following wind condition**	**Same as System Requirement. See Section 1.6**
Ice	**≤ 6 mm (0.25 inch)**	**Same as System Requirement. See Section 1.7**
Snow	**≤ 304 mm (12 inch) / hr**	**Same as System Requirement. See Section 1.7**
Rain	**≤ 76 mm (3 inch) / hr**	**Same as System Requirement. See Section 1.7**
Lightning	**Compliance with IEEE Std. 1100 – 1999 and building facilities and other structure installation requirement for lightning protection defined by UL96A, 10th edition.**	**Protection shall be provided against lightning incidence in the area for those systems that are susceptible.**
Salt Atmosphere	**System components and finishes to withstand salt fog atmosphere (5% NaCl by weight) up to 48 hours without signs of corrosion**	**Same as System Requirement. See Section 1.7**

3 SYSTEM CONCEPT DEFINITION REQUIREMENTS, PART THREE

This section includes the requirements that define the specific attributes of a system concept. These requirements include the derived or system flow-down requirements, a functional description of the system, and establish the performance, design, development, test, and commissioning requirements for the site-specific system concept. These requirements are grouped by major subsystem.

3.1 VEHICLE

Key parameter list

Vehicle Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Levitation	Permanent Magnet Halbach Array 20.2 m^2 Area 5,627 kg/m^2	Levitation system concept: Permanent Magnet Halbach Array and ladder track design concept	1.1 1.5 1.6 1.7 1.8 1.9 1.13
Guidance	Permanent Magnet Halbach Array and LSM 1.6 m^2 Area (per side) of one guidance unit 12,446 kg/m^2 foot-print pressure	Guidance system concept: Permanent Magnet Halbach Array in combination with the Linear Synchronous Motor (LSM) Propulsion system	1.1 1.5 1.6 1.7 1.8 1.9 1.13
Propulsion	Active Guideway LSM	LSM was selected due to its advantages of providing a lighter vehicle, and its adaptability to the EDS system's characteristic of varying levitation gaps based on vehicle loading	1.1 1.5 1.7 1.8 1.9 1.13
Braking Subsystems	• Regenerative electric brake • Fail-safe emergency mechanical brake • Permanent magnet brake	Along with the primary brake system, redundant braking systems shall be included	1.1 1.2 1.3 1.4 1.5 1.7 1.8
Suspension, Secondary	Air Spring, Dampers and axial support struts	Baseline secondary suspension system.	1.4 1.13

Vehicle Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Auxiliary Power Subsystem	Hotel power estimated at 0.5kW	Suspension, lighting, signaling and communication. Based-on batteries, charged inductively.	1.10 1.13
Magnetic Fields, Cargo Compartment Allowable	Static Field: $\leq$ 5 Gauss AC Field (60 Hz): $\leq$ 1 Gauss	See Allowable Magnetic Fields, paragraph 1.8	1.8
Fire Safety, Combustibility and Toxicity Standards	Meet NFPA 70 and NFPA 130 Standards	National Fire Protection Association (NFPA) standards.	1.9
Lightning Protection Requirements	Protection shall be in compliance with installation requirements for Lightning Protection Systems, UL96A, 10thEdition	Protection shall be provided against lightning incidence in the area for those systems that are susceptible. See Operating Environment, paragraph 1.7	1.7
Weight Goal, Vehicle	53 Tonnes	Based on projections of the vehicle and its cargo, a weight goal of 53 Tonnes has been established.	1.13
Gap, Levitation	2.5 cm	Value derived to accommodate curve invasion, landing wheel invasion, dynamic motion, construction tolerances, and absolute minimum gap.	1.6 1.7 1.13 2.1

3.2 GUIDEWAY

Key parameter list

Guideway Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Guideway Design	Design Guideway to AASHTO LRFD Bridge Design specification, 2nd edition, along with the 1999 and 2000 Interim specifications.	Use of the AASHTO LRFD standard will result in the lightest and smallest cross-section guideway.	1.1 1.6 1.7 1.11 1.12 1.13

Guideway Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Construction Materials	Compressive strength 10,500psi – 17,000 psi Tensile strength 3,000psi (first crack @ 1,500psi)	High strength concrete box beam with top deck. The girder will be constructed using Steel Fiber Reinforced Concrete (SFRC). Normal strength concrete piers (T-shaped or L-shaped). Normal strength concrete footings. Normal strength concrete caissons.	1.6 1.7 1.11 1.12 1.13
Design Loads	53 Tonnes	Preliminary design based on 250,575 kg [552,423 #] for each vehicle. Refer to System Concept Definition Requirement. See Section 3.1	1.1 1.6 1.7 1.12
Tracks, Number of	2	Dual track guideway required for efficient movement of cargo containers	1.1 1.9
Cross Section	1,068 mm tall by 1,000 mm wide box beam with a 152 mm x 2,000 mm "T" deck.	Simply supported spread box beam with up to a 30,000 mm span.	1.1 1.6 1.7 1.12
Piers, Footings and Caissons	Cast-in-Place or Segmented Piers with a T-Shaped or L-Shaped Hammerhead. Cast-in-Place Footings. Drilled Caissons.	Optimum shape (rectangular or circular) and construction method (cast-in-place or segmented) TBD by construction consultant. Hammerhead shape determined by alignment requirements. Optimum shape (rectangular or circular) TBD by construction consultant.	1.1 1.6 1.7 1.12
Guideway Switches	TBD	Minimum number of switches at either end of the alignment and an off-line maintenance facility.	1.6

Guideway Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Guideway, Tolerances – Construction and Installation	**Caissons: ± 50 mm Vertically and Horizontally** **Footings: ± 25 mm Vertically and Horizontally** **Piers: ± 15 mm Vertically and Horizontally** **Beams: ± 10 mm Vertically and Laterally** **Beams: ± 5 mm Longitudinally** **Plate Supports: ± 2 mm Longitudinally and Laterally**	**Coarse and absolute construction tolerance.** **Coarse and absolute construction tolerance.** **Rough and absolute construction tolerance.** **Fine and relative construction tolerance.** **Fine and relative construction tolerance.** **Fine and absolute shop installation tolerance.**	**1.13**
Levitation Track Adjustability	**± 2 mm Vertically and Laterally**	**Driven by ride quality at a reasonable cost.**	**1.4**
Guideway, Nominal Height **(Maximum Elevation)**	**9,200 mm**	**Nominal height required for ample clearance over freeways and local streets and minimum clearance over railroads.**	**1.1** **1.5** **1.6** **1.7** **1.10**
Super Elevation, Maximum	**9 Degrees maximum (15.8 % slope) with spiraling**	**Magnitude of superelevation related to acceptable lateral acceleration for a vehicle speed of 45 km/hour (28 mph) on a 100m turn radius.**	**2.1**
Propulsion and Power System Interface	**TBD**		**1.2** **1.3**

Guideway Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Seismic Requirements	Design per acceleration coefficient, A, and the site coefficient S_i given in Division 1-A: AASHTO code.	System shall be designed to survive indicated seismic level without permanent damage. Based on Division I-A of the Standard Specifications for Highway Bridges, 16th Ed., 1996 (AASHTO code). Same as Alignment Requirement. See Section 2.4	1.7

3.3 PROPULSION & POWER DISTRIBUTION

Key parameter list

Propulsion & Power Distribution Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Utility Interface Compatibility	Harmonic Distortion < 3% into utility grid	Each power substation should be equipped with harmonic compensators to prevent the harmonic distortion from the Maglev system getting back to the utility (IEEE 519-1992)	1.9
Propulsion System Layout, Design and Installation	LSM designed to meet all system requirements, such as acceleration, braking, headway, etc.	LSM was selected due to its large gap operation, efficiency, and ability to achieve high through-put.	1.2 1.3 1.6 1.7 1.8 1.9
Propulsion, LSM Block-length, Inverter and Switching Stations	TBD		1.2 1.3 1.6 1.7 1.8 1.9
System Efficiency	TBD	Power losses in the power conditioning equipment and distribution line should be less than 5%. Efficiency is a function of block length.	1.9

Propulsion & Power Distribution Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Overload Protection	Limited Protection	Power conditioning equipment should be able to withstand 20% overload for 1 minute or 50% overload for 10 seconds, whichever is worse.	1.9
Fault Protection	100 % Back-up and interlocked to prevent paralleling	100% back-up to protect the overall system from a short duration power fault. The main breaker-tie breaker-main breaker will be interlocked to prevent paralleling the transformers and to prevent closing into the secondary bus fault. The switching arrangement will be automated to transfer to standby operation and retransfer to normal operation.	1.9
Lightning Protection	Compliance with IEEE Std. 1100 – 1999 and building facilities and other structure installation requirement for lightning protection defined by UL96A, 10th edition.	Protection shall be provided against lightning incidence in the area for those systems that are susceptible. IEEE Std. 1100 references UL96A for approved lightning protection components. IEEE Std. 1100 Std. 1100 also references NFPA 780 for risk assessment procedures.	2.4
Input Power Reliability (Redundancy)	From 2 or more sources	Provide two-utility source system over separate lines from separate generation points so that system disturbances or storms are not apt to affect both supplies simultaneously.	1.9
Power Conditioner Redundancy	100% Redundancy	The input power conditioners including transformers will have 100% back-up capacity so that no interruption due to the power conditioner can be possible.	1.9

Propulsion & Power Distribution Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Load Interruption Protection	Full Load Interruption	The switch's quick-make, quick-break mechanism will interrupt full load current while fusing provides accurate, permanently calibrated short circuit detection and interruption. Kirk Key interlock scheme will give positive assurance that simultaneous energization will not occur.	1.9
Transient Voltage Surge Protection (TVSS)	Fully Protected	The purpose of a TVSS installed in the substation's Metal Clad Switchgear is to prevent transient voltages that originate either inside or outside the power distribution system. When internal, neighboring plants or work areas start or stop large equipment (motors, presses, etc.) voltage spikes can also travel into the system. TVSS provides lightning protection also.	1.9
Guideway power	TBD		1.2 1.3 2.1
Power, Housekeeping	0.5 kW / Vehicle		1.2 1.3 1.9

3.4 COMMAND, CONTROL AND COMMUNICATION

Key parameter list

Communication Command & Control Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
System Architecture	ATCS Architecture Document	The control system consists of devices located on each vehicle, at each station (Wayside), and at the central control (Central) room.	1.1 1.9 1.10

Communication Command & Control Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Total Traffic Control (TTC)	System Operation Requirement. Total Traffic Control Computer.	Total fleet will be controlled and monitored by a TTC computer at the Central Control Room (CCR). The TTC computer will communicate with the wayside control logic to control headway, distance between vehicle, etc. The Automatic Train Supervision (ATS) functions as the automatic route requesting for the vehicle operating on the system.	1.1 1.9 1.10
Automatic Train Control (ATC)	System Operation Requirement.	This is the combined system of Automatic Train Protection, Automatic Train Operation and Automatic Train Supervision.	1.1 1.9 1.10
Automatic Train Operation (ATO)	System Operation Requirement based on predetermined speed pattern.	The train motion, including stopping, is controlled by Wayside Control logic (Train is passive). During the normal operation, the train will operate based on the predetermined speed pattern. The speed pattern takes into account curves, grades, motor capability, etc.	1.1 1.9 1.10
Automatic Train Protection (ATP)	System Operation Requirement to prevent collision and over speed	Train speed and locations are continuously detected & monitored. If the train exceeds the civil speed of the location, a vital request is sent to the wayside logic to slow down. Collision between trains will be precluded with moving block ATC logic that controls distance between trains.	1.1 1.9 1.10
Surveillance Communication System (SCS)	System Operation Requirement	This system provides the means for transmitting images onboard each train for the central control operator to view.	1.1 1.9 1.10

3.5 STATIONS AND MAINTENANCE FACILITIES

Key parameter list

Cargo Station Vehicle Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Stations, Aesthetics and General Layout	TBD		1.1 2.1
Maintenance Facility Requirements	System Operational Requirement Minimum of one Maintenance and Storage Facility	The Maintenance Facility, which includes the maintenance building and storage yard, will be the location of all repair and maintenance required for vehicles and other systems. The maintenance building should have three distinct functional areas: 1) cleaning and daily inspections, 2) major repair areas, and 3) shops and administrative offices. The size of the maintenance facility will be dependent on the number of total vehicles in the system. Storage area will be provided for replacement parts, tools, repair equipment, etc.	1.1 2.1

3.6. SECURITY

Key parameter list

Alignment Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Security, Vehicle	Create Security Plan. Audio and Visual Communications, Lighting, Guards etc.	Same as System Requirement. See Section 1.10	1.10
Security, Station	Create Security Plan. Audio and Visual Communication, Lighting, Guards, Fencing, etc.	Same as System Requirement. See Section 1.10	1.10

3.7. RELIABILITY, AVAILABILITY, MAINTAINABILITY AND SAFETY (RAMS)

Key parameter list

Alignment Parameter	Value	Comment	Requirements Flow Down (Paragraph #)
Reliability, Vehicle Goal	**MTTF = TBD**	**Technically MTBF should be used only in reference to repairable items, while MTTF should be used for non-repairable items. Since it is not possible to repair the vehicle en-route, when a failure occurs that cause a delay, it is counted as a failure, and system availability is affected. In order to allocate an MTTF, it will be necessary to conduct a simulation sensitivity analysis of the safety risk. See Appendix C.**	**1.9**

PARAMETER INDEX
The following table is an index of all the parameters that are contained is this requirements document with a cross-reference to its type of requirement and its location and page number within the specification.

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Parameter	System Requirements	Alignment Requirements	System Concept Definition
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General Atomics
Electric Cargo Conveyor (ECCO) Sytem
Requirements Document

Appendix A

Requirement Change Control Process

Change request number/name: _________________________
(Assigned by project office)

Proposed Requirements Change Request
Electric Cargo Conveyor (ECCO) System

Date:
Requestor:
Phone:
E-mail:
Title of change:____

Proposed change: *Describe proposed change to requirements document. This may include revision to existing requirement as well as either added or deleted requirements.*

Range of values/options considered: *Describe the range of range or options considered.*

Recommended value or option: *Be specific.*

Rationale for recommendation: *Include supporting analysis and/or data for recommendation.*

Impact on system or sub-components: *List known and potential impacts.*

Recommended trade study and/or test to resolve selection: *Define trade study or test needed.*

Project office resolution: *To be provided by project office.*

Approved: ____________________________________
Team Member (as appropriate)

Approved: ____________________________________
H. Gurol, Program Manager

Electric Cargo Conveyor (ECCO) System Requirements Document

Appendix B

Abbreviations, Acronyms, & Definitions

Acronym	Description
AASHTO	American Association of State Highway and Transportation Officials
ACGID	American Conference of Governmental Industrial Hygienists
ACI	American Concrete Institute
ANSI	American National Standards Institute
APTA	American Public Transit Association
ASCE	American Society of Civil Engineers
ATC	Automatic Train Control
ATCS	Automatic Train Control System
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
dBA	Decibels
CBTC	Communications Based Train Control
CCR	Central Control Room
EDS	Electro Dynamic System
EMS	Electro Magnetic System
HSST	High Speed Shuttle Transport
HVAC	Heating Ventilation and Air Conditioning
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ISO	International Standardization Organization
IEEE	Institute of Electrical and Electronic Engineers
LIM	Linear Induction Motor
LRT	Light Rail Transit
LSM	Linear Synchronous Motor
MDBF	Mean Distance Between Failure
MTBF	Mean Time Between Failure
MTTR	Mean Time to Restore
NEMA	National Emergency Medicine Association
NFPA	National Fire Protection Association
CCS	Cargo Communications System
SCS	Surveillance Communication System
TCRP	Transit Cooperative Research Program
TLV	Threshold Limit Values
TTC	Total Traffic Control
TVSS	Transient Voltage Surge System
UBC	Uniform Building Code
UL	Underwriters Laboratories
UTM	Urban Transport Maglev

Electric Cargo Conveyor (ECCO) System Requirements Document

Appendix C

System Availability Requirement

System Availability Requirement

A CBTC system shall have a total availability of [TBD]%, where system availability (As) shall be defined as the probability that a system is capable of operating at a random point in time. As depends upon Mean Time Between Functional Failures (MTBFF), Mean Time to Repair (MTTR), and Mean Repair Travel Time (MRTT), and can be expressed as:

$$As = \frac{MTBFF}{MTBFF + MTTR + MRTT}$$

Discussion

Availability is the capability of a system to perform its intended function when called upon to do so. That is, it is the probability at a point in time rather than over an interval of time. Operational readiness is a concept tied more closely to and is descriptive of system effectiveness.

The availability of a system or equipment is a measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for at an unknown (random) time. It is the probability that an item is operating satisfactorily at any point in time when used under stated conditions, where the time considered includes operating time, active repair time, administrative time, and logistics time [MIL-HDBK-338-1A].

It is also useful to define another term, "intrinsic availability."

The intrinsic availability of a system or equipment is the probability that it is operating satisfactorily at any point in time when used under stated conditions, where the time considered is operating time and active repair time.

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

Intrinsic availability excludes from consideration all free time, storage time, administrative time, and logistics time. It refers primarily to the built-in capability of the system or equipment to operate satisfactorily under stated conditions.

These definitions allow realistic assignment of responsibility in case an unsatisfactory condition exists. If an improvement in intrinsic availability is required , responsibility can properly be assigned to the design and production engineers - assuming, of course, that the operating conditions are compatible with design specifications. However, if availability is unsatisfactory and improvement in intrinsic availability is not indicated, the responsibility may be placed on the operator to effect the required improvement by reducing administrative and logistic delays. If neither of these is indicated and operational readiness is not satisfactory, improvement depends on changes in free time and storage time, implying more efficient use of the system equipment.

The Achieved Availability (A_A) is given by

$$A_A = 1 - \frac{\text{Downtime}}{\text{Total time}} = \frac{\text{Up time}}{\text{Total time}}$$

Where downtime includes all repair time (corrective and preventive Maintenance time), administrative time and logistics time.

Issue

All transit systems are assessed in terms of its degree of on-time performance. It is important in the design and operation of any transit/rail system to express the on-time performance assessment in terms that are intuitively clear and appropriate, and that can be measured routinely in a practical way. In transit systems, the conventional measure is Availability and Dependability, which are defined as a percentage of all revenue trips that are started without delay, and which are defined as a percentage of all revenue trips that are completed without interruption respectively. However, these performance measures treat all delays equally regardless of duration or the number of delays.

The Automated Guideway Transit Service Availability Workshop (October 1976) concluded that a performance indicator was necessary that took into account directly the delays experienced, rather than just equipment performance. The idea of Service Availability was also expressed. Service Availability may be defined as a concept, which provides a measure of the consistency of a transportation service. The service availability is judged based on the wait and travel time variations of the service provided. The operator, on the other hand, is concerned with the impact of service consistency on ridership and the impact on operating and maintenance costs. The developers, on the other hand, are concerned with translating these measures into equipment reliabilities. One of the difficulties of reaching the desired goal is related to the capability to gather data on a day-to-day basis on origins and destinations of individual trips that could be used to accumulate cargo-miles of travel and cargo-hours of delay due to failures.

To better understand how availability is used let us first define system effectiveness. System effectiveness is the probability that the system can successfully meet an operational demand within a given time when operated under specified conditions. System effectiveness may be defined as:

SE = [A][D][C]

Where A = availability, (a_i) is the probability that the system is in a state (i) at the beginning of the mission
D = dependability, (d_{ij}) is the probability that the effective state of the system during the mission is (j)
C = capability, (c_{jk}) is the value of the capability of the k^{th} figure of merit, conditional on effective system state (j)

On-time performance is referred to as dependability. It was expressed by (Anderson 1978) as a percentage of hours experienced entering a transportation system with no delays. Or, it may be stated as one minus the ratio of the number of cargo-hours of delay due to system failures per year to the number of cargo-hours of operation per year.

Availability can also be expressed as:

$$A = 1 - \frac{\text{Revenue-Trips Delayed} > t_a}{\text{Total Revenue Trips}}$$

Where the delay threshold of t_a minutes provides an acceptable waiting tolerance for on-time performance. This would be set by the contracting authority or operator.

The dependability includes the concept of reliability, which is the probability that a system will perform satisfactorily for at least a given period of time when used under stated conditions. Dependability can be expressed as:

$$D = 1 - \frac{\text{Cargo-hours of delay/yr}}{\text{Cargo-hrs of operation/yr}}$$

Alternatively,

$$D = 1 - \frac{\text{Revenue-vehicle-hrs of delay/yr}}{\text{Revenue-vehicle-hrs of operation/yr}}$$

Let T_i be the normal trip time for the i-th of a series of trips. If there are N revenue trips per year, the revenue-vehicle-hrs of operation per year are obtained by summing successive values of T_i given by

$$\text{Revenue-vehicle-hrs of operation/yr} = \sum_{i=1}^{N} T_i$$

Now let T_i^a be the actual time taken for trip i. Then $\Delta T_i = T_i^a - T_i$ is the delay for trip i.

$$\text{Dependability} = 1 - \frac{\sum_{i=1}^{N} \Delta T_i}{\sum_{i=1}^{N} Ti}$$

Availability

The Total Revenue Trips is defined as N. The Revenue-Trips Delayed > t_a is an accumulated sum of the number of values of ΔT_i greater than t_a minutes. If N_d is the number of revenue-trips delayed more than t_a minutes, then

$$\text{Availability} = 1 - N_d / N$$

To relate these measures of performance to equipment, let $MTBF_i$ be the mean time between failures of i-type subsystems. In a simple example, i=1 could correspond to vehicle failures, i=2 to failures of station equipment, i=3 to wayside zone-controller failures, and i=4 to failures of central control. Let θ_i^{yr} be the number of hours of operation of i-type equipment per year. Then $\theta_i^{yr} / MTBF_i$ is the number of failures of any single i-type subsystem per year. Let there be r_i subsystems of the i-th type in the system. Then $r_i\, \theta_i^{yr} / MTBF_i$ is the total number of failures of i-type subsystem per year.

$$\text{Revenue-Trips Delayed/yr} > t_a = \sum_{i=1}^{E} r_i\, \theta_i^{yr} / MTBF_i$$

in which the sum is over all types of equipment, where E is the number of types for which $\Delta T_i > t_a$, and Revenue Trips per peak hour is N_v/T_{trip}. N_v is the number of vehicles in the system, and T_{trip} is the average trip time in hours counting station delays. Therefore, from data on component reliability and mean times to restore service, Availability can be written as

$$\text{Availability} = 1 - \frac{\text{Revenue-Trips Delayed/yr} > ta = \sum_{i=1}^{E} r_i\, \theta_i^{yr} / MTBF_i}{\text{Total Revenue Trips} = N_v/T_{trip}}$$

in which the sum is taken over failures for which $\Delta T_i > t_a$.

Since all delays are not treated equally, it is prudent to introduce weighting factors to delays that would provide an indication of dissatisfaction. These can be introduced as follows:

Class	Length of delay	Weighting Factor
A	ta < 3	0
B	$3 \leq t_b \leq 25$	1.5
C	$25 \leq tc \leq 45$	2.0
D	$t_d \geq 45$	4.0

The appropriate weighting factor could then be multiplied by the number of Revenue-Trips Delayed and summed over the year. This would have the affect of increasing the Revenue-Trips Delayed by equipment failures relative to the dissatisfaction. The actual value of the weighting factors would be set by contracting authority or the operator.

APPENDIX B

OVERVIEW OF THE GENERAL ATOMICS TEAM

GA leads a team with unique credentials in maglev technology, which we believe will revolutionize urban and cargo transportation. GA is a leading expert in maglev systems, superconducting magnet technology, linear motors, power conversion, and systems integration. The role of team member California State University, Long Beach (CSULB) is to define system requirements and processes as they relate to container traffic at the Port of Los Angeles, and to serve as both an impartial arbiter in technology evaluations and catalyst for community involvement. The team members and specific responsibilities for this project are:

- General Atomics (GA) – Project leader responsible for system integration, maglev, and vehicle control systems
- California State University Long Beach (CSULB) – System requirements and technology evaluation
- Hall Industries (HI) – Vehicle and chassis design
- Mackin Engineering Company (MEC) – Alignment and guideway engineering
- Union Switch and Signal (US&S) – Communication and signaling system
- Lawrence Livermore National Laboratory (LLNL) – Technical liaison in electromagnetics

The following paragraphs contain descriptions of the team members' overall capabilities.

General Atomics — System Integrator, Maglev, and Vehicle Control Systems

General Atomics (GA) is responsible for providing the integrated design for a maglev cargo system that will meet the needs of the Port of Los Angeles. GA is a privately held, international company with over 4,000 employees worldwide. The San Diego, California headquarters houses a staff of over 800 engineers and scientists with an industry-wide reputation for developing complex, high-technology, first-of-a-kind systems that push technological boundaries, in particular in the areas of energy, magnetic systems and high power electronics for transportation and Navy systems, and unmanned air vehicles. This expertise has its origin in magnetic fusion energy research, a field in which the company has been the world's leading industrial participant for 30 years. This has provided GA with extensive experience in developing, integrating, and operating sophisticated networks entailing a large range of specialized high-power equipment. GA has demonstrated its technical, management, and system integration capabilities on many large programs as described in the following paragraphs.

- The design, fabrication, and operation of the Department of Energy (DOE) DIII-D Tokamak at GA headquarters in San Diego, California (Fig. B-1), the largest and most productive magnetic fusion test facility in the U.S., representing over $0.75B dollars investment by the DOE over several decades of operation.

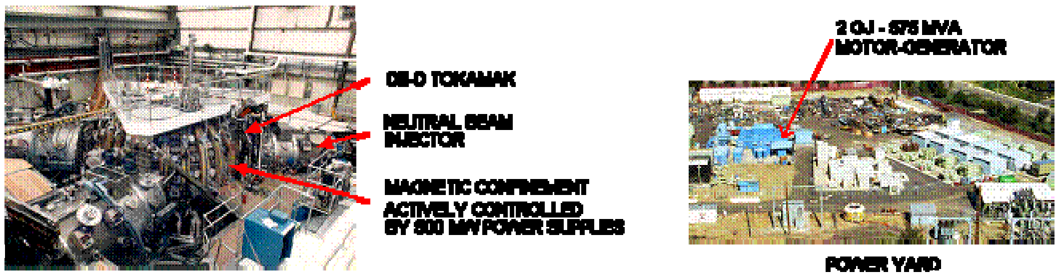

Fig. B-1. DIII-D National Fusion Facility

- The design, fabrication, and deployment of the Predator (Fig. B-2), an unmanned air vehicle (UAV), demonstrates GA system-level integration expertise. GA is now the number one supplier of UAVs in the nation. General Atomics Aeronautical Systems (GA-ASI) employs over 1,000 employees.

Fig. B-2. The Predator UAV

- Prime contractor for the U.S. Navy Air Warfare Center to develop, and test an Electromagnetic Aircraft Launch System (EMALS). This electric-powered catapult will replace the traditional steam catapults on the Navy's next generation aircraft carriers (Fig. B-3); total contract value $225M.

Fig. B-3. EMALS testing in Lakehurst, New Jersey, will lead to replacement of steam catapults

- Prime contractor for the U.S. Navy Air Warfare Center to design, develop, and test an Advanced Arresting Gear (AAG) for aircraft recovery on existing and next generation aircraft carriers; contract value $96M.
- Design and fabrication of superconducting magnets for many high-visibility national programs including the Superconducting Super Collider (SSC), the Mirror Fusion Test Facility (MFTF), Large Coil Program (LCP), Elmo Bumpy Torus (EBT), Texas Accelerator Center, Prototype Magnet System (PMS) for isotope separation, Superconducting Magnetic Energy Storage (SMES) for magnetic ore separation, International Thermonuclear Experimental Reactor (ITER) central cell solenoid (world's largest stored energy magnet).
- Supplier of superconducting magnet systems for all of Toshiba's magnetic resonance imaging (MRI) units worldwide. Over 500 MRI magnets have been manufactured in the last 7 years.
- GA Power Inverters designs and builds power equipment for the mass transit industry. Examples include the design and manufacturing of LIM propulsion systems for the Vancouver (Canada) Skytrain light-rail system, onboard power units for the Bay Area Rapid Transit (BART) system in San Francisco, power units for passenger locomotives for Metra, a division of the Regional Transportation Authority in Chicago, and inverters and controls for mining trucks.
- Member of the American Magline Group, a private partner of the California Nevada Super Speed Train Commission, under contract to the Federal Railroad Administration to develop, construct, operate and maintain a high speed maglev system, based on the German Transrapid technology (Fig. B-3), to run from Las Vegas, Nevada, to Anaheim, California. GA is leading the systems engineering, with responsibility for the electrification and the linear motor systems.
- Prime contractor for the Maglev Upgrade of the High-Speed Test Track (HSTT) at Holloman Air Force Base in New Mexico. Designed and tested a superconducting, magnetically levitated rocket sled (Fig. B-4) propelled to speeds of nearly Mach 2 (the eventual goal is Mach 10); contract value $25M.

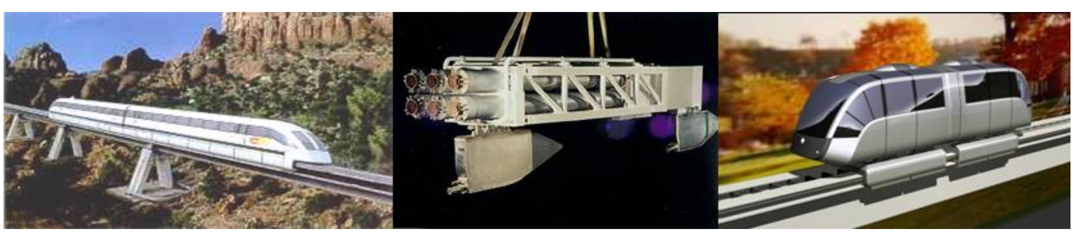

Fig. B-4. GA Maglev projects: high-speed Las Vegas-Anaheim system based on Transrapid technology, Holloman superconducting rocket maglev, and urban maglev permanent magnet technology system

- Prime contractor for the FTA's Urban Maglev program for the design, development, and demonstration of an urban maglev system to provide an environmentally sound solution for future transportation needs. A full-scale 400 ft test track in San Diego is currently undergoing testing. Total contract value: $23M.

California State University, Long Beach

California State University, Long Beach (CSULB) is a large, urban, comprehensive university in the California State University system—the second-largest campus in the largest higher-education system in the country. Its mission is to become the university-of-choice among western state universities for students seeking high-quality education leading to a broad range of bachelor and master degrees spanning the liberal arts and sciences, and many applied and professional fields.

CSULB has been ranked as one of the top three public masters' granting universities in the west and first among masters' universities with the lowest debt load by U.S. News and World Report in its 2005 America's Best Colleges Guide. The Princeton Review has also designated CSULB as a 2005 Best Western College, upholding the standards of the Best Regional distinction in excellence award.

Located within the fifth-largest city in California, CSULB is an accredited university with 35,000 students and more than 950 full-time faculty members. Since the founding of the university in 1949, CSULB has awarded over 178,000 bachelor degrees and 36,000 master degrees. The university currently offers 80 bachelor and 66 master degree programs through eight colleges in 84 permanent buildings on 323 acres. The CSULB campus is reflective of the surrounding region—rich in racial and cultural diversity and mindful of community engagement. More than 30 centers, institutes, and programs conduct applied research, training, and community service programs as well as consulting for public and private organizations.

The College of Engineering (CoE) at CSULB is one of the larger engineering colleges in the western United States and is rapidly becoming a premier institution in its offerings for engineering education and research. Most recently, the CSULB CoE has earned a spot in U.S. News and World Report's annual college survey as one of the Top 50 Undergraduate Engineering Programs at schools whose highest degree is a bachelor or a master in the nation.

The primary mission of the CSULB CoE is to develop and conduct undergraduate and graduate (including joint-doctoral) degree programs, certificate programs, and continuing education programs to help satisfy local, national, and international industry needs. Secondary missions involve the conduct of scholarly and creative activities, including research and service to the university, the community, and the nation. As a leading college of engineering in Southern California, the CSULB CoE is committed to maintaining its high standards of excellence by continually enhancing the quality of its academic programs and by developing new programs to meet society's changing needs.

Over 3,000 students are currently enrolled in degree programs at CSULB CoE through five departments: Chemical Engineering, Civil Engineering and Construction Engineering Management, Computer Engineering and Computer Science, Electrical Engineering, and Mechanical and Aerospace Engineering. Certificate programs are also offered to meet additional needs for qualified practicing engineers, computer scientists, and engineering technologists.

The Center for Commercial Deployment of Transportation Technologies (CCDoTT) is CSULB-sponsored, government-approved and -supported R&D center dealing with maritime-related transportation issues on behalf of both commercial and military interests. It was established in 1995 to address dual-use issues relating to emerging High-Speed Ships and their related Agile Port Systems. CCDoTT has since assumed an expanded role to also address the issues of Rapid Deployment, Decision Support Tools (Command and Control), and was involved with programs improving port Security associated with marine related cargo movements before 9/11/2001.

The objectives of the CCDoTT program is linking University research capabilities to commercial and military research capacity to advance national transportation technology requirements. CCDoTT's program initiatives are within the 6.3 category (applied research) associated with government R&D program designators. CCDoTT combines these efforts to tap into the maritime research and validation potential of the largest port in the United States, the combined Port of Los Angeles and Long Beach, to create a program of unparalleled potential and capability. CCDoTT is unique in its focus on maritime research and access to the greatest local resources and facilities. The assessment of goods movement in the Los Angeles/Long Beach regional area identifies the ways and means to more effectively employ the existing port, terminal, intermodal cargo transport systems in view of the projected continual increases in trade through these two port areas coupled with the Alameda corridor.

Hall Industries – Vehicle Design and Fabrication

Hall Industries (HI), headquartered in Pittsburgh, Pennsylvania, is a diversified manufacturing and engineering organization specializing in custom design prototyping and detail design of transit vehicles and components. Hi is heavily involved in the transportation field where they provide products for the automotive, freight and passenger rail, aviation, and aerospace markets. Their largest single-market sector is concentrated in the passenger transit area. HI is a significant contributor to a number of maglev transportation systems being planned for the Pittsburgh area (the Pittsburgh Civic Arena Shuttle System – CASS, the Pittsburgh Airborne Shuttle System - PASS, and the California University of Pennsylvania Shuttle System). HI is extensively involved in the development of vehicle systems and components, including the integration of maglev components into the vehicle chassis, the design of the secondary suspension system, vehicle maintenance, emergency response systems, and ride quality.

Mackin Engineering Company – Guideway Structural and Alignment Design and Integration

Mackin Engineering Company (MEC), located in Pittsburgh, Pennsylvania, specializes in transportation engineering, planning, and environmental studies. MEC has a staff of approximately 110 design professionals and support personnel who provide services for guideway, station, and alignment design, as well as environmental clearances. MEC is currently participating in the FTA's Low-Speed Maglev Technology program as a subcontractor to GA, and in the past ten years has provided preliminary engineering for various maglev projects including CASS and PASS, as well as the California University of Pennsylvania Shuttle System. The firm also has extensive experience in environmental studies and highway design, and has recently completed the Environmental Impact Statement for the Mon/Fayette Expressway, as well as performing the preliminary design of Sections 51F, G, and J of the 23 mile Mon/Fayette Expressway, and the Final Design of Section 51G.

Union Switch and Signal – Advanced Communication and Signaling

Union Switch and Signal (US&S) is a pioneer in the communication, control, and signaling field. Having more than 100 years of involvement with the rail industry, US&S provides approximately 40% of all rail industry communication, signaling, and safety services in the world. US&S serves as a full-line supplier of signaling and automation systems, equipment, and services for all types of domestic and international railway operations. Segments include mainline and local freight railroads, intercity passenger railroads, heavy-rail commuter lines, light-rail transit systems, people movers, and industrial and mining railroads.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is an internationally recognized leader in the fields of electromagnetic systems, including fusion magnetic confinement, passive magnetic bearings, and magnetic levitation, The LLNL Inductrack permanent-magnet maglev system adopted and licensed by GA was invented at LLNL, and a theory of its operation was experimentally confirmed through internally-funded model tests, followed by additional testing funded by the National Aeronautics and Space Administration (NASA) (in connection with the NASA program for electromagnetic launching). Since that time, LLNL has worked closely with GA, as a member of its urban maglev team, to develop new theoretical analyses and computer codes and then, based on this work, to perform confirmatory experimental tests aimed at enhancing the performance of GA's test track. Together with GA, LLNL received the prestigious R&D-100 Award in 2004, given to the developers of the 100 technological developments that were deemed to be the most significant, worldwide, for that year.

APPENDIX C

RESPONSE TO QUESTIONS
FROM THE PORT OF LOS ANGELES ON

CONCEPTUAL DESIGN STUDY FOR THE
ELECTRIC CARGO CONVEYOR (ECCO) SYSTEM

DRAFT FINAL REPORT (15 JUNE 2006)
GA-C25498

Executive Summary

Page 3-
Include average speed of vehicles in the 4.7 mile run. What is the average speed required to meet 5,000 moves per day?

GA Response:

The average speed between Terminal Island and the SCIG is 85 mph. This high average speed is obtained by accelerating to speed in 20 sec, cruising at 90 mph for 3.3 min, and decelerating another 20 sec. The overall cycle time (complete round-trip including loading/unloading) is 32.7 min. As a matter of interest, the peak speed of 90 mph was chosen for two reasons: (1) it allows the system to meet the throughput, and (2) the bigger vision is to extend the system to a future dessert intermodal site.

Page 5-
The red and green alignments are not shown in Figure.

GA Response:

This figure shows the vehicle dynamic simulation. Only the base alignment was used for the simulation.

Page 8-
Need to justify how maglev is cost competitive compared to highway and rail transportation.

GA Response:

While a comparison of maglev with rail and road is beyond the scope of this study, a general cost comparison of superimposing a dedicated container corridor onto the existing port infrastructure can be made. The cost of elevated truck lanes proposed for alleviating I-710 congestion has been estimated at $250M/mile. Also (though totally unrealistic from a railroad operational perspective) extending Alameda Corridor rail capacity to the port would cost $150M/mile. These costs are extremely conservative relative to the projected maglev cost in that the road and rail estimates do not include the cost of pollution mitigation, severe environmental impact, and new bridges. New bridges for rail and road would have severe environmental impacts, causing costly time delays as well as disruption of existing infrastructure at the port.

It is also appropriate in this response to report on cost comparison studies we have performed previously for passenger systems. We anticipate that many of the cost drivers for passengers and cargo will be similar. We have found that for a given right-of-way, the biggest single factor driving the cost is the throughput (whether passengers per hour, or containers per hour). The throughput determines the required overall power level, the number of vehicles, as well as the size of the stations/cargo handling facilities.

Our studies for passenger maglev systems (summarized in the Low Speed Maglev Technology Program Report, DOT-CA-26-7025-02.1, March 2002), show that maglev is very competitive compared to rail and rubber tire systems, when normalized to the same conditions (for example, elevated, comparable throughput, etc.). Table C-1 uses data from that report and shows maglev system capital costs for different throughput conditions, comparing them with existing systems, including the recently completed Las Vegas Monorail and SD Trolley Mission Valley East.

TABLE C-1
CAPITAL COSTS

System	**Capital Costs** ***$ M/mile***
Urban Maglev – 3,000 pphpd*	56.3
Urban Maglev – 12,000 pphpd*	88.3
SD Trolley Mission Valley East – 9,600 pphpd	87.2**
Las Vegas Monorail	89.0
World-Wide LRT (Average)***	80.4
World-Wide LRT (Low)***	23.0
World-Wide LRT (High)***	177.0
World-Wide Average Urban Automated People Movers***	103.2
World-Wide Average Airport Automated People Movers***	118.8

* Maglev costs are for a complete double track, elevated system, including stations, vehicles, power, communication and signaling. No tunneling or unusual civil structures assumed. Data from Low Speed Maglev Technology Development Program, Final Report, March 2002.

** Based on SANDAG. System is 5.8 miles long, 51% elevated, 36% at-grade, and 13% underground.

*** Automated People Mover Applications: A Worldwide Review, 1994, by Shen, Huang & Zhao (Escalated from $1994 to $2001).

With respect to freeways, again the throughput is a major determining factor in the cost. It has been shown that freeways "free-flow" at 60 mph with 1,600 vehicles per hour per lane (based on the Parsons study: "Comparison of Maglev to Freeway," April 2003). Therefore, 8 lanes (4 lanes in each direction) will provide a capacity of 10,608 passengers per hour per direction at 60 mph. Highway costs vary greatly by location; in San Diego County, the average cost per lane-mile is $11.2M, resulting in total highway infrastructure cost of $89.6M per mile (this does not include the cost of the vehicles which will add another $5.3M, according to the report). Therefore, maglev costs for comparable capacity are seen to be very competitive with highways.

A major advantage of maglev over truck transport is that maglev is all electric. This results in zero local emissions and reduced emissions overall, since electric power is significantly more efficient (also see additional response below). In addition, benefits also come from congestion reduction and lower maintenance on existing roadways.

Also, explain how operation and maintenance costs are greatly reduced due to the contact-free system.

GA Response:

The O&M costs will be significantly less than conventional equipment due to the contact-free, and driverless operation of the maglev. Table C-2 is taken from the FTA-funded urban maglev program, and shows the cost per vehicle mile for a number of existing systems, as well as the projected cost for maglev.

TABLE C-2
O&M COSTS COMPARISON

Magnetic Levitation	
GA Urban Maglev	$3.67
Light Rail	
San Diego Trolley	$4.53
St. Louis BSDA	$7.47
San Jose VTA	$12.62
Pittsburgh PAT	$14.86
Boston "T"	$16.00
San Francisco Muni	$19.07
People Mover	
Miami	$16.24
Detroit	$17.27
Jacksonville	$32.31

*

- GA O&M cost projections are from Urban Maglev 6th quarter report; maintenance costs include periodic replacement of magnets, which is conservative based on experience to date.
- San Diego Trolley O&M costs are from recent published SANDAG data.

Page 9-
$13M for O&M costs are based on what costs?

GA Response:

The cost of operating the system is based on personnel costs required to operate the control center and provide security, as well as the cost of energy to run the vehicles. The maintenance costs are based on assumed periodic replacement of magnets, electrical equipment and inspection. Table C-3 provides a cost summary.

TABLE C-3
O&M COST SUMMARY

Annual Operations Costs	Personnel	Salary & Benefits	Cost
Labor			
Control Center Operator	10	$60,000	$600,000
Security	5	$40,000	$200,000
Total Labor			**$800,000**
Non-Labor			
Energy			$8,212,500
Management & Administration			$200,000
Total Annual Operations Costs			**$9,212,500**

Annual Maintenance Costs	Personnel	Salary & Benefits	Cost
Labor			
Vehicles	6	$90,000	$540,000
Electrical Systems	8	$90,000	$720,000
Guideway Inspection and Maintenance	5	$90,000	$450,000
Total Labor			**$1,710,000**
Non-Labor			
Spare Parts			$1,800,000
Total Annual Operations Costs			**$3,510,000**

All-electric propulsion eliminates what kind of local sources of emissions?

GA Response:

It eliminates 100% of all local sources of emissions. Electric propulsion is also significantly more efficient (~75%) than thermal cycles used by diesel trucks and locomotives (~30%), resulting in fewer net emissions at the site of the power plant.

1. Introduction

Fig. 1-1. Potential Cargo Maglev Network.

GA Response:

Will make change.

Pages 1-2
Include vehicle average speed for the 4.7 mile guideway.

GA Response:

Will make change.

3. *System description*

1. ***The report is not clear on how the system is able to handle 5,000 lifts per day. What is the total time for 1 trip (1-way move between transfer facilities including loading time, dwell time until the guideway is available, travel time on the maglev system, and unloading time)?***

   GA Response:

   The throughput analysis was performed using the color-coded spreadsheet attached. The system consists of two tracks; each track has two loading/unloading spurs at the ends, which are accessed by a track switch. Each track has a total of 36 vehicles, and 18 vehicles can be accommodated by each spur. The spreadsheet shows all the vehicles on the vertical axis (vehicles 1-36 for tracks 1 and 2); the horizontal axis shows the elapsed time in seconds. The color coding indicates the state of each vehicle on the track (acceleration/deceleration, high-speed cruise North or South, loading/unloading, and waiting). As an example, following vehicle 1 on track 1, it accelerates to a peak speed of 90 mph in 20 sec, then travels at speed for 200 sec (3.3 min) covering the 4.7 miles between Terminal Island and the SCIG. This is followed by a 20-sec deceleration to a stop at one of the track spurs. The vehicle is then loaded/unloaded in 400 sec (6.7 min). This is followed by a wait time of 680 sec (11.3 min), while the remaining 17 vehicles fill up the spur and are loaded/unloaded. The last vehicle entering the spur (# 18) has no wait time. Vehicle 18 is the first one to start the return trip to the other end. The different arrival/departure times of the vehicles results in the staggered profiles shown on the spreadsheet. The total cycle time (round-trip) is 1960 sec (32.7 min). Each track handles 18 vehicles in 16.35 min (0.2725 hr) in each direction. Hence, the throughput for a dual-track system is 2 x 18 vehicles / 0.2725 hr = 132 vehicles per hour per direction. 24-hr operation leads to a peak capacity of 3,168 vehicles per direction per day. Assuming an operational safety margin of 20%, leads to ~2,500 vehicles per direction per day, or a total number of containers handled of 5,000 per day.

2. ***What is the average speed of each vehicle on the guideway?***

   GA Response:

   The 4.7 miles is covered in 200 sec, resulting in an average speed of 85 mph.

3. ***Include profiles of the red and green alignments.***

   GA Response:

   The red and green alignments are shown in Section 1.1, Planned Alignment.

4. Cost Estimate

1. ***Provide itemized cost estimates for construction (with unit costs, for example: per lf guideway, cost of each vehicle)***

   GA Response:

   The itemized unit construction cost estimates for the major elements of the system are as follows:

   - Vehicles - $0.8M each
   - Guideway civil structures - $17M/mile-dual track (~$3,200/ft)
   - Maglev track and propulsion components - $41M/mile-dual track (~$7,700/ft)
   - Electrical energy supply equipment - $22M/mile - dual track (~$4,200/ft)

2. ***Are there any contingency costs included in cost estimate?***

   GA Response:

   All cost values have a 10% contingency.

3. ***What is the annual operation and maintenance cost based on?***

   GA Response:

   See above (page 9, Executive Summary)

4. ***Provide comparison costs to rail and highway to justify that maglev is competitive in cost.***

   GA Response:

   See above (page 8, Executive Summary)