Final Scientific/Technical Report

Project Title: Low Floor Americans with Disabilities Compliant Alt. Fuel Vehicle Project

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Award Number: DE-FC07-02ID14322

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Executive Summary:

This project developed a low emission, cost effective, fuel efficient, medium-duty community/transit shuttle bus that meets American's with Disabilities Act (ADA) requirements and meets National Energy Policy Act requirements (uses alternative fuel). The Low Profile chassis, which is the basis of this vehicle is configured to be fuel neutral to accommodate various alternative fuels. Demonstration of the vehicle in Yellowstone Park in summer (wheeled operation) and winter (track operation) demonstrated the feasibility and flexibility for this vehicle to provide year around operation throughout the Parks system as well as normal transit operation. The unique configuration of the chassis which provides ADA access with a simple ramp and a flat floor throughout the passenger compartment, provides maximum access for all passengers as well as maximum flexibility to configure the vehicle for each application. Because this product is derived from an existing medium duty truck chassis, the completed bus is 40-50% less expensive than existing low floor transit buses, with the reliability and durability of OEM a medium duty truck.

To fully assess the adaptability of this chassis configuration, this project included an assessment of the compatibility of the Low Floor bus chassis with community transportation needs, specifically the Head Start Program Allowable Alternate Vehicle Criteria defined in 45 CFR 1310.3. This portion of the project was lead by Idaho National Engineering and Environmental Laboratory and Supported by ARBOC Ltd.

Based upon the findings of the project, a vehicle specification was prepared and provided to customers and partners of this project. (NPS, FTA, DOE, DOI) This specification provides the recommended content of vehicles for the full range of applications studied within the project scope.

**Accomplishments,
goals, objectives:**

Chassis configuration

Currently mid sized transit/community buses (20-30ft.) are built on conventional cutaway and stripped chassis's. To comply with ADA they are equipped with lifts that are difficult to use, displace several passenger seats and require over 10 minutes loading passengers in wheelchairs. Additionally all passengers, including those with lesser physical disabilities must climb 3-4 stairs to enter and exit these buses. Currently low floor ADA compliant buses that can be accessed by a simple ramp are pusher (rear engine) units that cost 150% or more than the cutaway based high floor buses. Efforts to produce cost effective mid sized ADA compliant Low Floor buses have been aftermarket, front drive vehicles that have proven unsatisfactory in service. The objective of this project is to develop a cost effective rear drive chassis that complies with ADA via a simple ramp at a cost that is at least 40% less than the current pusher buses. Results of this project demonstrate this objective has been accomplished.

The configuration of the chassis developed for this program achieved the goal of providing an ADA compliant bus with the attributes stated above. The chassis was configured around the storage requirements of CNG. A total of 40 GGE of fuel @3600 psi were incorporated into the chassis. This fuel capacity is located between the frame rails and below the floor for optimum protection with no intrusion into the passenger area. The successful package of this quantity of CNG assures that adequate space is provided for other gaseous alternate fuels as well as liquid fuels.

Low Floor Chassis with
40 GGE CNG storage

Low Floor Chassis with
65 gallons of propane

Sufficient space is provided to package up to 65 gallons of propane or bio-diesel within the same space utilized by the CNG storage.

Base Vehicle Selection

Selection and/or development of a compatible alternative fuel, low emission power-train was a key element of the project. To achieve this goal the original project utilized the Ford Econoline E550 equipped with a 6.8Liter engine as the base vehicle. The initial chassis was designed, built and prepared for installation of the bus body. Coincident with this completion in January 2003, Ford announced the cancellation of the E550 vehicle and withdrew support for a 6.8 liter V10 alternate fuel engine. This required conducting a search for an alternate chassis, also capable of achieving low emissions on alternate fuel.

Because the ARBOC Ltd ADA compliant Low Floor chassis is adaptable to other Class 4, 5 and 6 commercial chassis's, a review of available chassis's from other manufacturers was immediately undertaken. This review showed that the recently introduced GMT 560 chassis offered the most potential for use as the base vehicle for the ARBOC Ltd ADA compliant chassis.

Contact with General Motors was initiated and encouraged by support of our Bus Manufacturing partners. These discussions resulted in agreements to proceed with the ARBOC Ltd ADA compliant chassis on March 14, 2003. This agreement permitted continuation of this project on a production viable OEM vehicle, including incorporation of a low emission CNG derivative powertrain.

Chassis specifications were minimally affected by this change to the GMT 560 chassis as vehicle parameters are quite similar. The GMT chassis offers a wide range of chassis GVW's from 17,500 through 25,500 lbs in production. This chassis also offers significantly improved maintenance because of the tilt hood configuration. At the time of selection of the GM chassis, the 8.1 liter engine is alternate fuel prepped, but no fuel control system was certified.

To develop a low emission CNG control system a separately funded project, in cooperation with the GM alternate fuels activity and GFI, an alternative fuel system company that currently provides these for other GM products was planned. The 8.1L GM engine is already authorized for use with alternative fuels, this means only the engine control system needs development. This system development was to be funded separately from this project and have no financial impact on this project. The fuel control system development would be undertaken on a separate schedule that has not permitted incorporation of a low emission CNG engine control system into the project chassis by project completion. The CNG fuel storage and delivery system remains essentially unchanged and is compatible with currently available engine control hardware and strategies. Discussions continue with

existing manufacturers of compatible base vehicle chassis's as well as alternative fuel engine control system suppliers for both CNG and Propane as a means of utilizing the capabilities of this chassis for customers desiring or requiring the benefits of alternative fuels for their applications.

The chassis as configured for the prototype bus is show below:

Body configuration

To establish key vehicle features several workshops and discussions were held with park personnel, concessionaires, private operators and interested park visitors. The prototype vehicle was configured to incorporate key functional features desired for operation in national parks with particular attention to those required passenger friendly operation in the Yellowstone Grand Teton Park System. The overall vehicle is approximately 26 ft in length and has flexible seating to accommodate up to 17 passengers in comfort. Three wheelchair positions are provided within the wheelbase of the vehicle. Wheelchair passengers access the vehicle via a simple ramp deployed from the curbside entrance door. The bus body has a retro styled rear area to provide a look and connection to the previous Yellowstone and Glacier Park buses.

A particularly key feature desired for Yellowstone Park vehicles was an opening or transparent top to permit viewing of the wide vistas. The prototype was fitted with a retractable fabric roof. This proved to be popular for warm weather conditions, but was not usable for rainy or winter conditions. During the winter testing a transparent roof panel was installed. This permitted viewing under all conditions. A production feasible version with transparent panels is being pursued for future vehicles

Picture of
Completed
Yellowstone
Park Bus

In addition to the features noted above the finished vehicle contains the following features established by the team. These include, but are not limited to 17 passenger seating with two wheelchair positions located forward of the rear wheels. Sure-Lok automatic hold downs provide quick and effective retention of passengers traveling in wheelchairs, larger windows to provide unobstructed viewing and the left side windows are clear and the right side windows have 17% tint. This was done to assess the affect on photographic images versus sun loading. Results of this experiment showed that the tinted windows were preferred as they did not obstruct photography and helped reduce heating and cooling requirements during operation. A 22 inch LCD monitor and DVD player were installed to offer presentation of related information during tours. The exterior of the vehicle was painted in two tone black and Yellowstone yellow to compliment the retro bustle back shape and other nostalgic cues. The full kneeling capability of the chassis combined with the low floor configuration provides a 10 inch entrance step and a flat floor throughout the passenger area.

The bus was completed and driven to Yellowstone Park for the 100th celebration of the Roosevelt Arch on August 25, 2003. From August 22 through September 4, 2003, the vehicle was demonstrated and evaluated by park personnel from Yellowstone, Grand Teton and Glacier, Gateway officials, Concessionaires and other interested parties. Comments were overwhelmingly positive. The functional attributes were judged correct for the parks application. Comments were gathered on suggestions for changes. These suggestions indicated only minor revisions were needed to optimize the vehicle for most parks applications. These changes will be evaluated for incorporation into future units.

The bus was then taken to Death Valley for high ambient temperature testing for heat management and Brake system evaluations. Testing was successfully completed for all procedures evaluated.

Following the Yellowstone debut, the bus was returned to Michigan where minor updates were made prior to rolling out the bus in Washington D.C. The bus was shown and demonstrated to congressional delegates for both the house and senate, as well as displaying it to team members from FTA/DOT, DOE, and DOI/NPS. A press briefing was held on September 25 which included DOI Secretary Gale Norton, and senators Burns, Sarbains, Crapo and Baucus. Comments received in D.C. were consistent with the experiences from the Western Parks tour.

To fully assess the acceptance of the vehicle for applications from Parks service to municipal transit, an extensive tour was conducted across the country from September 2003 through

November 2003. Demonstrations were conducted and comments were collected from interested participants. A summary of these comments are included on **Attachment 1**. Acceptance of the vehicle was positive at all venues with consistent appreciation noted for the Low Floor access and step free interior. The spacious interior and large windows also received note. The open roof option was a preference of operators and agencies that conducted tours. The ride quality of the vehicle was also appreciated by passengers that participated in the demonstration rides.

Additionally a study lead by the Idaho Energy and Environment Laboratory assessed the compatibility of this chassis and bus configuration to be utilized with the Head Start Program Allowable Alternate Vehicle Criteria Defined in 45 CFR 1310.3. After studying the requirements it was determined that the Low Floor ADA compliant chassis complies with the Head Start criteria and provides the capability to serve children with wheelchair bound disabilities, as well as other children enrolled in the program, with significantly reduced time to load the children safely, with the same vehicle. The front entrance ramp reduces the load/unloading time by a factor of 4 to 5 times versus the high floor vehicles equipped with lifts, that are currently utilized for Head Start programs. In summary the report stated that this chassis provides improved flexibility of operation, as the needs of all children enrolled in the Head Start program can be met in one affordable package. These results have been previously reported to the U.S. Department of Transportation Federal Transit Administration under interagency agreement No. DTFT60-03-X-00003.

Winter operation/ track system

Winter operation in Yellowstone requires vehicles to run “over the snow” on groomed trails. To assess the feasibility of using the Low Floor rear Drive chassis for winter operation over snow, a unique rubber track system was adapted to the chassis. Key issues to be resolved were:

- Ability to operate over snow with a 2 wheel drive system.
- Power requirements to operate an approximate 10 ton vehicle on snow at the 7,000+ ft altitude of Yellowstone
- Determine the acceptable unit pressure and track tread that permits operation without causing deterioration of the groomed trails.
- Assessment of the vehicle features while operating at the low ambient temperatures typical in Yellowstone during the winter season.

To assess the items listed above, a track system based on existing commercial systems was adapted to the prototype vehicle

for operation over the snow in Yellowstone Park. A target was established at a maximum ground pressure of 4 lb/sq. in. Projected system weight for the tracks indicated that the 4 lb/ sq. in. was not feasible, for the rear driving tracks, without significantly exceeding package space of the vehicle. The front non-driven system was able to achieve an approximate unit pressure of 5 lb/ sq. in. while the rear system provided a unit pressure of approximately 6.5 lb/sq. in. These loadings functioned satisfactorily for all conditions encountered during winter testing. These loadings also aligned closely with the unit loadings of the Challenger tractors used to groom the trails.

Because the base configuration of the low floor bus is rear wheel drive it is highly desirable to operate on tracks without the need to add four wheel drive. The rear drive only track drive again operated satisfactorily throughout the winter test period under all conditions encountered. The vehicle was able to operate and steer on snow conditions that ranged from hard pack ice to un-groomed snow and drifted snow. The vehicle was able to drive through un-groomed snow depths of 2-3 feet and routinely broke through wind blown snow drifts over 3 feet in depth. It was determined that a limited number of studs needed to be added to the rubber tracks to allow the vehicle to climb steep grades covered with packed ice. The addition of 2-4 studs per cleat was sufficient to permit the vehicle to operate on these surfaces with complete control. The track system exhibited a vibration when operating on hard pack surfaces. This issue can be mitigated by revising the front roller height. This revision will be incorporated in future track systems.

Vehicle pass-by noise while operating on tracks was measured following the protocol of SAE J1161 for snow vehicles. Based upon this procedure the calculated noise level for the vehicle is 66dBA. This level for the total bus compares favorably to a single snow mobile. **See Attachment 3.**

The prototype vehicle was operated throughout the winter season in Yellowstone Park. Demonstration rides and test operation results confirmed that the vehicle was capable of operating on all park groomed trails and under all conditions encountered during the season. The prototype track system revealed minor issues that need to be addressed in future systems:

- The main outer pivot bearing for the rear tracks was under capacity and failed repeatedly. Analysis showed that the light weight ball bearing needed to be upgraded to a higher capacity roller bearing. This upgrade will be incorporated in future systems and does not impact the system function
- The idler wheels showed signs of delamination. Analysis showed that this is caused by over loading of the rubber

during operation. Selection of a higher durometer rubber or urethane material in combination with a minor increase in the roller diameter will significantly increase roller capacity and extend life to acceptable limits. These changes will also be incorporated into future systems.

- The track tensioning system utilizes oil charged with nitrogen from accumulators. This tensioning system leaked down and required recharging at regular intervals. The systems were also interconnected across the vehicle this necessitates discharging the system during installation or removal of the tracks from the vehicle. Separation of the system on each track and utilization of grease as the tensioning medium will provide a more robust approach to the tensioning of the tracks. It is recommended that future track systems incorporate these revisions.
- Track vibration on hard packed surfaces was noted during operation. The source of this vibration is the impact of the track tread with the snow, as it rolls over the leading wheel. To significantly reduce this issue the leading roller of each track will be raised approximately 1 inch to provide a less abrupt impact with the snow.

The high power requirements to operate the prototype with tracks at the 7,000+ ft altitudes of Yellowstone became apparent immediately. The vehicle was unable to exceed 20 mph when equipped with the 8.1 liter gasoline engine. Calculations indicated that the power requirements dictated the torque of a turbocharged diesel to operate at Yellowstone altitudes. **See Attachment 4.** Based upon these power needs it is unlikely that any alternate fueled vehicle that is naturally aspirated can provide acceptable winter time performance while operating on tracks. It is therefore recommended that any vehicle destined for track operation be turbocharged diesel powered.

To confirm the accuracy of these projected power requirements to operate the prototype vehicle on tracks, a 6.6 liter Duramax diesel engine was installed, replacing the 8.1 liter gasoline engine. With the diesel engine, vehicle speed increased to acceptable levels. The vehicle was able to maintain 30 mph on level terrain and climb all grades within the park at a minimum speed of 20 mph under all road conditions encountered during testing. The vehicle was able to achieve 40 mph on some of the road and trail surfaces, and was able keep up or exceed the speed of other snow coaches encountered within the park. The fuel utilized for the majority of this test period was 20% Bio-Diesel (B20). Engine performance was not affected by use of the Bio-Diesel fuel. No difference in performance was noted when compared to standard diesel fuel. Cold start and fuel feed under the low ambients encountered at Yellowstone were acceptable throughout the test

period. Fuel economy ranged between 3.3 and 3.6 mpg during the test period. The prototype vehicle was equipped with fuel storage of approximately 60 gallons, providing a usable range of at least 180 miles. This range capability will minimize the need to refuel within the park, thereby reducing impact on the parks limited winter fuel supply. Additional detail for Winter Testing can be found on **Attachment 2**.

Patents: No patent application has been made resulting from this award.

Attachment 1.

YELLOWSTONE PARK VEHICLE TOUR (2003)		
DESTINATION	CONTACT	COMMENTS
Rock Island, IL	Bob Jennings, Transportation Manager	Want the retro styling for downtown development district to promote the revival of downtown.
YNPS Roosevelt Arch Ceremony	John Sacklin, Advanced Planning Transportation Manager	The vehicle was presented to the Park at the Arch ceremony. The vehicle was used for shuttle service and many comments on the ease of ingress/egress were noted. Most also liked the open top as a feature. Everyone thought the styling was key to acceptance in the park and to entice visitors to ride the vehicle
Yellowstone National Park	Susanne Lewis Park Superintendent	The vehicle was run on all segments of the Park road system with a variety of riders, Concessionaires, Tour guides, visitors, Park personnel, Park Management, etc. All riders were excited about the ease of entry, the barrier free interior and the visibility, both top and side views. The camera provides an added dimension in highlighting scenery and wildlife onto the TV. Children were very aware of the IT features.
Livingston, MT	City Manager, City Council	Want to start a shuttle from Livingston to the North entrance of the Park and to provide shuttle service in the downtown area.
Bozeman, MT	City Council, Chamber of Commerce, County Manager, Karsch Bus Service	Want shuttle service to connect college to downtown, reduce the congestion in downtown, provide senior citizen transportation, Provide transportation to/from Park and Transit Service.

Glacier National park	Park Superintendent; Lou Sommerfield-Facilities Manager; Gary Dansyck-Mitigation Manager; Susan Law-Transportation Scholar	want ADA vehicle to supplement the "Old Red Bus" fleet in service on Road To The Sun for tours. Want vehicles for Flathead River Valley Transit service to include the Park. Want to identify the Park as a part of the Gateway communities. All thought the vehicle styling, other features were excellent for interfacing. Thought the vehicle was too wide for Road To The Sun Tours.
Idaho Falls, ID	Mayor, City Council & staffs	Want the styled vehicle for Transit service and the connection to Yellowstone. Thought the open top was great for the open air feeling
Idaho Falls, ID	Senator Crapo & staff	Supports the efforts to establish a Transit District for the 3-State Gateway Communities. Liked the Retro style of the bus.
Idaho Falls, ID	INEEL (Idaho National Engineering & Energy Laboratory)	Participated in the YNPS Project. President of INEEL stated that it was gratifying to participate in a successful project that goes to production. Want vehicles to transport visitors around site that have project ties.
Driggs, ID	Lou Christianson, Mayor & City Council	Liked the ADA compliance (Lou is confined to wheelchair) and wants the freedom to roll on/off. Want the Retro style to tie to the Parks. Vehicles to provide shuttle to/from Jackson for commuters.
Jackson, WY	Mayor, City Council & staffs	Liked the Retro styling, the tie to the Parks, The ease of ingress/egress. Want to do a downtown route to relieve congestion. Like the top. Want to participate in the 3-State Transit District. Want to provide shuttle from Airport to Town and Park
Grand Teton National Park	Transportation manager, Flagg Ranch Transportation Managers, Concessionaires	Want to work with the Transit Group for district approval. Need a Tour vehicle that is inviting to visitors with the open top. Thought the vehicle was great but wrong color. (Any color is available)

Washington, DC	US Senators, US Representatives, Department of Energy, Department of Interior, Department of Transportation, Bureau of Federal Lands, US Postal Department, National Disabled Veterans, Mall of the Americas	Press conference was held w/ Gayle Norton-Secretary of Interior: Senators Crapo-ID; Senator Burns-MT; Fran Mainella- Director, National Parks; Reviews by House and senate staffs provided many positive comments with interest for applications in their home districts.
Detroit River International Flyway	Gale Norton-Secretary of the Interior; John Dingell- US Representative	Presented the vehicle for tours. Everyone liked the ingress/egress and great views.
Albuquerque, NM	City Council, Chamber of Commerce, County Manager,	require larger buses but liked the features. Would require turbo CNG vehicles to compensate for altitude
Las Vegas, NV	APTA	General consensus was positive for features/amenities/styling
Las Vegas, NV	Las Vegas Airport/Transit	Want Low Floor ADA with style but require CNG engine
San Diego, CA	San Diego Transit	want larger capacity (30+) vehicles w/Low Floor ADA capability. Liked the vehicle
Chino, CA	Chino Transit	require larger buses but liked the features.
Chino, CA	Creative Bus	Think the vehicle will sell as either a Styled/Shuttle vehicle

Attachment 2.

Winter Test results of the ADA compliant Low Floor Bus Equipped With Snow Tracks 1/5/2004 through 3/14/2004

The Low Floor ADA compliant bus introduced to Yellowstone on August 2004 was adapted for winter use through the addition of rubber tracks replacing the wheels of the vehicle. These tracks are attached to the vehicle primarily utilizing wheel fasteners. Additional attachments are added to react steering and turn loads to the vehicle chassis. Although the initial installation required several days to complete, the system is designed to be removed or installed in approximately one day with two mechanics. Addition of the tracks raises the vehicle approximately 9-10 inches. The front track package size did not permit full use of the 54 degree turn angle of the GM vehicle. The added steering resistance of the tracks also necessitated a reduction of the pitman arm length. A revised length reduced the turn angle to approximately 41 degrees, accomplishing both of the objectives noted above. The vehicle demonstrated superior turn diameter to all of the snow coach vehicles currently in use in the park. The vehicle is a rear wheel drive 4x2 configuration. Determining the feasibility of operating a vehicle of approximately 20,000 lb, on tracks with only rear wheel drive was one of the key objectives of the test program.

To assure continued ADA access with a simple ramp to the Low Floor passenger area a ramp extension was constructed that is carried with the vehicle to extend the vehicle ramp in compliance with ADA criteria. Additionally a retractable step was added to the vehicle entrance door to allow easy entry for all passengers. The only other modifications to the vehicle were added cutouts around the rear wheels to accommodate the tracks and spacing of the front bumper forward approximately 5 inches to clear the tracks in turn conditions.

The track system was manufactured by Omintrac to specifications provided by ARBOC Ltd. The base tracks were adaptations of their existing rubber track systems with mountings tailored to the unique chassis configuration of the Low Floor chassis. The front tracks are 16 inches wide and had a snow contact length of approximately 50 inches. This provided a surface contact pressure of 4.5 to 5.0 lb/sq. in. The rear tracks are 20 inches wide and have a snow contact length of approximately 66 inches, this provides a surface contact pressure of 6.0 to 6.5 lb/sq. in. Although the target surface pressure was established at 4.0 lb/sq.in, the increased surface pressure of the prototype vehicle performed successfully under all conditions encountered throughout the test schedule. Approximately 3,000 test miles were accumulated during the winter testing.

The vehicle was initially tested with the 8.1L gasoline powertrain. The 8.1L gasoline engine was operated at WOT in low gear to attain 10 mph on 5% grades and produced excessive heat from the catalytic converter due to the altitude. The decision was made to replace the engine with a diesel 6.6L Duramax. The 6.6L Duramax which has 300 HP and 540 lb-ft torque provided adequate power. The vehicle was able to maintain speeds of 35-40 mph in 3rd gear under various snow conditions and altitudes. The Duramax 6.6 L diesel was installed and vehicle was able to negotiate 5+% grades at 20-25 mph in various snow conditions. The power required was maximum output of the engine. Diesel fuel economy ranged from 3.3-3.6 mpg, operating on various snow conditions and terrains. The fuel utilized for the majority of this test period was 20% Bio-Diesel (B20). Engine performance was not affected by use of the Bio-Diesel fuel. No difference in performance was noted when compared to standard diesel fuel. Cold start and fuel feed under the low ambients encountered at Yellowstone were acceptable throughout the test

period. The prototype vehicle was equipped with fuel storage of approximately 60 gallons, providing a usable range of at least 180 miles. This range capability will minimize the need to refuel within the park, thereby reducing impact on the parks limited winter fuel supply.

The track system was judged to be acceptable with suggested modifications. The tracks were able to negotiate the various conditions experienced within the Park. The track system negotiated the various moguls and snow ramps encountered in the park operation. Photos were taken to document the clearances and function of the tracks. The tracks maintained the alignment settings. Initially the adjustment bolts w/locking nuts were not torqued. After torquing properly, no issues were encountered. The track tension was initially set at 1200 psi front and 1500 psi rear. Tension varied from 900 to 1800 psi with no noticeable difference in performance. A recommendation was made to incorporate shutoff valves to isolate the tracks, side to side. The tracks rotated into the bumper, removed 2½" from the lower corners of the bumper. The clearances are acceptable for all jounce/rebound and operating conditions. The removal of the front track mechanisms is acceptable. The rear track system will require some modification to easily remove the cross shaft. A documented installation/removal procedure with photographs will be developed for production (i.e. Provide a grease zerk to pressurize the center collar to force the shaft apart). Overall service on the track system is acceptable. However, the outer bearings should be removable w/o removing the structure. A design change is required to load the bearings from the outside w/bearing stop positioned to the inside. The service manual with parts diagrams, part numbers and photos will be provided for production.

Initial attempts to maneuver an off-camber corner, (falling away) was not possible w/out snowstuds. The vehicle could be pushed, fully loaded by one person to stay out of the snow bank. The installation of hardened drill point screws in the outer cleats only, allowed the vehicle to traverse the corner and any other conditions encountered within the Park. The track treads did not pack the snow down, but rather duplicated the Challenger groomer performance. The track/tread did not throw snow up but rather the tread cleats exit the snow w/o lifting snow into the air. The only things thrown up were mud in the thermal areas and fresh buffalo dung. The track/tread design was not susceptible to creating the moguls encountered with other tread designs. The tread blocks, are very rigid and may have contributed to the resonant vibrations experienced within the vehicle. Omnitrac recommended siping the tread blocks, however, after numerous failed attempts in the field, this idea was held for later development.

Vehicle steering efforts and stability were acceptable with the design modifications incorporated (shortened pitman arm). Brake system was totally acceptable as released, in all conditions.

The air compressor performed in all conditions acceptably (60° F to minus 25° F.) The compressor was tested in extreme temperatures and cycled 4-5 times per day, operation included airing up a depleted tank each cycle. Care was taken to observe the oil level and overall performance of the compressor. The compressor discharge line must be secured due to the tight package conditions in the engine bay.

The water separator operated without any concerns in all operating conditions.

The suspension systems, front & rear performed acceptably. The vehicle maintained the stable ride of the wheeled vehicle. The vehicle rode so smoothly, there was a tendency to drive faster than other vehicles.

The engine compartment remained clear of snow/ice buildup. The vehicle underbody (body) collected snow in the wheel wells and to the rear of the rear tracks. The rear condensers collected snow such that the operation would be stopped with the snow/ice buildup encountered. The body sides remained virtually free of snow/slush buildup. The rear of the vehicle collected snow, (up to 4" at times). The rear lights must be heated to allow them to be visible to approaching vehicles. The clear top remained clear of any snow buildup and was thought to be very acceptable to all passengers. The side window defrosting was not acceptable in below 20° F operation. Extra fans mounted on the roof bows provided some extra defrosting. It was concluded that a second set of ducts, located above the windows, blowing down would be necessary to clear the windows. Thermopane windows might also be used to help eliminate the frost. The interior heat had no circulation, with little if any control to modulate the heat. The controls do not allow for any other setting, other than high/low fan operation, venting must be provided and better air distribution within the cabin. It was impossible for the driver to determine the heat in the rear of the vehicle. A rear thermocouple or control that senses the temperature is required. A ventilation system is also required to vent the hot/stale air from the vehicle. The water pump could be controlled by a rheostat to vary the water flow to help control the temp.

The ramp heater did not melt the ice, but rather enhanced the buildup of ice in the doorway by melting the snow into more ice as passengers entered the vehicle. Vicon is designing & releasing a 12 volt thermo mat to melt the ice from the ramp surface.

The seats were acceptable as located. The individual seats provided good back/seat support. The flip seats were not contoured and did not provide the comfort of the other seats. The seats rattled badly and were easy to get to resonate. An anti-rattle package must be included in the specification. The seat/aisle spacing was thought to be excellent. The ramp functioned in all weather conditions. The ramp extension will require design work to locate a mounting location when transported. The step functioned in all weather conditions, wired to the door would greatly improve the function/operation. The rearview mirrors were acceptable in all weather conditions.

The camera added another dimension to the viewing of the park. Viewing of birds and animals was greatly improved and brought many comments from the passengers. The new cameras provided better stability and reduced the tendency to migrate down when locked in location. The mechanical ratio could be slower for ease of focus and maneuvering. Second camera had much better clarity but still has RFI lines in the picture. Flat panel screen provided excellent quality. RFI lines were present in picture while stability as excellent.

Concessionaires reactions were generally very good. Park management personnel as well as press personnel viewed the bus as excellent. The park visitors and general public thought the bus was outstanding.

Vehicle was tested versus snowmobiles and was quieter than groups of snowmobiles at 15 mph.

Attachment 3

Technical Report on a Noise Pass-By Test
of the “Yellow Bus/Snowcoach”

For Yellowstone National Park

Grand Teton National Park and Yellowstone Soundscape Program
Report No. 15313543.1325464b

March 2004
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Summary

On Friday, 27 February 2004 a noise pass-by test of the Heart International prototype "yellow bus/snowcoach" was conducted following the protocol of SAE J1161 for snow vehicles.

Table 1 includes the site specific parameters. Two of the environmental test conditions violated the protocol. There was six inches of new snow covering the test area with snow falling during the test. The protocol limits loose snow to a maximum of three inches. The station or absolute barometric pressure was 22.73 inches of mercury. This is below both the SAE protocol and Yellowstone's regulation minimum level of 27.5 and 23.4 inches of mercury, respectively. Therefore, the noise level would likely be higher than is reported here under standard protocol conditions.

Table 2 presents the noise levels during the test. The vehicle speed was determined from the vehicle speedometer and reported by the driver, Dick Rief. Independent verification was not available. The SAE protocol requires that test runs be repeated until three readings within a 2 dB range are obtained. The first three runs on the driver's side met this criterion. The first three runs on the passenger side also met this criterion. However, obtaining identical decibel readings on three consecutive runs is statistically unlikely, so I collected data from additional runs to ensure the instrumentation was functioning properly. After four additional runs I was satisfied that the instrumentation was functioning properly and therefore the first three readings were used.

Following SAE J1161 protocol, the sound level reported from this test is the average measurement (rounded to the nearest integer) from the side with the highest average measurement using the first three readings within 2 dB. Therefore the calculated noise level reported for the "yellow bus/snowcoach" from these measurements is **66 dBA**.

In addition to this pass-by test, sound levels inside the vehicle at 15 mph were approximately 72 dBA. Noise measurements collected opportunistically on 14 Feb. 2004 indicated that at a cruising speed of about 32-24 mph the sound level of the "yellow bus/snowcoach" at 50 feet (test distance) was approximately 80 dBA.

Table 1. Noise pass-by data form used for prototype "yellow bus/snowcoach".
Yellowstone National Park, Wyoming on 27 February 200

Shan Burson			
PO Drawer 170, Grand Teton National Park, Moose, WY 83012			
307 739 3584			
Date 27 Feb 04			
Location: Description: Old Faithful west parking lot in front of Ranger Station	Lat: 44 27.445	Long: 110 49.808	
	<u>Type</u>	<u>Serial #</u>	
Microphone	Type 1 GRAS 40AE	38820	
Preamp	Type 1 PRM902	2686	
Sound level meter	Type 1 Larson Davis 824	2707	
Calibrator	Larson Davis Cal 200	3689	
Elevation	7388 ft- GPS		
Weather	Light to heavy snowfall		
Temperature	25 degrees F		
Wind speed/direction	Calm		
Cloud cover	100%		
Precipitation	Snowing		
Humidity	100% (dew point- 25)- sling hygrometer		
Station Barometric pressure	22.73 in Hg		
Snow conditions	<u>Depth</u>	<u>Density</u>	
On track	6 inches new power	Base of compacted/groomed snow	
Between road and microphone	same	Same	
Ambient sound level:	Up to 52 dBA		
GPS time at start of recording/data logging: 0745 Time at end of test: 0758 Calibration: 94.0 dBA at 0745; all instrumentation within calibration date Photographs: 2			

Table 2. Decibel level of prototype “yellow bus/snowcoach” during pass-by testing at Old Faithful, Yellowstone National Park, Wyoming on 27 February 2004.

Vehicle Type	SAE J192 old/ J192new/ J1161	Trial #	Direction¹	Speed²	Max dBA³
Yellow Bus/Snowcoach	J1161	1	W	15	65.2
		2	W	15	64.0
		3	W	15	64.7
		4	E	15	65.8
		5	E	15	65.8
		6	E	15	65.8
		7	E	15	63.5
		8	E	15	63.7
		9	E	15	65.8
		10	E	15	64.4

- 1 W indicates driver’s side closest to microphone; E indicates passenger side
- 2 Speed within 2 mph as indicated by vehicle speedometer
- 3 Maximum sound level during pass-by, sound level meter set to slow response, measured at 50 feet

Attachment 4

May 5, 2004

Subject: Parks Snow Coach Speedability Problem.

Attached please find the result of a detailed calculation to determine the cause of the Snow Coach Speedability problem encountered out West. In summary, this calculation leads the writer to draw the following conclusions:

- The track system to ground/snow interface has a relatively high rolling resistance coefficient when compared to more conventional tire conditions.

$$f_{\text{concrete}} = 0.012$$

$$f_{\text{medium hard surface}} = 0.06$$

$$f_{\text{snow_tracks}} = 0.125$$

$$f_{\text{tires_in_sand}} = 0.25$$

- The resulting tractive effort requirement of the Snow Coach, $F_T = 2,745$ lbf, requires more power and torque than the 496 cubic inch Chev spark ignition truck engine can develop. Further, operation at 7000 feet causes the loss of 19% of the engines power capability. An engine with intrinsic altitude compensation is recommended.
- The 2003 GM Duramax 6.6L Diesel Engine was evaluated for this application, it was found to be able to attain a maximum speed of 27 mph on level ground. This result is judged acceptable.