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AGS Project Memo

To:	CDOT DTR, AGS PLT & AGS Technical Committee	Date:	November 8, 2012
		Subject:	Review of Statements of Technical Information (SOTI)
From:	Mike Riggs, PE	Project No:	AZE1208

The purpose of this memo is to provide CDOT, the AGS PLT, and the AGS Technical Committee with the recommendations as to technologies to be further studied in the AGS Feasibility Study.

On September 7, 2012, we issued the Request for Statements of Technology Information. The SOTIs were received on October 10, 2012. We received 18 SOTIs. Table 1 below presents the technologies that submitted SOTIs.

Table 1: SOTIs Received

ET3	Owen Transportation Group
American Maglev	Personal Rapid Transit Consulting
Flight Rail	Public Personal Rapid Transit Consortium
General Atomics	Roane Inventions (TriTrack)
Kestrel	SkyTran
MagneMotion	Swift Tram
Mediatrik/Techtronics	Talgo
MegaRail	TransRapid
Monobeam	Tubular Rail

The 18 SOTIs were first reviewed for conformance to the submittal requirements of the RFSOTI. All were found to be substantially in compliance.

In order for technology providers to move forward for further consideration, they were required to be able to meet six qualifying criteria. Those criteria include:

Qualification Criteria 1: Travel Time (Section 3.1) – Responses as to how the technology will meet the minimum speed requirements and provide a minimum capacity of 4,900 passengers per hour in the peak direction by 2035 will be evaluated to determine if the technology is qualified for further analysis.

Qualification Criteria 2: Grade (Section 3.5) – Responses as to how the technology can cost-effectively traverse the grades within the I-70 Mountain Corridor will be evaluated to determine if the technology is qualified for further analysis.

Qualification Criteria 3: Safety (Section 3.6) – Responses to how Technology Providers will meet applicable safety standards and test data or system expectations concerning safety will be evaluated to determine if the technology is qualified for further analysis. Responses to how the technology addresses requirements to provide grade-separated and wildlife crossings, an access controlled guideway, emergency egress from the vehicles and guideway including guideway on structure and guideway in tunnels, and system security will be evaluated to determine if the technology is qualified for further analysis.

Qualification Criteria 4: Weather/Wind (Section 3.7) – Responses as to how technologies can operate in severe weather events and extreme alpine windstorms while still maintaining safety and reliability will be evaluated to determine if the technology is qualified for further analysis.

Qualification Criteria 5: Light Freight (Section 3.11) – Responses from Technology Providers as

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to how they will be able to accommodate light freight will be evaluated to determine if the technology is qualified for further analysis.

Qualification Criteria 6: Technology Readiness (Section 3.25) - Responses as to how the technology will meet the Technology Readiness Level (TRL) requirements (3.25) will be reviewed. Because being at TRL 9 by 2017 is a prime requirement of the candidate technologies, this is a qualification criterion. The Consultant Review Team will assess the Technology Provider's verified plan to attain Technology Readiness Level 9 by 2017 and will determine, based on the current TRL and the demonstrated ability to reach TRL 9 by 2017, if the technology is qualified to be included for further analysis.

Mike Riggs and Pamela Bailey-Campbell were the principal reviewers for the qualification criteria. They reviewed each of the SOTIs to determine if the responses provided by the technology providers were sufficient to meet the minimum requirements of each qualification criteria. If only minor clarification from a technology provider was needed, a Request for Clarification (RFC) was issued to the technology provider. If a technology provider failed to provide information on multiple criteria or if their responses to any of the criteria were below the minimum required, then they were not qualified for further review and analysis.

Table 2 provides the results of the qualification criteria analysis.

Table 2: Qualification Criteria Analysis Results

Technology Provider	QC 1	QC 2	QC 3	QC 4	QC 5	QC 6	Qualified	RFC
American Maglev	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Flight Rail	Yes	Yes	Yes	Yes	Yes	Yes	Yes	RFC Sent 10/18/12
General Atomics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
MagneMotion	Yes	Yes	Yes	Yes	Yes	Yes	Yes	RFC Sent 10/17/12
MegaRail	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Owen Transportation Group	Yes	Yes	Yes	Yes	Yes	Yes	Yes	RFC Sent 10/17/12
Public Personal Rapid Transit Consortium	Yes	Yes	Yes	Yes	Yes	Yes	Yes	RFC Sent 10/17/12
SkyTran	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Swift Tram	Yes	Yes	Yes	Yes	Yes	Yes	Yes	RFC Sent 10/18/12
Talgo	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
TransRapid	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
ET3	Yes	Yes	No	Yes	Yes	No	No	No
Kestrel	No	No	No	No	No	No	No	No
Mediatrik/Techtronics	No	No	No	No	No	No	No	No
Monobeam	Yes	No	No	No	No	No	No	No
Personal Rapid Transit Consulting	No	Yes	Yes	Yes	Yes	Yes	No	No
Roane Inventions (TriTrack)	Yes	Yes	Yes	Yes	Yes	No	No	No
Tubular Rail	No	No	No	Yes	Yes	No	No	No

In total, 11 of the 18 SOTIs were found to be qualified for further review.

A Consultant Review Team made up of AZTEC, TYPSA, CA Group, OV Consulting, Jacobs and Exponential Engineering then reviewed each SOTI, concentrating on specific criteria for which they have expertise. The following review assignments were made:

AZTEC – Travel Time, Grade, Weather & Wind, Safety, Freight, Technology Readiness, Additional Technology Information
TYPSA – Tunnels, Vehicles, Passenger Comfort, Baggage Capacity, Cost
CA Group – Footprint, CSS, Right of Way
OV Consulting – Station Characteristics
Jacobs – Travel Time, Grade, Weather & Wind, Safety, Freight, Technology Readiness, Interface with Existing & Future Transit Systems, Noise, Scalability and Growth, Sustainability, Termini, Owner/Operator, Environmental, Reliability, Headway
Exponential Engineering – Power Generation, Transmission, Energy Efficiency

The role of the Consultant Review Team is to make recommendations to DTR and the PLT as to which technologies meet each of the system performance and operational criteria, meet the Technology Readiness Level requirements and which technologies should be invited to participate in the Technology Forum.

The Consultant Review Team was provided with an Adjectival Evaluation Matrix. They were asked to review the information provided in the SOTI and rate the responses. Because it was anticipated that some SOTI responses would require minor clarification, the Consultant Review Team was asked to prepare RFCs that were forwarded to the technology providers.

Table 3: Adjectival Evaluation Matrix

Adjective	Description	Maximum Points
Excellent (E)	Proposer demonstrated (1) an approach that significantly exceeds stated criteria in a way that is beneficial to Department; (2) a consistent level of quality; and (3) an extremely strong ability of successful Project performance. There are essentially no weaknesses. Proposer exceeds the requirements or stated criteria	**5**
Very Good (VG)	Proposer demonstrated (1) an approach that exceeds many stated criteria; and (2) generally better than acceptable quality. Weaknesses, if any, are minor, and could slightly affect successful Project performance adversely.	**4**
Good (G)	Proposer demonstrated (1) an approach that meets stated criteria; (2) an acceptable level of quality; and (3) a reasonable probability of success. Weaknesses exist but can be overcome with reasonable measures in a manner that meets the requirements of the RFP. Proposer meets	**3**

Adjective	Description	Maximum Points
	the requirement or stated criteria.	
Fair (F)	Proposer demonstrated (1) an approach that is deficient in many stated criteria; and (2) a considerable marginality in terms of the required content and/or amount of information provided for evaluation. Modification would be required for the Proposal to be acceptable. Such weaknesses would adversely affect successful Project performance.	**2**
Poor (P)	Proposer demonstrated (1) an approach that significantly fails to meet the stated criteria; and (2) a lack of essential, required information, and/or conflicting or unproductive information. Weaknesses and/or deficiencies are so major and/or extensive that there is little likelihood of success.	**1**
None	Proposer fails to address the requirements or stated criteria in any material fashion or entirely fails to meet the requirements and stated criteria.	**0**

Even though the AGS Feasibility Study will not end up with a “preferred technology”, the ranking of individual technology providers gives a good indication as to which technologies are more “feasible” than others. Table 4 provides rankings of the SOTIs for each technology provider.

Table 4: SOTI Rankings

Technology Provider	Rank
American Maglev Transit	1st
Talgo	2nd
Transrapid	Tie – 3rd
Owen Transit Group	Tie – 3rd
MegaRail	Tie - 4th
PPRTC	Tie – 4th
General Atomics	Tie – 5th
SkyTran	Tie – 5th
Swift Tram	6th
FlightRail	7th
MagneMotion	8th

In order to provide CDOT, the AGS PLT, and the AGS Technical Committee with a summary of each technology, the technology providers were asked to submit a paragraph describing their technology. These are provided below.

American Maglev Transit

With a strong focus on sustainability, AMT's transit technology is based on optimized magnetic levitation and linear induction propulsion that is entirely electric and non-polluting. This technology is well suited for Colorado, as it is designed to traverse steep grades of up to 10% and is extraordinarily compatible with wintry climate conditions since the traction is frictionless and is inherently not affected by moderate levels of ice or snow. Daily passenger demands will be accommodated with vehicles that will comfortably carry approximately 200 passengers as well as their luggage and recreational equipment, while offering an excellent level of service with wireless internet and restroom facilities. Traveling by AMT technology will reduce trip times between DIA and Vail; the trains will operate faster than a car with no traffic atop a grade-separate, dedicated guideway within the I-70 corridor -- no additional rights-of-way are needed. The technology is fully automated and requires little maintenance, therefore featuring very low capital and operating costs that can be recovered by reasonable transit fares and revenues. AMT technology is fully compliant with the US FTA Automated Peoplemover Code and all applicable regional standards as well. Since its inception in 1994, AMT has invested millions of dollars in research and development of its advanced zero-emitting, next-generation transportation technology, which has attracted world-class strategic partners and significant corporate investment. In April 2010, AMT signed a 10-year exclusive partnership with Grupo ACS for joint development of transportation projects worldwide. In August 2012, the team contracted with Lockheed-Martin to add tremendous value in manufacturing and technical expertise to the team. Rather than simply provide rail technology components, AMT, ACS and Lockheed-Martin specialize in the broad capability to design, finance, build, operate and maintain transportation systems over a project lifetime. Most importantly, the team has the ability to bring private financing packages and create sustainable Public-Private-Partnerships that create transformative change in the development and management of transportation infrastructure.

FlightRail

The VECTORR™ is a high-speed, light weight atmospheric transportation system that uses vacuum/air pressure to move passenger modules along an elevated guideway. Stationary power systems create vacuum/pressure inside a continuous pneumatic tube located centrally below rails within a truss assembly. As these power systems pull the air from the tube, they create a vacuum in front of a free piston that is rail guided inside the power tube. The free piston is magnetically coupled to the passenger modules above. Additionally, air enters the tube behind the free piston to create a differential pressure. The magnetic coupling allows the interior of the power tube to be a closed system to maintain the desired pressure differential in the tube. The transportation unit operates above the power tube on a pair of parallel, steel rails which receive, support, and guides the wheels of the truck assemblies. The passenger modules feature independent wheels angled at 45° that are locked onto the rails. This wheel configuration allows the system to operate in severe weather conditions. Since traction conditions are not required, the guideway can be lubricated for reduction of friction and noise abatement. Flight Rail Corp. currently has a 1/6 scale pilot model operating on an outdoor test guideway. The guideway is 1500 feet long and incorporates 2%, 6%, and 10% grades. The pilot model operates at speeds up to 25 m.p.h. which equates to a scale speed of 150 m.p.h. Preparations are being made to extend the guideway an additional 700 feet to include a 180° curve with a 48 foot radius. This equates to a full size train operating on a 288 foot radius or 20° curve (at restricted speeds). The foregoing characteristics would fit well with the requirements of

the I-70 Corridor. The power tube and supporting structure are very adaptable to enabling ice and snow removal and also serve as a power distribution platform related to power requirements between major power stations.

General Atomics

More than 30 firms and financial institutions, in close concert with the Federal Transit Administration (FTA), have collaboratively developed the technology we are proposing for installation along the I-70 mountain corridor. The Colorado MAGLEV Group is prepared to commence immediately to finance, design, build, operate, maintain and own or lease an advanced guideway transportation system that serves the needs of corridor communities. Research that shaped this technology started in 1990 and more than $40 million from, private, federal, and state coffers have been spent during its development. We believe it to be the most advanced, American designed MAGLEV technology currently available for transporting freight and passengers. The $14 million test track constructed by our team at the General Atomics campus in La Jolla, California, has demonstrated that the following performance characteristics would serve the unique service demands of the I-70 corridor: (1) no right-of-way purchases would be required as the technology can be placed entirely within the existing I-70 envelope, (2) the system can be deployed on an elevated structure supported by 30 to 60 foot columns holding 80 to 100 foot double track guideway platforms (22 ft. in width) that can be produced locally and placed with light cranes deployed from completed sections, (3) capital costs of the guideway are only a third those of light rail or rubber tired alternatives, (4) operating and maintenance costs will be a fourth those of rail systems, (5) environmental impacts (esp., noise and emissions) are minimal as the MAGLEV technology is friction free and relies on a linear synchronous motor for propulsion which is embedded in the guideway, (6) the system should operate reliably (99+%) in all but the most extreme weather conditions and command grades of as much as 15% without a degradation in speed or performance, (7) the esthetics of columns and structures supporting the vehicles, including stations, can conform with community preferences, (8) speeds of 150 mph are possible with headways of as little as 20 seconds between consorts, (9) 100 passenger cars in four car trains would be standard, and (10) it has been demonstrated that this technology will carry standard truck containers using the existing guideway configuration. Levitated with Halbach permanent magnet arrays installed in the guideway, control systems are greatly simplified and largely limited to providing appropriate electrical inputs to the linear synchronous motor.

Magnemotion

The MagneMotion Maglev System ***"M3"*** is designed as the "Green" alternative to all conventional guided transportation systems. Efficient Linear Synchronous Motor (LSM) propulsion and control enables small, closely spaced, light weight vehicles to meet passenger capacities of 12,000 people per hour per direction at an estimated cost of $30M per km of dual guideway (after land acquisition and station costs). Operational costs are reduced with automated controls, reduced power requirements, and regenerative braking. Trip times are reduced with higher accelerations and greater vehicle density. ***M3*** development has been funded as part of a cooperative agreement between MagneMotion and the Federal Transit Administration. There are two operating test systems, one indoors at MagneMotion, and a second outdoor demonstration system at Old Dominion University in Norfolk Virginia. These systems have met their design goals and as of October 31, 2012, have logged a combined total of more than 6,850 km, 1084 hours and 145,500 start and stop cycles.

MegaRail

High-speed ***MegaWay*** systems provide electrified, all-elevated, maintenance-free stainless steel ***SuperWays***™ and a family of electrically powered, rubber-tire vehicles that operate in a similar manner to that of road vehicles on standard freeways. It is a multi-purpose system capable of transporting passengers, people in their own, standard cars, and both light and heavy cargo intermixed on the same ***SuperWay***. It offers a high-speed, low-cost, electrically powered, low air pollution, *all-weather* alternate to cars and trucks on roads with traffic capacity equivalent to that of a six-lane freeway. Passengers ride seated in comfortable cabins or in their own standard cars. Light and heavy cargo is carried in enclosed, weatherproof containers fully compatible with standard flatbed and box trucks. Factory-built ***SuperWays*** include enclosed wheelways that contain traction surfaces, wheels, power pickups, power and steering rails, position references, digital communication links and failure-tolerant guideway control systems. The unique wheelways protect all functional items from weather. Full operation is possible in all weather including 150-mph winds. The exact 600-vdc power used by vehicles is generated by small, natural gas powered generators on ***SuperWay*** support columns. Welded, stainless steel gas supply lines are supported below the ***SuperWay***. Standard grid power lines or substations are not required.

Owen Transit Group

OTG offers both high-capacity transit and high speed rail systems, using individual passenger vehicles running quietly in two directions on opposite sides of a single elevated concrete monorail beam, high above the snows and traffic. The systems require no changes to existing roadways, and use tilting cabin design for operating within the curving I-70 corridor. They have very high horsepower VFD electric motors for ascending mountain grades while using multiple brake systems for descending mountain grades, returning power to the electrical grid. Rails are steel, heated to remove ice and snow. Construction costs per mile are low, as are the operating costs for the automated systems, allowing them to be self-sustaining with competitive fares. Although they have not yet been built as systems, the technology is proven because it uses proven-in-service off-the-shelf components.

PPRTC

The PPRTC template for urban efficiency starts with a Personal Rapid Transit (PRT) system, or pod-cars on a fixed guideway that deliver 1 to 4 passengers at-a-time or freight container(s). The vehicles use an air lifting mechanism integrated with magnetic induction propulsion. The cushion of air generated underneath the pod-car takes the place of maintenance-intensive wheels effectively eliminating friction; sequential application of electromagnets between the guideway and vehicle accelerate, brake and stop the vehicle. The elevated guideway, which preserves grade level spaces, also serves as the conduit of system power and telecommunications. Housing the power and fiber-optic communications components inside the PRT's carbon-fiber pylons and guideway makes them impervious to extreme weather or other attack both physical and virtual. The generation of system power occurs onsite at each PRT station using Hydrogen Fuel Cells (HFCs) initially fed by natural gas, eventually migrating to a diversity of renewable sources of Hydrogen. With a Microgrid Power Management (MPM) scheme, realtime data and keen predictive formulae are used to control generation with surgical precision. HFC generation and MPM together make it possible to achieve a zero carbon footprint while having zero impact on the grid. PRT is the ideal choice for an I-70 AGS because whether at high or low velocity, a trip experience is "Rapid" due to never waiting for transit per

schedule and never stopping en route, that is, point-to-point and on-demand. These two features, intrinsic to the PRT model, plus the fact that it is a driverless medium (50-75% of the cost of transit), make it significantly more efficient than conventional modes saving time, energy and money for the operator and the rider. Moreover, untold efficiencies are to be had in the building and maintaining of 1 construct versus 3 with a deployment schedule measured in months versus the years that traditional solutions take. Finally, by generating multiple revenue streams from the various components of the template the operation can achieve economic sustainability.

SkyTran

SkyTran is an Automated Transit Network (ATN) technology that provides on-demand, point-to-point, non-stop service. These characteristics boost ridership by providing a level of performance, convenience and comfort that meets or exceeds an automobile ride. SkyTran uses a fleet of two-passenger automated electric vehicles (AEV) that travel on a network of slim, elevated guideways. The AEV uses a breakthrough maglev-linear motor powertrain that delivers high-speeds (100 mph), high reliability (no wheels to fail) and a comfortable ride (seats wider than a first-class airline seat). SkyTran technology is designed for building scalable networks. This capability is ideal for the AGS as SkyTran can provide direct feeder service to mountain communities by making a no-transfer connection to the main I-70 alignment. SkyTran's vision is to deliver the ultimate customer experience: a one seat ride from Denver International Airport to the ski resort of your choice.

SwiftTram

Swift Tram is in business to manufacture a new rapid transit system based on the century-old concept of the hanging train. Swift Tram is a people-mover and freight-mover that's electrically powered and elevated. It's a fully automated fixed guideway transportation system featuring coaches in two sizes suspended from the guideway by a hinge. Drive bogies traveling inside the guideway at speeds that can exceed 100 miles per hour provide 'swarm computing' intelligence, system diagnostics, and routine system maintenance. System operation will be available on both a scheduled and an on-demand 24/7 basis. Swift Tram is a Boulder Colorado-based startup in design and engineering stage, currently applying for patents on 12 technology patents for the system. Swift is successfully addressing the issues of grid power outage and emergency & ADA passenger evacuation. This right-sized, light-footprint system is considerably less expensive to install than light rail, and is considerably less expensive to operate than BRT. The company is creating the safest, cleanest, most cost-effective, and most energy efficient rapid transit system in the world.

Talgo

Talgo offers a unique combination of innovation and proven technology that assures a high degree of satisfaction among all concerned, passengers, owners and operators. Furthermore, the equipment Talgo will propose will be fully compliant with US DOT, Federal Railroad Administration regulations and fully* compatible with the US railway network, eliminating regulatory uncertainty while providing unexcelled flexibility for years to come. Talgo's "independent wheels" and "natural tilting" system will reduce wheel wear and permit faster speeds within the I-70 right-of-way than will be possible with conventional railroad equipment, yet the technology used to produce this result has proven itself over nearly three decades' of continuous service. Propulsion energy will come from the commercial electric grid and be applied to the rail using frame hung traction motors and conventional adhesion. (We are not

proposing a cog railway). While this arrangement will mean the route will need to divert from the I-70 alignment at some places, the same will true of every other technology other than "bus rapid transit" because none can share the existing E-J Memorial Tunnel bores. Regenerative braking will be used to minimize the net power requirement, likely producing the most energy efficient form of transportation that will be offered.

Transrapid

Flying on the ground….Quiet, comfortable, fast, safe, clean, reliable - one of the most modern high-speed Transportation Systems in the world. Developed over the last 30 years in Germany, the Transrapid high-speed Maglev system consists of the electromagnetic levitation, the guidance and the propulsion system. Support magnets lift the vehicle up to the guideway, while guidance magnets located on both sides of the vehicle keep the vehicle lateral to the track. The synchronous long-stator motor acts as both, the drive and the braking system. The drive, consisting of stator packs with a three-phase traveling field coil is built into the guideway rather than into the vehicle. Here electricity produces an electromagnetic travelling field which either pulls the magnetic levitation train forward or slows it gently down. The train speed is continuously variable and controlled via the frequency of the alternating current. Since the electromagnetic traveling field determines the direction of movement, it is impossible for two vehicles to move towards each other. Derailments are not possible since the vehicles 'wrap around' the guideway and are therefore firmly fixed to the guideway. Transrapid today is well proven and in day-in-day-out revenue operation in Shanghai China. Since the Pudong International Airport Connector went into operation in 2004 it has travelled more than 6.5 million miles and 32 plus million people have taken the 19 mile ride between the Airport and Shanghai, operating seven days per week at a punctuality of 99.9 %. Further developed today with emphasis on system capital cost reduction and even lower electric energy consumption per seat and mile traveled, makes Transrapid a premier choice for the Colorado AGS Project. Transrapid is capable to overcome the stringent grade differentials, is able to maneuver the tight curves in the I-70 corridor ROW and can meet the challenges of the Colorado weather. Transrapid is proven and ready to be deployed. Safety certifications have been granted in Germany and in China. In a 'Memorandum of Understanding' the German Government and the FRA have addressed a cooperation to jointly develop the 'Rules of particular Applicability' in order to arrive at the safety certification for a U.S. Transrapid Maglev System. It is the intent of Transrapid to engage in a 'Technology Transfer' with qualified American companies to manufacture the system components in the U.S. rather than to import. This approach could foster the formation of a U.S. high-speed passenger transportation industry, started and based in Colorado.

In summary, the Consultant Review Team is satisfied that the 11 technologies who were found to be qualified are credible contenders for a technology that could be deployed on the I-70 Mountain Corridor for purposes of determining feasibly of an AGS.

Technology Forum

Five technology providers will be invited to make presentations at the Technology Forum on December 13 and 14. In order to get a good cross section of the various technologies, the Consultant Review Team recommends that the following five technology providers be invited to make presentations:

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- American Maglev Transit
- MegaRail
- Owen Transit Group
- Talgo
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