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skyTran

Automated Transit Network Development & Deployment Plan

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SkyTran Automated Transit Network
Development & Deployment Plan

Executive Summary

In order to increase the attractiveness and ridership of public transit, SkyTran has developed a system that provides a level of service comparable to that of a car. Key innovations include: 1) non-stop, on-demand service within the network; 2) average speeds of 45 mph in urban areas and highway speeds for longer trips; 3) a dramatic reduction of GHG emissions and energy consumption (120 Wh per mile); 4) capacity of 11,500 passengers per hour in each direction[1] and; 5) improved access with as little as quarter mile between stations; 6) improved safety by fully grade separated guideway and automated control. Unlike bus and rail, which recover no capital costs and only partial O&M costs[2], SkyTran's business model allows for full cost recovery of capital and O&M costs (see *Business Model* section).

SkyTran Inc. intends to develop a proof of concept of its automated transit technology and then incrementally deploy a network that extends from the NASA Ames Research Park to the greater Mountain View, CA area. The three phases of the plan include the developmental stage Hardware Reference Platform (HRP), the Initial Operating Segment (IOS) in the NASA Ames Research Park, and the Mountain View Automated Transit Network (MV-ATN).

The HRP will be constructed at the NASA Ames Research Center in two phases over 18 months at a cost of $3.4 million. After HRP evaluations are completed and a pilot manufacturing capability is in place, the IOS, connecting the Ellis Street light rail station to Ames Research Park will be built. The IOS will be constructed in 12 months followed by a commissioning process at a budget of $19.25 million. Subsequently, the MV-ATN will be built for a cost of $117 million and commissioned within 24 months as a public-private partnership. Based upon real-time traffic simulation of the SkyTran system, the 13-mile network can serve five central stations and 16 smaller stations using 500 vehicles to handle up to 8,000 passengers per hour. The ADA compliant system has the capacity to alleviate projected trip demand in the area over the next decade and can be scaled to handle additional growth beyond.

The proposed plan provides an opportunity to demonstrate innovative ATN technology solutions that leverage existing public transit assets to increase overall local ridership, greatly improve regional connectivity, and reduce vehicle miles traveled (VMT). The MV-ATN is a project of national significance as it can serve as a model for transit-oriented development and, in California, help communities meet SB 375 greenhouse gas reduction targets as part of their region's Sustainable Communities Strategy (SCS).

1. Two passengers per vehicle at 0.5-second headway between vehicles. [2] Average O&M cost recovery is 21% for buses, 25% for light rail, and 41% for heavy rail. Source: National Transportation Database 2009 Table 26.

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Overview

New innovations in ATN technology hold great promise by offering new tools in the national effort to reduce congestion, mitigate greenhouse gases and achieve energy independence. For Mountain View, ATN technology could greatly improve the connectivity of the city's existing transportation resources and meet the needs of future growth.

ATN is a proven transit technology with 35 years of service history that outperforms all other modes in safety, costs and consumer preference. ATN, also referred to as personal rapid transit, or PRT, is unique among transit systems in that it is highly rated by consumers for delivering an on-demand, point-to-point ride like an automobile. In contrast to scheduled service in a large vehicle shared with other riders, the small ATN vehicle offers one or two riders a personalized, non-stop travel experience for the duration of the trip. A fleet of ATN vehicles traveling on a single guideway has potential capacities equal or exceeding light rail and buses. Because vehicles move on-demand, not on schedule, and the system is automated and elevated, stop-and-go vehicle movement is eliminated, thus greatly improving energy efficiency and emission reductions.

Boeing deployed first-generation ATN in 1975 at West Virginia University in Morgantown, WV. The rubber-tired, electrically powered computerized vehicles travel at a top speed of 30 mph on at-grade and elevated concrete guideways. Five stations serve the 8.65-mile system. Currently, about 15,000 riders use the system daily with a peak capacity of 30,000 passengers. The system has suffered no fatalities or serious accidents after more than 35 years of service making it among the safest transit systems in the world. A number of second-generation ATN technologies have been developed in the wake of the Boeing system. The largest of these deployments uses the Ultra system and is operated by the British Aviation Authority at Heathrow Airport. Ultra, like the Boeing system, uses rubber-tired, electrically powered computerized vehicles on a dedicated elevated roadway but with modern improvements to system hardware and software. The Heathrow system has a maximum speed of 30 mph and makes approximately 1,200 trips a day.

The next generation of ATN innovation is the SkyTran system under development at the NASA Ames Research Center in Mountain View; CA. SkyTran replaces wheels by combining a linear motor and passive maglev suspension for higher speeds, greater reliably and scalability. Vehicles travel on an aerial electric powered guideway. To provide better rider comfort in banked turns vehicles are suspended from the guideway. The wholly elevated system offers significantly improved safety from ground level hazards. Vehicles are aerodynamically designed and seat two passengers to achieve maximum energy efficiency. This design approach reduces system weight and bulk. Lighter vehicles result in slimmer, more attractive guideways with longer beam lengths (up to 100 feet) that can be supported on standard steel utility poles.

Business Model and Competitive Advantage

SkyTran's competitive advantage has two key elements: 1) scalability of networks as a result of high-speed, on-demand service and 2) lower capital cost by dramatically reduced weight of infrastructure. These advantages are enabled by a passive maglev ATN technology that is a refinement and technological leap forward from first and second-generation systems. Earlier ATN systems, like the ULTra system at Heathrow Airport in London, and the Masdar system in Abu Dhabi, UAE are slow-moving (30 MPH), limiting the size of networks and thus hampering ridership. In contrast, SkyTran's revolutionary passive magnetic levitation system eliminates the need for wheels and is capable of highway speeds, making it scalable to networks of any size which enables high ridership. SkyTran's energy efficient powertrain minimizes the number of moving parts resulting in significantly lower operations and maintenance costs. SkyTran's modular system of mass produced, inexpensive vehicles and guideway allows for easy delivery and on-site assembly. Unidirectional guideway costs $9M per mile* and vehicles are $15,000 each. To give an idea of cost, a small 10 mile network, with 20 stations and 1000 vehicles can be installed for roughly $113 million. Assuming an average trip length of 5 miles and fares of $0.25 per mile at 7% interest, the system generates a profit with only 20,000 daily riders. This business model, combined with a desirable user experience, opens the door to private investment and rapidly scaling up networks based on market demand.

Company Background

SkyTran Inc., a Delaware corporation, owns SkyTran technology. The system was invented by a Stanford aeronautical engineer and veteran of the NASA Apollo Moon Project and developed under a four-year U.S. Department of Transportation RITA grant. The program successfully demonstrated the passive magnetic levitation vehicle and linear motor technology. The company is headquartered at NASA Ames Research Center in Mountain View, CA and is collaborating with NASA under a Space Act Agreement. The Agreement allows for the formal bi-lateral transfer of technology in the areas of prognostics, human factors and software control systems. NASA and SkyTran, Inc. recently renewed the Space Act Agreement for an additional three years. The company has secured patents on key technology innovations (U.S. Patents 7,562,628 and 8,171,858) with additional patents pending.

*Not including ancillary costs (permits, EIS, ROW, utility realignment, etc.). Those ancillary costs are expected to be lower than conventional transit (LRT, BRT) given smaller system size and ROW footprint.

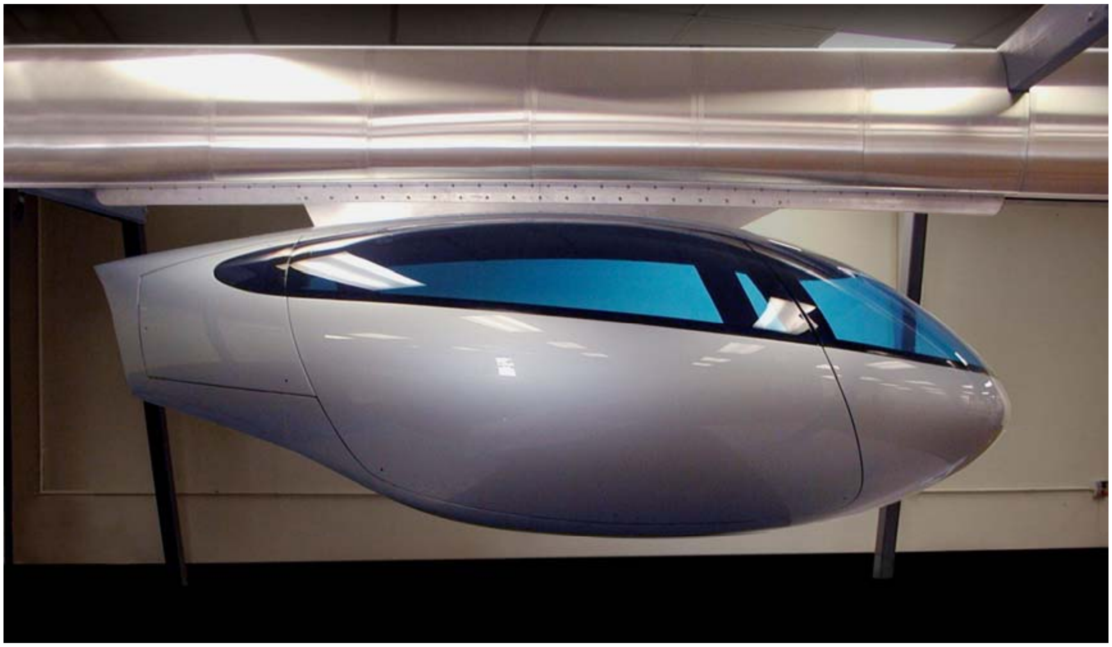


Figure 1 – SkyTran prototype and guideway at the NASA Ames Research Center at Moffett Field, CA.

Project Team

The project team is comprised of world-class technology and engineering firms with the skill and expertise needed to successfully execute the development plan. The core project technical team worked together to advance the technology under a 4-year US DOT grant and includes the following individuals:

John Cole is CTO of SkyTran and serves as Project Team leader. His past experience includes managing the development of several leading edge medical devices and also the development of missile guidance systems for Loral, a major defense contractor. Mr. Cole has a BS in chemistry from the United States Military Academy at West Point and a Masters in Systems Management from the University of Southern California.

John Lee Wamble is SkyTran's VP of Electromagnetics and is responsible for development and implementation of laboratory testing programs for integrated maglev, guidance and propulsion systems. Mr. Wamble is co-founder of Advanced Maglev Systems LLC in Seattle, WA. He has a BS in Electrical Engineering from the University of Washington.

Robert Baertsch, Ph.D. is SkyTran's VP of Software Development. He was formerly with the NASA Ames Green Team's sustainable energy technology research program. Dr. Baertsch led a team that developed a multi-national software application for the United Nations. He received his BS in Electrical Engineering from the University of New York, Stony Brook and has a Ph.D. in Bioinformatics from the University of California at Santa Cruz.

Clark Foster is SkyTran's VP of Mechanical Engineering. The USPTO lists Mr. Foster as a Prolific Inventor with over 125 US patents. He is a Licensed Professional Engineer in the State of Washington and received a BS at the University of Washington in Mechanical Engineering.

NASA is collaborating with SkyTran, Inc, under a bilateral Space Act Agreement. **Nans Kunz**, Chief Engineer of the NASA Engineering & Safety Center, will lead the NASA effort. Mr. Kunz has over 31 years of engineering experience at NASA, most as a Project Chief Engineer, and has been responsible for the success of many important NASA projects and programs. He has a BS from Oregon State University, and a MS from Stanford University, both in Mechanical Engineering.

Moog CSA Engineering, Mountain View, CA, provides world-class system engineering and integration expertise in high precision systems. **Paul J. Keas,** Senior Engineer has worked on NASA's most challenging dynamic problems. Mr. Keas received his M.S. in Mechanical Engineering from Santa Clara University and a B.S. in Electrical Engineering from Cal Poly, San Luis Obispo. Among CSA's clients are: NASA, Boeing, Ford, General Dynamics, GE, and IBM. www.csaengineering.com.

One Cycle Control, Inc., Irvine, CA, is a leader in Smart Grid power electronics and the exclusive providers of CalTech-UC Irvine-developed, OCC technology. **Greg Smedley, Ph.D.**, CEO/President, leads the innovative OCC team. **Keyue Ma Smedley Ph.D.** is a world-renowned expert in Power Electronics and inventor of One-Cycle Control. She is an IEEE Fellow and Founder/Director of the University of California Irvine Power Electronics Lab. OCC has executed government contracts from DOE/ DOD/ CEC/ CIEE, received the Army SBIR Achievement Award in 2010, completed UL-safety approval of 15 products in 2011, and has established a 95% domestic supply chain and scalable manufacturing in Irvine, CA www.onecyclecontrol.com.

Strategic Partners

In support of its technologies, SkyTran, Inc. has engaged a broad spectrum of strategic partners representing the most innovative engineering, management and technology companies. Each of these companies has attended meetings, committed resources and provided insight into the technologies and products that place them in the vanguard of their sector and each of them has agreed to support SkyTran with the HRP.

Among these companies are:

- **The Sapa Group**, North American headquarters Rosemont, IL, is world leader in the manufacture of extruded aluminum profile-based building systems. Sapa's extruded guideways will enable SkyTran to place a world-class product in the market at the lowest possible cost. Sapa has operations in 32 countries and customers in the transport, building, engineering and telecom industries. www.sapagroup.com.
- **Jenkins Gales & Martinez**, located in Los Angeles, is internationally recognized transportation project management firm. JGM's expertise allows SkyTran to come to national and international tenders for transportation systems with a pre-qualified team of world-leading transportation engineering expertise. Among JGM's better-known projects are: The Beijing Transit Terminal; The Alameda (Southern California) Corridor; and The Los Angeles MTA Light Rail Network. www.jgminc.com.

- **IDEO,** Menlo Park, CA, is Silicon Valley's preeminent human factors and product design company. IDEO's unique approach to design and human interaction design has won it awards worldwide and will allow for the SkyTran user interface system to be as groundbreaking and intuitive as were the first smart phones (itself the product of IDEO's insights and design). Among its clients are: Toyota, Chrysler, and Grid Systems. www.ideo.com.

- **ADM Works,** Santa Ana, CA, is automotive vehicle prototype development company located in Santa Ana, CA. ADM made SkyTran's first prototype vehicle and continues to work with the company to bring its special design processes to SkyTran transportation innovations. Among its clients are: The Ford Motor Company; Lexus and Hyundai. www.adm-works.com.

- **Nanosolar,** San Jose, CA, is a solar energy company that prints solar cells and assembles panels to enable the most cost-efficient solar electricity. Nanosolar and SkyTran are exploring ways in which to coat SkyTran's guideways with Nanosolar panels efficiently and effectively in order to power SkyTran and the grid with low-cost, clean, energy. www.nanosolar.com.

- **Loisos + Ubbelohde**, Alameda, CA, an architecture and consulting firm specializing in sustainable design and high performance buildings. It holds twenty-nine American Institute of Architecture awards, three AIA/COTE Top Ten Green Projects, and five LEED platinum certifications. L&U has provided SkyTran with architectural drawings, blueprints and CAD/CAM renderings to assure that SkyTran's end product reflects its groundbreaking approach to mobility. Clients include The Guggenheim; Apple; and NanoCity. www.coolshadow.com

- **Magna Steyr North America,** is headquartered in Troy, MI. Magna Steyr offers its customers complete vehicle and systems engineering through divisions located in North America. Magna Steyr has approximately 11,400 employees. www.magnasteyr.com.

Background – Lessons Learned from FTA Low and High Speed Maglev Programs

FTA's evaluation of its Low and High Speed Maglev Programs came to conclusions that have critical implications for the future of maglev technology development. Key findings determined that *"…maglev is feasible, but the results of multiple projects have indicated that substantial up-front costs exist.* " In addition, *"…maglev poses a fundamental change in technology that is viewed as being both a major risk and cost-prohibitive by transit agencies and investors.* "

The development of SkyTran's maglev-linear motor powertrain and overall system design has been informed from these lessons learned. In the following section describing SkyTran technology, specific technical and performance improvements are identified that dramatically lower up-front costs and increase operational reliability.

By and large, SkyTran cost advantages are due to an overall design that emphasizes lightweight, aerodynamic structures. SkyTran's compact, simple maglev-linear motor powertrain elegantly leverages this design approach. Cost of infrastructure is directly related to weight. The more a structure weighs, the more it costs to build, transport and install. Cost estimates can be difficult to predict. However, when weight serves as a proxy for cost, an informative comparison of infrastructure costs emerges.

Table 1 - System Weight Comparison

System	**Vehicle Loading** kg/m	**Guideway** kg/m	**Total kg/m**	**Cost (based on weight)**
BART (bi-directional)	1,500	3,000	6,000	16x
Transrapid (bi-directional)	1,400	10,000	12,800	34x
Magnemotion (single direction)	850	400	1,250	6x
ULTra (single direction)	100	400	500	2.5x
SkyTran (single direction)	30	170	200	1x
SkyTran (bi-directional)	30	340	370	1x

Sources :
http://www.dot.state.ga.us/aboutGeorgiadot/Board/Documents/2010Presentations/April/TransrapidMaglevTech.pdf
http://www.mtc.ca.gov/planning/bay_bridge/rail_study/chap3.htm
http://www.bart.gov/docs/BARTenergyreport.pdf
http://www.ultraprt.com/prt/infra/infra-specifications/
FTA Urban Maglev Report

FTA's evaluation of the Low and High Speed Maglev Programs also described serious management issues that existed with these programs noting *"while the very nature of this research program draws creative individuals who are interested in solving complex problems, but very often are not as concerned about following sound project management principles, let alone Federal guidelines for submitting required reports on time."*

SkyTran has partnered with Moog Inc to bring rigorous project management to the engineering effort. Moog's CSA Engineering group has had extensive hands-on experience in past maglev system development and has an excellent track record in managing projects for NASA and other federal agencies.

Technology Description

Present state of the art automated transit networks (ATN), also known as personal rapid transit, use a battery powered, wheel-based powertrain that restrict maximum speeds (35 mph) and therefore limit network scalability. SkyTran's powertrain overcomes these limits with the following innovations; 1) new magnetic levitation system that (unlike Inductrack or electro-magnet based maglev) does not use active or passive coils in the guideway; 2) new motor design that solves problems associated with traditional linear synchronous motor (LSM) and linear induction motor (LIM) designs and; 3) SkyTran vehicles derive power from the guideway eliminating costs associated with large on-board batteries.

1) New Magnetic Levitation System

To operate at high speeds and prevent contact between vehicle and guideway all existing maglev systems require precisely flat guide-way structures to maintain the small air gap between the vehicle and guideway. FTA's evaluation of the Low and High Speed Maglev Programs noted this issue, stating *"…tolerances on the guideway are extremely tight and drive the cost per mile up. Large levitation gaps may help reduce that cost as the same level of precision in construction and manufacture that is required for smaller gaps are not necessary."*

SkyTran's novel and proprietary levitation system maintains constant lifting force independent of typical variations in guideway linearity. As a result, the SkyTran design overcomes what FTA describes as the key compromise, which is "between using beams that are too large and expensive and a guideway that does not provide good ride quality." Specifically, SkyTran is a maglev system where the lift force is related to forward velocity instead of distance of magnet to coil. This design, combined with a pitchable magnet wing, allows for a smooth ride even if the lightweight guideway deflects. Combining a 150mm vertical travel in the levitation and using an independent suspension for the motor allow very large gaps and very loose tolerances in the structure. Effects on ride quality from guideway deflection can be minimized by altering the vertical path of the vehicle. By using this unique technology, lighter guideway construction, less material and longer spans are possible.

With pole spacing of 60 ft column loading is less than 2.5 tons. SkyTran also eliminates expensive guideway components, producing levitation from simple, thin aluminum rails. This advanced levitation also allows switching without moving or active components in the guideway. The active switching components are all contained in the vehicle and are redundantly activated and verified with sensors well before the vehicle enters the switch, eliminating time delay and maximizing throughput.

Table 2   Maglev Performance Comparison

	Transrapid (Siemens)	Magnemotion	LEVX	JR / Yamanashi	Inductrack/ GA Urban	Applied Levitation	SkyTran
Air Gap Size	✗	●	✓	✓	✗	✓	✓
Linearity Tolerance	✗	●	✓	✓	✗	✓	✓
Eliminates Active Coils in Guideway	✗	✗	✓	✗	✗	✓	✓
No Magnetized Guideway	✓	✓	✗	✓	✓	✗	✓
No Active Levitation	✗	✗	✓	●	✓	✓	✓
Starting Mag Drag "Hump"	✓	✓	✓	●	✗	✓	✓
Speed Capability	✓	●	✗	✓	●	✗	✓
Guideway Cost	✗	✗	✗	✗	●	✗	✓

2) New Linear Motor Design

SkyTran uses permanent magnet components to enhance field strength resulting in a larger air-gap per unit of power when compared with conventional LIMs. A large gap between the moving and stationary parts of the motor reduces cost by relaxing the constraints on the tolerances, strength and stiffness of the physical infrastructure. LIMs typically have an air gap of 0.020 to 0.120 inches and require mechanical bearings to maintain this tight tolerance. This limits the overall speed of the system and introduces mechanical wear points. LSMs typically use permanent magnets and can throw a larger magnetic field and can function well with a larger air-gap. However, LSMs require a coil and power electronics in the stator element of the guideway that dramatically increases cost. SkyTran's unique propulsion system combines the best characteristics of LIM and LSM in one robust system, eliminating all coils and power electronics associated with LSMs and dramatically lowering system cost without introducing the problems of small air-gap found in today's LIMs.

3) Efficient Electric Propulsion Powered From Guideway

By using lightweight (~500 lb.) vehicles and drawing power from the guideway for propulsion and regenerative braking, energy consumption of 100-150 watt hours per mile is achievable. This is about half the energy used by electric cars and 5-10x less than used by liquid fueled cars. The GHG emissions reduction is estimated to be 300 tons of CO2 per million vehicle miles traveled. Vehicles are powered by the guideway, but have an on-board battery for emergency operation during blackouts. In order to ensure stability of the power grid, peak power consumption will be managed by vehicle velocity control, stationary energy storage (cheaper than on-board batteries), and alternate power generation.

4) Elevated Guideway and Stations

SkyTran's lightweight, transformational guideway has a minimal footprint that allows the system to be placed in congested urban environments where right of way is costly or unavailable. Offline stations provide immediate boarding and immediate departure.

The guideway serve two major functions: First, it is a structural frame that is sized to handle the combined loads from deadweight, wind loads, transient vehicle loads at maximum capacity, snow loads, dynamic and seismic loads. Second, it provides a conductive conduit for the bogie to transit and interact with for levitation, steering, thrust and braking functions. The structural element is a series of 15m long steel beams supported on steel poles anchored to concrete foundations. The beam is an inverted channel about 450 mm wide and 675 mm deep with an average wall thickness of 5mm.

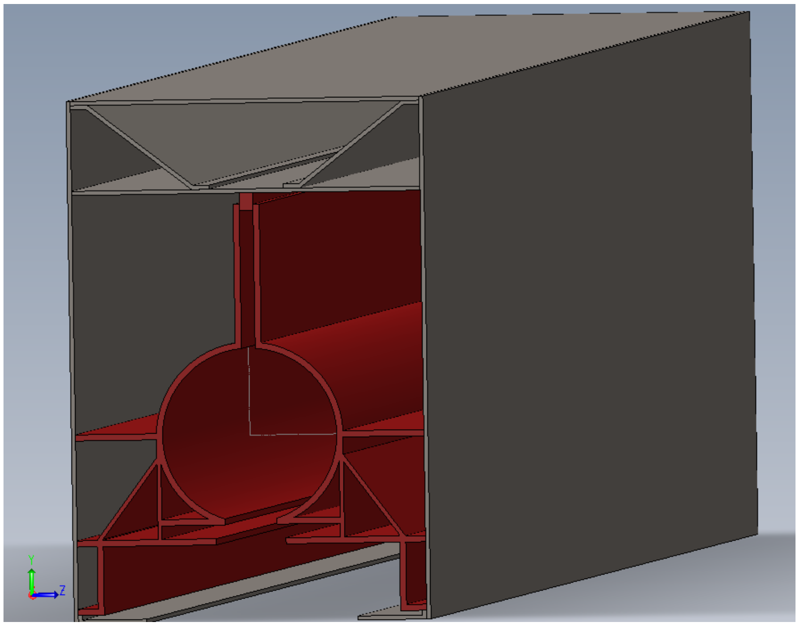


Figure 2 – Guideway cross-section showing steel beam structure (gray) and aluminum extrusion segment (red).

A second mid-level deck completes a closed profile to support torsional loads. The beam can be fabricated as either straight or curved sections using conventional sheet steel fabrication techniques. The space between the downward facing flanges of the inverted channel are sized to receive a series of straight segmented aluminum extrusions. The straight segmented aluminum extrusions are secured to the flanges with through bolts.

A series of nested, straight segmented aluminum extrusions are bolted to the beam structure and form a conductive conduit that provides levitation,steering, thrust and braking reaction surfaces. Compound guideway curves can be easily fabricated by conforming a series of straight segmented aluminum extrusions to the shape of the steel beam and thereby produce a smooth conduit for the bogie to move along.

5) Single Party Vehicles with On-Demand Service:

A passenger takes a direct, non-stop, high-speed ride, an advantage that can't be realized by automobile performance. Local bus and light rail systems offer scheduled, stop-and-go service with average speeds of 15-20 mph with BRT and commuter rail rarely exceeding 30 mph. In contrast, SkyTran has the capability to achieve point-to-point speeds of 35-65 mph, where appropriate, allowing for safe travel above pedestrians, auto traffic or other surface obstructions.

6) Vehicle-Controlled Switch

The SkyTran switch is designed for full-speed operation with no moving components in the guideway. This provide two major benefits: 1) there is no delay going through the switch that could lead to congestion, 2) there are no moving parts to wear and break, all maintenace is performed on the vehicle.

7) Fully Automated Vehicles

SkyTran provides improved throughput and capacities of 11,500 passengers per hour per line with two passenger vehicles. The development team has run real-time physics based simulations of vehicle movements on large networks composed of thousands of vehicles. These simulations have confirmed that with close vehicle spacing, one guideway can carry as much traffic as a three-lane freeway. Distributed routing of vehicles with algorithms similar to those used to route packets on the internet allows robust, efficient and safe operations with the potential for much higher passenger safety than currently possible with cars.

8) Reduced Right of Way

SkyTran's lightweight powertrain and vehicle design substantially reduces the footprint for guideway support and station size. Standard steel utility poles (18"-24" diameter) can be used to support guideway lengths up to 100 feet. Longer spans can be achieved with suspension structures to cross large intersections and other impediments. This minimal footprint reduces ROW costs and impacts.

9) Livability

SkyTran provides more transportation choices and enhances economic competitiveness of communities by reducing dependence on automobiles and associated costs, both public and private. SkyTran is ideal for transit-oriented development (TOD) as it is neighborhood friendly due to quiet, wheel-free vehicles and a slim guideway whose modest profile merges with the skyline. SkyTran's frequent small stations (up to ¼ mile) allow TOD to expand out from rail and BRT corridors into broad networks. As TOD increases urban density, SkyTran's network design enhances traffic calming and helps eliminate the need for parking thus, increasing potential urban open space and community parks. In addition, SkyTran guideways can be used to consolidate aerial utilities and eliminate visual pollution.

10) Collision Avoidance Methodology

The most serious event to occur on an online guideway would be a random event that suddenly blocks the guideway, such as a tree falling over onto the guideway. In that event, the software would initiate the following sequence:

Lead vehicle initiates maximum braking by stopping the motor drives from spinning. This results in dual stationary motor spools acting as eddy current brake. Air bags deploy. Lead vehicle stops at up to 1 G.

There are multiple systems for triggering an emergency stop:

1) power failure
2) communication failure
3) signal from leading vehicle to stop
4) signal from forward looking radar

Vehicles have a rear-mounted corner reflector on each vehicle that provides a strong radar signal to the following vehicle.

11) Emergency Egress

If a vehicle stops for some unexpected reason while on the guideway, there are two methods for evacuation of passengers. First, an onboard battery that is capable of moving the vehicle at least 5 miles can propel the vehicle forward without any external power. Using the radar to ensure there are no obstacles, the vehicle moves to the next station with a free berth and allows passengers to disembark. If the path is blocked or movement is not possible, then the fire department can be dispatched to safely remove the passenger. Vehicle doors can be opened externally by emergency personnel. For safety, a passenger cannot open the door from the inside. However vents can be opened to allow fresh air to circulate inside the cabin.

SkyTran Maglev Development History

Over the last ten years SkyTran engineers have studied magnetic levitation and propulsion technologies in an effort to develop the best possible means of conveying vehicles within a networked guideway system.

Up until now all magnetic levitation, or maglev, methods can be grouped into three general categories, two of which, electromagnetic suspension (EMS) and electrodynamic suspension (EDS), have good potential for application in the field of long distance transportation; indeed, real world deployments exist for both methods. The third maglev method, the use of direct diamagnetism, has limited potential for long distance transport due to its dependence on exotic materials and magnetic fields of unusually high flux density, both factors contributing to excessively high cost. Any of these three methods can be augmented with the use of mechanical stabilizing components to overcome inherent instability problems and this arrangement is sometimes termed pseudo-maglev. Also, any of these three methods can be applied to limited travel or rotary motion machinery in which case the term magnetic bearing is more commonly used than the term magnetic levitation or maglev. Magnetic bearings and maglev transportation share components and a parallel developmental history but the latter application presents more difficult challenges for the system designer because it requires finding robust, inexpensive and practical means to carry vehicles at high velocities over extended distances.

In an EMS system magnetically energetic sources usually attract toward magnetically permeable components or other magnetic sources or a combination of both. Because the attractive force between these components increases with decreasing separation this arrangement requires additional mechanical components to maintain separation or, more commonly, active modulation of the magnetic field strength. Active EMS requires sensors to detect the relative positions and/or velocities of the components and a means of calculating corrections to electric currents within the magnetic sources and means to modulate those currents. EMS systems have seen some limited deployments in commercial maglev transport systems, most notably the German Transrapid system, now in service between Shanghai and Pudong Airport. Due to the requirement for active sensing and position modulation to maintain levitation, as well as the risks associated with loss of levitation at high velocity, this method was eliminated from consideration for SkyTran.

By contrast, in an EDS system magnetic sources act to repel components carrying electric currents, those currents typically being induced by the rapid passage of the magnetic fields. Because the repulsive forces between components naturally increase with decreasing separation, EDS systems can be made passively stable in the levitating direction. This characteristic means that EDS systems are simpler to operate and fail gracefully. For instance, if a vehicle is traveling and levitating when power is interrupted the vehicle continues to levitate as it coasts down to lower velocity. For these reasons the SkyTran engineering team initially focused on electrodynamic suspension (EDS) as the most likely candidate for use in a SkyTran system.

EDS systems have seen commercial deployments, most significantly in the Japanese JR Maglev system. Inductrack, created at Lawrence Livermore Laboratories, is an elegantly simplified EDS method that is currently under limited development by General Atomics in San Diego. It incorporates high energy permanent magnets and a conductor stack formed from laminated metallic sheets or shorted coils.

SkyTran began its research by evaluating Inductrack as the primary means of levitation. We knew of certain drawbacks. For instance it requires a somewhat complicated and expensive construction within the conductor stacks. It also develops significant drag in a low velocity range where the induced currents create more drag than lift (this is known as the startup drag hump). We worked to mitigate these drawbacks by introducing new componentry and eventually by completely redesigning the conductor stack.

Our first research effort produced an enhancement to Inductrack that created centering forces. We next introduced direct magnetic repulsion as the primary lifter with EDS to produce centering force. To explain briefly, a direct magnet to magnet repulsion system can be made to produce lifting force at zero velocity but it will require additional position stability through the use of active electromagnetic components or mechanical constraints. In this case we used passive EDS components to produce the required stability for a permanent magnet to permanent magnetic repulsion levitation system. But primarily because of the expense in providing a magnetized guideway we eventually discarded this method as applicable to SkyTran. We then developed an improved conductor construction and configuration that developed centering force and lifting force from a single EDS system.

However, over time we began to recognize this fact: a common characteristic and a primary weakness in all existing maglev methods is that they rely on force between opposing planar faces of components and the direction of the useful force is perpendicular to those planar faces. The concept of magnetic pressure is useful to describing the operation of such systems. Magnetic pressure is the force per unit area developed between the opposing faces of the paired components. As the opposing faces get closer or farther apart the magnetic pressure and thus the force between them increases or decreases rapidly so it is important to keep the separation within a fairly tight range. Because of the difficulty, expense, bulk or mass required to project a sufficiently dense and deep magnetic field, the space between the opposing faces is generally quite small relative to the movement one typically finds in a high speed transport system. This fundamental incompatibility between available magnetic field depth and allowable displacement puts severe requirements on the overall system. The maglev control system has to be fast and powerful or the track has to be very flat and straight. Or the magnetic sources have to be intense enough to produce a magnetically rigid suspension. Often all these criteria must be met. In the real world it is difficult, i.e. expensive, to build a track flat enough and straight enough to sustain travel at velocities of 50 to 150 m/s (110 – 330 mph). In the Transrapid EMS system the gap between mutually attracting components is on the order of 10mm. To maintain levitation of the massive train and yet avoid contact the track must be flat to within an extremely tight tolerance.

In an EDS system the separation space can be made somewhat larger to better accommodate variations due to vehicle perturbation of track deviations. However, the modulation in spacing during typical operation causes consummate modulation in magnetic drag forces, which complicates the propulsion and motion control systems. Even in the largest EDS systems the requirement for a smooth track puts extraordinary requirements on its construction. These requirements drive up the cost and limit the range of installation location.

To address this fundamental drawback in all existing maglev technologies SkyTran engineers developed a completely new and substantially different method of magnetic levitation that addresses these challenges: the electromagnetic induction wing, or simply the magnetic wing.

What is needed is a maglev system wherein levitation forces are developed orthogonal to the separation dimension between the components. In other words, a method in which the force vector lies in the same plane as the opposing faces of the hardware- and orthogonal to the direction of motion. If we can satisfy that criterion then one of the planar surfaces can be made large in the force direction and the other component can be free to find a position on that face that is less dependent on the absolute straightness of the track. For example, if the stationary planar surface is oriented vertically and is thirty centimeters tall while the moving component held in close lateral proximity to this surface develops vertical force as it travels longitudinally, then the moving component is free to move up and down over those thirty centimeters while continuing to develop a steady vertical force. The lateral magnetic stiffness of the gap between the opposing components is not critical because the moving component can be mounted with a compliant suspension in that dimension without loss of stiffness in the vertical lifting dimension. In this way the vehicle can travel in a straight line even if the stationary maglev component, the track, is not optimally straight in either the vertical or lateral directions. This is because the traveling component of the maglev system has the space to move up or down over the face of the stationary component and its compliance in the lateral direction allows for positional variation there as well. No existing systems exhibit this characteristic. Just to distinguish, many maglev systems develop force counter to their direction of motion and this force is indeed orthogonal to the separation dimension of the magnetic gap, but it is not a useful force. Rather, it is magnetic drag and is generally an unwanted byproduct of the maglev system.

To accomplish this orthogonal force criterion, what we propose is a set of magnetic sources that produce flux fields shaped to act like long narrow fins or wings penetrating an electrically conductive planar element. As these magnetic wings traverse the plane in the direction of the wings' long axes the induced electrical currents and the resulting drag forces are relatively small due to two factors: the small dimension perpendicular to the travel direction, i.e. the thickness of the magnetic wings, and their length, which produces a relatively slow time varying magnetic field within the conductor. But as the wings move perpendicular to their long axes large electrical eddy currents are induced due to the large spatial dimension of the field perpendicular to this off-axis motion and the rapid time variance of the fields in that direction. Simply put, the induced currents act to retard the motion of the wings transverse to their long axes but allow easy motion of the wings along their long axes. If the wings are arranged so that their transverse axes are substantially vertical and their long axes are pointed primarily in the direction of travel but tilted up slightly then with motion in the travel direction lifting forces will result on the wings. If the wings point slightly downward an anti-lifting force is developed. Likewise, if the magnetic wings and accompanying electrically conductive planes are rotated around the travel axis to be arranged so that their transverse axes are to the sides of the vehicle, then centering or steering forces are developed. The immediately graspable benefit of such an arrangement is that the forces developed are substantially parallel to the conductive plane and no complicated machining of that plane is required. Indeed, the most likely construction of a conducting plane is a solid flat bar of aluminum. By comparison to other typical maglev components this is an extremely inexpensive and robust structural element made from an abundant and clean to produce resource. The magnetic sources for the wings can be electromagnets or, more likely, permanent magnets with or without permeable pole pieces. In the future they are likely to be superconductive electromagnets as the cost of that technology falls. The combination of inexpensive materials and construction with a track that has large tolerances for deviation from a linear travel path brings the possibility of a maglev transport system that is much less expensive than any existing design.

A mechanical analogy may help illustrate the concept. If an EDS system is like a surfboard sliding along the surface of the ocean, our proposed system is like a hydrofoil with slender wings well beneath the surface. The lifting force of the surfboard depends on the surface area of the board and on the board attaining some minimum speed at which it planes over the surface of the water. Below that speed the surfboard is sluggish in the water and requires a lot of power to overcome drag. When its planing speed is achieved the surfboard slides easily across the surface. But as the speed continues to increase the roughness of the water produces ever more violent ride characteristics for the surfer. Only with a very smooth surface can very high speeds be attained. By comparison the hydrofoil wings develop lift proportional to their speed in the water and their drag is a relatively constant function of that speed. At a speed where sufficient lift is produced the hydrofoil wings will “fly” through the water at some distance beneath the surface. But with the hydrofoil, as its speed increases the surface roughness does not affect its ride quality. The hydrofoil rider can experience much higher speeds even with rough surface conditions. This is, incidentally, a real world example.

By further analogy an EMS system, which makes use of attraction, would be like a suction cup sliding along the underside of a smooth stationary surface. In this case roughness of the surface is even more detrimental to ride quality and accommodating surface irregularities with a larger air gap requires a larger expenditure of power along with a commensurate capability to modulate that power.

Another positive aspect to our new maglev method is its inherent high damping characteristic. The useful force developed by the wing is dependent on its velocity transverse to its axis---not on its position. Therefore, as perturbations occur to the position of the magnetic fin on the conductive plane, the induced force producing currents are modulated according to the perturbation velocity---not the position. So the system behaves very differently than other maglev systems wherein perturbations act as displacements to a spring-mass system and generally require supplementary damping. Our system possesses passive positional stability without the need for sophisticated active damping subsystems.

Current Technology Status

A Technology Readiness Level (TRL) of 4 has been achieved with a functional magnetic wing sub-scale prototype at the NASA Ames Research Center (Figure 3a) and 50 kg vehicle bogie (Figure 3b & 3c) that demonstrates successful levitation and propulsion of vehicle bogie on a straight guideway section. In order to reach TRL-7, two technical issues need to be addressed; switching and automating a number of vehicles in a fully operational guideway environment. For a detail technology readiness assessment for each component of the system, please consult Appendix VIII.

Figure 3a - Magnetic wing sub-scale prototype of guideway NASA Ames Research Center. Guideway has been inverted for testing. The center tube is the reaction tube for the propulsion system. The two outer rails provide a reaction surface for the levitation wings. In full-scale operations, bogie and vehicle hang from guideway.

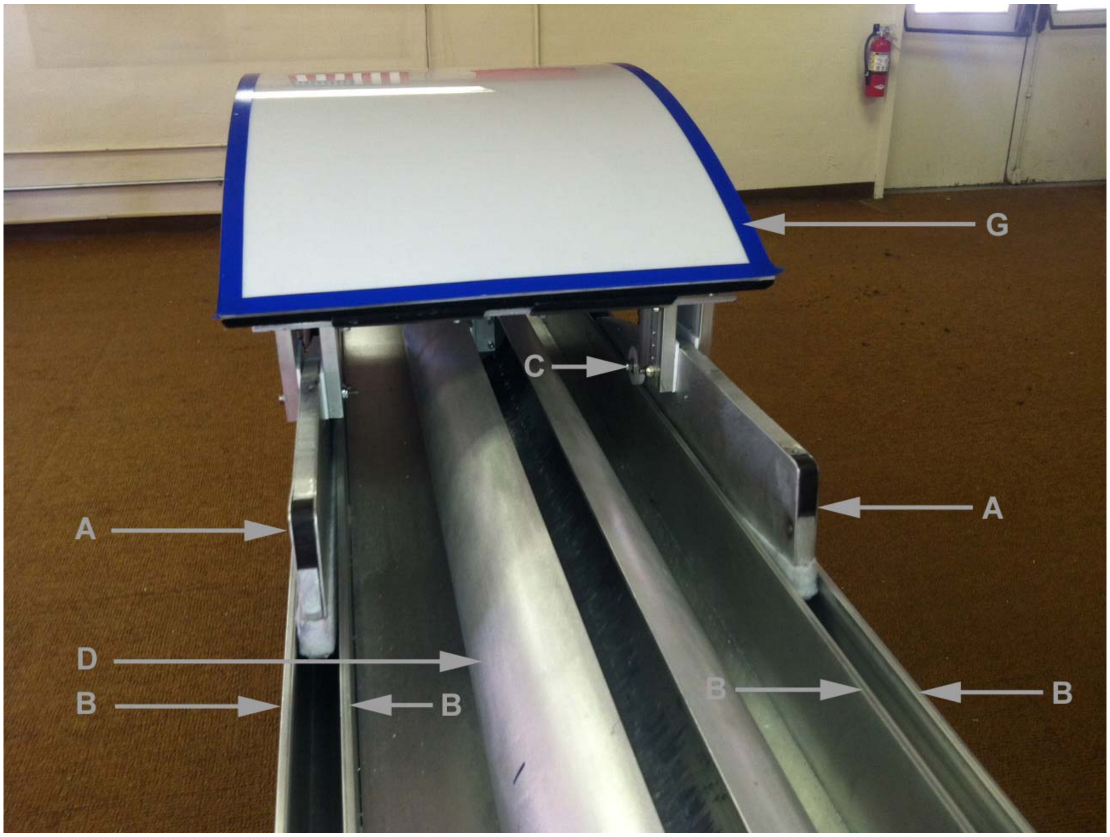


Figure 3b – Front view

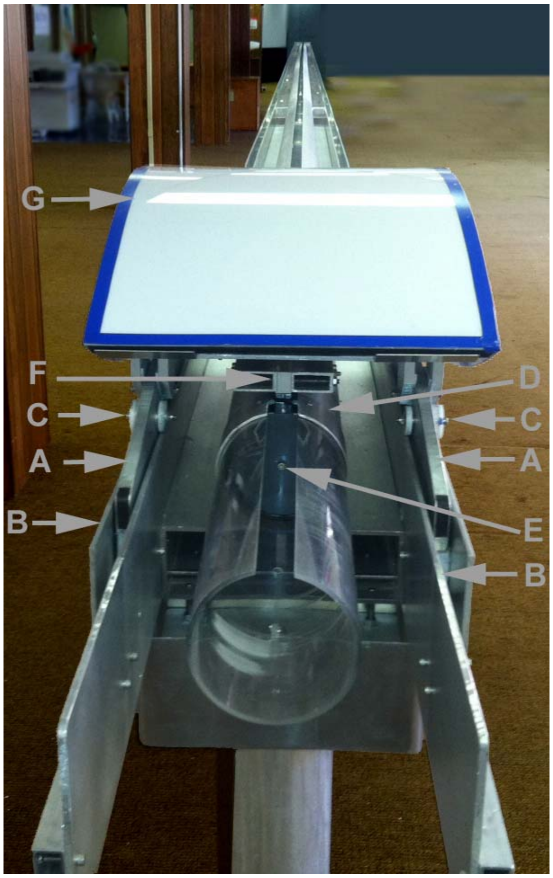


Figure 3c - Rear view

Levitation reaction rails (B) provide stationary support for magnetic wings (A) to lift against. Lift force is proportional to forward velocity. Magnetic drag is proportional to pitch of wings (patent pending). Wheels (C) support vehicle weight when forward velocity is less than take off threshold (nominally 4 m/s). Propulsion tube (D) provides reaction surface for cylindrical propulsion motor (E). Bearing-less motor suspension is magnetic and only operates when motor is spinning eliminating wearing parts. Motor support (F) moves independently of levitation system allowing motor (E) to fly independently of levitating bogie (G). During flight, vehicle levitations between 1 and 3cm (~10-15 cm travel in full scale vehicle). Guideway has been inverted for testing. In full-scale operations, bogie and vehicle hang from guideway.

Figure 3d - Vehicles traversing the guideway can pass over gaps without any contact. Gaps also allow for thermal expansion of rails without warping or buckling common in rail systems.

Hardware Reference Platform (HRP) Development Plan

The HRP serves as a demonstration of SkyTran ATN hardware and software, provides a tool for developing manufacturing pilot production processes and supports the activities of government and regulatory authorities to evaluate deployment issues.

The HRP consists of four major components; 1) an elevated guideway; 2) three automated vehicles; 3) two switches; and 4) an offline guideway serving a station. The project will be constructed in two phases over a period of 18 months.

Phase I

The first phase is budgeted at $1.84 million and will require 9 months to complete. The HRP site will be at a restricted location on Moffett Field at the NASA Ames Research Center. All permitting approvals have been secured for the site including a NEPA categorical exclusion under a previously negotiated lease. Upon program funding, NASA will execute the updated lease and site preparation will begin. This will include establishment of electrical infrastructure and the installation of guideway supports consisting of steel utility poles between 18-24” in diameter. Long lead-time activities, including vehicle and software development will be initiated. A Human Occupancy Vehicle (HOV) specification will be developed and delivered to the Magna Steyr vehicle development team.

Laboratory Confirmation

The primary mission of the first phase is more accurately characterize propulsion and levitation demonstrated by the subscale prototype bogie and guideway and extend that understanding to steering and switching by conducting a step-by-step series of laboratory demonstrations that lead to a full-scale powertrain and guideway. The strategy is to design, build, model, test, iterate and confirm performance of integrated system components in a laboratory setting and then build out the HRP.

Phase I Budget

Resources	**Total**
Labor	$315,000
Contract Labor	
Installers	$72,500
Engineering Services	$155,000
Indirect costs	
Software Development	$150,000
Equipment	
Guideway Sections (60 ft)	$380,000
Guideway Hangers	$30,000
Steel Utility Poles	$100,000
Pole Support Platforms	$40,000
Production Vehicle	$125,000
Propulsion-Maglev Unit (Bogie)	$50,000
Vehicle Power Electronics (5kW unit)	$10,000
Guideway Power Electronics (40 kW unit)	$10,000
Switch Section Testbed	$50,000
Propulsion-Maglev Testbed	$100,000
Photovoltaic Power System	$10,000
Contingency - 15%	$239,625
TOTAL	**$1,837,125.00**

Propulsion-Levitation Wheel to Develop Control Authority for Levitation and Centering

The first step in this process will be to design and build a 30-foot propulsion-levitation wheel apparatus in the laboratory. The apparatus will consist of a circular section of guideway rotated on its axis with the vehicle bogie fixed to the apparatus chassis. In this configuration, analysis and refinements to the design can be achieved more rapidly due to the continuous operation of the vehicle-guideway components. Basic levitation, centering, and drag characteristics will be obtained from the wheel. Moog CSA Engineering will use that data to develop a computer model of the guidance system. The model will be updated with wheel data to more accurately reflect system dynamics. After initial testing, the wheel will be upgraded with two reaction plates to gather further data on bogie levitation, drag and roll characteristics. The model will be updated and analyzed.

Full Scale Guideway to Test Vehicle and Guideway Dynamics

Based upon these results, the next step is to design and build a full-scale guideway test section in the laboratory. The goal is to successfully demonstrate a single truck bogie transiting various guideway configurations and conditions. The initial guideway will consist of three 50-foot straight sections supported on short poles. The propulsion system will be integrated with a wheeled hanging single truck bogie for guideway testing. The propulsion system will be battery operated. Bogie and propulsion system behavior in the straight guideway test section will be characterized and the system model updated with the new data. The single truck bogie will be upgraded to test maglev system performance on the straight guideway test section. A series of maglev tests will be executed to determine the performance of; 1) fixed pitch edge-riding maglev and fixed pitch edge-ride centering; 2) variable pitch edge-riding maglev and fixed pitch edge-ride centering and; 3) variable pitch edge-riding maglev and variable pitch edge-ride centering. The system guidance model will be updated with these results and analyzed.

Guideway Deflection Analysis

Deflection testing of static guideway supported on short poles will be performed. The guideway will be jacked up to create an uneven contour for the bogie to transit. The single truck bogie will be operated to test variable pitch edge-riding maglev and variable pitch edge-ride centering. The model will be upgraded and analyzed. Tests of dynamic uneven guideway will be conducted by removing and shifting pole spacing to allow guideway deflections under transiting load. The model will be upgraded with test data and analyzed. Dissipative energy in the guideway will be confirmed. The primary excitation mode that is calculated from the computer model can be verified by launching a second bogie down the guideway at the appropriate time interval. Vehicles will be launched at ½ second interval and tests conducted to confirm energy dissipation in the guideway from the second vehicle.

Curve Section

A curved guideway section will be designed and built. The curve will be added to the existing three straight sections to test single truck bogie performance. The model will be upgraded with test data and analyzed.

Switch Development

A switch will be designed and constructed independent of the main loop. The switch will be inserted between two 15m guideway sections and tested using the single truck bogie. Test data will be used to update model and switch performance analyzed. (See description above)

Powered Guideway

A DC bus bar to deliver power to the vehicle will be installed inside the guideway. Wipers and power electronics will be installed on the single truck bogie to conduct power from the rail to the propulsion system. The single truck bogie will be operated and tested using power from the guideway.

System Dynamics Testing

The guideway will be raised onto 20-foot poles to provide the operational conditions to test and run dynamics analysis. Tests of uneven guideway will be conducted by removing and shifting pole spacing to allow guideway deflections under load. The model will be upgraded with test data. System vibration and resonance will be analyzed.

Vehicle Development

HOV specifications and development milestones will be reviewed and refined in collaboration with Magna Steyr.

Control & Communication System

The SkyTran communication and control system consists of the following components: (1) Vehicle control subsystem (VCS); (2) Guideway Control subsystem (GCS); (3) Station control subsystem (SCS) ; (4) Switch Control subsystem (SWCS) ; (5) Merge control subsystem (MCS) and (6) Regional control subsystem (RCS). Each of these components is responsible for control, communications, and collision avoidance.

Vehicle Control Subsystem (VCS)

The vehicle controller has the primary responsibility for collision avoidance. It is composed of two redundant controllers, an interface to the motor and levitation controllers, configuration database, wireless communication, inertial guiadance system and a sensor array. The sensor array includes an RFID reader to sense RFID tags that are embedded in the guideway and a automotive radar range finder to detect objects in the vehicle path. This forms the basis for a double redundant safety system with multiple mechanisms to stop the vehicle. If either of the redundant on vehicle controllers does not get a periodic signal that it is safe to move, the vehicle will activate an eddy brake that slows the vehicle at 1G (10 m/s^2). For the HRP system running at a maximum speed of 13 m/s (30 mph), stopping distance will be 9m (27 ft) over 1.3 seconds, well within the initial proposed headway of 15 seconds. Activating the eddy brake also cuts power to the propulsion motor via a solid state relay without any software required. This system will activate after a set timeout in the event of loss of communications or lack of a signal from the guideway or merge controller. A second method to stop the system uses a radar range finder that detects objects in the path of the vehicle. For example, Delphi manufactures an automotive forward-looking radar collision detection system that has an maximum speed of 100 m/s (223 mph), with an update time of 50 milliseconds, and is capable of recognizing 64 different objects up to 174m away. The device is already in high volume production (since 2004) and is certified for use in cars. Finally, the regional controller (RCS) can issue of the command to stop a vehicle remotely if there is a problem that cannot be detected by the onboard vehicle systems.

Guideway Control subsystem (GCS)

The guideway controller monitors the position of all vehicles on the section of guideway under its domain of control. It also monitors the health of the wayside power converters. If any vehicle loses communication contact or follows to closely, the guideway controller can remove power from the entire section and prevent collisions in the rare event that a vehicle controller cannot stop the vehicle.

Station Control Subsystem (SCS)

The SCS controls the vehicle while approaching and traversing stations and vehicle berths inside the stations.

Control System Hardware

Both the FAA and the auto industry have adopted hardware/software platforms that support the running of redundant code. This technology has been certified to operate safety-critical transportation systems. SkyTran plans to use one of these existing off-the-shelf platforms to shorten development and certification time. Software running on the dual CPU’s on a single chip is continually cross-checked in hardware, allowing fault detection and triggering of safety protocols in the event of a hardware problem. Pre-certified hardware, compilers and operating systems that are specifically designed for transportation systems will allow a faster and lower risk path to system operations and certification.

Safety and System Certification

With guidance from NASA, our strategy for assuring system safety and ease of certification is based upon a two part strategy: 1) use existing standards where possible; 2) work with a combination of NASA, FTA and external consultants to develop independent verification and validation procedures to certify technologies that don’t fit into existing standards. Working with these external groups, we intend to follow the path of self-certification that has been resulted in the successful implementation of the Morgantown PRT system and also the San Francisco airport people mover system. In the case of the airport people mover, a System Safety Program Plan (SSPP) was accepted by the California Public Utiliites commission (general order 164-D) as authority to carry passengers. The SSPP developed for SkyTran will include:

- A statement of clear definition of goals and objectives for the safety program along with a description of how the organzation that operates the SkyTran system will meet those objectives.
- The plan must include roles and responsibilities, a process to approve changes to the SSPP.
- A process for identifying, tracking, investigation, analyzing and eliminating hazards.
- A process to address safety concerns in modifications to system components that do not require formal safety certification.
- Documentation of the process used to collect, maintain, analyze, and distribute safety data.
- A process to report (internally and externally), investigate and identify corrective action for accidents.
- An emergency management plans.
- Description of process to conduct safety reviews.
- Description of process for compliance with safety regulations.
- Description of process for safety inspections and audit records.
- Description of safety training and certification program for employees.
- Description of the configuration management process covering changes to hardware and software (and authority to make changes and reporting of changes).
- Description of the hazardous materials program, including the process used to ensure knowledge of and compliance with program requirements.

- Description of the drug and alcohol program and the process used to ensure knowledge of and compliance with program requirements.
- Description of the measures, controls, and assurances in place to ensure that safety principles, requirements and representatives are included in the procurement process.

Existing Safety Standards

The independent verification and validation team (composed of NASA, qualified consultants, and state regulators) will use the following standards to build on industry best practices and speed the safety approval process while ensuring a high level of passenger safety:

- EN 50126 RAMS (Reliability, Availability, Maintainability, Safety) and life cycle with railways
- EN 50129 Safety of systems in signaling equipment
- IEC 61508 SIL-3
- EN 50128 Software
- EN 50159-1 Safety-relevant communication in a closed transmission network
- EN 50159-2 Safety-relevant communication in an open transmission network
- Automotive AEC-Q100 standard

For performance monitoring, we plan to use the existing US standard for automated people mover published by TRB:

- ACRP Report 37A *Guidebook for Measuring Performance of Automated People Mover Systems*

Power Distribution System

The Power Distribution System (PDS) of SkyTran has been designed to include many redundant features to minimize the impact of failure. For example, for each mile of guideway the SkyTran system receives power from two independent, 12.5 kV, three-phase feeders. For each mile of bi-directional guideway, there will be a substation installed to provide power to both sections of track. Adjacent zones can provide power if one section loses power.

Under normal operation, power is received from the primary 12 kV Service Switchgear via 12 kV feeders to the main medium voltage circuit breakers located at each substation. Each transformer transforms the 12 kV to 480 VAC on the secondary and feeds to the respective 480 volt main breaker. Each main breaker feeds 480 VAC power to a bank of power converters that supply 750 VDC to the guideway power rails through feeder breakers. A 480 VAC bus tie breaker is provided to feed both guideways from one transformer should the other transformer be out of service. This keeps the guideways independent during normal operation. The transformers are sized to handle the total load if one of the transformers is out of service.

The Main 12 kV Service Switchgear will consist of three 15 kV vacuum circuit breakers with the associated relaying and metering.

Each unit substations will consist of:

- Three (3) - 15 kV, draw-out vacuum circuit breakers.
- Two (2) - 12 kV to 480 volts, 3 phase, 60 Hz dry type transformers (KVA of transformers varies per location).
- 480 volt switchgear with draw out and molded case circuit breakers, relaying and metering and PLC, installed and wired to the guideway controller.
- Power Factor Correction Equipment.

***Figure 4** – Hardware Reference Platform site*

HRP Site Development

Based upon analysis of hardware performance in the laboratory and software modeling, 600 feet of guideway and two double-truck bogies will be designed and fabricated. Guideway sections will be attached to support poles to form the elliptical loop. The two double-truck bogies will be tested on the guideway with the vehicle control and communications package. The model will be updated with test data and analyzed.

Two instrumentation vehicles will be designed, built and integrated with the two double-truck bogies. Data from the instrumentation vehicles will be used to update the model and evaluate system components, propulsion, maglev, structural loads, vibration, vehicle acceleration and controls. Photovoltaic panels will be installed on, or adjacent to, the guideway to supplement grid power. Planning and preparation for the IOS begins.

NASA human occupancy protocols will be used to validate hardware and software safety. These protocols, used by NASA to validate systems for manned space flight, will provide a high level of confidence in assessing the safety and reliability of SkyTran technology.

Phase II

Phase II is budgeted at $1.55 million and will require 9 months to complete. Two switches will be designed, built and inserted into the main 600-foot elliptical loop to connect an additional 450-foot offline guideway that will serve a station platform. Concurrently, a switch controller will be designed and built. An additional instrumentation bogie and vehicle will be built and join the two other vehicles on the guideway for testing. The control and communications system will be refined to test the performance of multiple vehicles in normal and abnormal modes. The model will be updated with new data from the various tests to evaluate automation control, switches, power electronics, vibration, PV performance and guideway structures. Upon receiving Human Occupancy Vehicles (HOV's) from Magna Steyr, SkyTran engineers will serve as passengers to evaluate ride comfort and experience. NASA human occupancy protocols will be used to begin validating hardware and software safety and the process will culminate in certification of the HOV's for NASA human occupancy. Manufacturing processes, techniques and tools to build the HRP will be appraised, modified and incorporated into a pilot manufacturing documentation package. TRL-7 will be achieved.

Figure 5 – Illustration of Hardware Reference Platform at NASA Ames Research Center showing completed Phase II configuration.

Phase II Budget

Resource	**Total**
Labor	$315,000
Contract Labor	
Engineering	$72,500
Installer	20,000
Indirect costs	
Software Development	$200,000
Equipment	
Guideway Sections (60 ft length)	$240,000
Guideway Hangers	$32,000
Steel Utility Poles	$80,000
Pole Support Platforms	$32,000
Instrumentation Vehicles	$20,000
Production Vehicle	125,000
Guideway Switches	$40,000
Propulsion-Maglev Unit (Bogie)	100,000
Vehicle Power Electronics	$20,000
Station Platform w/ stairways	$20,000
Photovoltaic Power System	$35,000
Contingency – 15%	$202,725
TOTAL	**$1,554,225.00**

HRP Development Schedule

The HRP can be completed in two phases over 18 months with a budget of $3,391,350.

Table 3 - Schedule

Resources	**Phase I**			**Phase II**			
	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**TOTAL**
Direct labor	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000	**$630,000**
Contract Labor	$74,500	$81,000	$72,000	$42,500	$30,000	$20,000	**$320,000**
Equipment	$250,000	$355,000	$300,000	$300,000	$274,000	$170,000	**$1,649,000**
Indirect Costs	$55,000	$50,000	$45,000	$75,000	$65,000	$60,000	**$350,000**
Contingency	$79,875	$79,875	$79,875	$67,575	$67,575	$67,575	**$442,350**
TOTAL	**$564,375**	**$670,875**	**$601,875**	**$590,075**	**$541,575**	**$422,575**	**$3,391,350**

Simulation

SkyTran will demonstrate software tools to simulate network operation of the system at peak rush hour capacity to ensure the following:

1. Sufficient capacity of the system
2. Provide NASA with a tool to validate and verify software control system
3. Plan for power requirements
4. Emergency and public safety planning

Initial Operating Segment Program

The goal of the IOS program is to commission the system for public use. This will require that the Technology Readiness Level of 7, achieved in the HRP phases, be advanced to TRL-9. Rigorous hardware testing and software development and validation will be key to this process. The initial system specification will limit vehicle speeds to 30 mph with 15 second headways between vehicles.

IOS software, hardware and installation is budgeted at $19.25 million and will be privately funded. This budget accounts for non-recurring engineering costs of the hardware and software components and will require 12 months to build. In parallel, extensive software development and independent verification and validation will be required to commission the IOS to carry passengers and to provide for the more complex network automation necessary for the Mountain View ATN system. Software development will begin in the HRP phases. IOS software development will require 16 engineers initially, and will scale up to 9 small tiger teams for a total of 40 engineers. The IOS software build requires a total of 82 man-years or $8.2 million. The independent validation and verification budget cannot be estimated at this time but using the well defined process documented in the *Safety and System Certification* section above, we intend to develop a IV&V process similar to that followed by the SFO airport people mover and Morgantown, with additional input from FTA, NASA, qualified consultants and state regulators.

NASA, and qualified vendors (for example MOOG/CSA) and a core team from SkyTran, will be engaged to develop the software operating system. Qualified vendors will also participate in developing the user interface and billing system.

NASA human occupancy protocols will be used to validate hardware and software safety and reliability. These protocols, used by NASA to validate systems for manned space flight, will provide a high level of confidence in assessing the safety and reliability of SkyTran technology.

In an effort to establish a reasonable regulatory framework for the operation of the IOS and future network expansion, the IOS development process will be open to federal, state and local authorities to provide an opportunity to observe the system in operation before commercial deployment and allow early participation in the design and testing process.

NASA supports the development and installation of the SkyTran IOS as a revolutionary tool that will enable the Transportation Demand Management (TDM) Plan conceived of as part of the NASA Ames Development Plan, Environmental Impact Statement (EIS).

During the EIS public process, NASA studied the implementation of an aggressive TDM Program that promotes alternative transit use for employees (See *Appendix VII, NASA Research Park Director letter re: TIGGER grant*).

Figure 6 – Initial Operating Segment connecting Ellis Street VTA light rail station to NASA Ames Research Park campus.

A half-mile alignment of bi-directional extruded aluminum guideway will be installed 20 feet above ground on steel utility poles that are between 18-24” in diameter. Two stations consisting of an ingress and egress portal will be located at the two terminuses of the alignment. A dumbbell loop allows vehicles to change direction at a station. Flexible photovoltaic panels will be integrated with the guideway structure and connected to a power storage system to supplement grid power.

The IOS will connect the VTA Light Rail station at Ellis Street to a central location near Hangar One inside the Ames Research Park campus. The IOS will provide a convenient connection from the VTA light rail station to NRP tenants that include the University of California, Carnegie-Mellon University, DeAnza College, and NRP greentech businesses. Ridership is anticipated to increase dramatically as the NRP campus expands with 3 million square feet of new construction within the next five years. The billion dollar integrated community will feature state-of-the-art research and teaching laboratories, shared classrooms, rental housing, accommodation for industrial partners, and modern infrastructure. The community is being designed to have a minimal carbon footprint and will serve as a model site to deploy and validate new renewable energy and resource conservation systems like SkyTran. It is anticipated that ridership will be very low at the outset; however, the IOS provides a valuable mechanism to validate the system on

Initial Operating Segment Budget

Resource	Total
Labor	$2,000,000
Contract Labor	$1,120,000
Indirect costs	
Software Development	$8,200,000
Miscellaneous	$800,000
Independent Validation & Verification	*
Equipment	
Guideway Sections	$1,800,000
Guideway Hangers	$400,000
Steel Utility Poles	$1,000,000
Vehicles	$750,000
Guideway Switches	$80,000
Propulsion-Maglev Unit (Bogie)	$500,000
Vehicle Power Electronics	$100,000
Guideway Power Electronics	$50,000
Station Platform (includes elevators & stairways)	$500,000
Misc. Equipment	$250,000
Photovoltaic & Energy Storage System	$500,000
Contingency	$1,200,000
TOTAL	**$19,250,000**

* An independent verification and validation budget ranges from $8-16 million depending on factors beyond our control. However, using the well defined process documented in the *Safety and System Certification* section above, we intend to develop a IV&V process similar to that followed by the SFO airport people mover and Morgantown, with additional input from FTA, NASA, qualified consultants and state regulators.

Federal property without the need for time consuming local government permitting. The NEPA process has been initiated on the IOS and NASA safety approvals are sufficient to allow for public use of the system. Completion and commissioning of the IOS will demonstrate a public system capable of being expanded to meet the requirements of the MV-ATN system.

Mountain View Automated Transit Network Program

Over the past decade, Mountain View has been transformed from Small Town USA to the hub of Silicon Valley; the veritable “center of gravity” around which so many Blue Chips, high-tech companies revolve. This transformation has brought many benefits to Mountain View and elevated its statewide and nation-wide profile as a good place to live and an even better place to grow a business. However, success has also brought congestion, pollution and increasing frustration as the community attempts to cope with these changing circumstances. If just a few years ago one could drive from one end of Mountain View to the other in a matter of minutes, today at some times of the day, a forty-five minute commute is common.

Companies in the North Bayshore are continuing to expand and hire new workers, with the local news reporting thousands of new employees forecast over the next decade. Despite three upgrades to the CA85-US101 interchange, traffic is at capacity and adding more parking is expensive and results in more congestion and lost productivity. North Bayshore local streets are heavily congested during rush hour with commuters and corporate commuter buses. The projected surge in vehicle miles traveled over time will exceed the carrying capacity of city streets, further degrade trip times on Highway 101 and substantially increase carbon emissions.

Keeping and attracting talent to the city and region will require innovative solutions to longstanding transportation problems. Public transit cannot be greatly expanded due to constraints of the large tax subsidies that are required. Corporate commuter buses used to transport regional commuters have met with mixed results. While Google captures 25% employees with its commuter buses, ridership experienced by other companies is very low due to slow travel times.

Current daily trips into North Bayshore range from 30,000 to 40,000 per day. These consist of 11,000 car trips and 4,000 transit trips twice daily. At peak periods, 3,000-4,000 cars per hour are on North Bayshore streets with another 1,500 people arriving every hour on corporate commuter buses.

If the goal is to double the employment base in North Bayshore and not increase car trips, then any alternative transportation system should have the capacity of at least 3,000 trips per hour and, ideally, have the capacity to double the throughput to allow for reduction of existing car and shuttle trips and reduce parking requirements.

The challenge is to provide an affordable and innovative solution that sensibly integrates existing transportation resources and can be scaled to accommodate future growth, both locally and regionally.

For Mountain View and other growing communities, reducing the cost and physical footprint of transportation requires rethinking how we move people. Using SkyTran technology to enable the MV-ATN innovates on a number of levels:

1. Reduces vehicle weight from 4,000 lbs to 500 lbs
2. Reduces infrastructure size
3. Elevates transportation freeing the ground space for other uses
4. Increases bike access by allowing every passenger to bring a bike. Reduction in car traffic improves bike safety
5. Reduces energy consumption compared with cars
6. Eliminates need for tax subsides for transit by lowering total cost to $0.30 - $0.40 per passenger mile (including capital cost)
7. Achieves significant environmental benefits

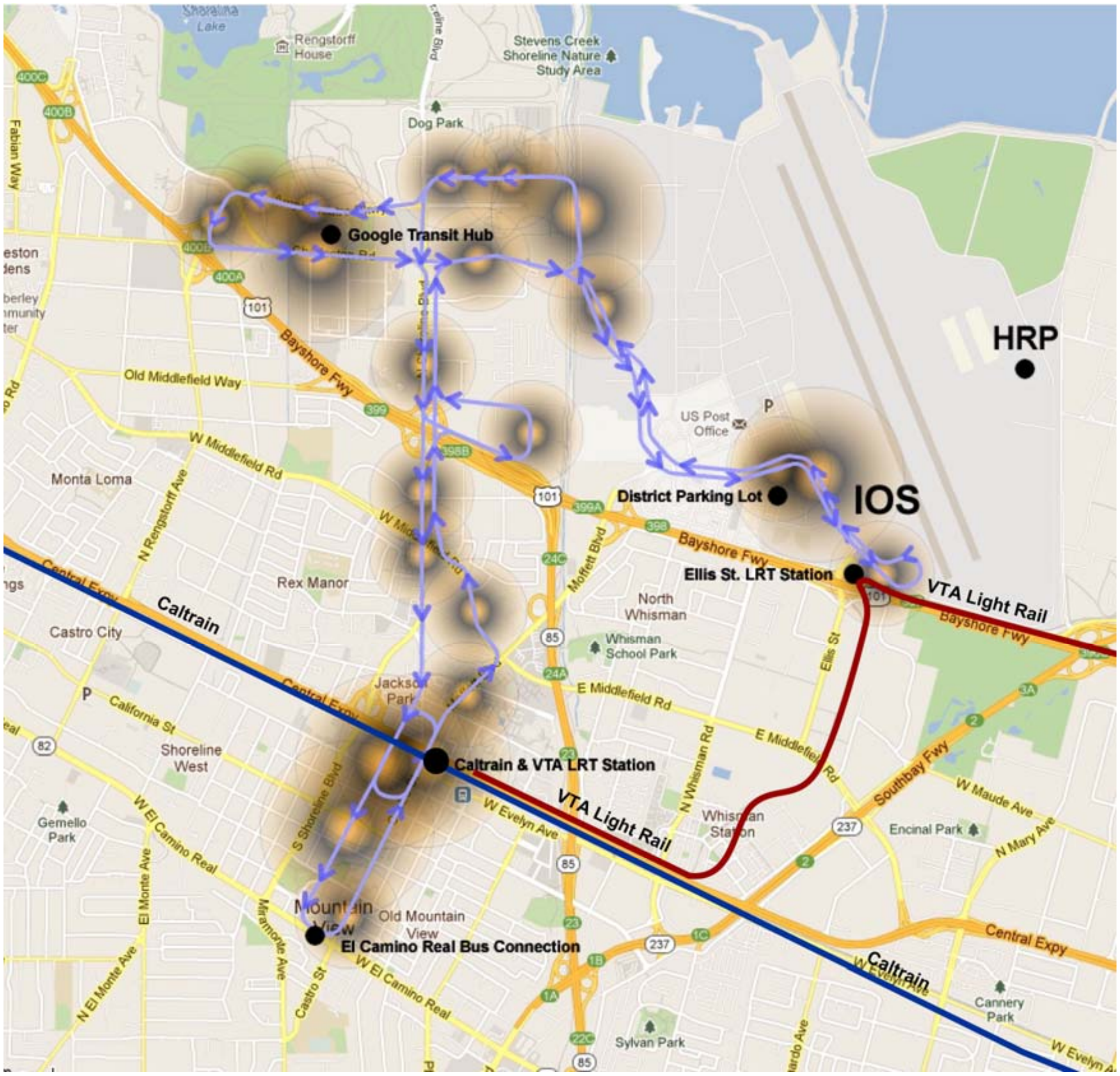


Figure 7 – The proposed 13-mile SkyTran ATN alignment in North Bayshore will provide citywide, 24/7 service and meet future projected trip demand by creating regional links via existing shuttle, city bus and rail systems. Blue lines are elevated guideway. Circles represent stations and the surrounding area that can reach the station in a 5-minute walk.

Goals of the Mountain View Automated Transit Network

1. Enable increased development without an increase in car trips
2. Reduce car traffic
3. Improve regional connectivity via Caltrain, VTA rail & bus
4. Reduce parking requirements, allowing increased Floor Area Ratio
5. Enable increased local economic activity
6. Create construction, software and manufacturing jobs associated with SkyTran
7. Comply with SB 375, AB32 and CEQA requirements to reduce VMT and allows communities to implement a Sustainable Communities Strategy by linking the regional transportation plan to state-level carbon reduction goals

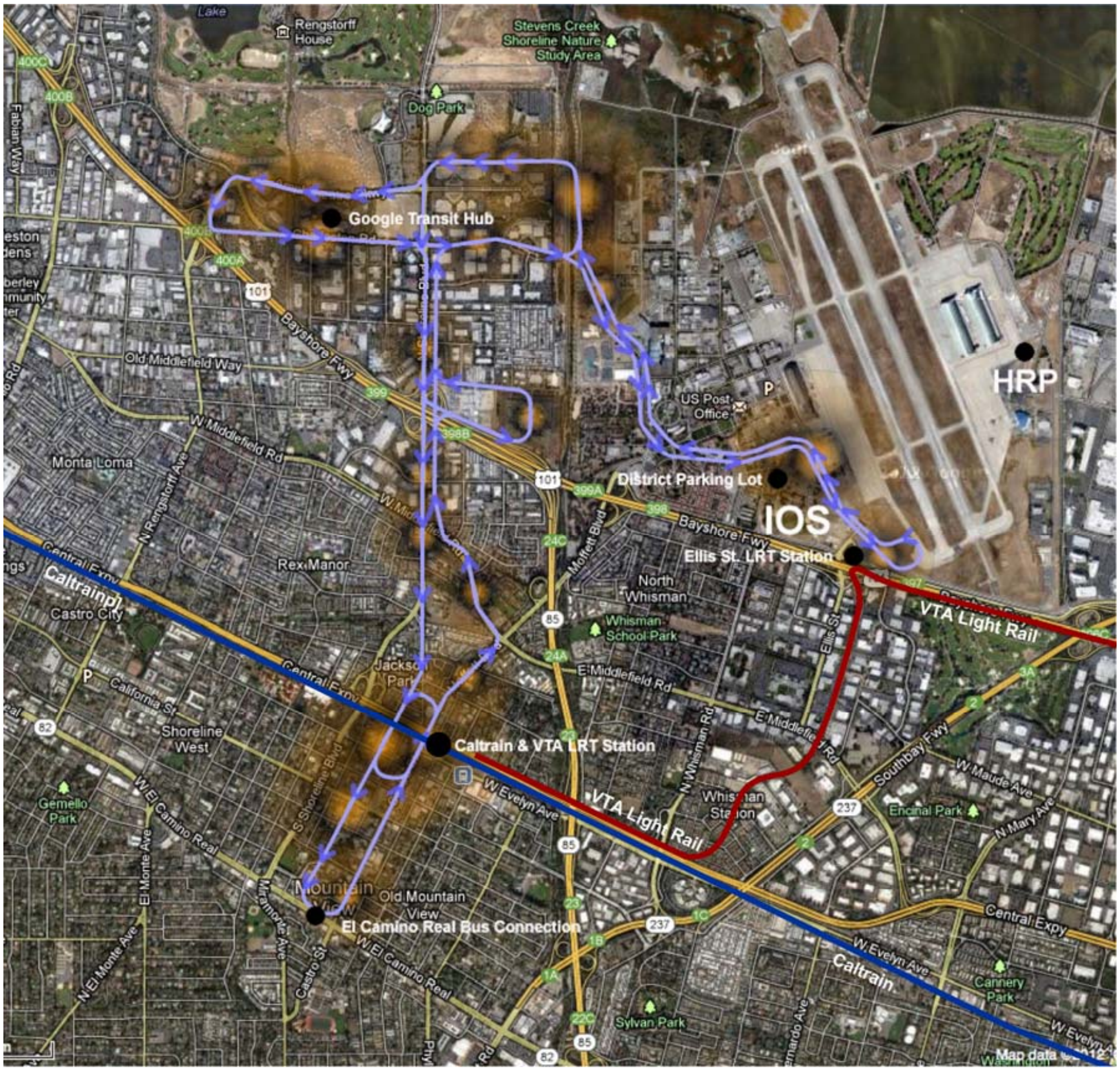


Figure 8– Satellite view of proposed SkyTran ATN alignment.

Proposed MV-ATN Alignment

The proposed system is our vision of what would best serve Mountain View's goals. MV-ATN will be built for a cost of $117 million and commissioned within 24 months as a public-private partnership. The 13-mile network will serve five central stations and 16 smaller stations using 500 vehicles to handle up to 8,000 passengers per hour.

The ADA compliant system will be substantially powered by photovoltaics mounted on the guideway surface and connected to energy storage systems (ESS). ESS will improve system efficiency by capturing regenerative power from vehicle decelerations in stations. Typical pole spacing will be 100 feet with longer spans achieved by using extra support structures above the guideway. The MV-ATN has the capacity to alleviate projected trip demand in the area over the next decade and can be scaled to handle additional growth beyond.

The existing bi-directional IOS guideway in the Ames Research Park would be extended across the campus to the western boundary of Moffett Field at Stevens Creek. From this point, the bi-directional guideway splits as it connects to a uni-directional loop serving the North Bayshore area. A central station at the Google Transit Hub located at Charleston Road between Alta and Huff would serve corporate commuter buses and carpools. Six smaller stations north of Charleston Road serve the broader area. The alignment heads south along North Shoreline Road and serves a smaller loop providing coverage to an area north of U.S. 101 and continues into the Mountain View central business district (CBD). A major station at the north side of the CBD provides a regional connection via the CalTrain and VTA light rail at Central Expressway and Castro Street. A major station at the south side of the CBD provides a connection to bus service along West El Camino Real. The loop exits the CBD via Moffett Blvd and reconnects to the North Bayshore loop via West Middlefield Road.

IOS Upgrades

The station at the northern end of the IOS would be upgraded to handle increased ridership from the planned district parking lot on Moffett Field. In addition, the station at the southern end of the IOS at the Ellis Street light rail station would also be upgraded. Capacity of the station here would be limited to the VTA light rail, which has 5 trains per hour that each holds a maximum of 513 people standing or 2,565 people per hour. Each 171-passenger rail car takes about 3 minutes to unload (1 passenger per second), so the SkyTran station at Ellis Street would need 20 berths to provide a “no-wait” transfer (this assumes that people will exit the train in 3 seconds and enter the SkyTran vehicle and depart in 15 seconds).

Control Room, Maintenance and Parking

A maintenance and control room facility will be located on the network requiring about 40,000 sq ft of warehouse space (location to be determined). A single story 25,000 sq. ft. building can park a fleet of 500 vehicles (50 sq. ft. per vehicle).

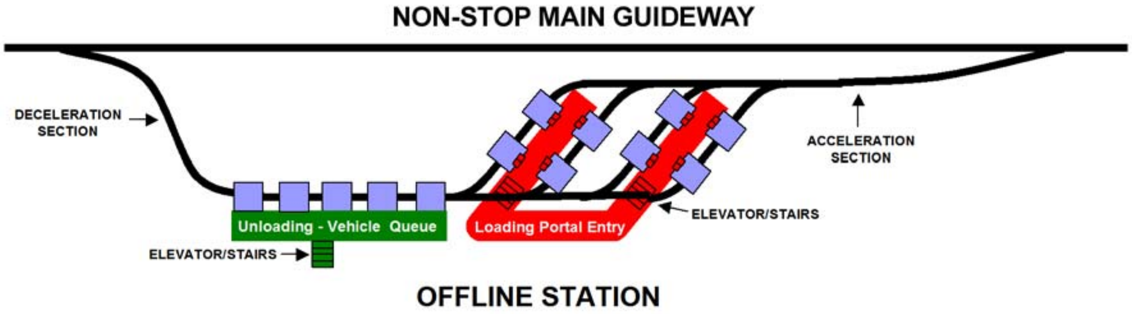


Figure 9 - Multi-berth stations can be scaled to manage various demand requirements by adding modular components. Loading and unloading are handled by separate portals at offline stations.

Station Design

The basic SkyTran station consists of a switched section of guideway serving an offline loading and unloading portal. A separate unloading portal provides for relaxed passenger egress and queuing of vehicles. Loading portals can ganged up in various parallel configurations to manage passenger demand as needed. For example, the offline station at the Google Transit Hub should have a capacity of 60 passengers per minute to handle corporate commuter buses and carpools arriving during the peak commute. Assuming that each individual berth can handle 4 loadings per minute or one every 15 seconds, this station would need to have 15 berths in order to handle the traffic with wait times under one minute. Berths can be configured for parallel launching to minimize boarding delays. Elevators provide ADA compliant access to station platforms.

Vehicle Design

Standard vehicles can handle up to two passengers with a maximum total payload of 500 lbs. Vehicles will be climate controlled and have the capacity to accommodate a bicycle. Special vehicles for ADA access will be available upon request through the ATN reservation system. In the future, privately owned vehicles operating on the network are envisioned but beyond the scope of this project.

Power Requirements for IOS

At full capacity, with 500 vehicles in motion, the total average system demand would be 3.3MW at 480 AC volts. At 45 mph, each vehicle requires 5 kW for propulsion and 1.5 kW for HVAC and on-board power. If five vehicles were launching from 20 stations without any vehicles decelerating, this would increase the total additional load of 5.3MW. The system could be designed to lower the peak load, if the local utility could not provide the spare capacity. Local battery storage can be supplemented to smooth out the peaks and limit overall power requirements to 3.3MW. 12kV to 480v 3 phase 250 KVA transformers will be placed every 1000-2000 ft along the guideway to provide power for the system. A 700 VDC bus runs inside the guideway to provide power to the vehicles.

Alternatives Analysis

Expansion of local shuttle service has been proposed to meet increased trip demand generated by companies in the North Bayshore area. An analysis of long-term trends show that by 2020 total local connection trips will increase to 7,000 per hour (*see Appendix I - Projected Local Connection Trip Demand*). A shuttle fleet of 70 vehicles would be required to manage this capacity. Assuming each shuttle carried its maximum capacity of 40 passengers with 2.5 trips per hour, the fleet could move 7,000 passengers per hour at a cost of $1.48 per passenger trip. The total cost of implementing a shuttle solution over a 30-year period, including capital and operations and maintenance costs, is $392 million. By comparison, the SkyTran MV-ATN using a fleet of 467 vehicles and carrying a maximum of two passengers per trip could move 7,000 passengers an hour at a cost of $1.56 per passenger trip. Total cost of implementing a SkyTran ATN solution over a 30-year period including capital and operations and maintenance costs is $227 million (see *Appendix II – Local Connector Modes* for complete analysis and *Appendix VI - Analysis Assumption*s)

Table 4 – SkyTran vs. Shuttle

Mode	Trips per Hour	Passenger per Trip	Fleet	Pass/ Hr	30 Yr. Capital Cost ($M)	Vehicle/Hour per year	Annual O&M ($M)	30 Year Total Cost ($M)	Cost per Trip
SkyTran	7.5	2	467	7000	$117	81,042	$3.7	$227	$0.86
Local Shuttle Bus	2.5	40	70	7000	$61	110,250	$11	$392	$1.48

The capacity of the SkyTran ATN and local shuttles to deliver passengers to regional connectors exceeds the current long-range public transit capacity of 2,250 passengers per hour provided by Caltrain, VTA light rail, El Camino bus service and other VTA buses. When corporate commuter bus and drivers using District Parking are added to public transit in the analysis, 7,000 passengers need to be handled by local connectors (see *Appendix III –Ridership Estimate for Local Connection*). However, the SkyTran ATN solution has dramatically lower costs than shuttles and has the capacity to encourage more people to use public transit due to faster trip times compared to shuttles. In this respect, SkyTran can more effectively feed regional connectivity provided by corporate commuter buses and planned expansion of Caltrain.

Various mode choice combinations show, that on an annual cost per employee basis, the lowest cost option is using SkyTran and a surface parking solution at the proposed District Parking lot (see *Appendix IV – Mode Choice Annual Cost Per Employee* and *Appendix V - Commuter Management Costs* for a comparative analysis of parking garage structure, surface parking, and corporate commuter bus costs.)

Other public transit modes were considered but preliminary analysis revealed that deployment of at-grade rail or bus rapid transit using dedicated lanes is impractical due to easement constraints. Elevated rail is a prohibitively expensive solution with costs in excess of $100 million per mile.

In conclusion, local shuttles, rail, and buses lack the on-demand, point-to-point non-stop ride offered by SkyTran ATN service. Compared to other modes, the consumer convenience of ATN is likely to significantly boost system ridership with concurrent reductions in automobile miles traveled. In addition, connections between downtown Mountain View and North Bayshore would be significantly improved due to reduced travel times SkyTran ATN could provide (5 minutes vs. 20 minute by local shuttle). In this scenario, ATN service has the potential to increase downtown economic activity by attracting more people to downtown at lunchtime or after business hours for social occasions. With the downtown parking situation close to saturation the extra business provided by the MV-ATN could increase city and local business revenue that would not otherwise be available. In addition, ATN service to the Google Transit Hub would make Google's corporate commuter bus service more efficient by providing faster last mile connections to Google's various facilities scattered across the North Bayshore area. Improved last mile service could potentially meet Google goals of boosting corporate commuter bus ridership to 50%. MV-ATN offers an enhanced solution that can reallocate existing bus and corporate commuter bus resources to more productive service.

SkyTran, Inc. is engaged in conversations with Mountain View's leadership. The MV-ATN program we propose offers a low cost, high throughput system that reduces congestion, mitigates greenhouse gases and greatly improves regional connectivity via Caltrain, VTA rail & bus. With that goal in mind, we are coordinating our effort with the Santa Clara Valley Transportation Authority (VTA) and the regional transportation planning process (SkyTran has worked with VTA previously on a TIGGER grant proposal). The system is in an evolving state of development and we will continue to work with the Mountain View in their process to adopt innovative solutions as the development of SkyTran proceeds. SkyTran's innovative design has created challenges to financing the technology's development. Aside from the U.S. DOT's $1 million grant, the development team has logged over ten man-years in unreimbursed time and collectively expended several hundred thousands dollars in personal funds to advance the program. The SkyTran team remains committed to realizing the transformative transportation and economic benefits this technology will bring to the United States.

Appendices

APPENDIX I: Projected Local Connection Trip Demand

Year 2020 Peak Period Demand

Company	2020 Total Trips	2012 Car Trips*	2020 District Parking Trips	2020 Bike + Carpool Trips	2020 Corporate Commuter Bus Trips	2020 Caltrain + Light Rail + Public Bus Trips	2020 Local Shuttle or SkyTran Trips**	Demand For Year
Google	30,000	9,000	7,000	1,000	9,000	4,000	14,000	7,000,000
Microsoft	3,000	1,500	750	100	0	650	1,400	700,000
Inuit	2,000	1,000	500	100	0	400	900	450,000
Linked in	2,000	1,000	500	100	0	400	900	450,000
Other	1,000	500	250	100	0	150	400	200,000
Total for Peak Period	**38,000**	**13,000**	**9,000**	**1,400**	**9,000**	**5,600**	**17,600**	**8,800,000**
Total Trips Per Hour	**15,200**	**5,200**	**3,600**	**560**	**3,600**	**2,240**	**7,040**	

Peak period is defined as 2.5 hour window in morning and afternoon. A trip equals one passenger.

* 2012 Cars Trips included to calculate demand projection

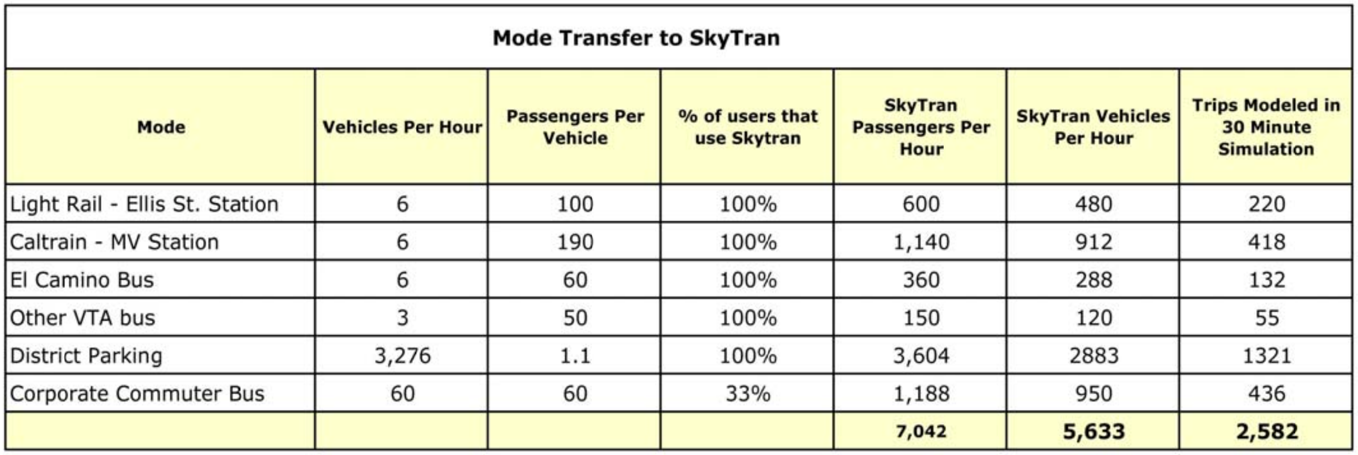
* * Assuming Local Shuttle or SkyTran ATN collects all public transit riders, district parking drivers and 1/3 of commuter bus arrivals.

APPENDIX II: Local Connector Modes

Alternatives Analysis

Mode	Trips Per Hour	Passengers Per Trip	Fleet	Passengers Per Hour	30 Year Capital Cost ($M)	Vehicle Hours Per Year	Annual O&M ($M)	30 Year Total Cost ($M)	Cost Per Trip	Cost per employee per year
SkyTran	7.5	2	467	7005	$117	681,042	$3.7	$227	$0.86	$431
Local Shuttle	2.5	40	70	7000	$61	110,250	$11.0	$392	$1.48	$742

APPENDIX III: Ridership Estimate for Local Connection



Mode Transfer to SkyTran

Mode	Vehicles Per Hour	Passengers Per Vehicle	% of users that use Skytran	SkyTran Passengers Per Hour	SkyTran Vehicles Per Hour	Trips Modeled in 30 Minute Simulation
Light Rail - Ellis St. Station	6	100	100%	600	480	220
Caltrain - MV Station	6	190	100%	1,140	912	418
El Camino Bus	6	60	100%	360	288	132
Other VTA bus	3	50	100%	150	120	55
District Parking	3,276	1.1	100%	3,604	2883	1321
Corporate Commuter Bus	60	60	33%	1,188	950	436
				7,042	**5,633**	**2,582**

APPENDIX IV: Mode Choice Annual Cost Per Employee

Option 1	Parking Garage + Local Shuttle	$3,742
Option 2	Parking Garage + SkyTran	$3,431
Option 3	Corporate Commuter Bus + Shuttle	$2,920
Option 4	Corporate Commuter Bus + SkyTran	$2,608
Option 5	Corporate Commuter Bus + Walk	$2,178
Option 6	Caltrain + Local Shuttle	$2,142
Option 7	Caltrain + SkyTran	$1,831
Option 8	Surface Parking + Local Shuttle	$1,609
Option 9	Surface Parking + SkyTran	$1,297

APPENDIX V - Commuter Management Costs

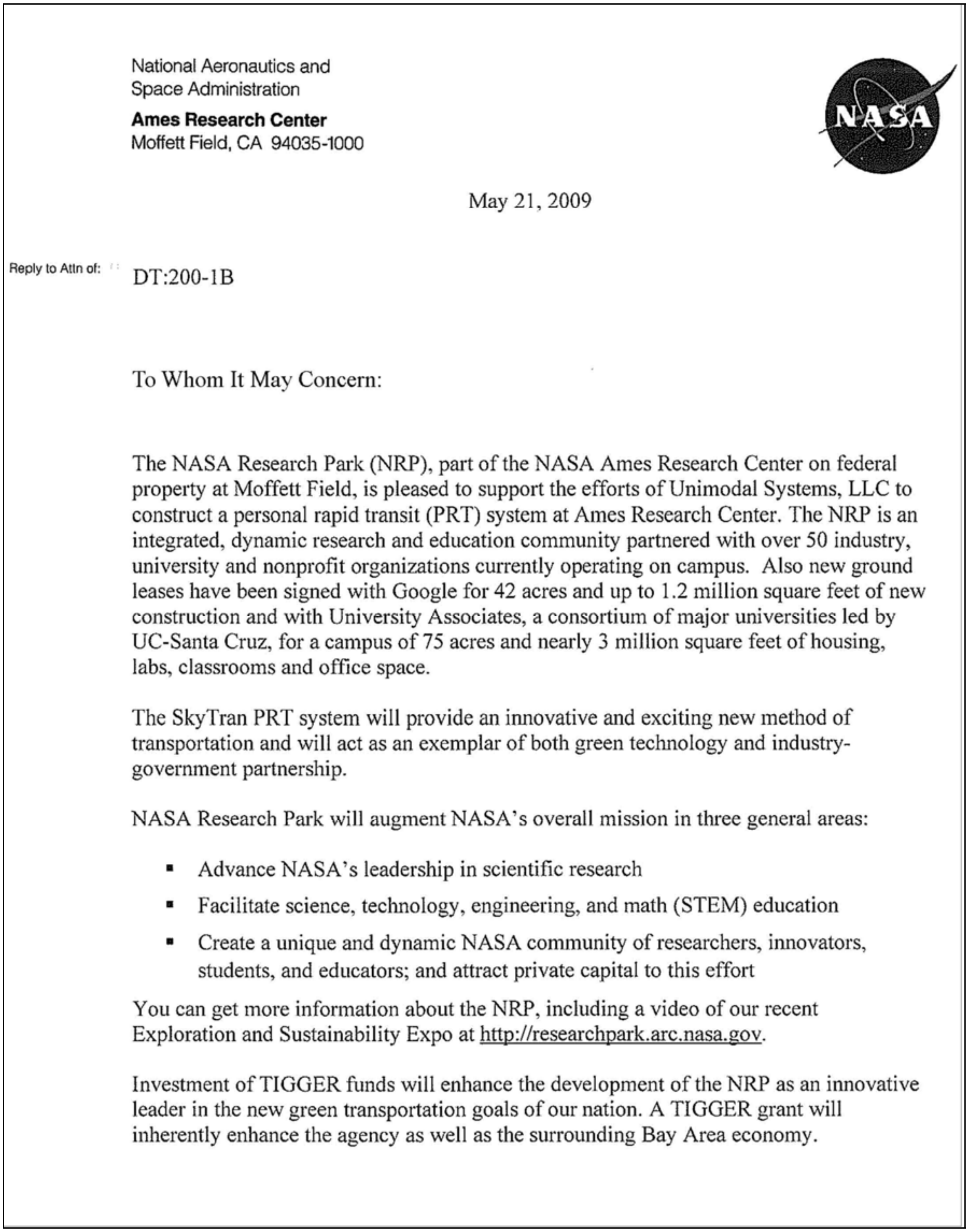
Comparative Costs

Mode	Trips Per Hour	Passengers Per Trip	Fleet	Passengers Per Hour	30 Year Capital Cost ($M)	Vehicle Hours Per Year	Annual O&M ($M)	30 Year Total Cost ($M)	Cost Per Trip	Cost Per Employee Per Year
District Parking - Garage					$270		$5	$405	$6.00	$3,000
District Parking - Surface					$90		$1	$117	$1.73	$867
Corporate Commuter Bus	1	35	105	3675	$92	165,375	$17	$588	$4.36	$2,178

APPENDIX VI : Analysis Assumptions

Life of a bus (years)	12
Cost of CNG Bus	$350,000
Total life of project (years)	30
SkyTran capital cost ($M per mile)	9
Total Unidirectional miles	13
Cost of Surface Parking Space	$10,000
Cost of Parking Garage Space	$30,000
Annual O&M per parking garage space	$500
Annual O&M per surface parking space	$100
Days per year	250
Peak hours per day	5
Off peak hours per day	13
Vehicles running off peak	10%
SkyTran O&M per passenger mile	$0.12
SkyTran MPH	45
Average trip (miles)	3
Bus Average MPH	15
Bus O&M per hour	$100
Bus O&M per mile	$7
SkyTran average miles per trip (including empty)	7
Caltrain Annual Pass	$1,400

Appendix VII – NASA Letter of Support



National Aeronautics and
Space Administration
Ames Research Center
Moffett Field, CA 94035-1000

May 21, 2009

Reply to Attn of: DT:200-1B

To Whom It May Concern:

The NASA Research Park (NRP), part of the NASA Ames Research Center on federal property at Moffett Field, is pleased to support the efforts of Unimodal Systems, LLC to construct a personal rapid transit (PRT) system at Ames Research Center. The NRP is an integrated, dynamic research and education community partnered with over 50 industry, university and nonprofit organizations currently operating on campus. Also new ground leases have been signed with Google for 42 acres and up to 1.2 million square feet of new construction and with University Associates, a consortium of major universities led by UC-Santa Cruz, for a campus of 75 acres and nearly 3 million square feet of housing, labs, classrooms and office space.

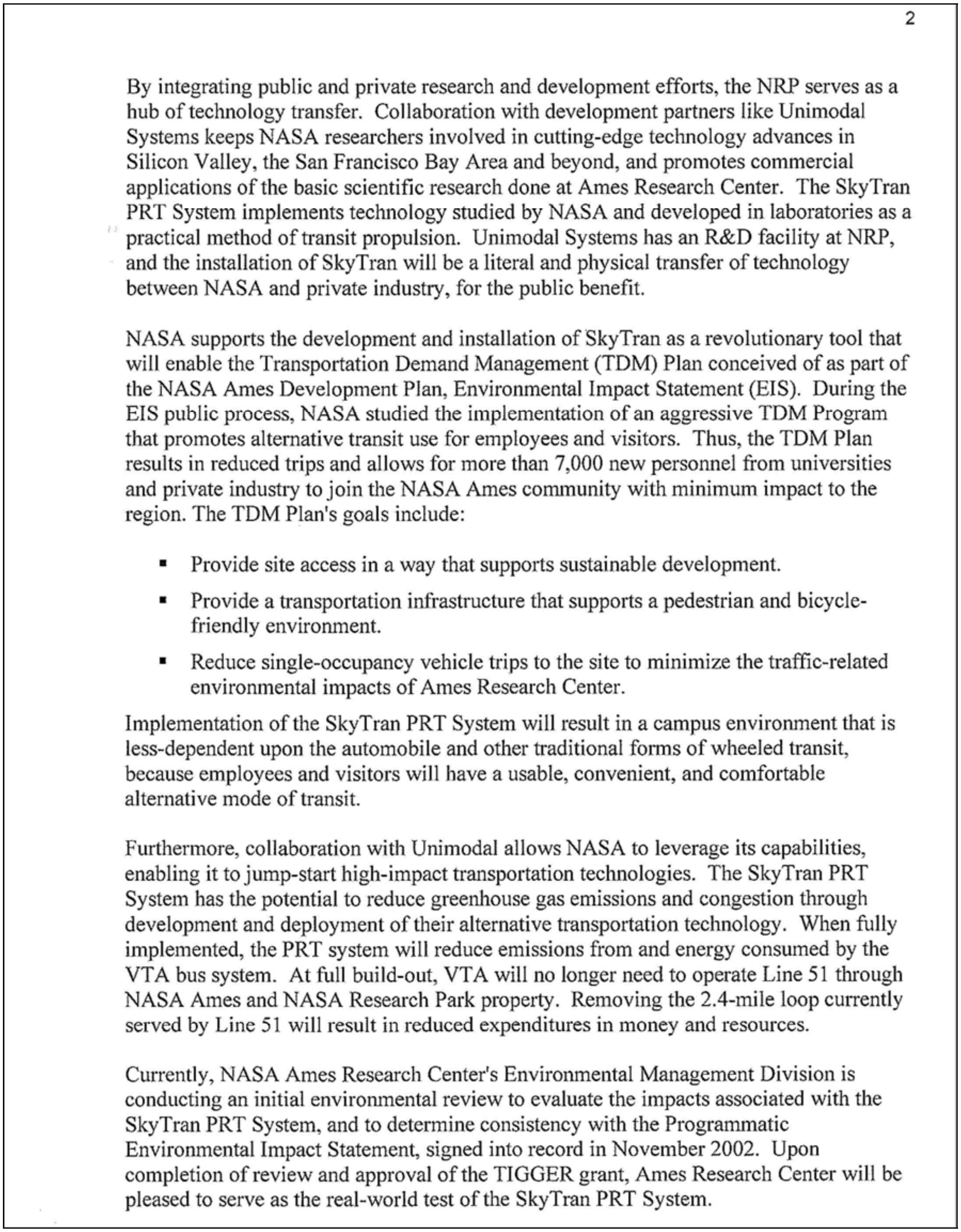
The SkyTran PRT system will provide an innovative and exciting new method of transportation and will act as an exemplar of both green technology and industry-government partnership.

NASA Research Park will augment NASA's overall mission in three general areas:

- Advance NASA's leadership in scientific research
- Facilitate science, technology, engineering, and math (STEM) education
- Create a unique and dynamic NASA community of researchers, innovators, students, and educators; and attract private capital to this effort

You can get more information about the NRP, including a video of our recent Exploration and Sustainability Expo at http://researchpark.arc.nasa.gov.

Investment of TIGGER funds will enhance the development of the NRP as an innovative leader in the new green transportation goals of our nation. A TIGGER grant will inherently enhance the agency as well as the surrounding Bay Area economy.



By integrating public and private research and development efforts, the NRP serves as a hub of technology transfer. Collaboration with development partners like Unimodal Systems keeps NASA researchers involved in cutting-edge technology advances in Silicon Valley, the San Francisco Bay Area and beyond, and promotes commercial applications of the basic scientific research done at Ames Research Center. The SkyTran PRT System implements technology studied by NASA and developed in laboratories as a practical method of transit propulsion. Unimodal Systems has an R&D facility at NRP, and the installation of SkyTran will be a literal and physical transfer of technology between NASA and private industry, for the public benefit.

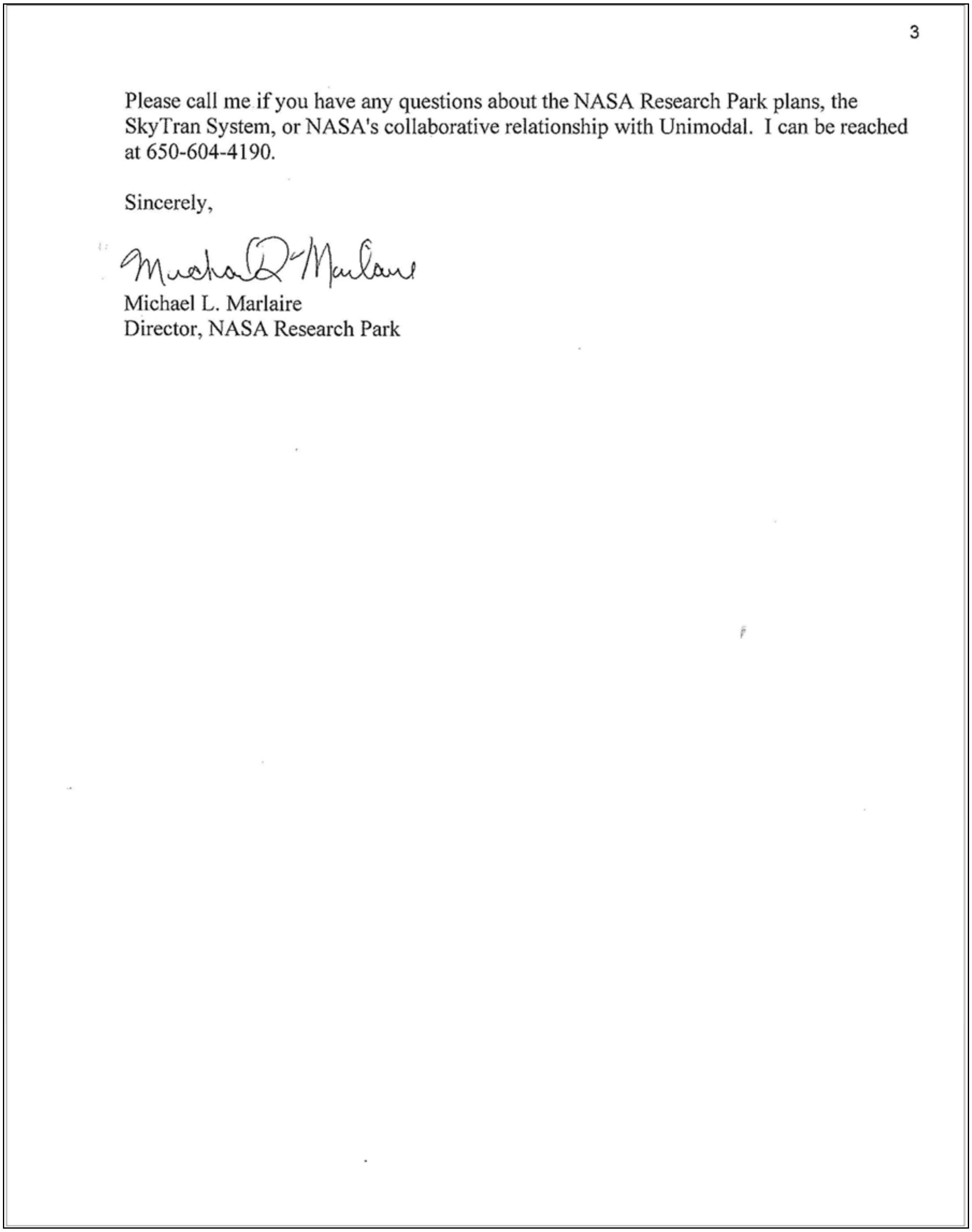
NASA supports the development and installation of SkyTran as a revolutionary tool that will enable the Transportation Demand Management (TDM) Plan conceived of as part of the NASA Ames Development Plan, Environmental Impact Statement (EIS). During the EIS public process, NASA studied the implementation of an aggressive TDM Program that promotes alternative transit use for employees and visitors. Thus, the TDM Plan results in reduced trips and allows for more than 7,000 new personnel from universities and private industry to join the NASA Ames community with minimum impact to the region. The TDM Plan's goals include:

- Provide site access in a way that supports sustainable development.
- Provide a transportation infrastructure that supports a pedestrian and bicycle-friendly environment.
- Reduce single-occupancy vehicle trips to the site to minimize the traffic-related environmental impacts of Ames Research Center.

Implementation of the SkyTran PRT System will result in a campus environment that is less-dependent upon the automobile and other traditional forms of wheeled transit, because employees and visitors will have a usable, convenient, and comfortable alternative mode of transit.

Furthermore, collaboration with Unimodal allows NASA to leverage its capabilities, enabling it to jump-start high-impact transportation technologies. The SkyTran PRT System has the potential to reduce greenhouse gas emissions and congestion through development and deployment of their alternative transportation technology. When fully implemented, the PRT system will reduce emissions from and energy consumed by the VTA bus system. At full build-out, VTA will no longer need to operate Line 51 through NASA Ames and NASA Research Park property. Removing the 2.4-mile loop currently served by Line 51 will result in reduced expenditures in money and resources.

Currently, NASA Ames Research Center's Environmental Management Division is conducting an initial environmental review to evaluate the impacts associated with the SkyTran PRT System, and to determine consistency with the Programmatic Environmental Impact Statement, signed into record in November 2002. Upon completion of review and approval of the TIGGER grant, Ames Research Center will be pleased to serve as the real-world test of the SkyTran PRT System.



Please call me if you have any questions about the NASA Research Park plans, the SkyTran System, or NASA's collaborative relationship with Unimodal. I can be reached at 650-604-4190.

Sincerely,

Michael L. Marlaire
Director, NASA Research Park

Appendix VIII - TRL Assessment Background

In preparing the TRL assessment, we used the GAO definitions as follows:

Technology Readiness Levels	**Description**
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in a rail vehicle or on an actual track system.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of a component of subsystem in its intended system to determine if it meets design specifications.
9. Actual system proven through successful deployment.	Actual application of the technology in its final form and under operational conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development.

Source: GAO/NSIAD-99-162

Various SkyTran components are at different levels of technology readiness, the following summary proposes a roadmap for bringing the SkyTran Technology Development System (TDS) at the NASA Ames Research Center Building 14 from its current state to TRL 9 by building the 1/4 mile Hardware Reference Platform (Phases 1 and 2), followed by the passenger-carrying Initial Operating Segment (IOS). The performance specification for vehicles carrying passengers will be restricted to 30 mph with 15 second headway between vehicles. The system will have to be re-certified for higher speeds and closer headways after operational data is collected.

Justification of the TRL level for each system follows the summary.

Summary

	TDS	HRP Phase 1	HRP Phase 2	IOS Start	IOS End
INFRASTRUCTURE					
Guideway	**4**	**7**	**7**	**8**	**9**
Switch	**2.5**	**6**	**7**	**8**	**9**
Poles & Foundation	**Commercially Available**				
Stations	**Commercially Available**				
Power System	**Commercially Available**				
VEHICLE					
Levitation & Propulsion	**4**	**7**	**7**	**8**	**9**
Motor Drive Electronics	**Commercially Available**				
CONTROL SYSTEM					
Communication System	**Commercially Available**				
Control System	**4**	**7**	**7**	**8**	**9**
Security System	**Commercially Available**				

Assessment # 1 of 10

Major System Element: Guideway

TRL Level (if not fully commercial): 4

Manufacturer or Source: SAPA

Substantiating Information: A subscale prototype system was installed at the NASA Ames Research Center in June 2012. The system includes eight functional sections of guideway mounted on one-meter tall poles that are positioned 4m apart. In order to demonstrate levitation and propulsion, a 50kg bogie was built. The bogie was composed of four adjustable pitch maglev wings that react with two pairs of vertical lifting members and a central maglev drive unit that reacts with a 15cm diameter hollow aluminum tube for propulsion. The bogie also has four wheels that are used to support the vehicle at slow speeds. Currently, the vehicle launches under its own power and levitations 1 cm above the track after reaching a speed that exceeds 4 m/s without any active guidance or control system. When the levitation force is too large, the magnets move vertically out of the rails and cause the levitation force to decrease. Complete failure of the control system does not result in loss of levitation force. The guidance and control system will serve to reduce magnetic drag and counteract loads from wind, guideway deflection and switching and steering. The data collected from these subscale experiments have allowed us to validate our model of lift, drag and propulsion. The full-scale vehicle bogie can now be finalized by simply linear scaling of the results from the subscale track.

Assessment # 2 of 10

Major System Element: Switch

TRL Level (if not fully commercial): 2

Manufacturer or Source (if commercially available):

Substantiating Information: The switch is composed of straight section of guideway and a curve without any propulsion tube. Conceptual design and a CAD model of the switch are complete. Next steps include modeling of the force in the switch and finalizing design parameters based on modeling results. There will be no control elements other than position sensors in the switch; all steering control will be handled in the vehicle. Upon completion of the prototype, we will be able to validate the forces in the model.

Assessment # 3 of 10

Major System Element: Poles and Foundation

TRL Level (if not fully commercial): Commercial product

Manufacturer or Source (if commercially available): We are in discussions with several vendors that can fabricate steel poles and the hanger element to our specifications.

Assessment # 4 of 10

Major System Element: Stations

TRL Level (if not fully commercial): Commercially available designs

Manufacturer or Source (if commercially available): Jenkins Gales Martinez

Substantiating Information (may be attached): Jenkins Gales Martinez has designed and built stations for major rail projects. SkyTran stations are similar in complexity to a light rail or people mover system.

Assessment # 5 of 10

Major System Element: Power System

TRL Level (if not fully commercial): Commercial Product

Manufacturer or Source (if commercially available): ABB

Substantiating Information: We have done extensive testing with the ABB M1 drive for both wayside power converter and in vehicle motor drive. This is an off the shelf product in high volume production.

Assessment # 6 of 10

Major System Element: Vehicle levitation and propulsion

TRL Level (if not fully commercial): 4

Manufacturer or Source (if commercially available):

Substantiating Information: The TDS platform at NASA building 14 is a fully functional subscale prototype that demonstrates levitation and propulsion on a 30m long track with a 50 kg bogie. Levitation exceeds one cm vertically, once the vehicle exceeds 4 m/s. We collected test data for the following parameters: velocity, acceleration, motor power, rpm, magnet mass, vertical position, take-off velocity. Experimental data confirms our mathematical model and gives us confidence to scale up to full size.

Assessment # 7 of 10

Major System Element: Vehicle motor drive

TRL Level (if not fully commercial): Commercial product

Manufacturer or Source (if commercially available): ABB

Substantiating Information: We have done extensive testing with the ABB M1 drive for in vehicle motor drive. This is an off the shelf fan-cooled product is in high volume production. This item has not yet been integrated into the TDS but will be part of the HRP system.

Assessment # 8 of 10

Major System Element: Communication system

TRL Level (if not fully commercial): Commercial product

Manufacturer or Source (if commercially available): Digi (wireless), Belden (wired)

Substantiating Information: The wired network routers and fiber optic cable require high temperature outdoor rating. Traditional communication products are design for environmentally controlled data centers and are not acceptable for our requirements. This led us to select Belden due to their expertise in designing products for hostile environments. Digi has excellent wireless products that can be used to keep high-speed vehicles in constant data communications with multiple wireless points spaced along the guideway.

Assessment # 9 of 10

Major System Element: Control system

TRL Level (if not fully commercial): 4

Substantiating Information (may be attached): All elements of the control system have been implemented and tested in the PRT simulator. Vehicle networks with 3,000 vehicles at 30 m/s speeds with half second spacing have been simulated using actual acceleration profiles of the actual vehicles. Although the algorithms are tested and verified, there is significant work to be done to test and modify the system to work in a full-scale prototype. The scope of the HRP project will be to demonstrate merging and switching with three vehicles only. Development (and regulatory approval) of the software necessary for larger networks is within the scope of the IOS project.

Assessment # 10 of 10

Major System Element: Security system

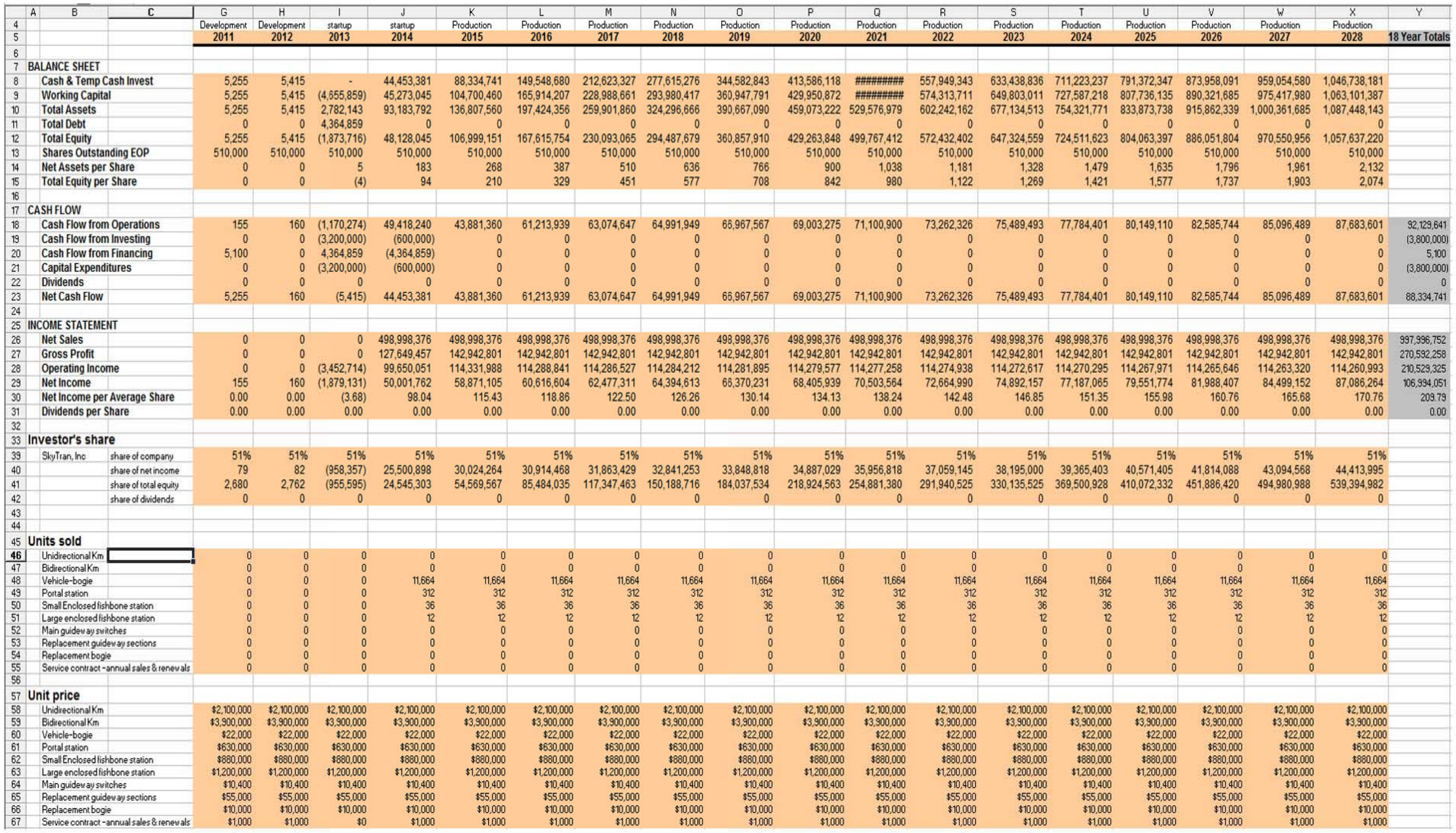
TRL Level (if not fully commercial): Commercial product

Manufacturer or Source (if commercially available): Belden

Substantiating Information: The network security requirements for Skytran are similar to other types of infrastructure projects and are within the scope of off the shelf products. Customization will be required to meet the specific software requirements and can be implemented as needed by the vendor.

Appendix IX

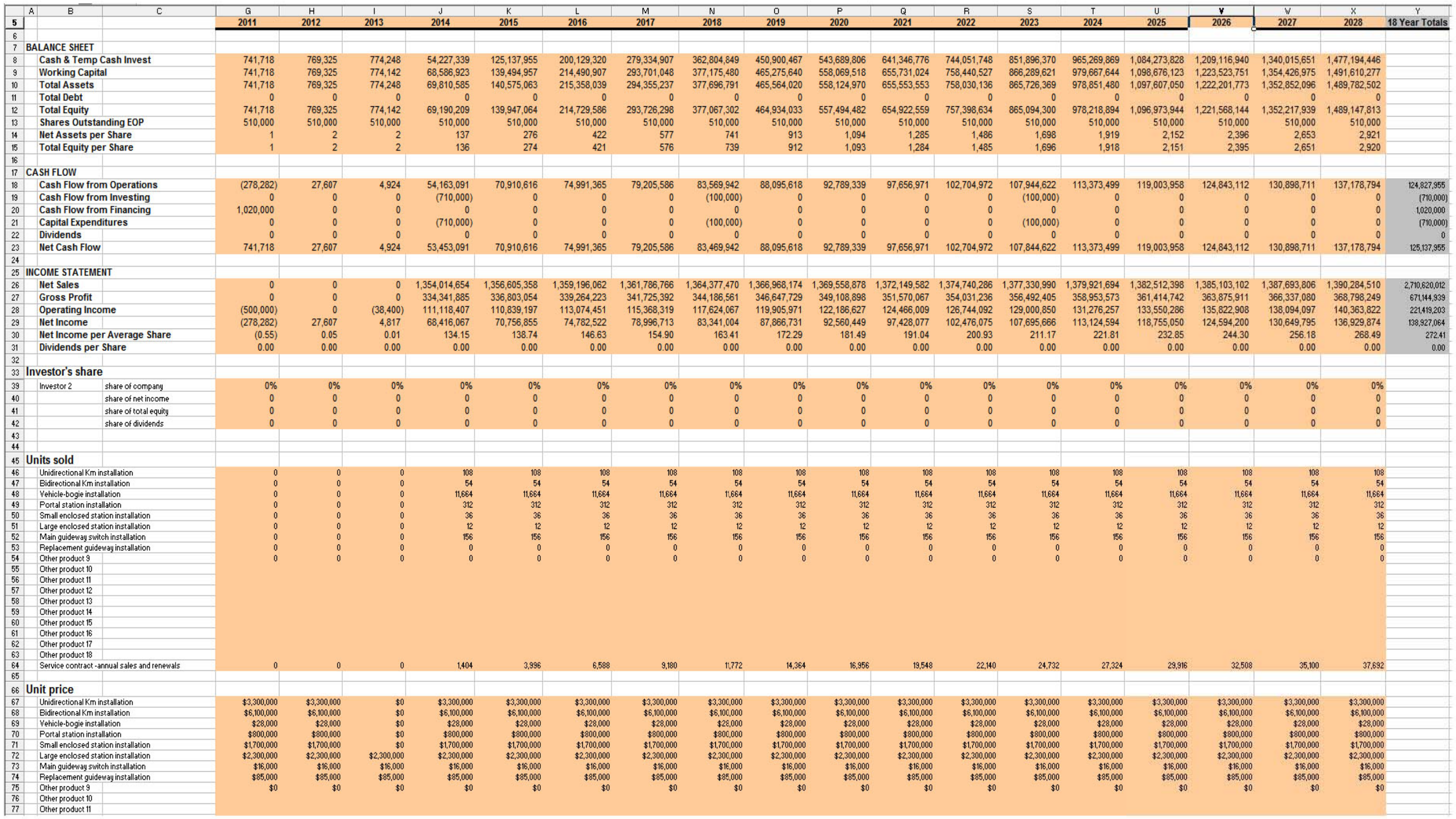
SkyTran Manufacturing
Financial Plan Summary



	A	B	C	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
4				Development	Development	startup	startup	Production	Production	Production	Production	Production	Production	Production	Production	Production	Production	Production	Production	Production	Production	
5				**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**18 Year Totals**
6																						
7	**BALANCE SHEET**																					
8		**Cash & Temp Cash Invest**		5,255	5,415	-	44,453,381	88,334,741	149,548,680	212,623,327	277,615,276	344,582,843	413,586,118	#########	557,949,343	633,438,836	711,223,237	791,372,347	873,958,091	959,054,580	1,046,738,181	
9		**Working Capital**		5,255	5,415	(4,655,859)	45,273,045	104,700,460	165,914,207	228,988,661	293,980,417	360,947,791	429,950,872	#########	574,313,711	649,803,011	727,587,218	807,736,135	890,321,685	975,417,980	1,063,101,387	
10		**Total Assets**		5,255	5,415	2,782,143	93,183,792	136,807,560	197,424,356	259,901,860	324,296,666	390,667,090	459,073,222	529,576,979	602,242,162	677,134,513	754,321,771	833,873,738	915,862,339	1,000,361,685	1,087,448,143	
11		**Total Debt**		0	0	4,364,859	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12		**Total Equity**		5,255	5,415	(1,873,716)	48,128,045	106,999,151	167,615,754	230,093,065	294,487,679	360,857,910	429,263,848	499,767,412	572,432,402	647,324,559	724,511,623	804,063,397	886,051,804	970,550,956	1,057,637,220	
13		**Shares Outstanding EOP**		510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	
14		**Net Assets per Share**		0	0	5	183	268	387	510	636	766	900	1,038	1,181	1,328	1,479	1,635	1,796	1,961	2,132	
15		**Total Equity per Share**		0	0	(4)	94	210	329	451	577	708	842	980	1,122	1,269	1,421	1,577	1,737	1,903	2,074	
16																						
17	**CASH FLOW**																					
18		**Cash Flow from Operations**		155	160	(1,170,274)	49,418,240	43,881,360	61,213,939	63,074,647	64,991,949	66,967,567	69,003,275	71,100,900	73,262,326	75,489,493	77,784,401	80,149,110	82,585,744	85,096,489	87,683,601	92,129,641
19		**Cash Flow from Investing**		0	0	(3,200,000)	(600,000)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(3,800,000)
20		**Cash Flow from Financing**		5,100	0	4,364,859	(4,364,859)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,100
21		**Capital Expenditures**		0	0	(3,200,000)	(600,000)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	(3,800,000)
22		**Dividends**		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23		**Net Cash Flow**		5,255	160	(5,415)	44,453,381	43,881,360	61,213,939	63,074,647	64,991,949	66,967,567	69,003,275	71,100,900	73,262,326	75,489,493	77,784,401	80,149,110	82,585,744	85,096,489	87,683,601	88,334,741
24																						
25	**INCOME STATEMENT**																					
26		**Net Sales**		0	0	0	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	498,998,376	997,996,752
27		**Gross Profit**		0	0	0	127,649,457	142,942,801	142,942,801	142,942,801	142,942,801	142,942,801	142,942,801	142,942,801	142,942,801	142,942,801	142,942,801	142,942,801	142,942,801	142,942,801	142,942,801	270,592,258
28		**Operating Income**		0	0	(3,452,714)	99,650,051	114,331,988	114,288,841	114,286,527	114,284,212	114,281,895	114,279,577	114,277,258	114,274,938	114,272,617	114,270,295	114,267,971	114,265,646	114,263,320	114,260,993	210,529,325
29		**Net Income**		155	160	(1,879,131)	50,001,762	58,871,105	60,616,604	62,477,311	64,394,613	66,370,231	68,405,939	70,503,564	72,664,990	74,892,157	77,187,065	79,551,774	81,988,407	84,499,152	87,086,264	106,994,051
30		**Net Income per Average Share**		0.00	0.00	(3.68)	98.04	115.43	118.86	122.50	126.26	130.14	134.13	138.24	142.48	146.85	151.35	155.98	160.76	165.68	170.76	209.79
31		**Dividends per Share**		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32																						
33	**Investor's share**																					
39		SkyTran, Inc	share of company	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	
40			share of net income	79	82	(958,357)	25,500,898	30,024,264	30,914,468	31,863,429	32,841,253	33,848,818	34,887,029	35,956,818	37,059,145	38,195,000	39,365,403	40,571,405	41,814,088	43,094,568	44,413,995	
41			share of total equity	2,680	2,762	(955,595)	24,545,303	54,569,567	85,484,035	117,347,463	150,188,716	184,037,534	218,924,563	254,881,380	291,940,525	330,135,525	369,500,928	410,072,332	451,886,420	494,980,988	539,394,982	
42			share of dividends	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
43																						
44																						
45	**Units sold**																					
46		Unidirectional Km		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
47		Bidirectional Km		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
48		Vehicle-bogie		0	0	0	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	
49		Portal station		0	0	0	312	312	312	312	312	312	312	312	312	312	312	312	312	312	312	
50		Small Enclosed fishbone station		0	0	0	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	
51		Large enclosed fishbone station		0	0	0	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	
52		Main guideway switches		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
53		Replacement guideway sections		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
54		Replacement bogie		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
55		Service contract - annual sales & renewals		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
56																						
57	**Unit price**																					
58		Unidirectional Km		$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	$2,100,000	
59		Bidirectional Km		$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	$3,900,000	
60		Vehicle-bogie		$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	$22,000	
61		Portal station		$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	$630,000	
62		Small Enclosed fishbone station		$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	$880,000	
63		Large enclosed fishbone station		$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	
64		Main guideway switches		$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	$10,400	
65		Replacement guideway sections		$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	
66		Replacement bogie		$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	
67		Service contract - annual sales & renewals		$1,000	$1,000	$0	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	

Appendix X

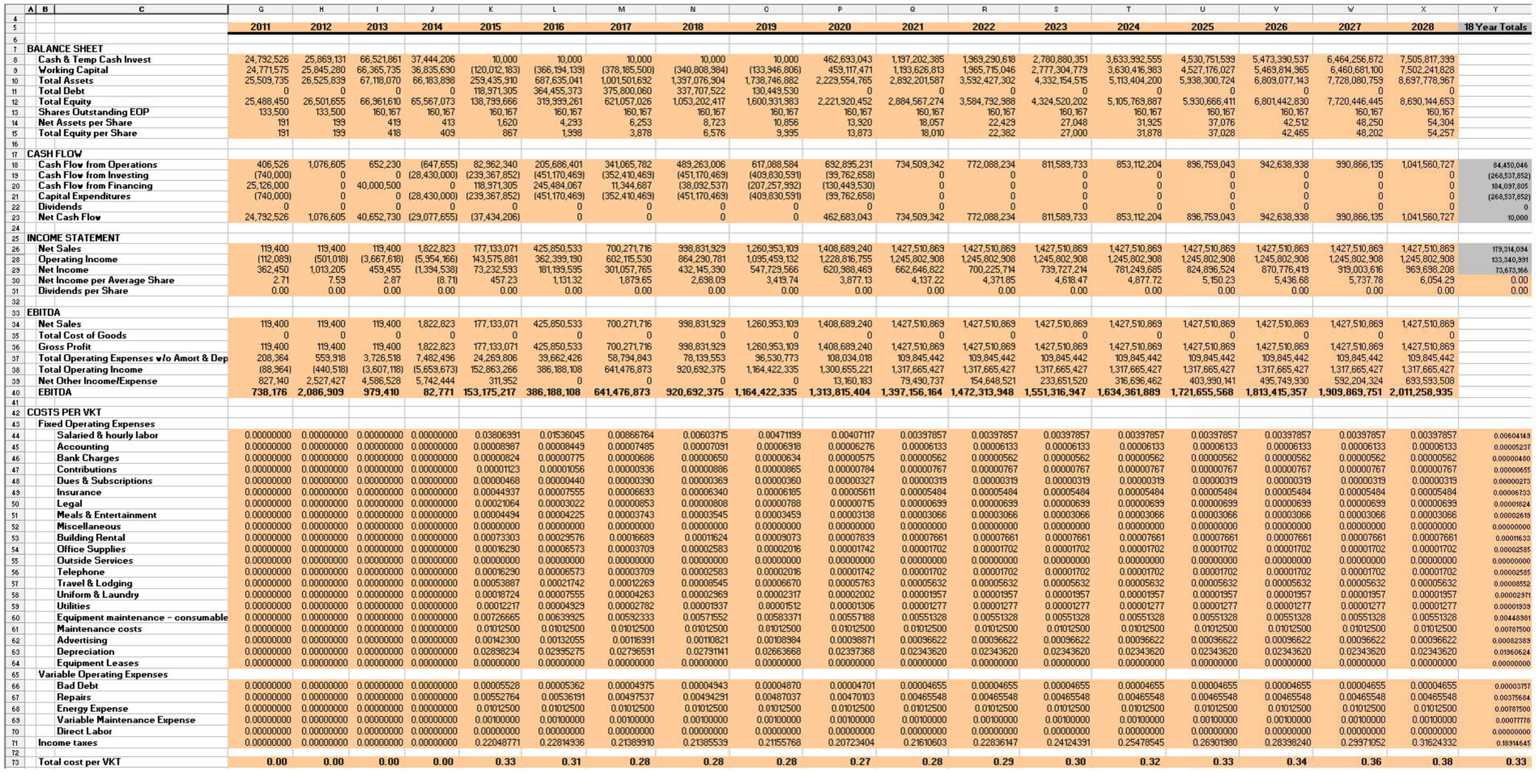
SkyTran Integration
Financial Plan Summary



	A	B	C	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
5				2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	18 Year Totals
6																						
7	BALANCE SHEET																					
8		**Cash & Temp Cash Invest**		741,718	769,325	774,248	54,227,339	125,137,955	200,129,320	279,334,907	362,804,849	450,900,467	543,689,806	641,346,776	744,051,748	851,896,370	965,269,869	1,084,273,828	1,209,116,940	1,340,015,651	1,477,194,446	
9		**Working Capital**		741,718	769,325	774,142	68,586,923	139,494,957	214,490,907	293,701,048	377,175,480	465,275,640	558,069,518	655,731,024	758,440,527	866,289,621	979,667,644	1,098,676,123	1,223,523,751	1,354,426,975	1,491,610,277	
10		**Total Assets**		741,718	769,325	774,248	69,810,585	140,575,063	215,358,039	294,355,237	377,696,791	465,564,020	558,124,970	655,553,553	758,030,136	865,726,369	978,851,480	1,097,607,050	1,222,201,773	1,352,852,096	1,489,782,502	
11		**Total Debt**		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12		**Total Equity**		741,718	769,325	774,142	69,190,209	139,947,064	214,729,586	293,726,298	377,067,302	464,934,033	557,494,482	654,922,559	757,398,634	865,094,300	978,218,894	1,096,973,944	1,221,568,144	1,352,217,939	1,489,147,813	
13		**Shares Outstanding EOP**		510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	510,000	
14		**Net Assets per Share**		1	2	2	137	276	422	577	741	913	1,094	1,285	1,486	1,698	1,919	2,152	2,396	2,653	2,921	
15		**Total Equity per Share**		1	2	2	136	274	421	576	739	912	1,093	1,284	1,485	1,696	1,918	2,151	2,395	2,651	2,920	
16																						
17	CASH FLOW																					
18		**Cash Flow from Operations**		(278,282)	27,607	4,924	54,163,091	70,910,616	74,991,365	79,205,586	83,569,942	88,095,618	92,789,339	97,656,971	102,704,972	107,944,622	113,373,499	119,003,958	124,843,112	130,898,711	137,178,794	124,827,955
19		**Cash Flow from Investing**		0	0	0	(710,000)	0	0	0	(100,000)	0	0	0	0	(100,000)	0	0	0	0	0	(710,000)
20		**Cash Flow from Financing**		1,020,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,020,000
21		**Capital Expenditures**		0	0	0	(710,000)	0	0	0	(100,000)	0	0	0	0	(100,000)	0	0	0	0	0	(710,000)
22		**Dividends**		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23		**Net Cash Flow**		741,718	27,607	4,924	53,453,091	70,910,616	74,991,365	79,205,586	83,469,942	88,095,618	92,789,339	97,656,971	102,704,972	107,844,622	113,373,499	119,003,958	124,843,112	130,898,711	137,178,794	125,137,955
24																						
25	INCOME STATEMENT																					
26		**Net Sales**		0	0	0	1,354,014,654	1,356,605,358	1,359,196,062	1,361,786,766	1,364,377,470	1,366,968,174	1,369,558,878	1,372,149,582	1,374,740,286	1,377,330,990	1,379,921,694	1,382,512,398	1,385,103,102	1,387,693,806	1,390,284,510	2,710,620,012
27		**Gross Profit**		0	0	0	334,341,885	336,803,054	339,264,223	341,725,392	344,186,561	346,647,729	349,108,898	351,570,067	354,031,236	356,492,405	358,953,573	361,414,742	363,875,911	366,337,080	368,798,249	671,144,939
28		**Operating Income**		(500,000)	0	(38,400)	111,118,407	110,839,197	113,074,451	115,368,319	117,624,067	119,905,971	122,186,627	124,466,009	126,744,092	129,000,850	131,276,257	133,550,286	135,822,908	138,094,097	140,363,822	221,419,203
29		**Net Income**		(278,282)	27,607	4,817	68,416,067	70,756,855	74,782,522	78,996,713	83,341,004	87,866,731	92,560,449	97,428,077	102,476,075	107,695,666	113,124,594	118,755,050	124,594,200	130,649,795	136,929,874	138,927,064
30		**Net Income per Average Share**		(0.55)	0.05	0.01	134.15	138.74	146.63	154.90	163.41	172.29	181.49	191.04	200.93	211.17	221.81	232.85	244.30	256.18	268.49	272.41
31		**Dividends per Share**		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32																						
33	**Investor's share**																					
39		Investor 2	share of company	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
40			share of net income	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
41			share of total equity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
42			share of dividends	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
43																						
44																						
45	**Units sold**																					
46		Unidirectional Km installation		0	0	0	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	
47		Bidirectional Km installation		0	0	0	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	
48		Vehicle-bogie installation		0	0	0	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	11,664	
49		Portal station installation		0	0	0	312	312	312	312	312	312	312	312	312	312	312	312	312	312	312	
50		Small enclosed station installation		0	0	0	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	
51		Large enclosed station installation		0	0	0	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	
52		Main guideway switch installation		0	0	0	156	156	156	156	156	156	156	156	156	156	156	156	156	156	156	
53		Replacement guideway installation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
54		Other product 9		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
55		Other product 10																				
56		Other product 11																				
57		Other product 12																				
58		Other product 13																				
59		Other product 14																				
60		Other product 15																				
61		Other product 16																				
62		Other product 17																				
63		Other product 18																				
64		Service contract -annual sales and renewals		0	0	0	1,404	3,996	6,588	9,180	11,772	14,364	16,956	19,548	22,140	24,732	27,324	29,916	32,508	35,100	37,692	
65																						
66	**Unit price**																					
67		Unidirectional Km installation		$3,300,000	$3,300,000	$0	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	$3,300,000	
68		Bidirectional Km installation		$6,100,000	$6,100,000	$0	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	$6,100,000	
69		Vehicle-bogie installation		$28,000	$28,000	$0	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	$28,000	
70		Portal station installation		$800,000	$800,000	$0	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	$800,000	
71		Small enclosed station installation		$1,700,000	$1,700,000	$0	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	$1,700,000	
72		Large enclosed station installation		$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	$2,300,000	
73		Main guideway switch installation		$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	$16,000	
74		Replacement guideway installation		$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	$85,000	
75		Other product 9		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
76		Other product 10																				
77		Other product 11																				

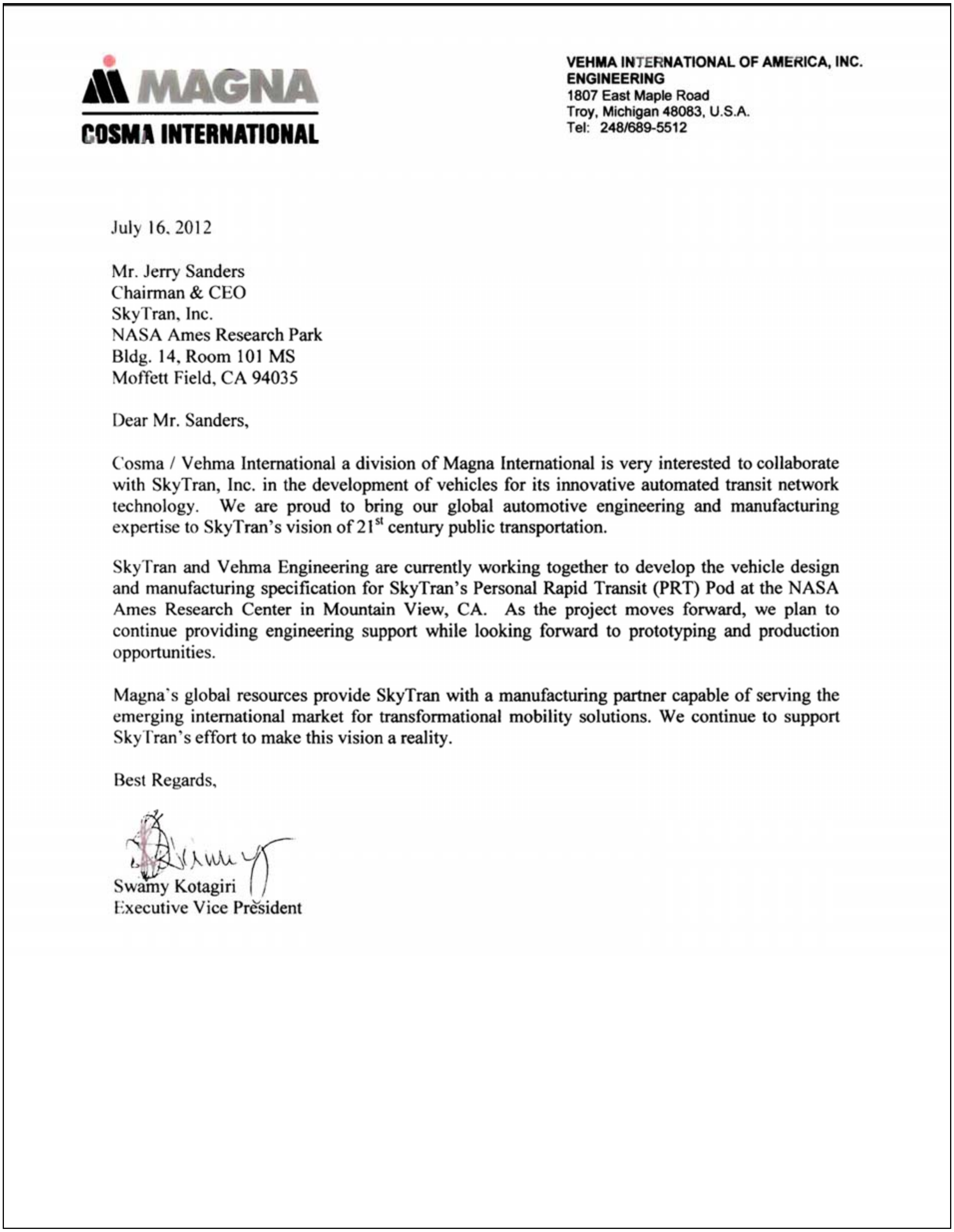
Appendix XI

SkyTran 20x10km Operations by 2020
Financial Plan Summary



	A	B	C	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
4																						
5				**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**18 Year Totals**
6																						
7	BALANCE SHEET																					
8		Cash & Temp Cash Invest		24,792,526	25,869,131	66,521,861	37,444,206	10,000	10,000	10,000	10,000	10,000	462,693,043	1,197,202,385	1,969,290,618	2,780,880,351	3,633,992,555	4,530,751,599	5,473,390,537	6,464,256,672	7,505,817,399	
9		Working Capital		24,771,575	25,845,280	66,365,735	36,835,690	(120,012,183)	(366,194,139)	(378,185,500)	(340,808,984)	(133,946,806)	459,117,471	1,193,626,813	1,965,715,046	2,777,304,779	3,630,416,983	4,527,176,027	5,469,814,965	6,460,681,100	7,502,241,828	
10		Total Assets		25,509,735	26,525,839	67,118,070	66,183,898	259,435,910	687,635,041	1,001,501,692	1,397,076,904	1,738,746,882	2,229,554,765	2,892,201,587	3,592,427,302	4,332,154,515	5,113,404,200	5,938,300,724	6,809,077,143	7,728,080,759	8,697,778,967	
11		Total Debt		0	0	0	0	118,971,305	364,455,373	375,800,060	337,707,522	130,449,530	0	0	0	0	0	0	0	0	0	
12		Total Equity		25,488,450	26,501,655	66,961,610	65,567,073	138,799,666	319,999,261	621,057,026	1,053,202,417	1,600,931,983	2,221,920,452	2,884,567,274	3,584,792,988	4,324,520,202	5,105,769,887	5,930,666,411	6,801,442,830	7,720,446,445	8,690,144,653	
13		Shares Outstanding EOP		133,500	133,500	160,167	160,167	160,167	160,167	160,167	160,167	160,167	160,167	160,167	160,167	160,167	160,167	160,167	160,167	160,167	160,167	
14		Net Assets per Share		191	199	419	413	1,620	4,293	6,253	8,723	10,856	13,920	18,057	22,429	27,048	31,925	37,076	42,512	48,250	54,304	
15		Total Equity per Share		191	199	418	409	867	1,998	3,878	6,576	9,995	13,873	18,010	22,382	27,000	31,878	37,028	42,465	48,202	54,257	
16																						
17	CASH FLOW																					
18		Cash Flow from Operations		406,526	1,076,605	652,230	(647,655)	82,962,340	205,686,401	341,065,782	489,263,006	617,088,584	692,895,231	734,509,342	772,088,234	811,589,733	853,112,204	896,759,043	942,638,938	990,866,135	1,041,560,727	84,450,046
19		Cash Flow from Investing		(740,000)	0	0	(28,430,000)	(239,367,852)	(451,170,469)	(352,410,469)	(451,170,469)	(409,830,591)	(99,762,658)	0	0	0	0	0	0	0	0	(268,537,852)
20		Cash Flow from Financing		25,126,000	0	40,000,500	0	118,971,305	245,484,067	11,344,687	(38,092,537)	(207,257,992)	(130,449,530)	0	0	0	0	0	0	0	0	184,097,805
21		Capital Expenditures		(740,000)	0	0	(28,430,000)	(239,367,852)	(451,170,469)	(352,410,469)	(451,170,469)	(409,830,591)	(99,762,658)	0	0	0	0	0	0	0	0	(268,537,852)
22		Dividends		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23		Net Cash Flow		24,792,526	1,076,605	40,652,730	(29,077,655)	(37,434,206)	0	0	0	0	462,683,043	734,509,342	772,088,234	811,589,733	853,112,204	896,759,043	942,638,938	990,866,135	1,041,560,727	10,000
24																						
25	INCOME STATEMENT																					
26		Net Sales		119,400	119,400	119,400	1,822,823	177,133,071	425,850,533	700,271,716	998,831,929	1,260,953,109	1,408,689,240	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	179,314,094
28		Operating Income		(112,089)	(501,018)	(3,667,618)	(5,954,166)	143,575,881	362,399,190	602,115,530	864,290,781	1,095,459,132	1,228,816,755	1,245,802,908	1,245,802,908	1,245,802,908	1,245,802,908	1,245,802,908	1,245,802,908	1,245,802,908	1,245,802,908	133,340,991
29		Net Income		362,450	1,013,205	459,455	(1,394,538)	73,232,593	181,199,595	301,057,765	432,145,390	547,729,566	620,988,469	662,646,822	700,225,714	739,727,214	781,249,685	824,896,524	870,776,419	919,003,616	969,698,208	73,673,166
30		Net Income per Average Share		2.71	7.59	2.87	(8.71)	457.23	1,131.32	1,879.65	2,698.09	3,419.74	3,877.13	4,137.22	4,371.85	4,618.47	4,877.72	5,150.23	5,436.68	5,737.78	6,054.29	0.00
31		Dividends per Share		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32																						
33	EBITDA																					
34		Net Sales		119,400	119,400	119,400	1,822,823	177,133,071	425,850,533	700,271,716	998,831,929	1,260,953,109	1,408,689,240	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	
35		Total Cost of Goods		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
36		Gross Profit		119,400	119,400	119,400	1,822,823	177,133,071	425,850,533	700,271,716	998,831,929	1,260,953,109	1,408,689,240	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	1,427,510,869	
37		Total Operating Expenses w/o Amort & Dep		208,364	559,918	3,726,518	7,482,496	24,269,806	39,662,426	58,794,843	78,139,553	96,530,773	108,034,018	109,845,442	109,845,442	109,845,442	109,845,442	109,845,442	109,845,442	109,845,442	109,845,442	
38		Total Operating Income		(88,964)	(440,518)	(3,607,118)	(5,659,673)	152,863,266	386,188,108	641,476,873	920,692,375	1,164,422,335	1,300,655,221	1,317,665,427	1,317,665,427	1,317,665,427	1,317,665,427	1,317,665,427	1,317,665,427	1,317,665,427	1,317,665,427	
39		Net Other Income/Expense		827,140	2,527,427	4,586,528	5,742,444	311,952	0	0	0	0	13,160,183	79,490,737	154,648,521	233,651,520	316,696,462	403,990,141	495,749,930	592,204,324	693,593,508	
40		EBITDA		**738,176**	**2,086,909**	**979,410**	**82,771**	**153,175,217**	**386,188,108**	**641,476,873**	**920,692,375**	**1,164,422,335**	**1,313,815,404**	**1,397,156,164**	**1,472,313,948**	**1,551,316,947**	**1,634,361,889**	**1,721,655,568**	**1,813,415,357**	**1,909,869,751**	**2,011,258,935**	
41																						
42	COSTS PER VKT																					
43		Fixed Operating Expenses																				
44			Salaried & hourly labor	0.00000000	0.00000000	0.00000000	0.00000000	0.03806991	0.01536045	0.00866764	0.00603715	0.00471199	0.00407117	0.00397857	0.00397857	0.00397857	0.00397857	0.00397857	0.00397857	0.00397857	0.00397857	0.00604149
45			Accounting	0.00000000	0.00000000	0.00000000	0.00000000	0.00008987	0.00008449	0.00007485	0.00007091	0.00006918	0.00006276	0.00006133	0.00006133	0.00006133	0.00006133	0.00006133	0.00006133	0.00006133	0.00006133	0.00005237
46			Bank Charges	0.00000000	0.00000000	0.00000000	0.00000000	0.00000824	0.00000775	0.00000686	0.00000650	0.00000634	0.00000575	0.00000562	0.00000562	0.00000562	0.00000562	0.00000562	0.00000562	0.00000562	0.00000562	0.00000480
47			Contributions	0.00000000	0.00000000	0.00000000	0.00000000	0.00001123	0.00001056	0.00000936	0.00000886	0.00000865	0.00000784	0.00000767	0.00000767	0.00000767	0.00000767	0.00000767	0.00000767	0.00000767	0.00000767	0.00000655
48			Dues & Subscriptions	0.00000000	0.00000000	0.00000000	0.00000000	0.00000468	0.00000440	0.00000390	0.00000369	0.00000360	0.00000327	0.00000319	0.00000319	0.00000319	0.00000319	0.00000319	0.00000319	0.00000319	0.00000319	0.00000273
49			Insurance	0.00000000	0.00000000	0.00000000	0.00000000	0.00044937	0.00007555	0.00006693	0.00006340	0.00006185	0.00005611	0.00005484	0.00005484	0.00005484	0.00005484	0.00005484	0.00005484	0.00005484	0.00005484	0.00006733
50			Legal	0.00000000	0.00000000	0.00000000	0.00000000	0.00021064	0.00003022	0.00000853	0.00000808	0.00000788	0.00000715	0.00000699	0.00000699	0.00000699	0.00000699	0.00000699	0.00000699	0.00000699	0.00000699	0.00001824
51			Meals & Entertainment	0.00000000	0.00000000	0.00000000	0.00000000	0.00004494	0.00004225	0.00003743	0.00003545	0.00003459	0.00003138	0.00003066	0.00003066	0.00003066	0.00003066	0.00003066	0.00003066	0.00003066	0.00003066	0.00002619
52			Miscellaneous	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
53			Building Rental	0.00000000	0.00000000	0.00000000	0.00000000	0.00073303	0.00029576	0.00016689	0.00011624	0.00009073	0.00007839	0.00007661	0.00007661	0.00007661	0.00007661	0.00007661	0.00007661	0.00007661	0.00007661	0.00011633
54			Office Supplies	0.00000000	0.00000000	0.00000000	0.00000000	0.00016290	0.00006573	0.00003709	0.00002583	0.00002016	0.00001742	0.00001702	0.00001702	0.00001702	0.00001702	0.00001702	0.00001702	0.00001702	0.00001702	0.00002585
55			Outside Services	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
56			Telephone	0.00000000	0.00000000	0.00000000	0.00000000	0.00016290	0.00006573	0.00003709	0.00002583	0.00002016	0.00001742	0.00001702	0.00001702	0.00001702	0.00001702	0.00001702	0.00001702	0.00001702	0.00001702	0.00002585
57			Travel & Lodging	0.00000000	0.00000000	0.00000000	0.00000000	0.00053887	0.00021742	0.00012269	0.00008545	0.00006670	0.00005763	0.00005632	0.00005632	0.00005632	0.00005632	0.00005632	0.00005632	0.00005632	0.00005632	0.00008552
58			Uniform & Laundry	0.00000000	0.00000000	0.00000000	0.00000000	0.00018724	0.00007555	0.00004263	0.00002969	0.00002317	0.00002002	0.00001957	0.00001957	0.00001957	0.00001957	0.00001957	0.00001957	0.00001957	0.00001957	0.00002971
59			Utilities	0.00000000	0.00000000	0.00000000	0.00000000	0.00012217	0.00004929	0.00002782	0.00001937	0.00001512	0.00001306	0.00001277	0.00001277	0.00001277	0.00001277	0.00001277	0.00001277	0.00001277	0.00001277	0.00001939
60			Equipment maintenance - consumable	0.00000000	0.00000000	0.00000000	0.00000000	0.00726665	0.00639925	0.00592333	0.00571552	0.00583371	0.00557188	0.00551328	0.00551328	0.00551328	0.00551328	0.00551328	0.00551328	0.00551328	0.00551328	0.00448981
61			Maintenance costs	0.00000000	0.00000000	0.00000000	0.00000000	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.00787500
62			Advertising	0.00000000	0.00000000	0.00000000	0.00000000	0.00142300	0.00132055	0.00116991	0.00110821	0.00108984	0.00098871	0.00096622	0.00096622	0.00096622	0.00096622	0.00096622	0.00096622	0.00096622	0.00096622	0.00082389
63			Depreciation	0.00000000	0.00000000	0.00000000	0.00000000	0.02898234	0.02995275	0.02796591	0.02791141	0.02663668	0.02397368	0.02343620	0.02343620	0.02343620	0.02343620	0.02343620	0.02343620	0.02343620	0.02343620	0.01960624
64			Equipment Leases	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
65		Variable Operating Expenses																				
66			Bad Debt	0.00000000	0.00000000	0.00000000	0.00000000	0.00005528	0.00005362	0.00004975	0.00004943	0.00004870	0.00004701	0.00004655	0.00004655	0.00004655	0.00004655	0.00004655	0.00004655	0.00004655	0.00004655	0.00003757
67			Repairs	0.00000000	0.00000000	0.00000000	0.00000000	0.00552764	0.00536191	0.00497537	0.00494291	0.00487037	0.00470103	0.00465548	0.00465548	0.00465548	0.00465548	0.00465548	0.00465548	0.00465548	0.00465548	0.00375684
68			Energy Expense	0.00000000	0.00000000	0.00000000	0.00000000	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.01012500	0.00787500
69			Variable Maintenance Expense	0.00000000	0.00000000	0.00000000	0.00000000	0.00100000	0.00100000	0.00100000	0.00100000	0.00100000	0.00100000	0.00100000	0.00100000	0.00100000	0.00100000	0.00100000	0.00100000	0.00100000	0.00100000	0.00077778
70			Direct Labor	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
71		Income taxes		0.00000000	0.00000000	0.00000000	0.00000000	0.22048771	0.22814936	0.21389910	0.21385539	0.21155768	0.20723404	0.21610603	0.22836147	0.24124391	0.25478545	0.26901980	0.28398240	0.29971052	0.31624332	0.18914645
72																						
73		Total cost per VKT		**0.00**	**0.00**	**0.00**	**0.00**	**0.33**	**0.31**	**0.28**	**0.28**	**0.28**	**0.27**	**0.28**	**0.29**	**0.30**	**0.32**	**0.33**	**0.34**	**0.36**	**0.38**	**0.33**

Appendix XII - Strategic Partners Letters



MAGNA
COSMA INTERNATIONAL

VEHMA INTERNATIONAL OF AMERICA, INC.
ENGINEERING
1807 East Maple Road
Troy, Michigan 48083, U.S.A.
Tel: 248/689-5512

July 16, 2012

Mr. Jerry Sanders
Chairman & CEO
SkyTran, Inc.
NASA Ames Research Park
Bldg. 14, Room 101 MS
Moffett Field, CA 94035

Dear Mr. Sanders,

Cosma / Vehma International a division of Magna International is very interested to collaborate with SkyTran, Inc. in the development of vehicles for its innovative automated transit network technology. We are proud to bring our global automotive engineering and manufacturing expertise to SkyTran's vision of 21st century public transportation.

SkyTran and Vehma Engineering are currently working together to develop the vehicle design and manufacturing specification for SkyTran's Personal Rapid Transit (PRT) Pod at the NASA Ames Research Center in Mountain View, CA. As the project moves forward, we plan to continue providing engineering support while looking forward to prototyping and production opportunities.

Magna's global resources provide SkyTran with a manufacturing partner capable of serving the emerging international market for transformational mobility solutions. We continue to support SkyTran's effort to make this vision a reality.

Best Regards,

Swamy Kotagiri
Executive Vice President

July 3, 2012

sapa:

Mr. Jerry Sanders
Chairman & CEO
SkyTran, Inc.
NASA Ames Research Park
Bldg. 14, Room 101 MS
Moffett Field, CA 94035

Dear Mr. Sanders,

Thank you very much for enabling the recent discussions on SkyTran's effort to develop the guideway components for its innovative automated transit network technology. As you are aware, Sapa Extrusions is the largest provider of aluminum extrusions in the world and we look forward to adding our world-class extrusion capabilities to your endeavors. Specifically, our City of Industry, CA and Portland, OR locations are conveniently located to support your production needs while our engineering specialists from our North American Tech Center (Portland, OR) are uniquely qualified to assist in our collaboration.

SkyTran and Sapa NATC engineers are currently working together to develop the guideway design and manufacturing specifications for SkyTran's Hardware Reference Platform at the NASA Ames Research Center in Mountain View, CA. This includes designing the necessary dies, materials and best design for the aluminum guideway for the NASA HRP project. This will also ensure a smooth transition as we progress from the design to manufacturing phases.

Sapa's global extrusion resources and production facilities provide SkyTran with a guideway supply partner capable of servicing the emerging markets for SkyTran's green, innovative transportation solution. We are proud to support SkyTran's effort to make this vision a reality.

Best regards,

Matt Zundel

Matthew M Zundel
Sales Director - West Region
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EXHIBITS

The following exhibits are available on Dropbox.com due to file size:

Exhibit A – MV-ATN Morning Rush Hour Start Up Simulation
Exhibit B – New Google Building @ NASA Station Simulation
Exhibit C – Guideway Merge Point Simulation
Exhibit D – Guideway Flyover Simulation
Exhibit E – Bus Transfer to Multi-berth Station Animation
Exhibit F – Visualizations
Exhibit G – NASA HRP Animation
Exhibit H – Sub-scale Maglev-Linear Motor Operation
Exhibit I – SkyTran Manufacturing Plant Financial Plan Summary
Exhibit J – SkyTran Integration Financial Plan Summary
Exhibit K – SkyTran 10 x20km Operations By 2020 Financial Plan Summary