PROTERRA

Pinellas Suncoast Transit Authority

Technical Proposal

RFP 21-980369

September 21, 2021

2021

PROTERRA

Pinellas Suncoast Transit Authority

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Pinellas Suncoast Transit Authority

1. Letter of Transmittal

PROTERRA

September 20, 2021

Alvin R. Burns Jr.
Director of Procurement
Pinellas Suncoast Transit Authority (PSTA)
3201 Scherer Drive
St. Petersburg, FL 33716

Subject: Letter of Transmittal, RFP 21-980369 Florida Electric Transit Buses with Charging and Associated Equipment

Dear Mr. Burns:

Proterra Operating Company, Inc. (Proterra) is pleased to submit this proposal to Pinellas Suncoast Transit Authority (PSTA) and excited about the opportunity to establish Proterra Battery Electric Buses (BEBs) and charging equipment on the Florida contract for Electric Transit Buses with Charging and Associated Equipment. We're excited to continue to work with transit agencies across Florida as they deploy BEBs in their fleets.

As North America's leading manufacturer of BEBs, Proterra is the only Heavy-Duty Bus Manufacturer who focuses solely on the design and manufacturing of BEB technology. Because we aren't tied to legacy heavy-duty bus platforms, we started with a clean sheet to design the world's best performing and safest purpose-built BEBs rather than re-purposing a conventional diesel, CNG or hybrid platform.

The 35' and 40' ZX5 BEBs proposed herein are Proterra's fifth generation BEBs and feature a more streamlined body design and a lower vehicle height that enables greater route access, as well as new shocks and enhanced ergonomics to provide riders and drivers with a smoother riding experience. The ZX5 is also optimized to allow optional overhead pantograph charging, offering greater flexibility and optionality for our transit customers. Additionally, the Proterra ZX5 features Proterra's advanced high-voltage battery systems, which have been proven on the road through more than 22 million miles in service for mass transit. Our battery systems are unrivaled in the North American transit industry and are further detailed in Tab 2 of the Technical Proposal.

<u>Key Points of the Proposal</u>

Since delivering our first BEB to Foothill Transit more than 10 years ago, Proterra has a demonstrable and proven track record in manufacturing BEBs for transit agencies across the United States. We are supporting deployments with major US transit agencies like New York City Transit and Chicago Transit Authority as well as deployments with much smaller agencies like Port Arthur Transit in Texas or Greater Portland Metro in Maine. We've also delivered BEBs to StarMetro in Tallahassee, LYNX in Orlando, Miami-Dade County, and Broward County.

For this proposal, Proterra is offering our 35' and 40' Proterra ZX5+ with 450kWh along with optional pricing for our ZX5 Max for the 40' buses (not available on the 35' buses); which has an industry leading range due to the size of the Energy Storage System (ESS) with 675 kWh of on-board energy storage.

For delivery, we are proposing delivery within twelve (12) months from the issuance of executed contract documents (NTP) with subsequent buses to follow based on the guidance contained in the RFP document.

The proposal pricing is valid for one hundred and eighty (180) days from the date of submittal.

Point of Contact for this Proposal

If you have any questions or concerns regarding this proposal, please feel free to contact individual below who is responsible for managing proposal related activities for Proterra's PSTA proposal:

Devin Ikenberry
Sr. Business Engagement Manager
Proterra Inc
1815 Rollins Rd
Burlingame, CA 94010
Phone: 256.499.5696
Email: dikenberry@proterra.com

Summary

Our goal at Proterra is to design, build, and deliver the world's best performing heavy- duty transit vehicles (that also happen to be zero-emission BEBs). We welcome the opportunity to provide detailed technical information about those vehicles to PSTA in this proposal.

Sincerely,

Ethan Carbaugh
Director of Business Engagement
Proterra Inc
1 Whitlee Ct
Greenville, SC 29607

PROTERRA

Pinellas Suncoast Transit Authority

2. Technical Proposal

RFP 21-980369

Vehicle Technical Proposal

Proterra is offering our fifth generation 35' and 40' ZX5+ Battery-Electric Powered Transit Buses (BEBs) with 450kWh of onboard energy storage as our base proposal; and we are also providing optional pricing for the industry's longest-range 40' BEB, the Proterra ZX5 Max with 675 kWh of on-board energy.

Proterra's electric buses are designed with industry standard SAE J1772 CCS charge ports; our proposal for PSTA includes one port at curb-side rear; and J3105 compliant overhead charge rails.

Purpose-Built EV Transit Vehicles Charging

Proterra's electric buses are unique when compared to other zero-emission battery-electric transit vehicles on the market as our buses have been designed from the ground up specifically to be the safest, most energy efficient, and best performing EV transit vehicle on the market. Other EV transit vehicle OEMs are forced work within the existing constraints of the originally purposed vehicle; often sacrificing safety by placing high-voltage batteries at multiple locations all over the vehicle both inside and outside of the passenger cabin (see below).

	PROTERRA	NEW FLYER	BYD	GILLIG
Battery locations	Under floor, roof (E2 max)	Roof, rear	Roof, rear, interior	Roof, rear, under floor
Max Energy	440 kWh (E2) 660 kWh (E2 Max)	466 kWh	324 kWh	444 kWh
Curb weight	30,050 lbs (E2)	33,842 lbs	31,890 lbs	33,970 lbs
Battery supplier	Proterra	XALT	BYD	Cummins

Proterra's bus body was designed from the ground up to be optimized for electric battery packaging

In addition to reducing passenger room on board the vehicle, that approach also increases vehicle weight, and therefore often negatively impacts efficiency and operating range. Alternatively, Proterra buses are designed with a lightweight, carbon fiber-reinforced composite body that optimizes battery placement outside of the passenger compartment; allowing Proterra to build the world's best-performing battery-electric buses.

Contents of this Technical Proposal

- Purpose-Built EV Transit Vehicle
- The Proterra Composite Body and Corrosion
- Energy Storage System
- Propulsion System / Drivetrain / Regenerative Braking
- Axles / Suspension
- Cooling System
- HVAC / Defroster
- Multiplex System
- Description of Base Fire Suppression System (FSS) and Equipment
- Base Door Systems
- Air Brakes & Air System
- Driver's Area Layout
- Driver's Window
- ITS Box
- Curb-Side Wheel Well Storage Box
- Seating Layouts
- Towing Procedures
- Route Simulation and Operating Range Data
- Warranty Documentation
- Altoona Testing
- Depot Charging Equipment
- On Route Charging Equipment
- Performance Reporting (TS 89.3)
- Exportable Power Supply (TS 90)

Introducing the Proterra ZX5

The Proterra 40' ZX5, Proterra's fifth generation BEB, features a more streamlined body design and a lower vehicle height that enables greater route access, as well as new shocks and enhanced ergonomics to provide riders and drivers with a smoother riding experience.

The ZX5 also offers faster acceleration and greater horsepower than earlier Proterra electric vehicle models and can be configured with Proterra's standard drivetrain or our industry-leading DuoPower drivetrain. For this proposal, we are offering pricing and technical information on our base offering (ProDrive).

Additionally, the Proterra ZX5 features Proterra's advanced high-voltage battery systems, which have been proven on the road through more than 21 million miles in service for mass transit. Our battery systems are unrivaled in the North American transit industry and are further detailed later in this Technical Proposal.

The presentation beginning on the following page includes additional details concerning the new ZX5 BEBs.

THE PROTERRA ZX5 ELECTRIC TRANSIT BUS

PROTERRA

WHAT SETS PROTERRA ELECTRIC BUSES APART

PROTERRA

- UNMATCHED PERFORMANCE
  - Best efficiency combined with the most energy storage for the **longest range**
  - **Accelerates 1.5 times faster** than a standard diesel bus, with nearly twice the horsepower
  - **Industry-leading hill climb** abilities, able to tackle steep hills with grades up to 27%

- PROVEN TECHNOLOGY PLATFORM
  - Refined based on 10+ years of experience, **most delivered** in North America, >13 million miles driven
- PURPOSE-BUILT
  - Advanced composite body, **best design for battery safety & capacity**, lower center of gravity for stability, non-conductive

REFINED BODY

- Streamlined roof to accommodate additional battery packs
- Reduced height to cover even more routes
- Flexible charging with additional front port

BUILT FOR SCALE

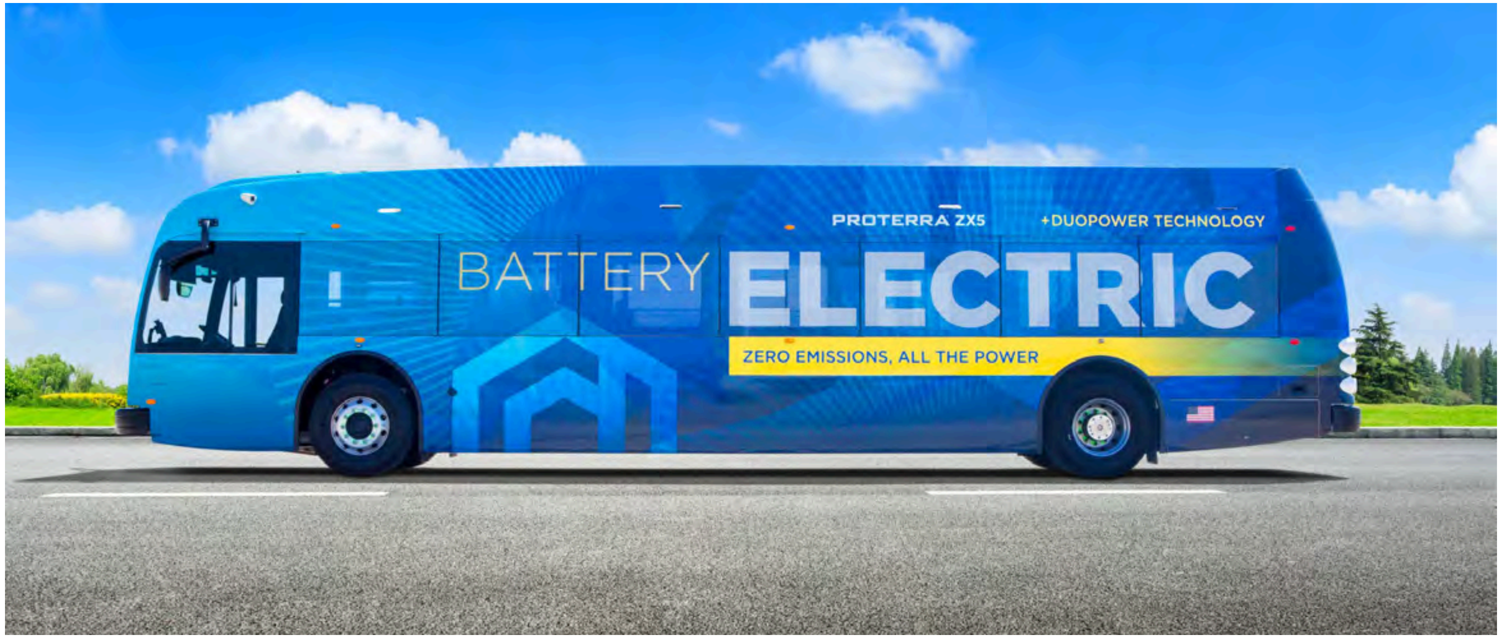
- Enhanced manufacturability for scaled production
- More commonality across platforms
- More advanced automotive approach

SMOOTHER RIDE

- New shocks and ride height system
- Improved maneuverability, faster kneeling
- Enhanced comfort and ergonomics of driver area

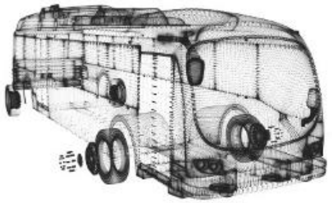
PROTERRA ZX5 —DIFFERENT BY DESIGN
PURPOSE-BUILT, COMPREHENSIVE PLATFORM

PROTERRA



Built from the ground-up as a battery-electric bus, the **Proterra ZX5** vehicle platform is designed to meet the needs of the most demanding transit routes.

Proterra ZX5



Highest Performance

Energy Systems

Ultimate Flexibility

Drivetrains

Best horsepower, acceleration and efficiency

Standardized Charging

Meet Every Route Need

THE PROTERRA ZX5 PLATFORM
ADVANCED COMPOSITE BUS BODY

Proterra's use of advanced composite materials makes the Proterra ZX5 not only the most efficient vehicle in its class, but extremely durable and safe as well.

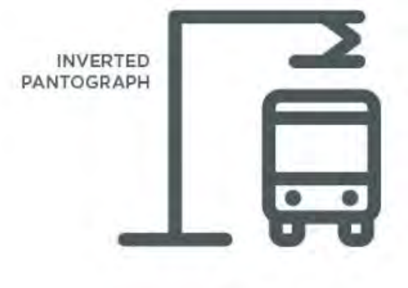
- Advanced carbon-fiber-reinforced composite material
- Super strong, lightweight and impact-resistant
- Non-conductive and rust-resistant

SMARTER CHARGING
COMPATIBLE WITH INDUSTRY-STANDARD CHARGING SYSTEMS

PROTERRA

OVERHEAD CHARGING
Keep your Proterra buses rolling with easy depot or on-the-road charging, made simple by industry-standard SAE J3105 overhead systems.

- Charge on the road for longer routes or enable 24/7 circulator operations
- Low maintenance costs and high availability
- Compatible with inverted pantograph systems, offered by Schunk and other suppliers



ADOPTED BY MAJOR OEMS

PROTERRA | GILLIG | NEW FLYER

PLUG IN CHARGING
Regardless of your fleet size, powering up your Proterra buses at the depot is as easy as plugging in a standard J1772-CCS Type 1 charger.

- Universal chargers are offered by Proterra and other suppliers
- ZX5 vehicles can be configured with two charge ports for flexibility at the depot
- Electric buses, utility vehicles and cars can share the same standardized chargers

ADOPTED BY MAJOR OEMS

GM | CHRYSLER | BMW | Ford | VW | DAIMLER | PROTERRA | GILLIG | NEW FLYER | VANHOOL | ALEXANDER DENNIS

NORTH AMERICAN ELECTRIC BUS DELIVERIES
MARKET SHARE BY MANUFACTURER

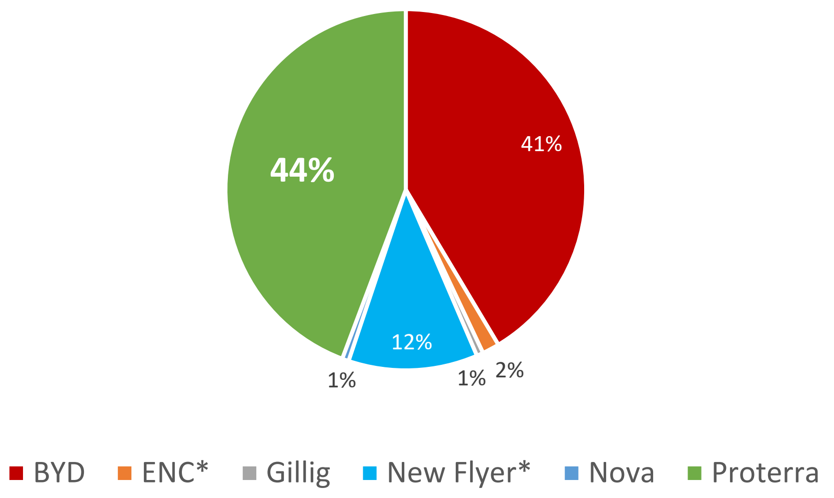
PROTERRA

- Proterra has delivered more battery-electric transit buses in North America than any other manufacturer to date

- **Proterra has delivered almost half of all** the battery-electric buses on the roads in North America

North American Electric Bus Deliveries

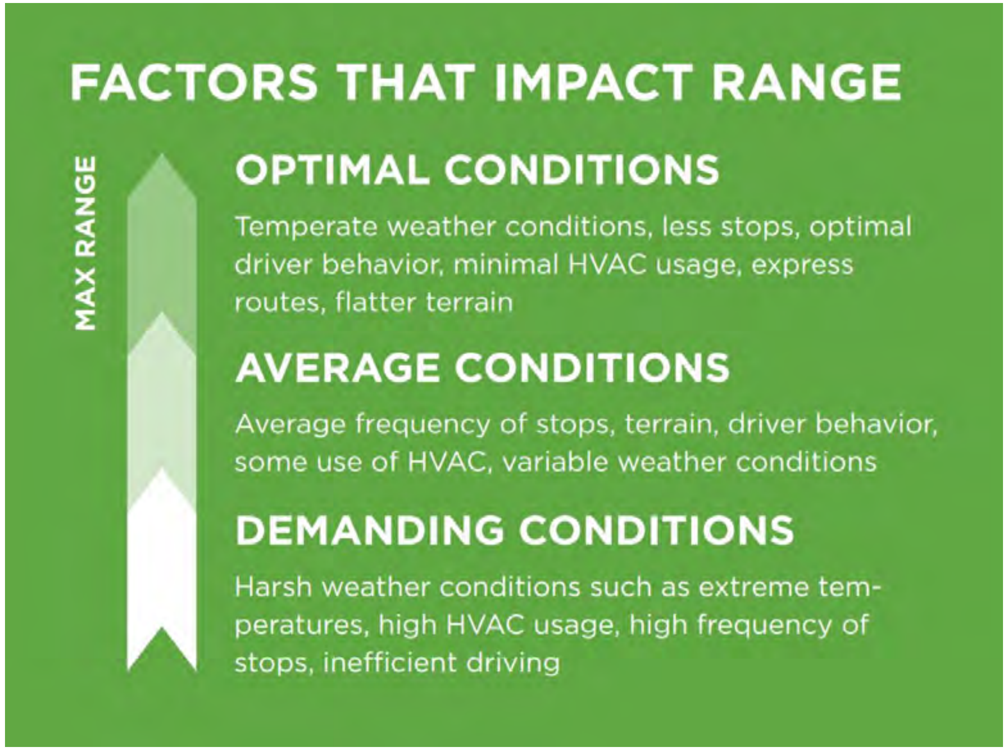
2017, 2018, & 2019



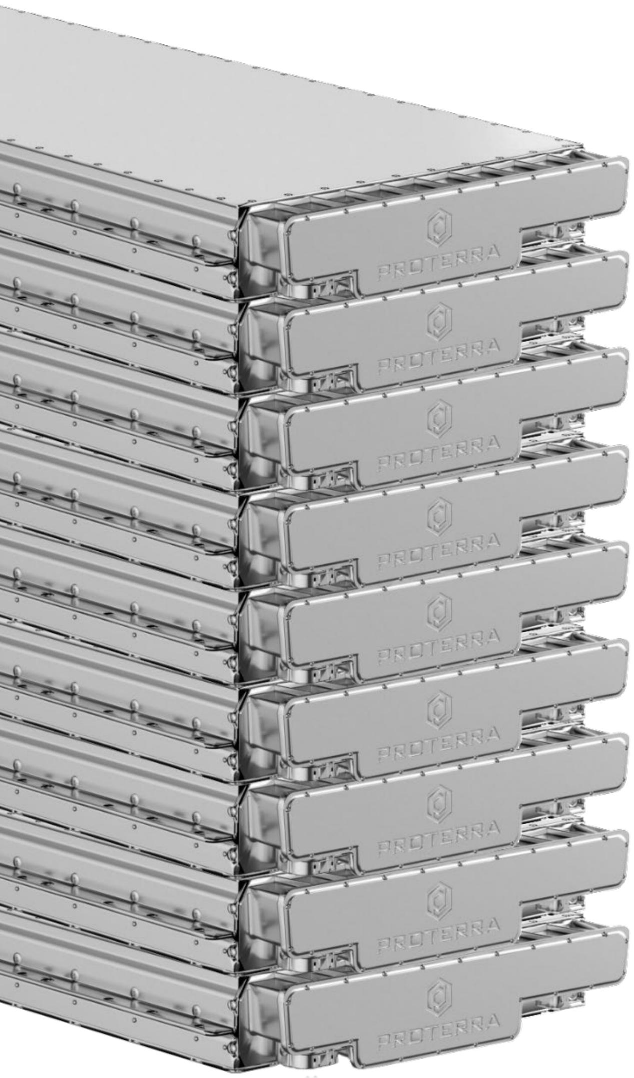
*ENC and New Flyer numbers include fuel cell vehicles

UNDERSTANDING RANGE

- With vehicles carrying up to **675 kWh** of battery capacity, the Proterra ZX5 has the flexibility to serve everything from local circulator routes to higher mileage routes.
- Proterra conducts a sophisticated **route analysis** before matching the on-board energy storage to your route requirements, total daily mileage and layover options.
- Operating range = $\dfrac{\textbf{Usable energy in battery pack (kWh)}}{\textbf{Operating efficiency (kWh/mile)}}$



PROTERRA BATTERIES
DESIGNED FOR REUSE AND RECYCLING



~1 MWh shown

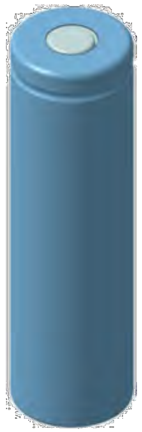
- Batteries will retain significant energy storage capability long after their first life in a transit bus
- Stackable design, retaining interface and safety features
- Hardware designed to exist >12 years in outdoor environmental conditions
- Capable of serving multiple storage requirements for renewable energy, grid services, demand management and emergency backup

- **Proterra battery packs are designed with recycling in mind**
  - Battery pack and module architecture allows for easy separation of components
  - Aluminum used in pack is 100% recyclable
- **Practicing responsible disposal and recycling**
  - Instead of sending batteries to a hazardous waste incinerator, Proterra works with top-tier recycling companies that specialize in extracting and repurposing materials inside lithium-ion automotive batteries
  - Proterra's recycling partners can recover 99% of precious metals used in Proterra batteries

ADVANTAGES OF CYLINDRICAL CELLS

PROTERRA

- **Quality**
  - Manufactured by Tier 1 cell supplier, LG Chem, the top lithium-ion battery producer by capacity
  - Tier 1 cell suppliers have higher quality requirements, more stringent spec tolerances, larger qualification sample requirements, higher bar for sub-supplier audits, more team members involved, greater documentation needs
  - Manufacturing in a cylindrical form factor has been optimized and mastered over more than a century.
- **Safety**
  - With thousands of cylindrical cells in each battery pack, if a single cell stops working it can have a minor impact on the whole pack and does not necessarily mean that pack replacement is required. A single cell failure does not have a significant impact on energy capacity or range
  - If a single cell has a thermal event, it's easier to contain with a small cell than with larger pouch cells.
  - Cylindrical cells are used widely in consumer goods and many applications; they are well standardized and produced by every Tier 1 battery manufacturer in the world
- **Energy Density**
  - Proterra has the most energy dense cells out of battery-electric bus manufacturers in North America



Cylindrical cell

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Purpose-Built EV Transit Vehicle

With a clean-sheet design, Proterra developed a light weight, safe, and durable bus body structure to achieve industry leading electric vehicle performance. This structure has contributed to Proterra's achievement of best in class efficiency, gradeability performance, weight, and acceleration. Additionally, the body passed an accelerated year life equivalent structural durability test at a third-party four-post test facility. This test simulated 750,000 miles of heavy service (equivalent to six consecutive Altoona tests at all three load configurations – CW, SLW, GVW) in less than a year, highlighting the exceptional robust and durable design of the composite body.

The Proterra Composite Body

Proterra worked with our suppliers to develop an all-composite, monocoque body design manufactured from a fiberglass laminate. Balsa is used as a core material to minimize weight while enhancing cross-sectional thickness and compressibility properties. Carbon fiber is also selectively applied in areas where high strength- to-weight and stiffness is required.

We selected fiberglass materials due to their favorable mechanical properties and wide range of availability and application in the wind, transportation and automotive industries. Utilizing commonly available materials supports serviceability, minimizes the body and repair costs, and standardizes repair work to across parallel industries. Finally, we selected the resin system for its mechanical properties and shrink rates that support the body's dimensional strategy.

The manufacturing process uses an open mold vacuum resin infusion. This process has a proven record of reliability and cost effectiveness over decades of use in various industries, including wind turbine blades, aerospace and marine. Machined male plugs are used to manufacture female molds from which the body components are produced using the open mold lay-up and resin infusion process.

Proterra's design philosophy results in a composite body vehicle with repeatable features and tolerances that allow for consistent installation of suspension, sub-assemblies and components. This disciplined and robust approach ensures that components and systems will consistently and correctly fit to the body.

Proterra incorporates the iterative series of Finite Element Analysis (FEA) studies and empirical testing to validate the body inputs and simulation assumptions. Physical test results supersede and supplement analyses and demonstrate the true physical performance of the design. Proterra tests on three levels -- component, sub-system, and vehicle -- to validate simulation results, and subjects the components and bodies to a regimen of static, quasi-static, dynamic and fatigue load conditions. The FEA analyses incorporate different load cases derived from various sources (e.g., the APTA white book). Notably, we use an explicit load case for side impact and crash based on a 4,000 lbs. vehicle crashing into the side of a Proterra vehicle at a speed of 25 mph. In this example, the Proterra body showed less than 2 inches of elastic deformation which significantly exceeds the specification requirements. Such results, in addition to our sixteen years of real-world crash incident data, demonstrates that this architecture is among the safest in the industry.

In addition to Proterra's experience with using an advanced composite bus body, the Los Angeles County Metropolitan Transportation Authority (LA Metro) has been operating hundreds of composite body buses for over 12 years. Below is an excerpt from LA Metro's statement regarding their experience with composite buses; as noted on their Advanced Transit Vehicle Consortium (ATVC) website https://www.metro.net/projects/atvc/

> *Following ATVC recommendations, in 2002 LA Metro took steps to develop a bus fleet that used advanced, lightweight, all-composite vehicle structures. Since that time, LA Metro has become the world's leading operator of advanced all-composite transit buses, and over 300 composite transit buses are currently in operation at LA Metro.*
>
> *Metro has plans to procure several hundred more composite buses in the coming year.* ***These composite buses have already proven to be highly durable and more cost effective than conventional transit buses****.*

In addition to the reference on their website, the ATVC also published a report on their experience with composite bodies that highlights the data in greater detail to support their claim. LA Metro's report is available at the following link (starting on page 9): http://media.metro.net/board/Items/2015/07_july/20150715atvcitem5.pdf

In addition to safety, the composite bus body has numerous advantages over traditional metallic bodies. For example, the composite body functions in the most corrosive environments without issue, or the requirement of special coatings or post processes. There is also a safety benefit in the electric vehicle application based on the non-conductive materials that isolate and separate the batteries from the passengers and impact zones.

The body also has effective inherent thermal properties due to the superior u-factors of the composite construction compared to metallic body structures. This property enables the vehicle HVAC and thermal management systems to maintain heating capacity and temperatures in the winter, and cooling capacity in the summer.

The body performs favorably with Noise Vibration and Harshness (NVH) because the structure is monocoque and, therefore, there is no relative movement between structural and decorative body panels as a one-piece design. This approach minimizes body squeaks and rattles and eliminates the potential for frame and structural mount/weld issues. The body structure is also very thick in most areas (>1") which provides good thermal and sound insulative properties as evidenced by external noise tests.

Finally, our clean sheet design builds around the batteries and vehicle systems to achieve a simple, efficient and manufacturable design. The batteries can be packaged neatly between the wheelbase, underneath the structural floor away from the passengers. This contributes to a low center of gravity that improves ride stability and handling, as well as minimizing body roll. The weight distribution also protects city roads and infrastructure by more evenly distributing the weight between front and rear axle and minimizing global weight on the road.

In sum, Proterra's holistically integrated composite bus body design integrates efficiency and performance for our battery electric vehicles. It is a marriage of innovative design with proven materials and processes, resulting in an industry leading fully electric vehicle.

Corrosion Resistant Body

Proterra's all-composite, corrosion- proof monocoque body is manufactured from high strength materials such as carbon fiber and molded fiberglass with a balsa wood core. The composite body design has numerous advantages over traditional metallic body structures in addition to safety.

Corrosion is a challenge to the transit and automotive industries and the composite body can function in the most corrosive environments without issue, or the requirement of special coatings or post processes. Thus, the preventative maintenance typically needed for a steel frame is not necessary for the Proterra composite body.

Steel components are uniquely integrated with the structural body to serve as mounting provisions for the bus suspension systems and drivetrain. A steel frame serves as a mounting support for the drivetrain components and some of the electronic components including DC-DC converters, VFD's, the motor controller and cooling pumps. In addition, steel torque plates are bonded to the interior of the structural body and incorporate threaded bosses to which exterior suspension bracketry mounts.

The Proterra design utilizes high-strength, low-alloy (HSLA) steels for all of the drivetrain, torque plate, and suspension mounting brackets throughout the vehicle. HSLA is utilized for its superior mechanical properties over regular alloy steels and stainless steels. Proterra utilizes HSLA's with a minimum yield strength of 50,000 psi ranging up to 80,000 psi depending on component application. Some advantages of HSLA include high strength to weight ratio, which allows for smaller cross-sections than conventional steels, and also increased toughness and higher resistance to corrosion compared un-treated to other plain carbon steels. These properties of HSLA also result in better performance than stainless steels in structural applications. Specifically, HSLA has better low and high cycle fatigue properties than stainless steel due to its tensile strength properties and resulting endurance limits. Fatigue cracking and failure that is more common in stainless steel structural components will not occur in properly designed HSLA structures. Finally, HSLA also offers better performance than stainless steels with respect to thermal fatigue. Austenitic stainless steels (300 series) are sensitive to thermal fatigue due to their high thermal expansion rate and low thermal conductivity.

Coatings: Stainless Steels are primarily chosen in applications for their resistance to corrosion, however, modern coatings and surface treatments can be utilized today to effectively achieve equivalent or better corrosion performance with the HSLA steels. Proterra utilizes both e-coating and powder coating to achieve corrosion resistance with HSLA steels. Depending on the component application, one of these processes can be chosen, or they can be used collectively. E-coating is an electrophoretic process in which colloidal particles suspended in a medium are deposited onto the electrically conductive substrate or component via an anodic or cathodic process. The e-coating process results in a consistent coating with a minimum thickness of 12.5 microns, that can adhere to non-line of site areas, crevices and welds. This coating provides corrosion protection which can exceed 1,000 hours of ASTM B-117 salt spray testing and chip and scratch protection. E-coating is also impervious to fluids including oil, hydraulic, acids, alkali's, and ethylene glycols.

To add even more protection on exposed structural and under-body HSLA components, Proterra utilizes powder-coating on top of the e-coat layer.

Powder coating adds up to an additional 152 microns in coating thickness via a dry powder that is applied electrostatically to the part and is then cured in heated ovens to allow it to flow and form a protective layer over the part. Powder coating can also be used as a stand-alone corrosion resistant and protective coating, and in this case is an additive layer and additional layer of protection for the HSLA parts. The powder coat can also provide UV protection for parts exposed in these applications.

This dual coating methodology of HSLA components results in a very desirable combination of properties which will allow for better performance than stainless and regular alloy steels. Used in conjunction with the composite body design philosophy, these components contribute to a stronger, lighter vehicle and structure that will maintain their performance throughout the demanding life cycle of the transit vehicle.

Energy Storage System

The Energy Storage System (ESS) is an integrated system that was designed with safety as top priority. The ESS will be described by the four main sections to this system: 1) the battery chemistry, 2) the mechanical design, 3) the electrical design, and 4) the control system interacting with the battery system.

Battery Chemistry

The ZX5 vehicles utilize a proprietary high energy density battery chemistry that falls into the broader category of lithium-ion batteries. Proterra and LG Chem, a global leader in lithium-ion batteries for automotive, stationery and consumer applications, co-developed a battery cell that has been optimized to meet the unique performance and safety demands of the heavy-duty vehicle market. The cell chemistry has been optimized for exceptional energy throughput capability, high charge rate acceptance, and industry leading energy density.

The use of these cells and purpose-built vehicle design allow for the ZX5 vehicles to carry more on-board energy storage without impacting the passenger cabin.

Mechanical Design

The mechanical design starts with the battery packs themselves and the carbon-fiber reinforced body structure, then continues through to the structure encasing the battery modules and the actual module designs. The bus body incorporates four primary composite stringers that run the length of the body, surrounding the underbody-mounted battery packs between the front and rear axles. Each of these four stringers incorporates full-length, pultruded carbon fiber stringers that maximize strength to weight ratio and add stiffness and rigidity to the battery box surround. It should also be noted that the body serves as a natural electric insulator due to its composite construction vs. a metal chassis normally associated with a transit bus. The vertical location of the battery boxes behind these beams is also located below bumper height of most vehicles which provides additional protection from a direct side impact. This location also provides for an extremely low center of gravity as well as an ideal weight distribution.

Each pack is contained in an aluminum enclosure that is reinforced with 3mm of a heavy-duty polyurethane spray-on covering that lends individual protection to its sub-components. The pack is designed to be sealed to IP66/7 and ANSI/ISE 60529-2004 standards. The pack also fully contains any electrolyte should a cell leak (pursuant to SAE J1766) and meets the 1,000 hours salt spray per ASTM B 117 testing. The packs are designed to handle 5g half-sine peak shock accelerations. The modules within the battery packs are actively cooled to keep the batteries in the ideal temperature range to maximize battery life and comply with the requirements from the battery cell manufacturer. The battery cooling system includes a chiller integrated with the HVAC system that runs if the ambient environment is too warm for the module manufacturer's desired system set points. The battery management system monitors cell voltage, temperature and current to ensure safe performance. Should the cooling system fail, the controls monitor and limit operation as a function of temperature, so that the vehicle will function and de-rate performance safely while indicating a fault to the operator. In this way, a cooling system failure will not result in a hard or immediate stop in operation.

Electrical Design

The wiring from each pack is insulated and shielded to industry standards and passes into the center cavity formed between the stringers under the vehicle, referred to as "Broadway". Broadway provides a protected route the length of the bus back to the high voltage junction box in the rear compartment of the vehicle. This is where the individual batteries are bussed together to provide for one high voltage electrical system. The high voltage interlock circuit and control wires for the battery system run along this route with the high voltage cables for maximum safety.

Each battery pack is internally fused and contains a set of contactors. The contactors are located near the pack outputs. Each pack also contains an individual pack controller which serves as a central hub to gather and report information specific to that pack. Each battery module has a monitoring board that measures voltage of each cell and performs cell balancing. This information is communicated to the pack controller via serial communication.

Control System

The battery control system is a hierarchical control with the energy storage module (ESM) acting as the interface and lead controller to the rest of the battery system. This module communicates on the main vehicle CAN bus to interface with the cooling, powertrain, charge and other systems. This module can also communicate on the separate battery CAN bus with all of the individual packs. The main controller exchanges information about battery input and output capability as well as cooling needs and diagnostic information.

The pack controllers control the contactors internal to the pack. They also gather the current information as well as pack voltage, cell voltage, and temperature information. Pertinent data is provided back to the master controller which uses this information to compute system limits, determine overall health status, and apply system-wide boundaries on use. The system uses algorithms and feedback to know the position of all contactors. The temperature measurements in the pack are redundant. There are also additional sensors that perform miscellaneous items like moisture detection in each pack. The battery system algorithms coordinate all activities related to the safety and performance of the system.

The battery control system provides system discharge limits to ensure that the lowest cell never goes below its minimum and that the highest cell never goes above its maximum allowable state. The system is also designed to monitor current imbalances between the packs, temperatures throughout all of the packs, moisture, and isolation detection. Should loss of communication occur with a pack or module; the system will gracefully handle this with independent fault actions.

Additional Battery Pack Information

More information about the Proterra battery packs is included on the subsequent pages, including a 3rd party confirmation of the battery pack design and safety considerations, our extensive battery testing, and examples of the validation testing we perform on our battery packs.

Exponent

External Memorandum

To: Brian Pevear

From: Exponent, Inc.

Date: February 5, 2018

Project: 1702336.000

Subject: Review Summary of Proterra High Voltage Battery (part number 022300)

Exponent was retained to perform a review of the high voltage battery pack (internally referenced as the “Colibri” battery) being developed by Proterra for use in electric buses. As part of the review, Exponent met with design/manufacturing/test engineers at Proterra, reviewed detailed design documentation and test data, inspected physical samples of the high voltage battery packs, inspected the battery production facility and was also given access to Proterra’s test labs where some of the battery abuse testing was performed. Exponent held numerous meetings with Proterra engineers during the course of the review that lasted several months. The goal of Exponent’s review was to:

- Review the configuration and safety requirements for the battery pack.
- Review the battery pack design and understand the response of the battery to electrical, mechanical and environmental abuse conditions.
- Review the detailed requirements and electrical design documents for the electrical/electronic protection circuits incorporated in the battery pack (the battery management system) to identify potential fault conditions that could lead to a battery failure.
- Review the design failure modes and effects analysis (DFMEA) performed by Proterra for the battery pack to determine what corrective actions/controls/validation tests were performed for identified failure modes.
- Review the construction of the battery pack to evaluate the overall battery assembly.
- Review the testing performed by Proterra on the battery pack.

Exponent was provided the following documents for review:

- UN Transportation Test report (UN DOT 38.3) for the Li-ion cells used in the battery pack.
- Battery Management System (BMS) requirements and safety manual.
- Battery mechanical, thermal, environmental, electrical and SAE J2929 test reports.
- Battery contactor test reports.
- Passive propagation resistance test report.

- Modal analysis for the battery pack (The battery pack contains fifteen battery modules. A number of the validation tests were performed by Proterra on batteries with five battery modules. The modal analysis was performed to justify testing batteries with five modules).
- DFMEA for the battery pack.
- Automotive Safety Integrity Level (ASIL) derivation worksheet for the battery pack.
- BMS test plan, validation matrix and test reports.
- BMS electromagnetic compatibility (EMC) test report.
- Electrical design documents (schematics, bill of materials and printed circuit board layout files) for the BMS.

The following high-level observations were made by Exponent during the review:

- Proterra has performed tests to characterize the mechanical durability, thermal durability, thermal endurance and environmental durability of the batteries. The abuse conditions simulated by Proterra during some of these tests are above and beyond the abuse conditions specified in test standards such as the FreedomCAR Electrical Energy Storage System Abuse Test Manual for Electric and Hybrid Electric Vehicles and SAE J2464 (Electric Vehicle Battery Abuse Testing). None of these tests resulted in battery thermal runaway.[1]
- Exponent's review of the DFMEA created by Proterra did not identify any gaps in the identification of failure modes. In addition, Exponent has reviewed the results of testing performed by Proterra on identified failure conditions with relatively higher risk priority numbers (RPNs). The failure conditions with relatively high RPNs were tested. None of the tests resulted in thermal runaway. The testing and analysis performed by Proterra indicates that failure modes with relatively higher RPNs are unlikely to lead to a thermal runaway of the battery.
- The BMS was reviewed. Exponent's review of the ASIL derivation worksheet indicated that all failure modes identified during the DFMEA were addressed in the ASIL derivation process.
- Exponent's visual inspection of a battery pack (focused on cell/module and bus bar layout in the battery) did not identify any construction related issues that increase the probability of a battery failure in the field.

Exponent's review of the design documentation and overall construction of the battery pack did not identify a fault condition that would result in a battery thermal runaway event.

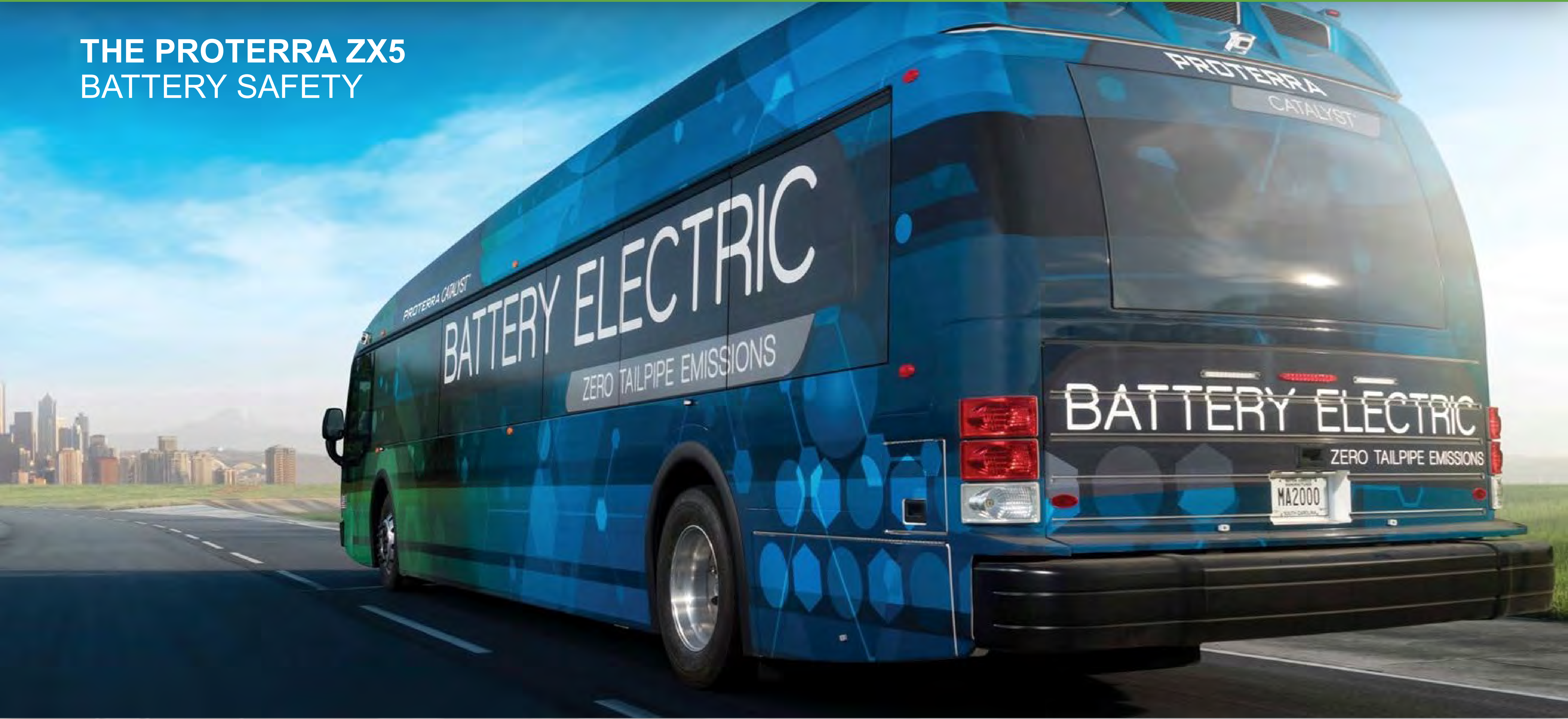
Limitations

Exponent's observations are based on the design documents and test reports provided to Exponent by Proterra. Exponent did not perform a tear down of battery modules or any testing on the battery pack, its module or its cells. In addition, the scope of Exponent's work did not include an evaluation of the manufacturing/assembly process for the battery pack. The observations and comments formulated during this review are based on information available at

[1] Except where thermal runaway was purposely induced by test engineers as a means to assess enclosure integrity.

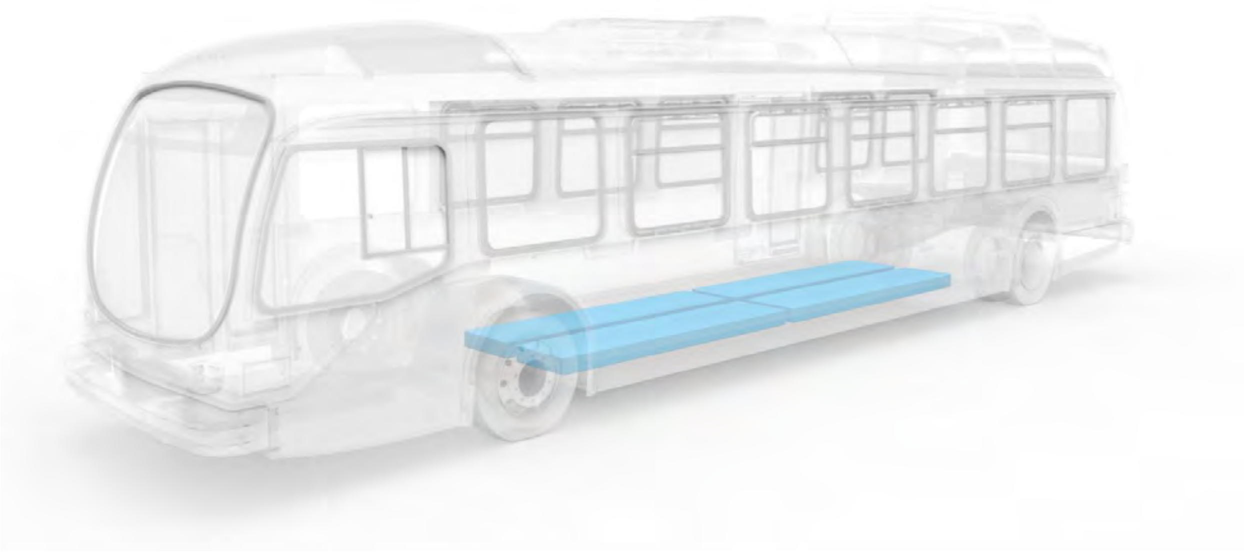
PROTERRA

THE PROTERRA ZX5
BATTERY SAFETY



PURPOSE-BUILT DESIGN ENABLES BEST BATTERY PLACEMENT

PROTERRA



Proterra buses are purpose-built from the ground up to be electric, enabling the safest placement of batteries

- Underneath and outside of passenger compartment
- Separated by a sealed bulkhead below the floor of the bus
- Avoids placing batteries in the rear of bus, which is a common crash zone
- Battery placement creates a lower center of gravity for greatest vehicle stability

THE PROTERRA® BATTERY
SMART. SAFE. EFFICIENT. PROVEN.

Proterra battery packs are designed specifically for safe operation in heavy-duty transportation.

- Protective, **ruggedized enclosure** made with ballistic-grade materials that can withstand the toughest conditions
- Pack design ensures service technicians and operators are protected from high voltage components
- Liquid cooling for **active thermal management** to ensure optimal operation in any climate
- More than **70 sensors** throughout each pack delivers continuous monitoring and diagnostics, enabling faster service
- If a single cell within the battery fails, the pack is designed such that the defective cell will be isolated to a small region of the pack and not cause complications throughout the entire pack.
- Rigorously tested and 3rd party validated

EXTENSIVE BATTERY TESTING
TO HIGHEST SAFETY STANDARDS

PROTERRA

Proterra battery packs have undergone extensive testing to meet the highest safety standards.

Tests performed to account for possible incidents such as:

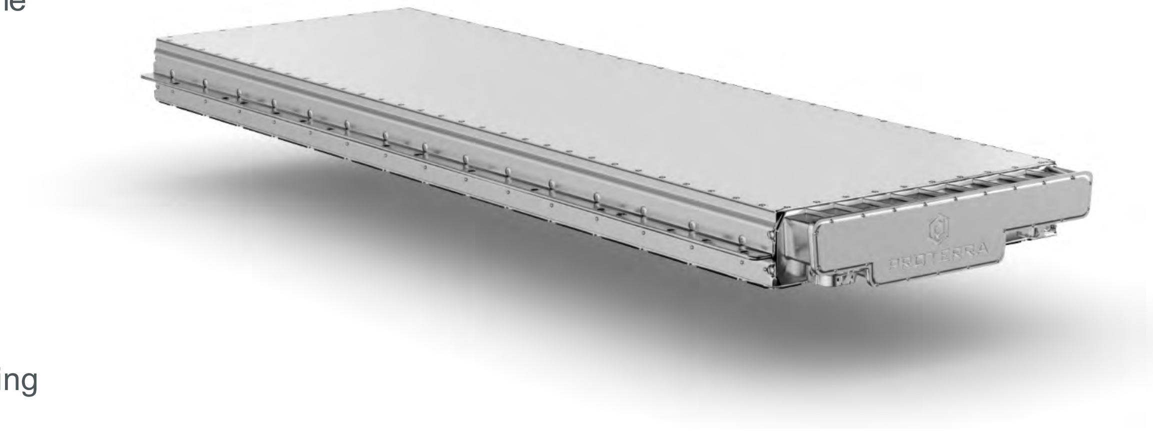
- Vehicle crash
- Road debris striking the battery pack
- Street manhole cover explosion
- Defective or failed cell within pack
- Overcharge of high voltage system
- Coolant flood internal to battery pack
- Fuel fire external to the vehicle (collision with a combustion engine vehicle)

BATTERY SAFETY BEST PRACTICES
PASSIVE PROPAGATION RESISTANCE (PPR)

PROTERRA

Proterra® batteries feature state-of-the-art safety features, including cell-level passive propagation resistance

- **Robust design and rigorous testing reduce the risk of a thermal event**
  - Pack architecture allows for proper venting, away from occupant cabin and doorways
  - Passive safety elements enable the release of energy over a longer period of time instead of all at once
  - Active safety elements extend time for occupant clearance and emergency response intervention
- **Industry experts agree the risk of a single cell failure cannot be completely eliminated**
  - Proterra has integrated safety mechanisms to stop a thermal event from spreading in the unlikely event of a single cell failure

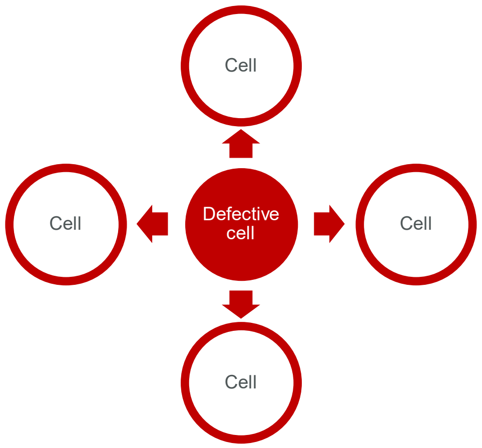


BATTERY SAFETY BEST PRACTICES
PASSIVE PROPAGATION RESISTANCE (PPR)

PROTERRA

WITHOUT PPR

Defective cell can cause cascading failure of adjacent cells

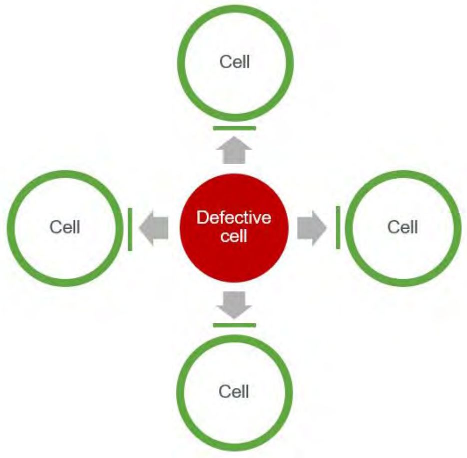


UNSAFE BATTERY DESIGN

Competitor battery design

WITH PPR

Adjacent cells are unaffected by defective cell



SAFE BATTERY DESIGN

Proterra battery design

PROTERRA BATTERY DESIGN ENABLES PPR

- Small format, cylindrical cells
- Pack is designed such that a defective cell will be isolated and will not cause complications throughout the entire pack

EXTENSIVE BATTERY TESTING
TO HIGHEST QUALITY STANDARDS

PROTERRA

Safety/Abuse Tests	Conditions	Reference	Performed
Mechanical Shock - Crash	10G, 100ms, X and Y axis	ECE R80	Yes
Impact/Underside Abuse	Manhole Cover, Pyramid, Ballistics	Proterra Internal	Yes
Drop	2m drop, concrete floor	SAE J2464 Sec 4.3.2	Yes
Battery Enclosure Integrity - Crush	100kN of force	SAE J2929 Sec 4.6 UL 2580 Sec 38 ECE R100 Annex 8D	Yes
Passive Propagation Resistance	Max Temp, Max SOC	SAE J2464 Sec 4.4.5 UL 2580 Sec 43	Yes
Forced Thermal Runaway	Confidential	Proterra Internal	Yes
Simulated Vehicle Fire	3 min exposure to fire underneath pack	SAE J2929 Sec 4.7 ECE R100 Annex 8E	Yes
Short Circuit	5mΩ hard short, 20mΩ soft short	ECE R100 Annex 8F SAE J2929 Sec 4.8 SAE J2464 Sec 4.5.1 UN 38.3	Yes
Coolant Flood	Forced cooling system leak internal of pack enclosure	Proterra Internal	Yes
UN/DOT Transportation	T.1, T.2, T.3, T.4, T.5	UN 38.3	Yes
Single-point and Multi-point Over Charge	Uncontrolled charge	SAE J2929 Sec 4.9 SAE J2464 Sec 4.5.2 ECE R100 Annex 8G	Yes
Single-point and Multi-point Over Discharge	Uncontrolled discharge	SAE J2929 Sec 4.10 SAE J2464 Sec 4.5.3 ECE R100 Annex 8H	Yes
Single-point and Multi-point Thermal Control Failure	Charge and Discharge without thermal management	SAE J2929 Sec 4.11 SAE J2464 Sec 4.4.3 ECE R100 Annex 8I	Yes
Fault Analysis	Fault analysis of battery system	SAE J2929 Sec 4.12	Yes
Protection Against High Voltage Exposure	IP2xB	SAE J2929 Sec 4.13	Yes

Note: Proterra Internal Reliability Requirements have been developed using specifications for from standards bodies such as SAE, ISO, and IEC and meet or exceed external standards.

POWERTRAIN RESEARCH & DEVELOPMENT LAB

PROTERRA

POWERTRAIN RESEARCH & DEVELOPMENT LAB
THERMAL CHAMBERS

PROTERRA

The environmental test station is used to perform accelerated life durability testing on electric vehicle components.
Each component is operated under extreme conditions to ensure the highest level of reliability in our vehicles.

3x Reach-in Thermal Chamber:

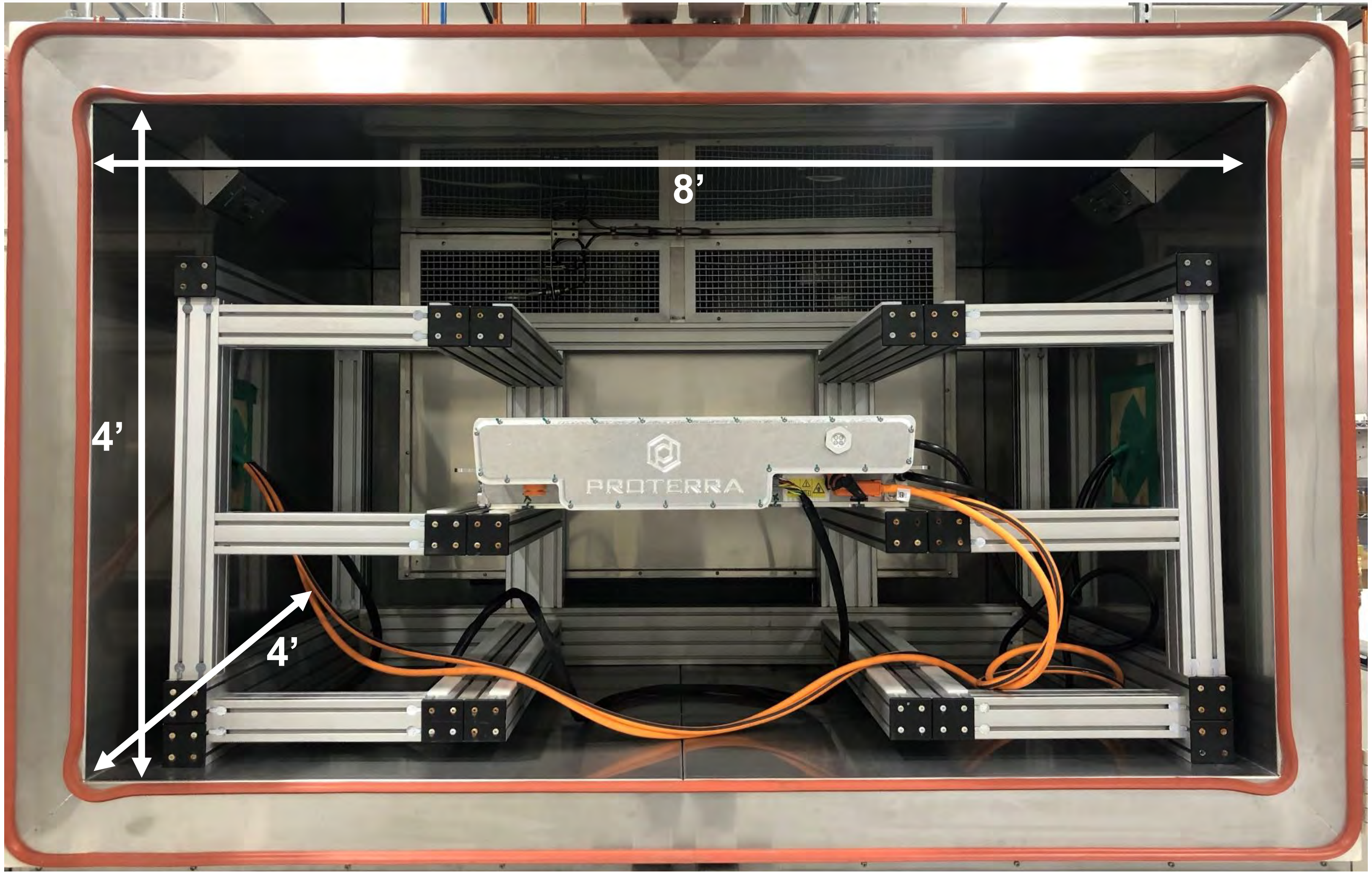
-70°C to 100°C up to 90% RH

Recirculating Chiller:

-30°C to 80°C 75 LPM Flow Rate

Power Cycler:

Bi-directional 160kW, 350A, 800V



POWERTRAIN RESEARCH & DEVELOPMENT LAB
THERMAL CHAMBERS

PROTERRA

1x Walk-in Thermal Chamber:

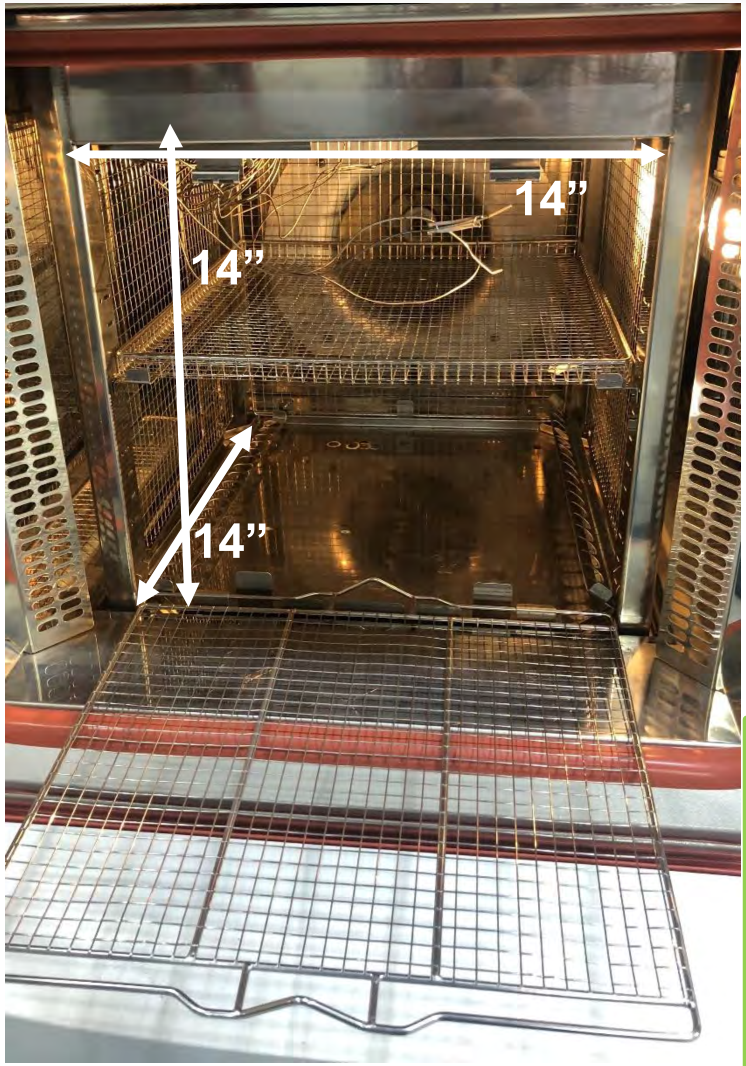
-70°C to 80°C up to 90% RH

Recirculating Chiller:

-30°C to 80°C 75 LPM Flow Rate

Power Cycler:

Bi-directional 160kW, 350A, 800V



2x Component Thermal Chamber:

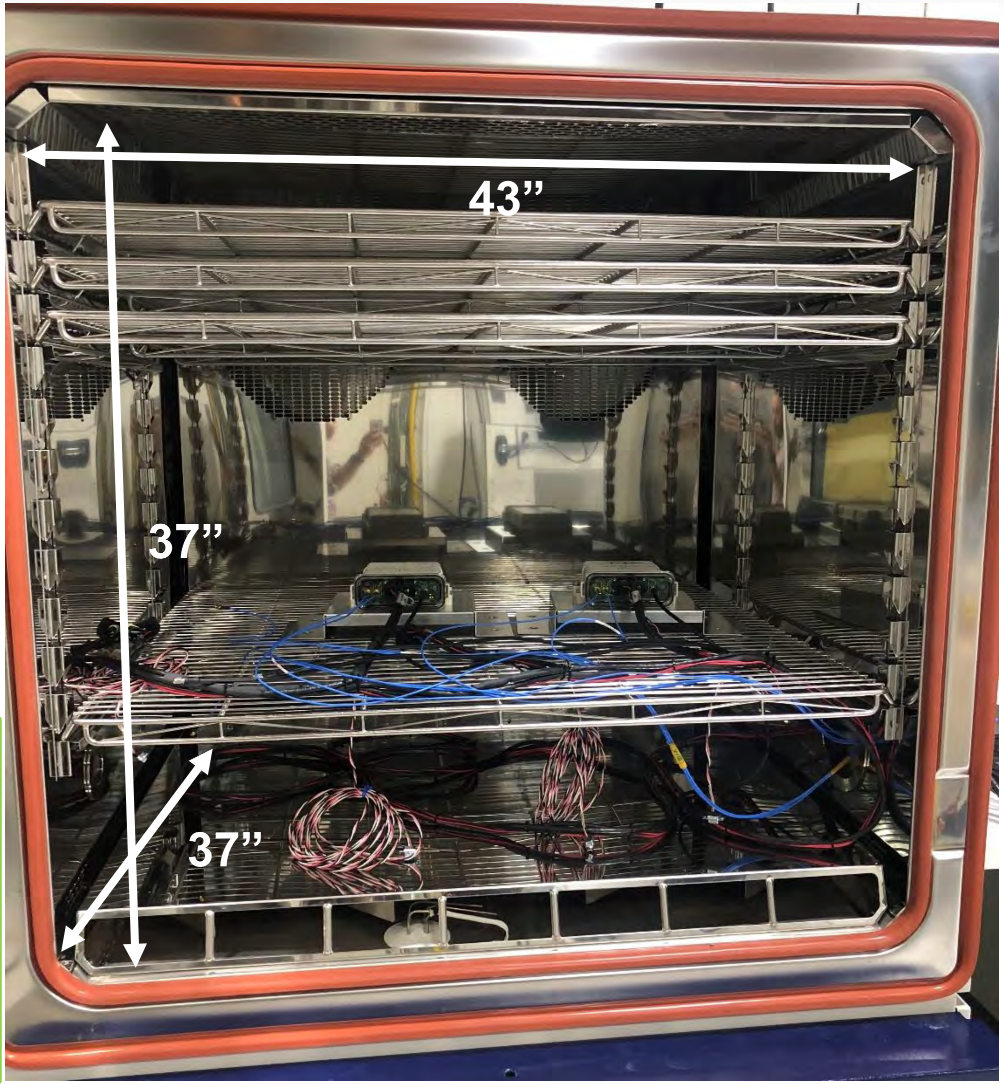
-40°C to 180°C up to 95% RH

1x Thermal Shock Chamber:

Cold Zone -80°C to 70°C

Hot Zone 50°C to 220°C

20kG Load Limit

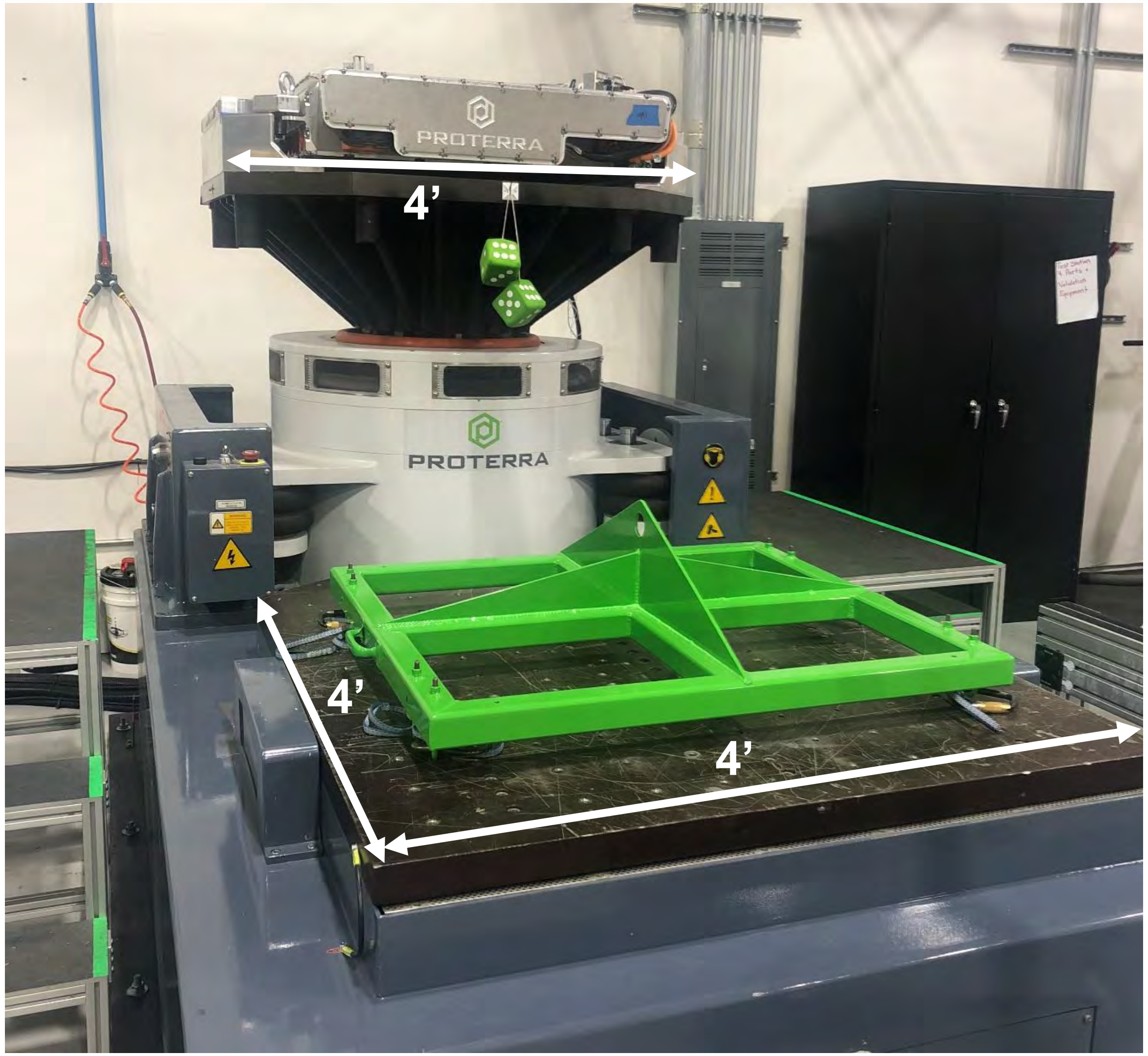


IPx6k Water Spray Test Rig: 145 PSI, 75 LPM

IPx9k Steam Jet Test Rig: 2000 PSI, 85°C

IPx7 Immersion Pool

The Electro-Dynamic Shaker system uses real world vibration profiles to induce the structural damage that a component will experience over the course of its life. Components are tested for more than 1,000,000 simulated miles to ensure the highest level of mechanical performance.

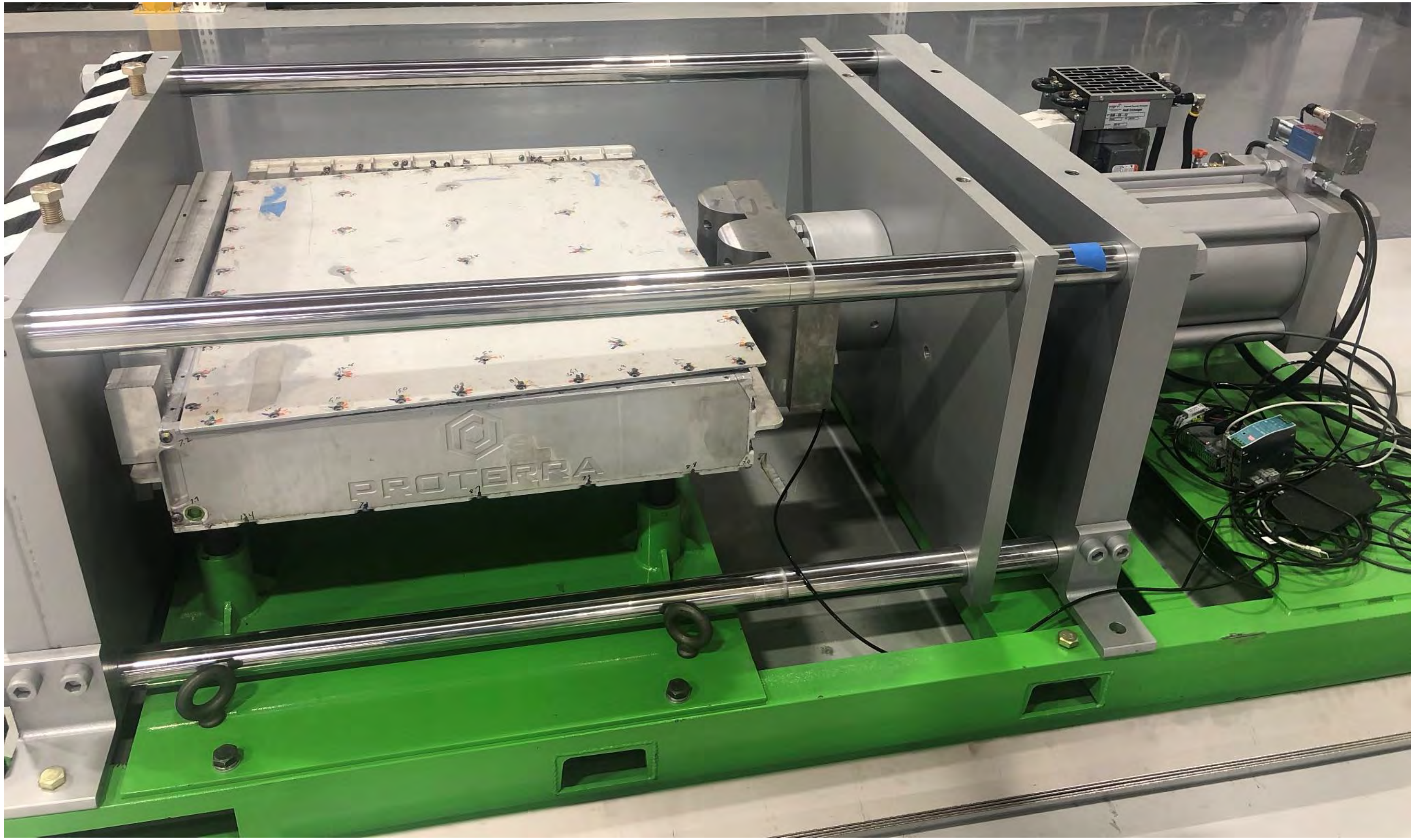


Footprint available to DUT is 1200mm x 1200mm

Available Mass for DUT and fixture 700kg

Max acceleration fully loaded 6G

The Hydraulic Crush Test Stand simulates the forces experienced during a vehicle collision. Over 150,000 pounds of force are applied to our battery enclosure to test its mechanical integrity and meets Proterra's stringent safety standards.



Mechanical Drop test fixtures include manhole cover and pyramid strike.

POWERTRAIN RESEARCH & DEVELOPMENT LAB
CELL CHARACTERIZATION

PROTERRA

192x Cell Cycling Channels: +-5A, 5V

Cylindrical Cell Chambers 10°C to 60°C

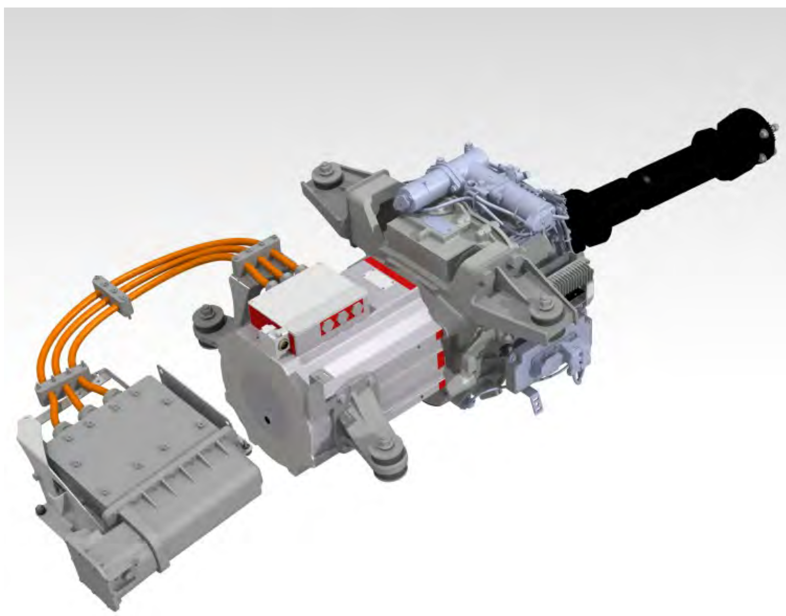
PROTERRA

Propulsion System / Drivetrain

Included herein are technical overviews of our next-generation ProDrive propulsion system.

The ZX5 standard ProDrive propulsion system consists of three major components; the traction motor, the power inverter, and the transmission.

Proterra uses a permanent magnet synchronous motor with a multi-speed automated manual transmission. The traction motor is capable of 240kW peak power and is controlled via an inverter which receives direct current power from the high voltage battery system. Both the motor and inverter are liquid cooled.



1. ZX5 ProDrive Propulsion System

The unique Proterra multi-speed transmission contains a planetary gear set with a pneumatically driven shift mechanism. The transmission is oil-cooled and contains an additional oil cooler to ensure that the transmission remain at ideal temperatures under the most difficult driving cycles. The output of the transmission supplies power to the ZF drop center rear axle.

All actuators and sensors for the transmission are connected to the Proterra powertrain controller which controls both the torque/speed commands of the traction motor as well as the transmission shift actuation. These controls have been optimized for transit bus service for best drivability and maximized efficiency. These controls are designed and calibrated using real world data from customer vehicles, engineering tests utilizing proprietary drive cycles and standard FTA drive cycles (CBD, Arterial, Commuter), and using our high-fidelity simulation tool similar to the model used for this fuel economy analysis.

With the multi-speed transmission Proterra is able to utilize a smaller, lighter traction motor to meet the needed performance requirements while still offering excellent efficiency. This transmission also allows the powertrain system the flexibility to provide the needed torque while also operating at more efficient traction motor operating points.

The combination of the traction motor, the power inverter, and the transmission are a primary reason why Proterra BEBs were able to break the Altoona records for acceleration, efficiency, and gradeability.

ProDrive Specifications	
Parameter	Specification
Peak Power	240 kW
Continuous Power	205 kW
Peak Torque	850 Nm
Continuous Torque	560 Nm
Max Speed	6000 RPM

Regenerative Braking

The Proterra bus utilizes two main systems to slow down or decelerate the vehicle, a standard pneumatic friction brake system and regenerative braking. Regenerative braking uses the traction motors to generate electricity which slows the vehicle. The ability to capture energy while braking results in a large improvement in energy efficiency of the vehicle. On a traditional vehicle, the energy created during braking is lost to heat through the friction brakes or the retarder.

When the driver lifts off the accelerator pedal (zero pedal) up to 50% of available regenerative braking torque is automatically applied. The remaining 50% of available regenerative braking is then applied linearly when the driver begins to press on the brake pedal. The pneumatic brakes begin to work linearly with increased brake pedal travel. The feel of the regenerative braking system is similar to a traditional retarder.

Regenerative braking is reduced below 3 mph to make low speed bus movement smoother. In the event of an ABS or Traction Control event, regenerative braking is automatically disabled until the vehicle comes to a complete stop. It is automatically re- enabled upon continuation. This is done to ensure vehicle stability in slippery conditions.

The Proterra regenerative-braking system will ultimately enable an efficient driver to drive almost entirely without the brake pedal. Drivers that anticipate stops and allow regenerative braking to slow the vehicle for maximum energy recapture maximize efficiency.

Advantages of the Proterra Regenerative Braking System:
- Substantially reduced break pad wear
- Regenerative braking while costing improves driver ergonomics due to the reduced need to apply brake pedal (aka: one foot driving)
- Regenerative braking improves vehicle range and efficiency by at least 25-40% depending on drive profile and driver skill.

Regenerating Performance
Proterra will offer 2 distinct regenerative braking levels. These levels will be driver selectable through the gear selector module located in the driver's area. These levels will predominantly affect the amount of regenerative motor torque during a coasting scenario (no brake or accelerator pedal application).

- While in D (Drive): the vehicle will have a nominal amount of regenerative torque application while coasting. As the brake pedal is applied, regenerative torque will increase proportionally with the pedal to smoothly decelerate the vehicle. Friction brakes will start to add additional braking force in coordination with the regenerative torque of the drivetrain.

- While in L (Low): the vehicle will have a more aggressive level of regenerative torque application while coasting compared to D (drive mode). This level of coasting regen will be similar to a conventional vehicle retarder. It will allow the vehicle to decelerate at a faster rate without application of the brake pedal. Similar to D, as the brake pedal is applied, regenerative torque will increase proportionally with the pedal to smoothly decelerate the vehicle. Additionally, friction brakes will start to add braking force in coordination with the regenerative torque of the drivetrain.

PROTERRA POWERTRAIN CONFIGURATION OVERVIEW

PROTERRA

1. Objective

To describe the different acceleration performance modes and regenerative braking configurations for the Proterra ZX5 bus platform ProDrive and DuoPower powertrain. To provide an understanding of how these configuration options impact range and energy economy.

2. Discussion

The Proterra powertrain system comes with the ability to configure the vehicle acceleration and deceleration drive feel to meet the customers' needs. These settings can be changed through the Proterra diagnostic tool when connected to a vehicle. There are two main drive feel settings:

- **Performance Mode**: This mode will change the maximum allowed vehicle acceleration rate
- **Regenerative Braking Configuration**: This selection will adjust the aggressiveness of regenerative braking when not accelerating (drivetrain-based braking)

2.1 Performance Mode

Proterra offers 3 distinct acceleration performance modes to tailor maximum vehicle acceleration to the customers' requirements. The three modes are called: Eco, Nominal and Max performance. These modes can be configured through the Proterra diagnostic tool variable **EP_usi_ZR32_PerformanceMode_x** (ECO= 0, Nominal= 1, Max= 2). The driver cannot change these modes real time through a button or switch.

Table 1 below shows the maximum achievable acceleration for each performance mode under peak motor conditions (no thermal derates). Proterra utilizes different acceleration limits to vary the performance of the vehicle. These acceleration limits will modulate torque to the drivetrain by monitoring the actual acceleration rate. If the acceleration rate of the vehicle approaches the limit, the traction inverter will reduce torque to ensure the limit is adhered to.

Acceleration limits primarily influence the vehicle speed below 30 MPH. Above 30 MPH, the vehicle speed is dictated by the power capability of the drivetrain. It is important to note that regardless of the performance mode, the powertrain will allow full power under scenarios where the acceleration limit is not being achieved. This is most critical under hill climb conditions. Therefore, the acceleration limit and performance mode will not impact vehicle gradeability performance.

Proterra recommends using the ECO Performance Mode (**EP_usi_ZR32_PerformanceMode_x = 0**) to maximize the efficiency of the vehicle.

Speed	APTA Whitebook	Eco Mode ProDrive	Eco Mode DP	Normal Mode ProDrive	Normal Mode DP	Max Performance Mode ProDrive	Max Performance Mode DP
(MPH)	time (s)	time (s)	time (s)	time (s)	time (s)	time (s)	time (s)
0	0	0	0	0	0	0	0
10	5	4.3	3.8	3.6	3.4	3.2	2.8
20	10	8.5	8.3	7.1	6.9	6.2	5.5
30	18	13.7	12.9	12.5	10.7	11.6	8.5
40	30	26.2	19.3	24.4	16.8	23.3	14.3
50	60	38.8	24.3	36.7	21.6	35.8	19.0
60	-	54.8	30.6	52.5	28.0	52.0	25.1

Table 1: Vehicle acceleration times for each performance mode, 0% grade, seated load weight

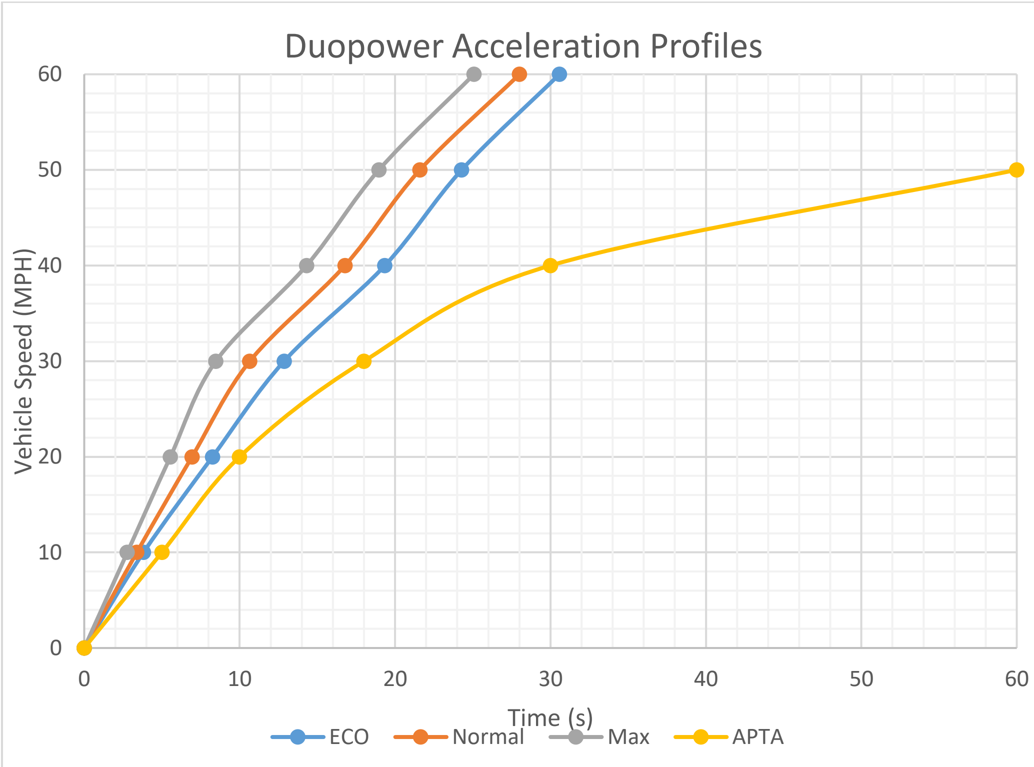


Figure 1: Vehicle acceleration chart for each Duopower performance mode, 0% grade, seated load weight

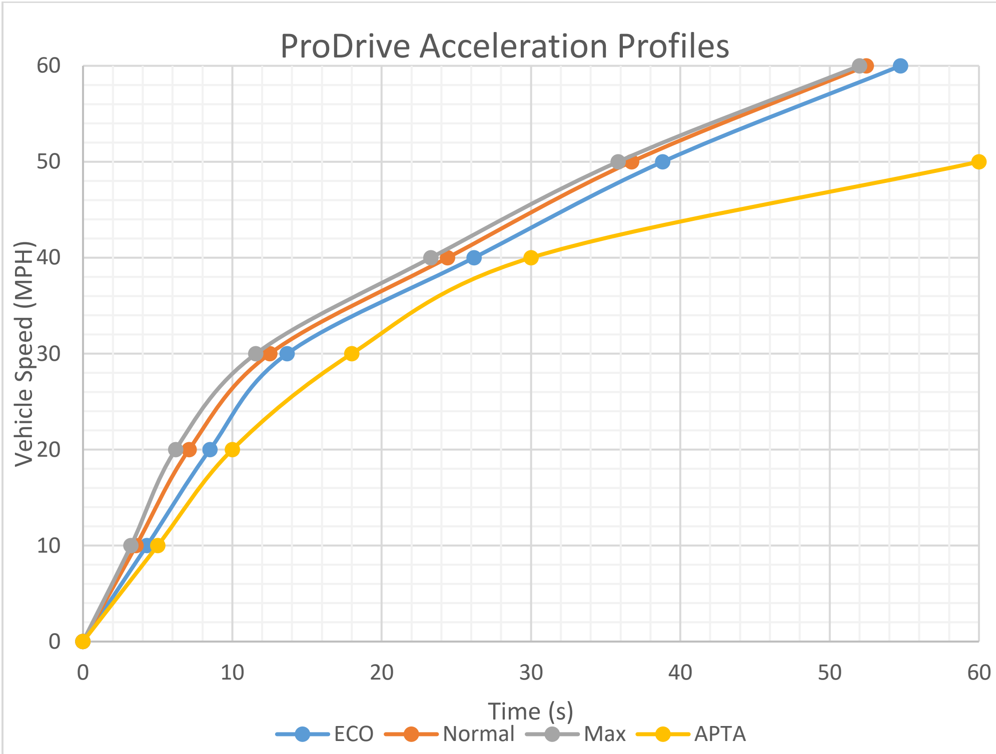


Figure 2: E2 vehicle acceleration chart for each ProDrive performance mode, 0% grade, seated load weight

2.2 Regenerative Braking Options with Gear Selector

Proterra offers two distinct driver selectable regenerative braking options through the gear selector module located in the driver's area. These levels will predominantly affect the amount of regenerative braking torque during a coasting scenario (no brake or accelerator pedal application).

Figure 2: Gear selector layout with D and L buttons

- While in D (Drive): the vehicle will have a nominal amount of regenerative torque application while coasting. As the brake pedal is applied, regenerative torque will increase proportionally with the pedal to smoothly decelerate the vehicle. Friction brakes will start to add additional braking force in coordination with the regenerative torque of the drivetrain.

- While in L (Low): the vehicle will have a more aggressive level of regenerative torque application while coasting compared to D (drive mode). It will allow the vehicle to decelerate at a faster rate without application of the brake pedal. Similar to D, as the brake pedal is applied, regenerative torque will increase proportionally with the pedal to smoothly decelerate the vehicle. Additionally, friction brakes will start to add braking force in coordination with the regenerative torque of the drivetrain.

2.3 Regenerative Braking Configuration

Proterra also offers the ability to configure the regenerative brake level and selection options through the diagnostic tool variable **EP_usi_ZR32_AllowedRNDLConfiguration_xx**. The driver cannot change these modes real time through a button or switch. This configuration setting will alter what the driver is able to select at the gear selector.

At a high level, this EEPROM setting allows different combinations of 3 distinct regen levels. It also enables the ability to "lock out' a driver selectable option. Meaning, regardless if the driver pushes the D or L push button on the gear selector, he/she will only get a single regen braking level. This enables the customer to better control how the vehicle is operated in the field.

Proterra recommends using the most aggressive regen level (**EP_usi_ZR32_AllowedRNDLConfiguration_xx = 3**) to maximize the efficiency of the vehicle.

EEPROM Value	Drive (D)	Low (L)	Notes
0	Moderate	Heavy	Driver selectable regen levels, moderate DRIVE regen and aggressive LOW regen.
1	Minimal	Disabled	Driver selectable regen level disabled, minimal regenerative braking.
2	Moderate	Disabled	Driver selectable regen level disabled, moderate regenerative braking.
3	Heavy	Disabled	Driver selectable regen level disabled, most aggressive regenerative braking.
9	Minimal	Moderate	Driver selectable regen levels, least amount of regenerative braking options.
13	Minimal	Heavy	Driver selectable regen levels, minimal DRIVE regen and aggressive LOW regen.
14	Moderate	Heavy	Driver selectable regen levels, moderate DRIVE regen and aggressive LOW regen. This is the same config as EEPROM 0

Table 2: Regenerative Braking Configuration EEPROM Settings

2.4 Impact on Range and Vehicle Efficiency

It is difficult to simulate how the vehicle efficiency and range will be impacted by the varying performance modes and regenerative braking configurations. However, through real world tests we have found a few key theme's:

1. **MORE aggressive acceleration yields LOWER vehicle efficiency and range**- higher acceleration rates lead to higher vehicle speeds and road loads. This ultimately reduces vehicle efficiency and range. Proterra has observed efficiency impacts up to 10% based on different acceleration rates in real world operation.
2. **MORE aggressive regenerative braking yields HIGHER vehicle efficiency and range**- for a transit vehicle with lots of stop and go driving and lower average speeds, maximizing regenerative braking leads to higher efficiency. Proterra has observed efficiency impacts up to 7% based on different regenerative braking levels in real world operation.

Powertrain related items that will directionally improve vehicle efficiency and range:

- Lower average vehicle speeds
- Lower vehicle acceleration
  - Proterra's acceleration control algorithm helps in this category. It minimizes a "heavy footed" driver's influence on range by only allowing the prescribed acceleration defined in Table 1. This also improves the consistency of the vehicle acceleration across load conditions.
  - Setting the Performance Mode variable **EP_usi_ZR32_PerformanceMode_x** to **ECO "0"** mode will **maximize vehicle range and efficiency**.
- Gradual braking
  - It is important to minimize the use of pneumatic friction brakes to improve range and efficiency. This method to slow down the vehicle is wasted energy that turns into heat.
  - Proterra's more aggressive regen options will improve efficiency under low speed driving by reducing the need to apply the brake pedal. Therefore, a larger percentage of energy can be recaptured by the battery system as regenerative braking operates.
  - Setting the Regeneration Configuration variable **EP_usi_ZR32_AllowedRNDLConfiguration_xx** to **"3"** will **maximize vehicle range and efficiency.**

Other benefits to consider:

- "Low mode" can be used on steep downhill descents to emulate a driveline retarder in a conventional vehicle. This will improve brake pad life.
- "Drive mode" does have its advantages that should be considered:
  - There may be ergonomic benefits to the driver's right foot. Less coasting regen will require less accelerator input to achieve similar torque output while maintaining the same speed. This may be more desirable on higher speed routes.
  - Less coasting regen may be more desirable under slippery scenarios such as snow or ice. Regenerative braking can induce wheel slip events in these conditions and Drive Mode may reduce the probability of wheel slip from occurring.
  - Certain drivers may prefer a more conventional feeling bus based on what they are used to. Drive Mode gives them that option.

2.5 Software and Hardware Compatibility

DuoPower Drivetrain

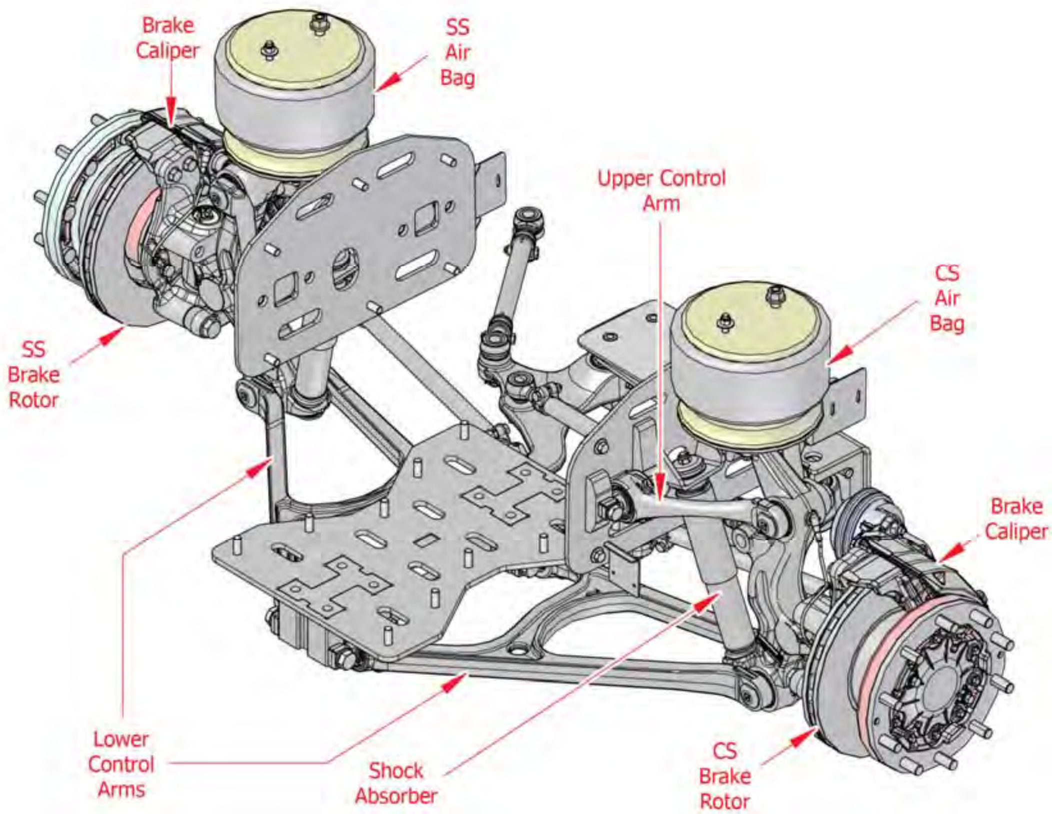
- The Performance Mode and Regenerative Braking Configuration features defined above are fully released and validated for DuoPower software v1.3.0 (SC-20-115) and body software v6.3.0 (SC-20-91).
  - Proterra recommends using the ECO Performance Mode (**EP_usi_ZR32_PerformanceMode_x = 0**) to maximize the efficiency of the vehicle.
  - Proterra recommends using the most aggressive regen level (**EP_usi_ZR32_AllowedRNDLConfiguration_xx = 3**) to maximize the efficiency of the vehicle.

ProDrive Drivetrain

- The Performance Mode and Regenerative Braking Configuration features defined above are fully released and validated for ProDrive software v4.2.0 (SC-20-163) and body software v6.3.0 (SC-20-91)
  - Proterra recommends using the ECO Performance Mode (**EP_usi_ZR32_PerformanceMode_x = 0**) to maximize the efficiency of the vehicle.
  - Proterra recommends using the most aggressive regen level (**EP_usi_ZR32_AllowedRNDLConfiguration_xx = 3**) to maximize the efficiency of the vehicle.

Front Axle & Suspension

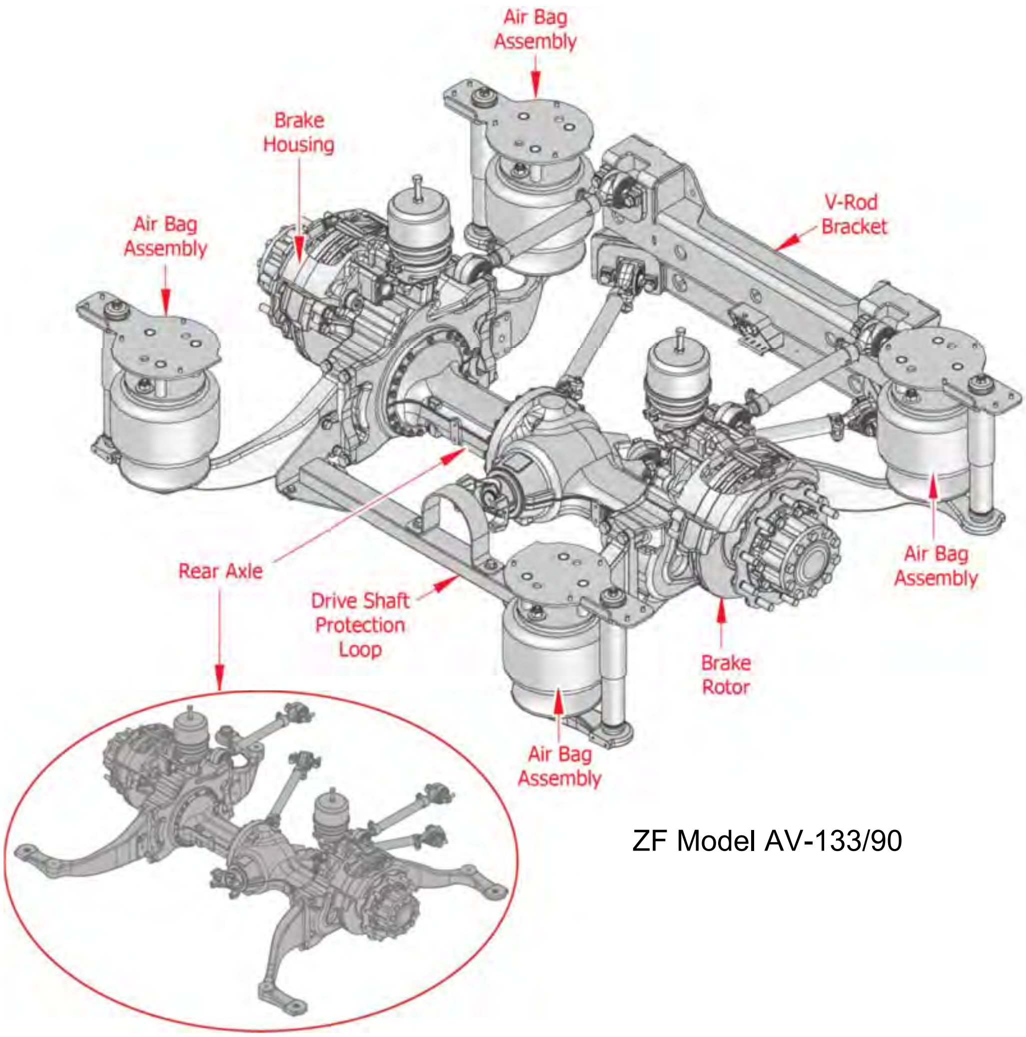
The ZX5 vehicle proposed for PSTA will have a heavy-duty independent front suspension, model RL-82EC, manufactured by ZF. The axle weight rating is 18,078 lbs. The design of this front axle and suspension system allows for improved steering, a tight turning radius, increased maneuverability, and excellent stability.



Rear Axle & Suspension

The rear axle and suspension system used in the Proterra ZX5 bus is a model AV-133/90 manufactured by ZF. The design of this rear axle allows a lower floor level inside the bus making it easier and faster to enter and exit the bus. This can reduce the overall time spent at each stop boarding and deboarding passengers. This rear axle is also very quiet, which is an asset to any city bus which has limited sound-proofing materials.

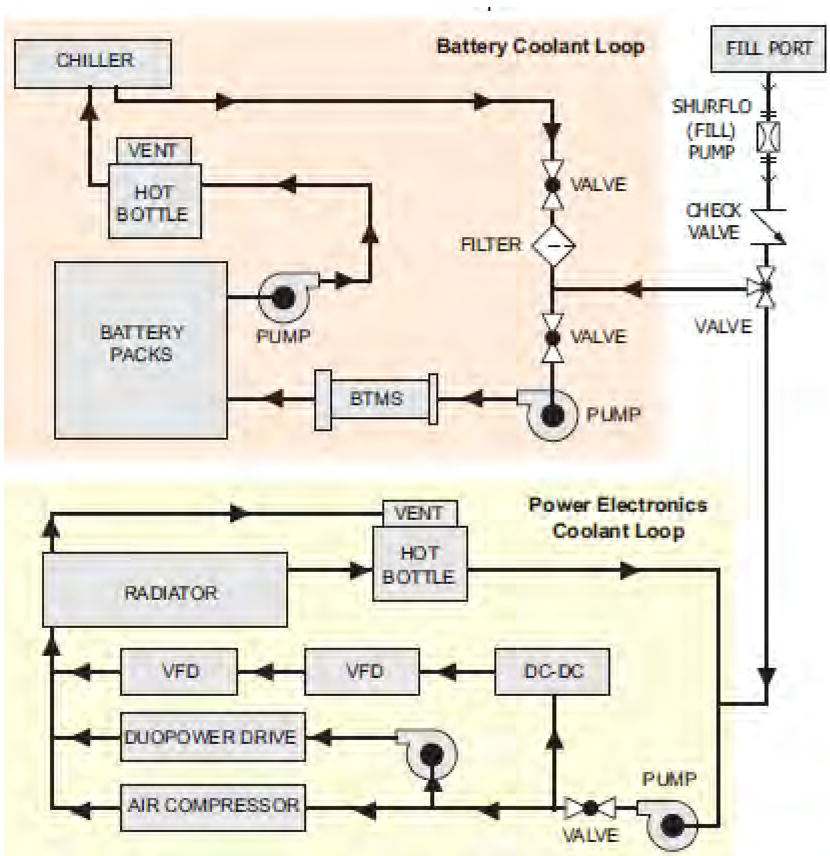
The AV-133/90 rear axle and suspension system includes the axle with disc brakes and all components needed for suspension, springs and damping, including the ABS/ ASR and brake wear sensors.



ZF Model AV-133/90

Cooling System

The ZX5 utilizes two independent cooling loops to cool the high-voltage batteries and the power electronics on the vehicle. The battery coolant loop has two dedicated coolant pumps that circulate coolant through the Battery Thermal Management System (for heating if needed), through the battery packs, an expansion tank, into the HVAC system (for cooling, if needed) and then through a filter to repeat the loop. The power electronics loop also has a dedicated coolant pump that circulates coolant through the power electronic units that require cooling, through a three-fan radiator and then through a filter to repeat the loop.



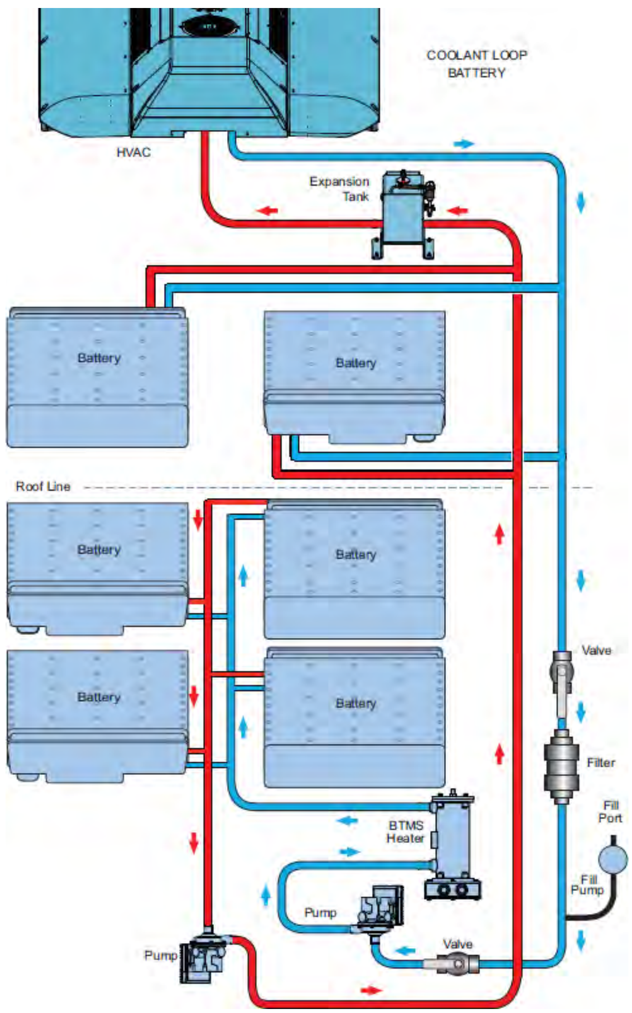
Battery Coolant Loop

The battery coolant loop provides liquid cooling/heating to each individual high-voltage energy storage battery pack. A rear cage mounted Battery Thermal Management System controls the temperature of the coolant. Coolant flow is provided by two CAN-controlled, variable speed pumps mounted in the rear cage frame. The pump speed is controlled by the vehicle controller via CAN messages. Speed is increased or decreased as required based on temperature readings. When the batteries require heating or cooling, the pump speed is increased to provide additional coolant flow. When increased coolant flow is no longer needed the pump speed is reduced to maximize energy efficiency.

The battery coolant loop also passes through a chiller mounted within the HVAC unit on the roof. This chiller, when activated by the main vehicle controller, can further reduce the temperature of the coolant to provide additional cooling to the batteries when needed.

Diagnostics monitor the performance of the Battery Thermal Management System, pumps, fan and chiller and will set faults in the event a problem is detected.
The batteries will automatically derate (reduce their power output) if they become too hot so that cooling system failures will not damage the batteries.

The following diagram shows the battery cooling system flow on a Proterra ZX5:
- The **RED** lines indicate warmed coolant flow
- The **BLUE** lines indicate the cooled coolant flow



Power Electronics Coolant Loop

The power electronics cooling loop provides liquid cooling to the following components:

- Traction Motors
- Traction Motor Inverter
- DC to DC Converter
- Air Compressor
- Dual-Output Variable Frequency Drive (VFD) - Rear Cage
- Single-Output Variable Frequency Drive (VFD) - Rear Cage

These components are liquid-cooled to increase their power density, efficiency and reliability. Coolant flow is provided by a CAN-controlled, variable speed pump mounted in the rear cage.

The pump speed is controlled by the vehicle controller via CAN messages. Speed is increased or decreased, as required, based on temperature readings of each of the components being cooled. When a component begins to heat up, the pump speed is increased to provide additional cooling. When increased cooling is no longer needed, the pump speed is reduced to maximize energy efficiency.

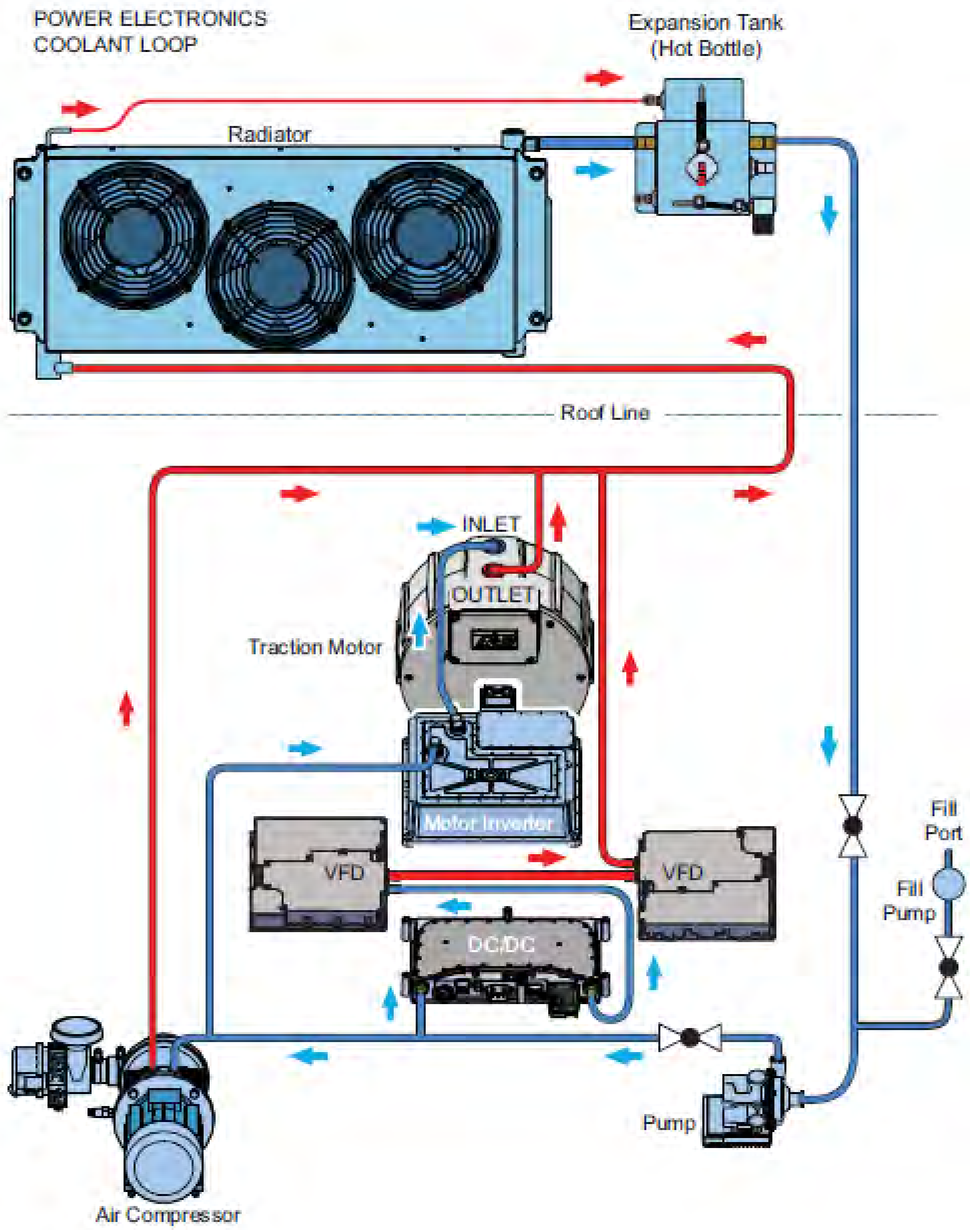
A rooftop mounted radiator reduces the temperature of the coolant. Warm coolant flows through the radiator, is cooled, and is then pumped through the power electronics devices. Three CAN-controlled, variable speed fans are mounted on the radiator and can be activated by the main vehicle controller to provide additional airflow through the radiator, thereby reducing the coolant temperature further.

Diagnostics monitor the performance of the pump and radiator fans and will set faults in the event a problem is detected. All of the devices in the power electronics cooling loop will automatically de-rate (reduce their power output) if they become too hot, so that cooling system failures will not damage these devices.

The power electronics cooling loop includes an expansion tank with a level sensor. The cooling system can be filled from ground level using a built-in fill pump inlet located near the low-voltage batteries.

The following diagram (next page) shows the power electronics cooling system flow on a Proterra ZX5 bus:

- The **RED** lines indicate warmed coolant flow
- The **BLUE** lines indicate the cooled coolant flow


POWER ELECTRONICS
COOLANT LOOP
Expansion Tank
(Hot Bottle)
Radiator
Roof Line
INLET
OUTLET
Traction Motor
Motor Inverter
VFD
VFD
DC/DC
Fill
Port
Fill
Pump
Pump
Air Compressor

Valeo Revo-E Global Overview

The Proterra HVAC system included in this proposal is manufactured by Valeo, formerly Spheros. The Valeo HVAC is our second HVAC offering for Proterra's fifth generation ZX5 model BEB. The Valeo unit comes with improved vehicle efficiency as it employs a heat pump which reduces power draw of the HVAC from 1/2 to 1/3 of power required using electric resistive heat only. The heat pump is used in conditions just below freezing and higher. In lower ambient temperatures a Postive Temperture Coefficient resistive heating element system which is the state of the art in electric heating which is inherently safer than metallic heating elements.. The driving philosophy around adding Valeo as an option is based on the principle that state-of-the-art BEBs should have the smartest, most efficient HVAC solutions.

Valeo Revo-E Global HVAC

The HVAC system controls the bus interior temperature and humidity levels within prescribed limits of comfortable conditions. This HVAC unit is specifically designed for use on an all-electric, heavy-duty, city transit bus. The HVAC unit receives high-voltage DC power from the vehicle for all high-power operation. A battery cooling system connection (conditioned water for a battery cooling loop servicing battery packs) is also contained in the HVAC System. The HVAC system is roof mounted HVAC unit.

Benefits of the Valeo HVAC

Low life-cycle costs

- Low consumption of energy due to efficient heating and low unit weight
- Dimensions allow space for battery system on the roof
- Long duration due to brushless EC blowers and hermetically sealed AC compressor
- Nearly maintenance-free

Environmentally friendly

- Safety against leakage due to the hermetically sealed refrigerant circuit
- Noise emissions optimized

PROTERRA

Comfort

• Cooling capacity of up to 30 kW
• Heating with PTC heater and heat pump included
• Tested and Validated for use on Proterra BEBs up to 120 deg F

Operating Range

• Maximization of the range due to the efficiency of the heat pump and low unit weight
• Optimized power consumption
• PTC heater used in cold ambient conditions where required

Others

• Integrated compressor, no installation of refrigerant lines necessary
• Designed for R 407C

Description

The Valeo HVAC is designed to keep the driver and passengers comfortable under all weather conditions from very hot to very cold. The system is mounted on the roof and is powered by High Voltage (HV) DC electricity directly from the vehicle main energy storage battery system. The system consists of the following major components:

- Electrically driven, hermetically sealed scroll-type compressor
- Evaporator and condenser heat exchangers
- HV Variable Frequency Drive (VFD) to provide the HV electricity to the variable speed compressor
- DC to DC converter to convert HV dc to 24v dc. The DC to DC converter is combined into one device along with the VFD
- 24v brushless DC evaporator fans
- Heat pump cycle and PTC heating elements provide the main cabin heat
- Parallel Loop battery chiller heat exchanger cools the coolant for the batteries
- Heat Pump and Battery Chiller allows heat scavenging operation between batteries and Cabin for maximum efficiency under certain operating conditions.

The Valeo unit has an integral chiller for battery cooling. The control system allows the unit to supply refrigerant for stand-alone cooling capacity or cooling capacity in concert with HVAC operation.

Capacities:

- AC: 30 kW (102364 BTU/Hr)
- Heat Pump: 30 kW (102364 BTU/Hr)
- PTC Heat: 20 kW (68243 BTU/Hr)
- Battery Thermal Management Coolant Chiller: Min 10 kW under any operating conditions

Refrigerant:

- R407c

Cabin Heating

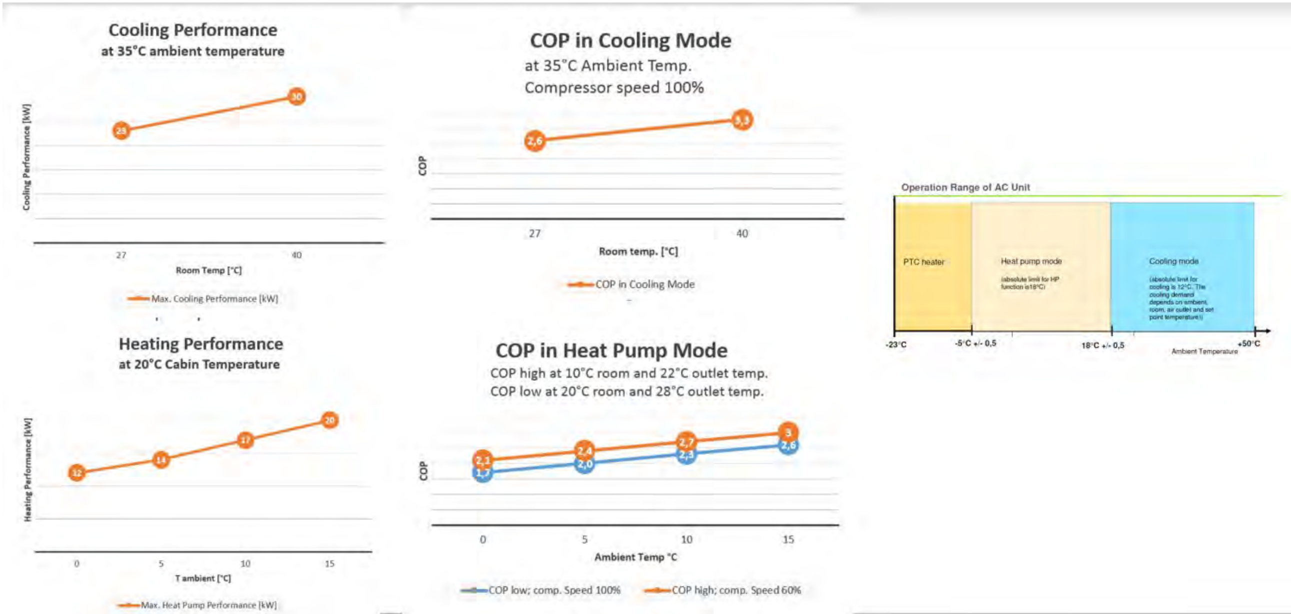
The Valeo HVAC heats the bus in one of two ways, though its electric resistive Positive Temperature Coefficient (PTC) heating elements or the refrigerant system. The PTC elements provide an inherent safety not included in the Eberspaecher system, the PTC elements draw lower current as they get warmer, thus helping to prevent overheat conditions that can occur on electric heating elements. The PTC elements do have a limitation per specification to only start heating when cold soaked to -25 deg C (-13 deg F) or higher. This does not preclude operating in colder conditions as after warm-up, the system can run to colder conditions. Proterra tested the Valeo HVAC system in a cold chamber down to -20 deg F without issue. The AC refrigerant system is able to provide cooling in warm conditions and heating in cold conditions. This “heat pump” system is able to provide cabin heat down to an ambient temperature of -5 deg C (23 deg F) and up to 18 deg C (64 deg F). This heat pump operation allows for significant improvement in efficiency over the electric heat. The heat pump can use as low as 1/3 to ½ of the power of electric heat, depending on ambient and cabin conditions. Like the cooling operation the total power used by the heat during heat pump operation is less than the equivalent heat supplied to the cabin. (Electric Heat is a one to one relationship between power draw and heat supplied). As heating is a major source of power draw this improvement will result in an improvement in range during cold conditions.
The Valeo system performs well in APTA testing conducted by Proterra and provides as much and more heat as the Eberspaecher unit. More detail information on performance of the Valeo HVAC in heating can be provided as required.

The Valeo system integrates fully with the optional Auxiliary heat system provided by Proterra and has been tested by Proterra to confirm operation with both heating systems.

Cabin Cooling

The Cabin cooling provided by the Valeo system is very similar to the Eberspaecher HVAC system used on previous Catalyst BEB models. The Valeo system uses a hermetically sealed scroll compressor as compared to the semi-hermetically sealed compressor used in the Eberspaecher unit. This hermetically sealed unit offers some leak reliability improvement some customers will desire per their specifications. The Valeo system is designed to work for both heating and cooling and the design constraints based on this make sizing the condenser smaller than the Eberspaecher unit. This results in a system that cannot dump as much heat out of the cabin into the very hot ambient conditions. However, based on testing results that Proterra has completed the Valeo system does perform well relative to APTA testing specification. More detail information on performance of the Valeo HVAC in cooling can be provided as required.

Vendor cooling and heating performance is shown in the below image COP (Coefficient of Performance) is the ratio of heat out/power in for both heating and cooling performance.



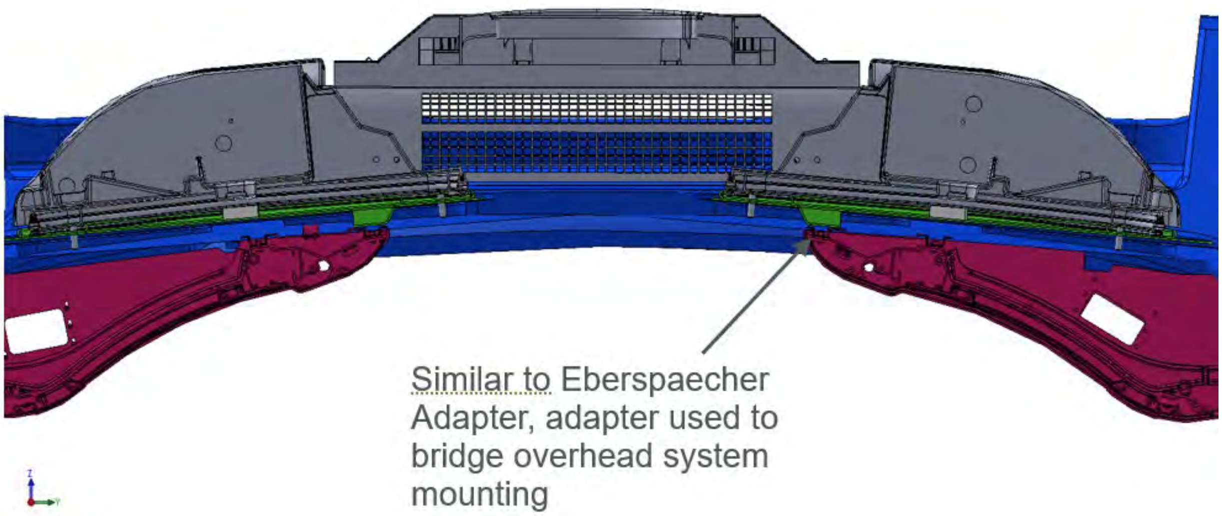
Coefficient of Performance

Electrical

The Valeo HVAC for Proterra has been designed such that it uses the same electrical interfaces as the Eberspaecher as required. The electrical integration has been confirmed on multiple buses. The connection with Low Voltage and High Voltage DC are the same as the Eberspaecher in connector type, definition and location. The Eberspaecher unit uses a remotely mounted (rear) water cooled Variable Frequency Drive (VFD) that provides electrical power to the HVAC fans, blowers and compressor. The Valeo unit differs from the Eberspaecher in that it uses an integrated air cooled VFD. This integrated VFD removes the need Low voltage power and HV power to (the VFD from the HVJB) and from (the VFD to the HVAC) the external VFD requires; simplifying the overall design. The air cooled VFD of the Valeo has been tested with the unit at ambient temperatures up to 115 deg F with no issues.

Mechanical

The integration of the Valeo HVAC has been accounted for in the latest Proterra ZX5 bus body design and will work with any of the ZX5 buses mechanically. The HVAC has been through install and rigorous thermal and durability testing on the Proterra bus with exceptional results. The mechanical integration of the Valeo unit (gray) its mounting plate designed for Valeo (green) the bus body (blue) and overheat system (maroon) is shown below.



Controls

The Valeo unit has the same operational control capabilities as the Eberspaecher unit. Controls integration has been done to ensure that the Valeo unit can work with base vehicle controls. This has been confirmed through testing with a base design control system. Can control of the unit has been confirmed including all modes and options and the BTMS (Battery Thermal Management System) chiller operation. The driver interface will change with the Valeo HVAC and an image of the driver interface for Valeo is shown on the next page.

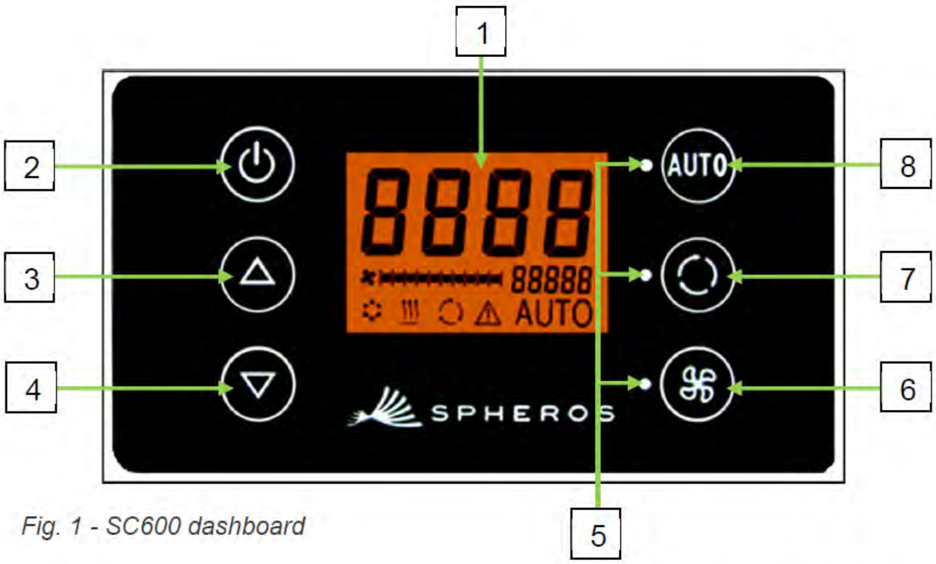
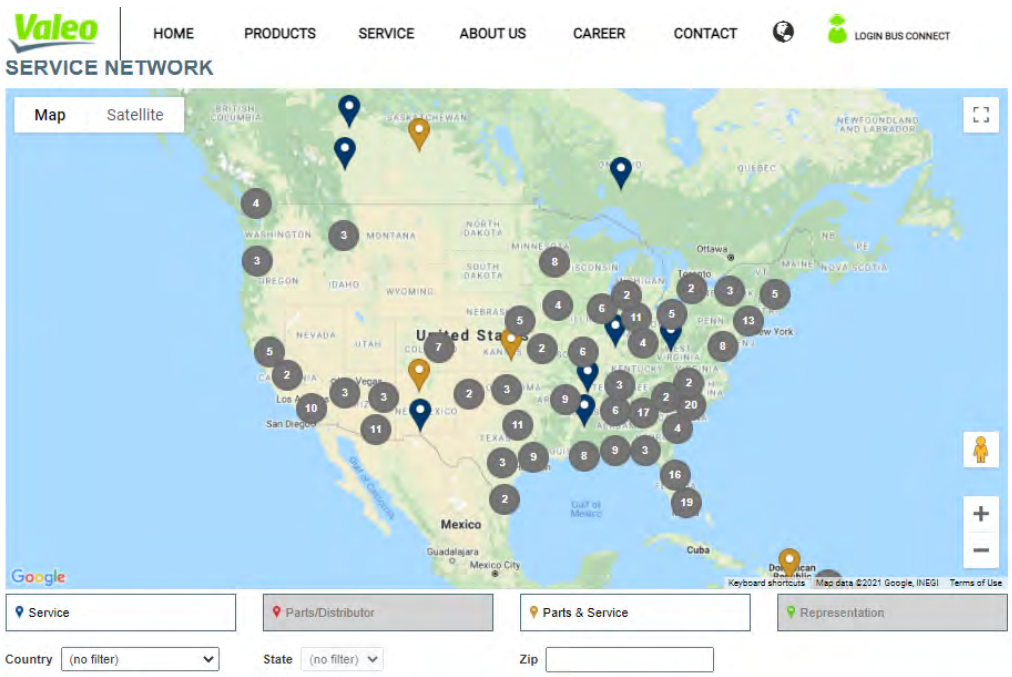


Fig. 1 - SC600 dashboard

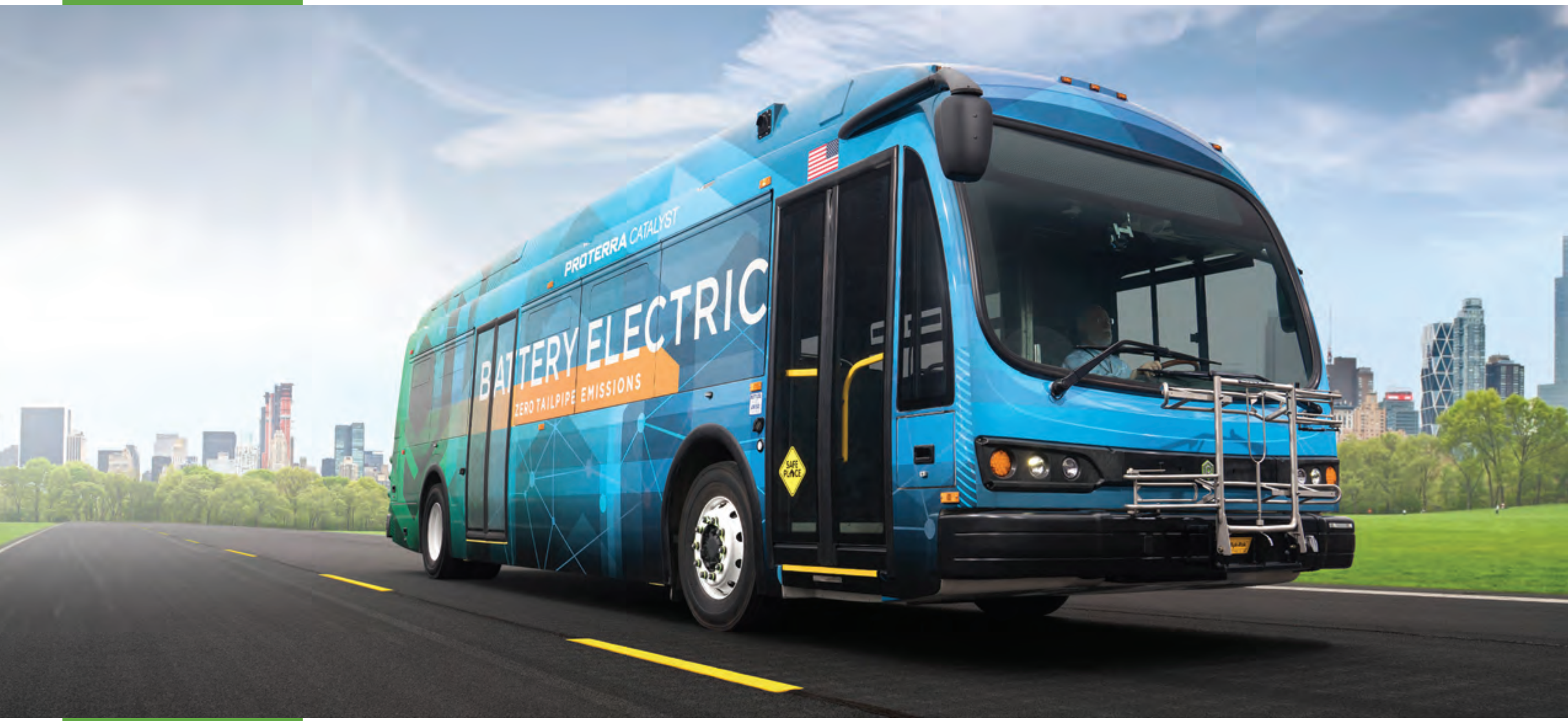
1. Display
2. On/off button
3. Scroll UP menu key
4. Scroll DOWN menu key
5. Function status light
6. Blower button
7. Fresh air/circulation air button
8. Auto button

Valeo Service Network

Valeo has an extensive, global service network to service its products. There are over 250 US locations providing service to its existing US customers. For this RFP, Valeo has six (6) Denver-area shops that will be able to provide service for the Valeo Revo-E Global HVACs.



HVAC SYSTEMS
IN PROTERRA® ELECTRIC BUSES



The HVAC systems used in Proterra battery-electric buses are designed to keep the vehicle operator and passengers comfortable in all climates and weather conditions. Proterra selects HVAC systems that are lightweight, energy efficient, easy to maintain, and most suitable for Proterra's purpose-built electric vehiclearchitecture. The system is mounted on the roof and is powered by High Voltage (HV) DC electricity from the main energy storage system that powers the vehicle drivetrain.

Key Product Considerations for HVAC Systems in Proterra Electric Buses:

- 800V system voltage
- Auxiliary evaporator heat exchanger: active battery cooling function
- Side discharge, center return air: compatible with our interior and other HVACs
- Full CAN control and integral aux heat control option – for common interface
- Packaging envelope on 35-foot and 40-foot platforms
- Efficiency and power supply
- Heating performance and element technology (PTC vs resistive)
- Cooling performance
- Heat pump option
- NVH
- Buy America compliant

HVAC SYSTEMS
IN PROTERRA® ELECTRIC BUSES

As a base platform element, HVAC systems in Proterra buses undergo:

- **Full vehicle thermal characterization**
  - Cabin temps, gradients, pull-up, pull-down testing
  - Battery coolant loop testing
- **Mechanical durability validation**
  - Vendor sub-system shaker testing to Altoona profile
  - Follow-up vehicle durability testing

  NVH measurements and tuning
- **Base vehicle controls integration**
  - High voltage supply or inverter pairing
  - Driver controls, including aux heat sub-control
  - Body controller CAN integration
- **Alpha/Beta/Pilot unit launch tests and BOM releases**
  - Base vehicle BOM release finished ~10 months before first customer delivery
  - All development and validation testing must be done before this release
  - Cannot switch in between customer pilot and ramp-up

40 FT

35 FT

ALL-ELECTRIC ROOFTOP AIR CONDITIONING UNIT FOR ELECTRO- AND HYBRID BUSES

REVO®-E GLOBAL

STRONG LIGHTWEIGHT ELECTRIFIES THE WORLD

The REVO®-E Global is supplementing our range of all-electric rooftop air conditioning units and is specifically oriented to the demands of the global markets. A special emphasis was placed on lightweight construction, performance and simple installation. In addition to heat pump technology, customers also have the option of PTC heating.

BEST-BUS-CLIMATE.COM

Valeo

REVO®-E GLOBAL

HIGHLIGHTS

Low life-cycle costs

- Low consumption of energy due to low unit weight
- Short dimensions allow space for battery system on the roof
- Long duration due to brushless EC blowers
- Nearly maintenance-free

Environmentally friendly

- Safety against leakage due to the hermetically sealed refrigerant circuit
- Noise emissions optimized

Comfort

- Cooling capacity from 23 to 33 kW
- Heating with PTC heater or heat pump possible as an option
- Tropical version: deployment up to 55°C outside temperature

Range of driving

- Maximization of the range due to the low unit weight
- Optimized power consumption
- Variable regulation of the PTC heater

Others

- Integrated compressor, no installation of refrigerant lines necessary
- Designed for R 134a & R 407C

Optionally with PTC heating, available in 20 kW versions.

PTC HEATER

The new high-voltage PTC heaters complement our heating systems. They are intended for use whenever there is simply an additional need for heating. In operation the PTC heaters can be infinitely adjusted by means of an electronic control unit developed by Valeo.

TECHNICAL DATA

REVO®-E Global REVO®-E Global T	Version 1 Cooling	Version 1 Trope Cooling (application up to 55 °C)	Version 2 Cooling + PTC heater	Version 3 Cooling + heat pump	Version 4 Cooling + heat pump + PTC heater
Cooling capacity (kW) Refrigerant R 134a Refrigerant R 407c	 25 33	 - 33	 25 33	 23 30	 23 30
Heating pump capacity (kW) Refrigerant R 134a Refrigerant R 407c	 - -	 - -	 - -	 13 19	 13 19
Current consumption (A) (26V DC)	nominal 70[1)]	nominal 70[1)]	nominal 70[1)]	nominal 70[1)]	nominal 70[1)]
Current consumption (A) (600V DC) Refrigerant R 134a Refrigerant R 407c	 Cooling max.12[2)]/regulated 7[3)] Cooling max.18/regulated 11	 - Cooling max.18/regulated 11	 Cooling max.12[2)]/regulated 7[3)] Cooling max.18/regulated 11	 Cooling max.12/Heat pump max.10[4)] Cooling max.15/Heat pump max.14	 Cooling max.12/Heat pump max.10[4)] Cooling max.15/Heat pump max.14
PTC heater (optional) (kW)	-	-	0 - 20	-	0 - 20
Fresh air	optional	-	optional	optional	optional
Weight (kg)	230	238	250	250	270
Dimensions L x W X H (mm)	3,100 x 1,900 x 295	3,550 x 1,900 x 295	3,100 x 1,900 x 295	3,100 x 1,900 x 295	3,100 x 1,900 x 295

1) Nominal (condenser 80%) (evaporator 70%)
2) Cooling maximum (compressor speed 90 Hz)
3) regulated (temperature passenger compartment at set-point 27 °C and ambient 35 °C)
4) Heat pump maximum (compressor speed 90 Hz)

Valeo Thermal Commercial Vehicles Germany GmbH
PO Box 1371 - D-82198 Gilching - Tel. +49 (0)8105 7721-0 - Fax +49 (0)8105 7721-119
www.valeo-thermalbus.com - Info-ValeoBus@valeo.com

PROTERRA

Multiplex System

The Continental VDO hardware was selected as the backbone for the vehicle MUX system due to its integrated design, I/O count, cost, superb support, and reliability. The system is easy to program, utilizing a hybrid of ladder logic as well as text and graphical programming. It consists of a centralized master controller, 7 multiplex nodes distributed throughout the vehicle, and the drivers display system.

The centralized master controller is the Continental ZR32A. This controller operates 2x32-bit RISC processor, has 2x512kByte internal flash, 2Mbytes of external flash, 6 CAN ports, and supports SAE J1939-73 DM1 messaging. The controller is programmed utilizing KWP2000 over K-line. The ZR32A controller maintains the configuration for the multiplex system and acts as the master logic controller. If it ever needs to be replaced, the controller will need to be programmed and configured. This task is simplified with the use of the Proterra Service Tool which allows the controller to be programmed and configured without the use of third-party software. The same service tool provides diagnostic support, troubleshooting, and calibration of other vehicle systems.

The multiplex units provide a dense I/O count per unit, 30 inputs and 32 outputs. This makes the system very adaptable to deployment throughout the vehicle. Each multiplex node can provide up to 30 amps of power at a time and each output includes short circuit detection and protection as well as open circuit detection. The multiplex nodes can be replaced while in the field without requiring programming as the communications addressing is all handled through wiring connections and the master controller retains the configuration.

The drivers display system consists of a MOKI3 and DMUX. These units combine to provide visual and audible feedback to the driver. This system also provides additional I/O for the control system. The MOKI3 allows for the customization and personalization of the analog style gauges and indicator lamps. It is a fully integrated Continental solution allowing for a simple and clean presentation of vehicle data in a timely and accurate manner. The DMUX provides the graphical based screen and additional I/O count. It operates on the same 24V nominal range as the rest of the control system. Graphics are powered by a 32-bit RISC processor and the logical I/O is powered with an 8-bit RISC processor. The logical section provides an additional 60 inputs and 28 outputs which greatly expand the configurability of the driver's workplace.

Wiring Pass Through Documentation

Proterra's battery electric buses do not have engines with combustible material in the rear powertrain compartment. The cables that pass through the rear bulkhead are Roxtec and Icotec products which provide a very rugged and water proof pass-through.

Jump Start Connector

Proterra's battery electric buses come standard with an Anderson 350A red jump start connector which is installed in the low-voltage battery compartment.

PROTERRA

TS 40.5 High Voltage Disconnect System

Please submit further explanation as part of your proposal for review by the evaluation committee:

The contactors are required to be located as close to the energy source as possible, preferably within the motor controller. The contactors on a Proterra vehicle are located within the high voltage batteries, making them extremely close to the energy source. This design meets the requirement and Proterra just wants to clarify they are within the batteries, not the motor controller. The contactors within the batteries are the primary means to disconnect energy from the vehicle. If a safety system is activated, these contacts are opened and are fully rated to interrupt the power. Both the BMS and vehicle controller are monitoring safety systems and either one can disrupt the energy. Additional contactors are contained with the HV junction box and can interrupt power to some HV loads. This this the redundancy we spoke of. When the HV system is disabled, these contactors, downstream of the HV batteries, will also open.

Proterra has a number of manual HV disconnects available depending on the Service situation. Each battery has a manual disconnect that will physically remove HV negative and prevent it from leaving the battery. The HV junction box also has a physical disconnect switch that will interrupt HV negative and prevent it from leaving the box.

TS 41.1.2 Shielding

Please submit further explanation as part of your proposal for review by the evaluation committee:

Our 3 phase motor cables are grounded at both the motor and inverter. This design is proven to provide the best protection to mitigate radiated energy from the powertrain.

PROTERRA

Fire Suppression System

The Amerex automatic fire suppression system provided in the base vehicles consist of the following components:

1. 25lb ABC Dry Chemical Suppressant Bottle
2. (4) 350F Detection Sensors
3. (4) Dispersion Nozzles
4. Control Panel
5. Manual Activation Switch
6. Distribution Network

www.proterra.com

Headquarters
1815 Rollins Road, Burlingame, CA 94010

East Coast Manufacturing
1 Whitlee Court, Greenville, SC 29607

West Coast Manufacturing
393 Cheryl Lane, City of Industry, CA 91789

1. FIRE SUPPRESSION BOTTLE

An Amerex fire suppression bottle containing 25lb of ABC dry chemical fire suppressant is mounted on the roof of the vehicle. Mounting location can be seen in Figure 1.

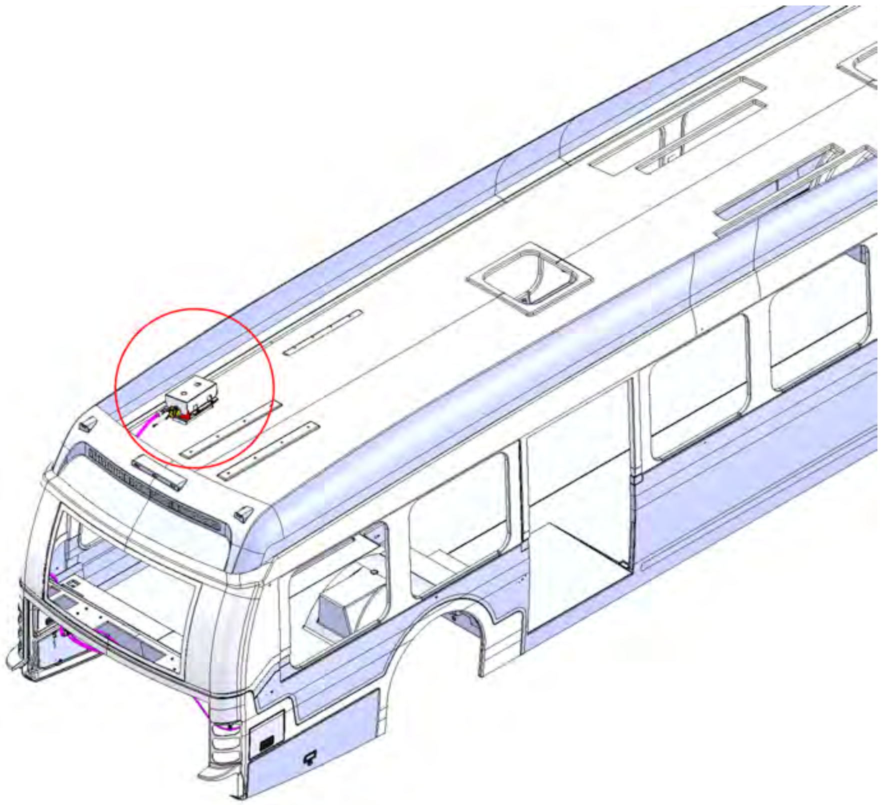


Figure 1: FIRE SUPPRESSION BOTTLE LOCATION

The bottle is mounted using threaded inserts which are installed into the body of the vehicle. The bracket is secured using (4) M12 fasteners.

2. DETECTION SENSORS

(4) 350F spot detection sensors provide detection capability for the following areas on the vehicle.

1. Auxiliary heat fuel tank
2. Auxiliary heater
3. Powertrain/high voltage junction box area
4. Low voltage battery box

Locations of sensors can be seen in Figure 2. Note that the view is referenced from the rear underside of the vehicle.

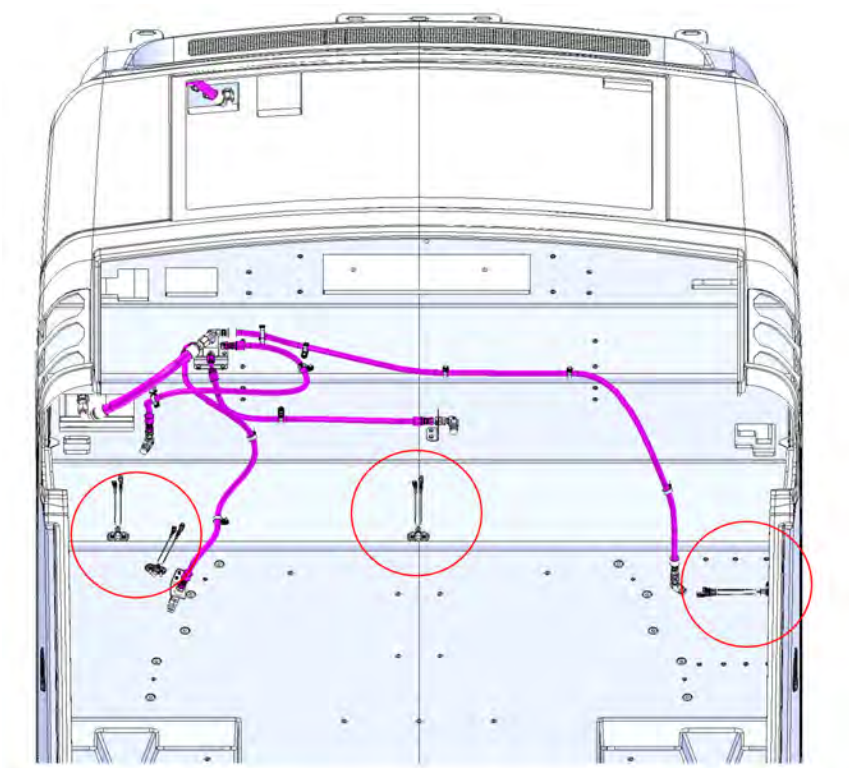


Figure 2: SENSOR LOCATIONS

Upon activation of one of the sensors vehicle will enter a 15 second countdown before dispersion of the fire suppressant.

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Headquarters
1815 Rollins Road, Burlingame, CA 94010

East Coast Manufacturing
1 Whitlee Court, Greenville, SC 29607

West Coast Manufacturing
393 Cheryl Lane, City of Industry, CA 91789

3. NOZZLES

4 brass nozzles with dust caps are located in the general area of each detection sensor. Nozzle locations can be seen in Figure 3. Note that the view is referenced from the rear underside of the vehicle.

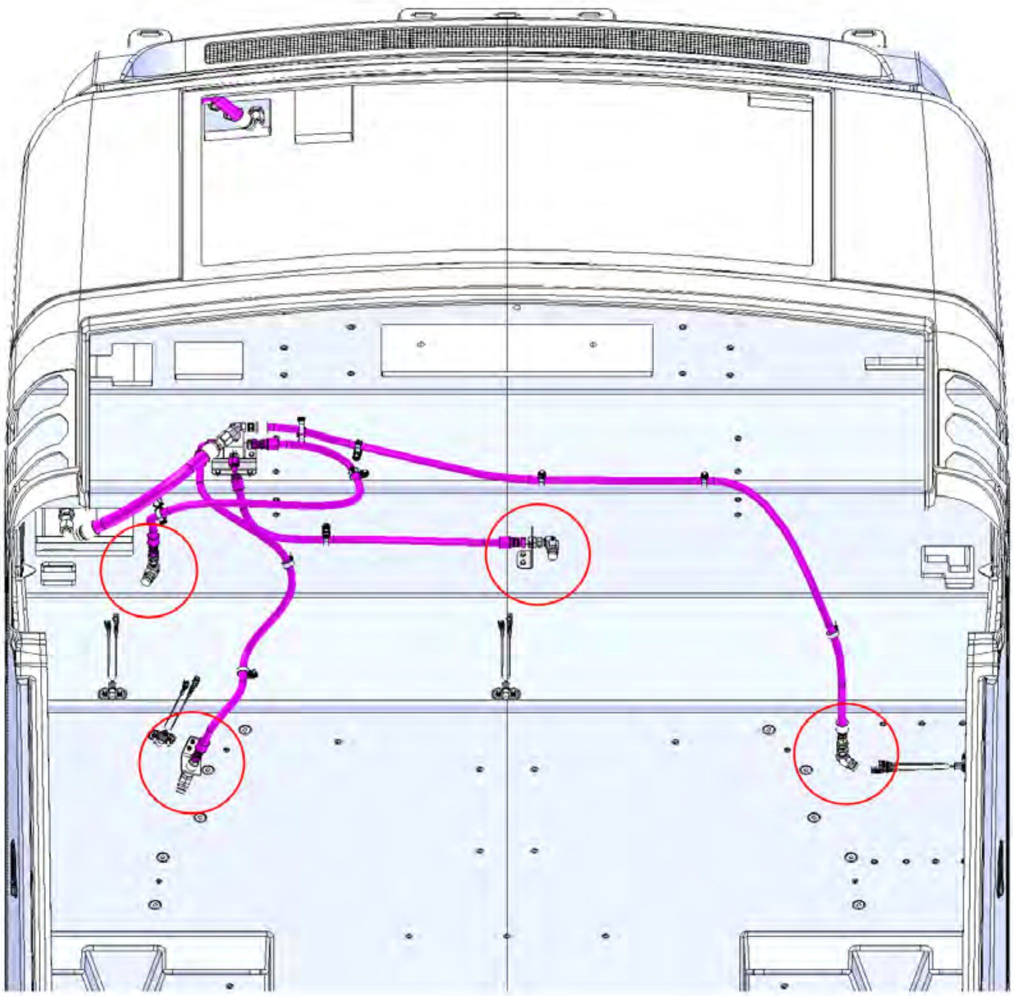

Figure 3: NOZZLE LOCATIONS

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Headquarters
1815 Rollins Road, Burlingame, CA 94010

East Coast Manufacturing
1 Whitlee Court, Greenville, SC 29607

West Coast Manufacturing
393 Cheryl Lane, City of Industry, CA 91789

4/5. CONTROL PANEL AND MANUAL ACTIVATION SWITCH

The fire suppression control panel and manual activation switch are both located in the driver's area on the driver's overhead panel. Figure 4 shows the location of the control panel and manual activation switch.

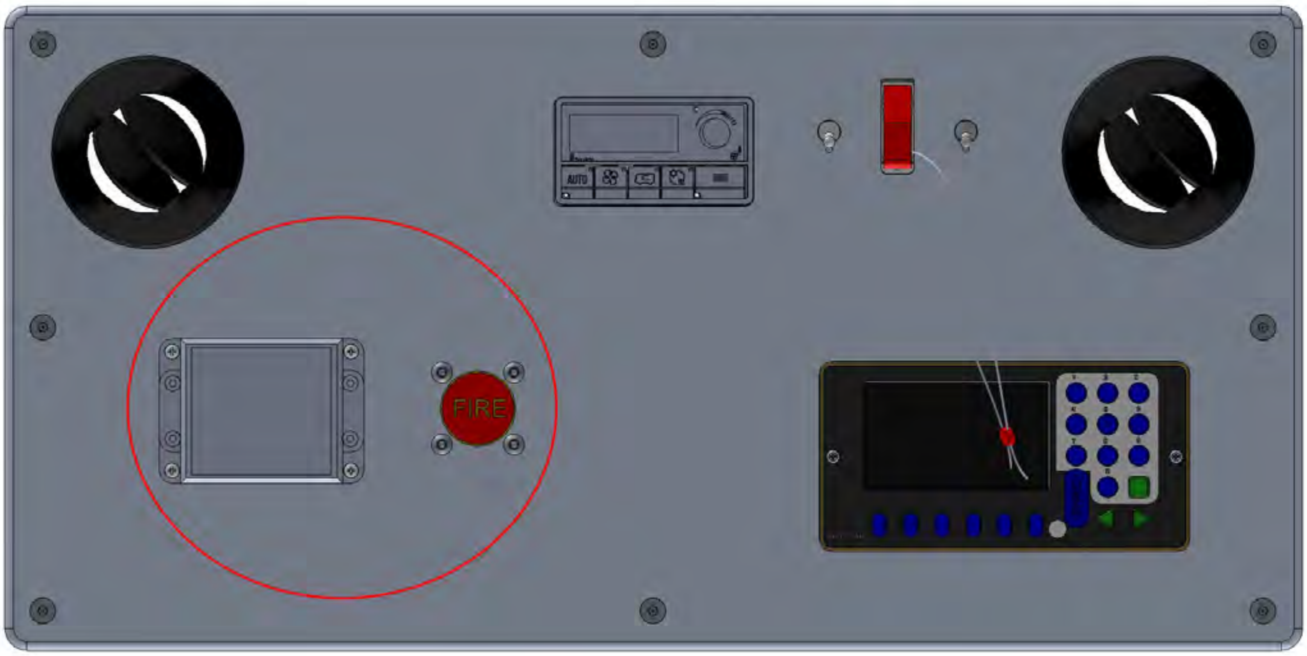


Figure 4: CONTROL PANEL AND MANUAL ACTIVATION SWITCH

The control panel displays system status as well as any faults or fire events. The manual activation switch allows the operator to activate the suppression system by removing a pin and pressing the "fire" button.

6. DISTRIBUTION NETWORK

The distribution network is composed of multiple ½" and ¾" SAE100R16 hydraulic hose and fittings. The distribution network routes the fire suppressant to the nozzles in the event of a fire. The bottle is connected to a distribution manifold which branches off to each nozzle. An overview of the distribution network is seen in Figure 5.

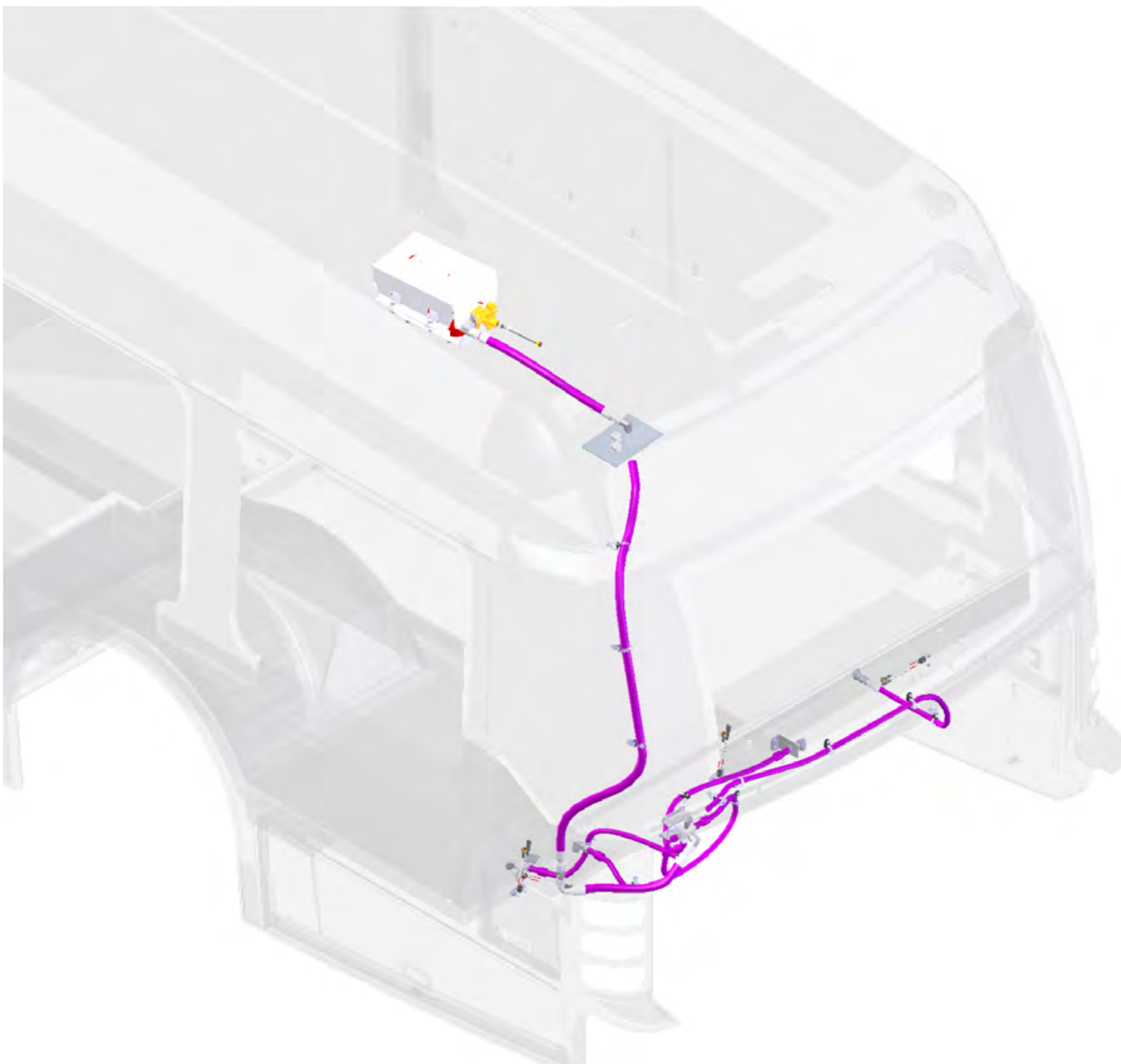


Figure 5: DISTRIBUTION NETWORK

Entrance Door

The entrance door is a Ventura Systems (Ventura) pneumatic in-swinging door. Two pneumatic actuators are used to rotate the door shafts. The actuators are connected to the lever at the top of the door shafts. When the actuators extend, it creates an inward gliding movement of the door panels.

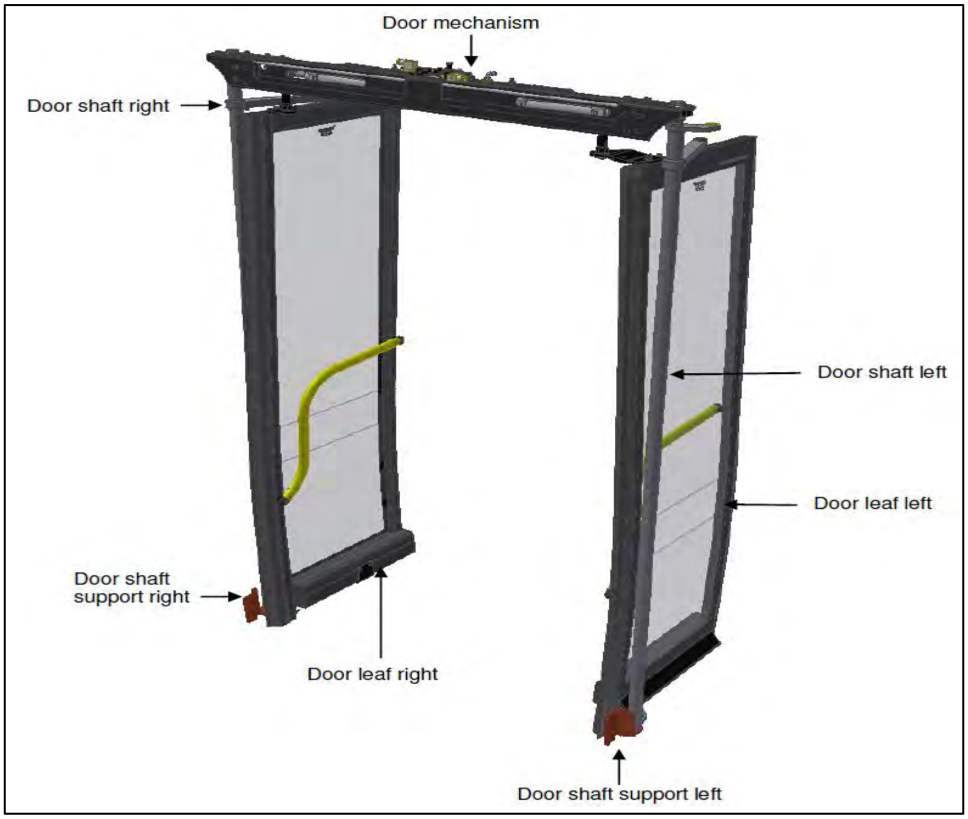
Two guiding brackets at the top of the door leafs are moving in the guiding rail of the door mechanism. These guiding brackets are needed to position the door leafs perpendicular with the step edge of the vehicle in the open position and stabilize the door leafs in open and closed positions. The potentiometers are connected to the door shafts by a tie rod and they track the position of the door panels.

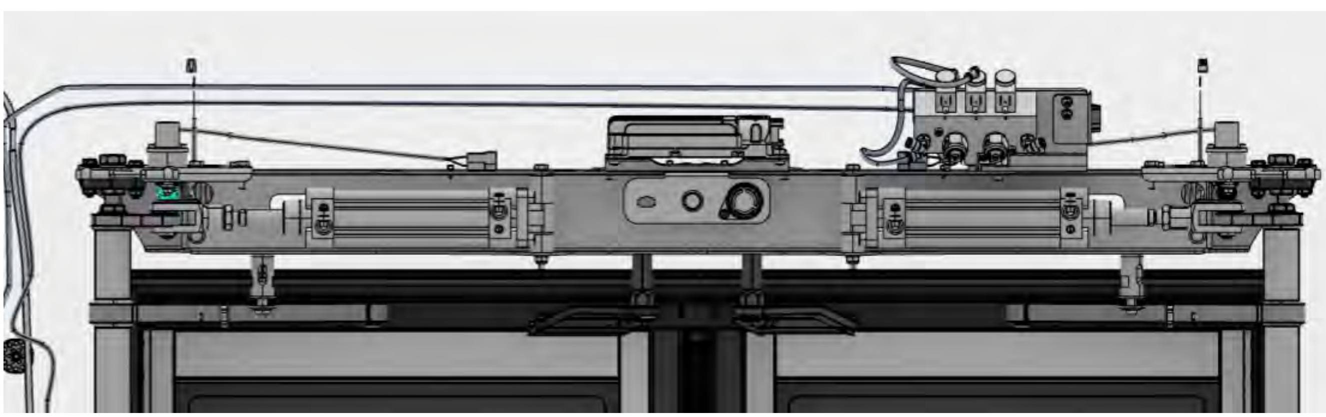
Each door panel has an electric sensitive edge. The controller also tracks speed of the door panels in the opening and closing direction. If the sensitive edges were to fail for any reason and the door panels hit an object, the controller senses the loss of door speed and will reverse the door panels.

Figure 17-1. Front and Rear Passenger Doors

PROTERRA

ENTRANCE DOOR





ENTRANCE DOOR MECHANISM

PROTERRA

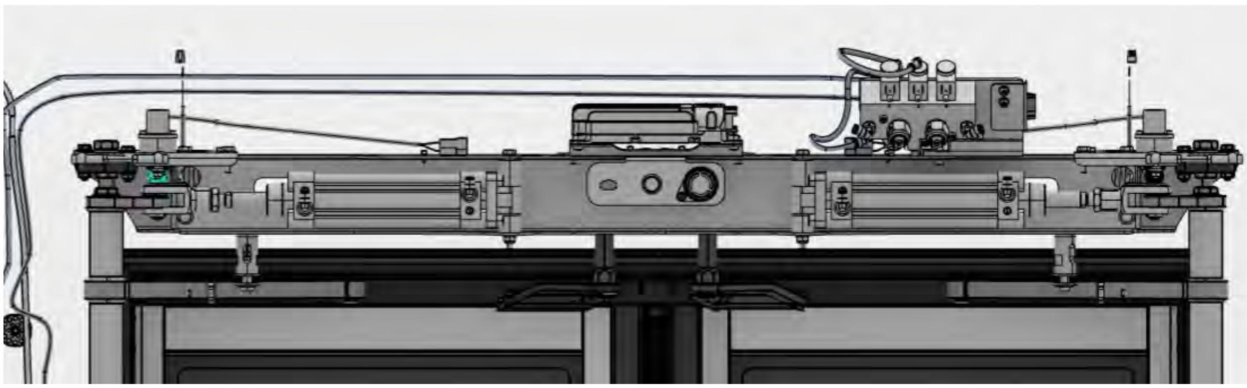
Rear Door

The rear door is a Ventura Systems (Ventura) pneumatic in-swinging door. Two pneumatic actuators are used to rotate the door shafts. The actuators are connected to the lever at the top of the door shafts. When the actuators extend, it creates an inward gliding movement of the door panels.

Two guiding brackets at the top of the door leafs are moving in the guiding rail of the door mechanism. These guiding brackets are needed to position the door leafs perpendicular with the step edge of the vehicle in the open position and stabilize the door leafs in open and closed positions. The potentiometers are connected to the door shafts by a tie rod and they track the position of the door panels.

Each door panel has an electric sensitive edge. The controller also tracks speed of the door panels in the opening and closing direction. If the sensitive edges were to fail for any reason and the door panels hit an object, the controller senses the loss of door speed and will reverse the door panels.

Both doors are Ventura off the shelf designs that were slightly modified to fit our bus. These doors have extensive use in transit buses especially in the European market.



REAR/EXIT DOOR MECHANISM

Past Performance with Ventura Systems

Ventura is based out of the Netherlands and sells doors into the European, Asian, African, & North American markets. They have thousands of transit bus doors in service. They report having a 15x higher MDBF (mean distance between failures) than any other door supplier in North America. Proterra has installed the Ventura door systems (both electric & pneumatic) on all of our 40' Catalyst buses. When we first started using their doors for the 40' Catalyst bus, we experienced some issues with the doors coming out of adjustment. We brought Ventura back in for additional, more extensive training with our production installers and the issues have since been mitigated. We have not installed any other door OEM products installed on our 40' Catalyst buses, although our original 35' BE35 EcoRide buses were originally outfitted with Vapor doors, before we switched over to the Ventura doors. Based on the field service data, the Ventura doors have performed much better in service. Additionally, some of our 35' BE35 EcoRide customers demanded that their buses be retrofitted to the Ventura doors as the previous OEM couldn't successfully address the issues in the field. Ventura has provided great service support to all of our fleet customers.

Working procedure:

1. Clean the door frame with help of primer and a piece of cloth.
2. Clean the ceramic screening of the glass with “Simson Cleaner I”.
3. Apply sealing tape and two-sided tape to the outside of the door frame. See figure **1** / **2**.
4. Apply glue (Simson STR 360) to the whole door frame (step 5-9 within 15 min due to drying period of glue). See figure **2**.
5. Remove the protection from the two-sided tape.
6. Position glass, Ventura logo according figure, DO NOT PRESS THE GLASS. See figure **3**.
7. SINGLE GLASS, position the glass (2mm) from the top (decisive), as shown figure **3** / **4**.
8. DOUBLE GLASS, position the glass (2mm) from the bottom (decisive, e.g. lock), as show in figure **3** / **4**.
9. Press the glass to the sealing tape.

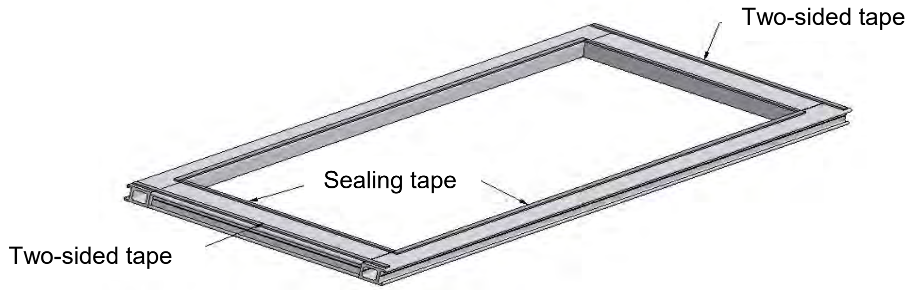


Figure **1**: Applying sealing tape and two-sided tape to the door frame

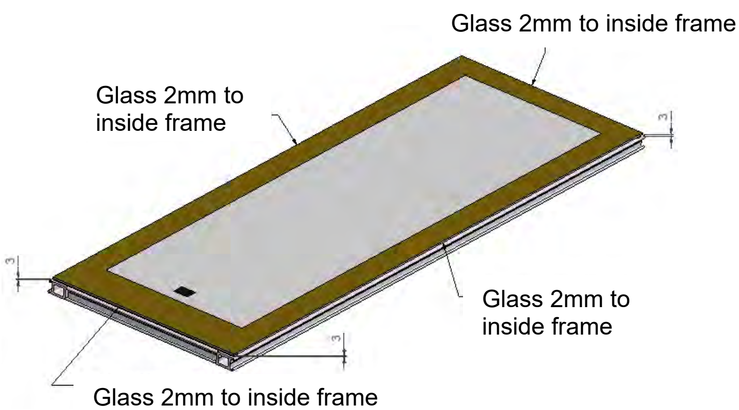


Figure **4**: Glass positioning

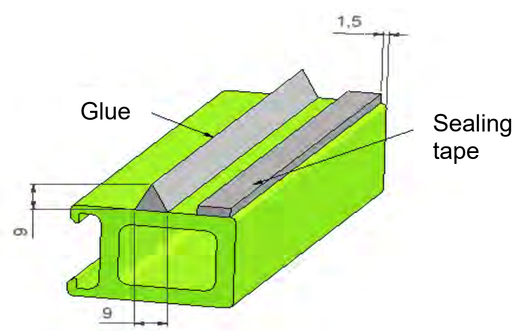


Figure **2**: Applying sealing tape

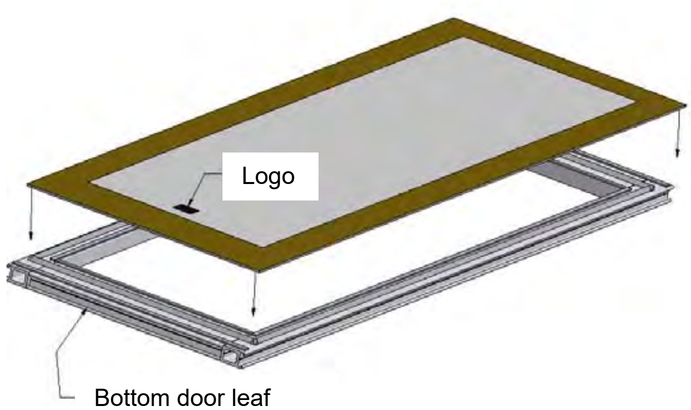


Figure **3**: Applying glass to door leaf

PROTERRA

Air Brakes and Air System

The pneumatic (air) system on the vehicle consists of the following components:

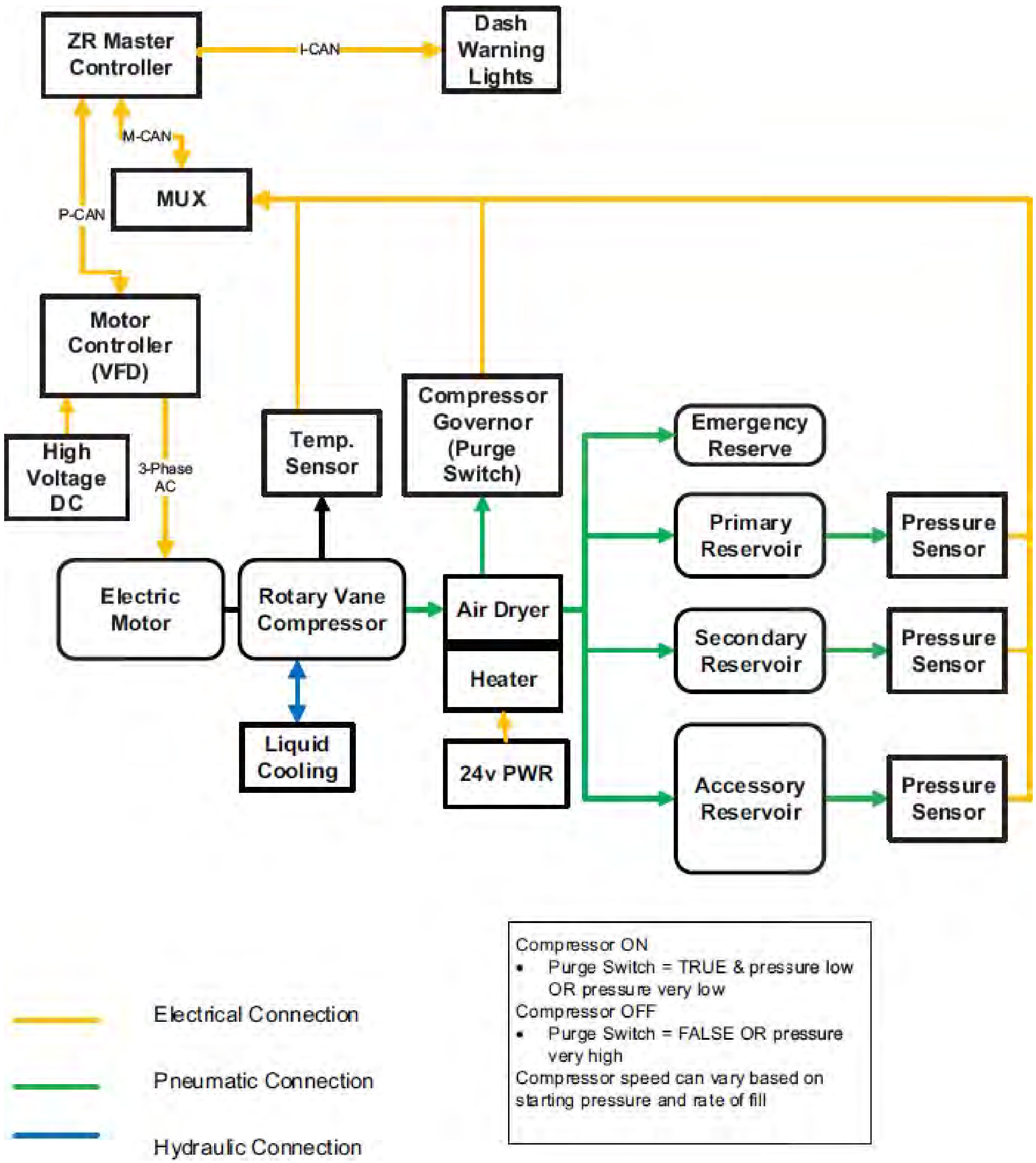
- Rotary, oiled, vane-style air compressor
- AC induction motor directly coupled to the compressor
- High-Voltage Variable Frequency Drive (VFD) to provide the HV electricity to the variable speed compressor. This VFD is a dual output device that also power the power steering motor.
- Air dryer
- Air tank and distribution system (Primary, Secondary, Auxiliary, Override)
- Pressure sensors and controls needed to operate the system

The pneumatic system feeds the following components:

- Foundation air disk brake
- Parking brake (spring safety brake)
- Air ride system (air bags)
- Doors - Pneumatic doors utilize air for all operation, electric doors utilize air for safety/air dump functions
- Driver's seat adjustment
- Gearbox shifters

When the vehicle master controller detects low air pressure from either pressure sensors located in the air tanks or from the purge switch located on the air dryer, it commands the VFD to enable and provide the necessary power to spin the air compressor. The compressor speed is variable and will change based on the current air pressure and rate of fill. The compressor will stop when the tanks indicate full based on the pressure sensors or the purge switch.

The high-pressure air from the compressor passes through an air dryer and then to the appropriate tank via manifolds. The tank fill sequence is governed by a series of check valves located in the air dryer manifold. The dryer contains a heating element that will activate automatically in cold weather to ensure the moisture relief does not freeze. Diagnostics monitor the performance of the VFD, compressor, air dryer, and sensors and will set faults in the event a problem is detected.



Air Compressor System Diagram

Air Dryer

The function of the Air Dryer system is to collect and removes air system contaminants in solid, liquid and vapor form before they enter the brake system. It provides clean, dry air to the components of the brake system which increases the life of the system and reduces maintenance costs. The necessity for daily manual draining of the reservoirs is eliminated. Additional detail is provided on the following pages.

AD-IS® AIR DRYER MODULE

INTEGRATED SOLUTION AIR DRYER

Enhance Performance, Reduce Maintenance Time

Evolutionary Charging System and Integrated Design

Bendix elevates air treatment to a new level with the Bendix® AD-IS® air dryer module, an integrated solution air dryer for removing liquid, vapor and solid contaminants from the air system. With a new concept in system charging and a modular design that combines a variety of air system components, the AD-IS® air dryer module enhances performance, simplifies maintenance, decreases the total number of parts, minimizes potential leak points and reduces system weight. The spin-on cartridge design makes replacement quick and easy.

Enhanced Performance

The AD-IS® air dryer module raises the bar over current industry standard air drying systems with its innovative system design. With four pressure protection valves located directly on the air dryer module, accessories can be plumbed straight from the air dryer as opposed to connecting through either of two air system reservoirs. This design feature reduces complexity and minimizes possible leak points.

The AD-IS® air dryer module purge cycle uses air from a self-contained reservoir instead of accessing either of two available air system reservoirs. As a result, the air system reservoirs maintain consistent pressure during the purge cycle and are fully dedicated to air system operations.

Simplified Maintenance, Reduced System Weight

The modular design of AD-IS® air dryer module combines the vehicle supply reservoir, governor and a number of charging system components, eliminating many maintenance trouble spots. Fewer components means lower system weight, fewer maintenance requirements and less opportunity for leaks. It also means service centers can inventory fewer parts.

The integrated design also extends the life span of some components. For example, because the governor is mounted directly to the air dryer – away from the heat and vibration of the compressor – it experiences less wear and tear. The majority of the sub-components of the air dryer module can be maintained individually and are easily accessed from one central location.

AD-IS® AIR DRYER MODULE

Spin-On Cartridge

Due to its spin-on design, the desiccant cartridge can be changed in less than 10 minutes, saving fleets maintenance and downtime. With the air dryer's integral purge volume, this spin-on cartridge meets today's highest performance standards, making the AD-IS® air dryer module an ideal solution for a wide range of applications.

Genuine Bendix Quality and Total Air Guarantee

With the Bendix® AD-IS® air dryer module, you can rely on Genuine Bendix quality backed by our Total Air Guarantee (T.A.G.) limited warranty. We're so certain of the Bendix® AD-IS® air dryer module performance abilities that, under normal usage, it's warranted for three years or 350,000 miles. And if it's installed as original equipment on a vehicle, you're eligible for our T.A.G. program. T.A.G. extends the warranty of other Bendix air and antilock brake system components also installed as original equipment on the same vehicle to three years or 350,000 miles.

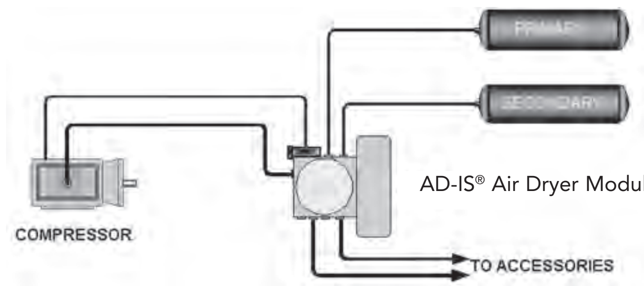
Specifications

Height:	11.5 inches
Width:	9 inches
*Projection:	10 inches
**Weight:	27 pounds
Heater:	12V and 24V
Purge Source:	Integral
Mounting:	SAE 4-hole thread pattern
Governor:	110 to 130 psi, integral to dryer
Models:	Standard and Extended Purge
Warranty:	T.A.G. limited warranty; 3 years/350,000 miles (for complete details on the T.A.G. warranty, refer to Bendix publication BW1716)

* Extended purge projection 12 inches

** Extended purge weight 31 pounds

BENDIX® AD-IS® AIR DRYER MODULE PART REDUCTION VS. TYPICAL CHARGING SYSTEM	
Category	Typical Reduction
Major Components	56%
Pneumatic Lines	44%
Pneumatic Connections	50%



Bendix® AD-IS® air dryer module system schematic

Bendix® AD-IS® Air Dryer Module System Benefits At-A-Glance

- Simpler charging system design reduces the number of possible leak points.
- Higher system air pressure (up to 135 psi) provides extra braking reserve.
- Number of components is reduced, resulting in weight savings.
- Reduced maintenance requirements.
- Spin-on cartridge design provides quick and easy servicing.
- PuraGuard® oil coalescing dryer cartridge available.

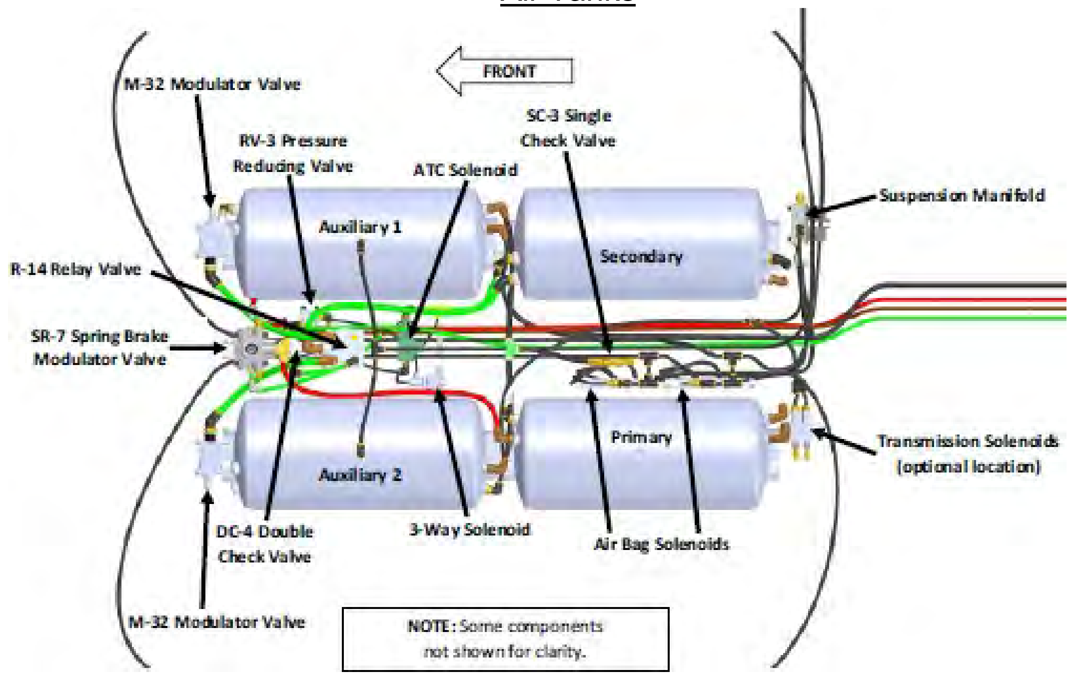
Get Ahead Of The Performance Curve With The Bendix® AD-IS® Air Dryer Module

Integrated design, enhanced performance and reduced maintenance time. Discover how the Bendix® AD-IS® air dryer module can enhance your commercial vehicle. Talk to your Bendix Account Manager, call 1-800-AIR-BRAKE, or visit bendix.com today.

Bendix Commercial Vehicle Systems LLC • 901 Cleveland Street • Elyria, Ohio 44035 • 1-800-AIR-BRAKE (1-800-247-2725)

PROTERRA

Air Tanks



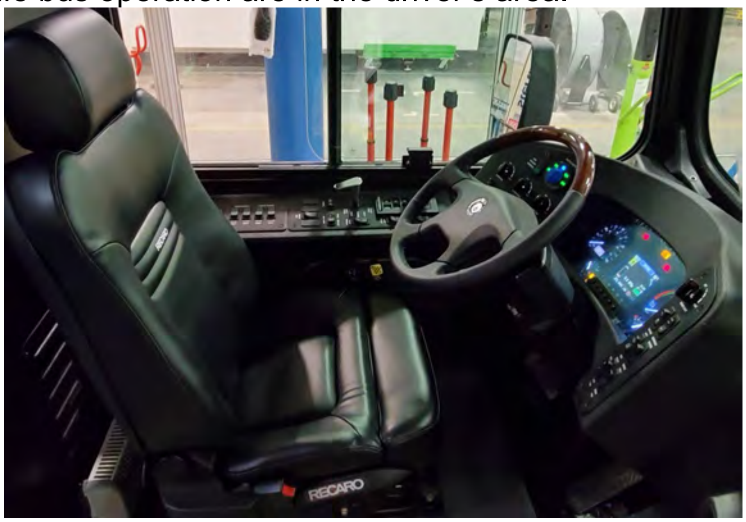
Air Compressor Technical Specifications

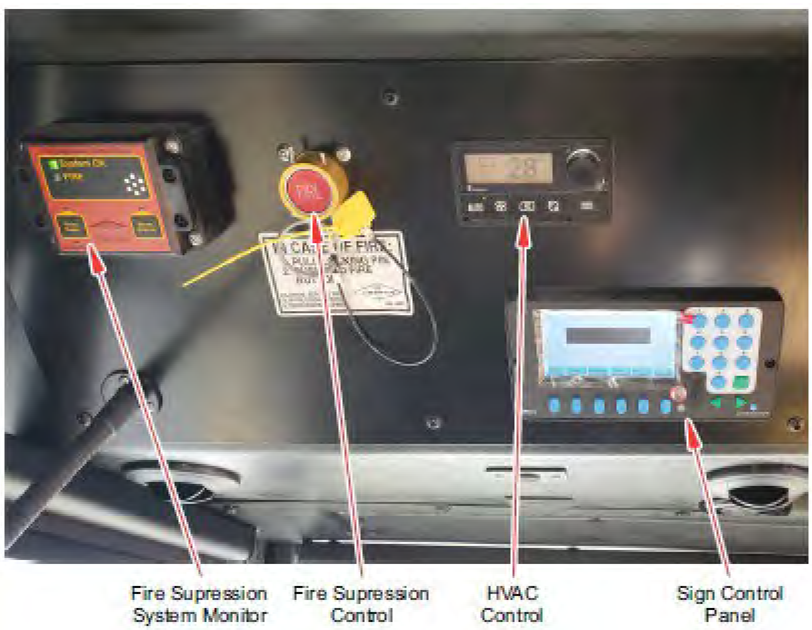
Parameter	Specification
Compressor Type	Hydrovane Transit 0009-0010 Water-Cooled Air End Compressor
Frame Foot and Flange Mount Type	LSMV 100L
Nominal Power	3kW
Rated Power	3.2kW @ 3200 RPM
Nominal Supply Voltage	230VAC 3-Phase, D Connection
Air Delivery	285 Nl/m (10 CFM) @ 9 Bar (130 PSI), 3200 RPM
Rated Speed	1000 to 3200 RPM, stepped speed operation
Max Operating Pressure	10.3 Bar (150 PSI)
Motor	Winding Squirrel Cage Induction Motor
Lubrication	VAFFHPO2000-4
Protection	IP 55 (IP 65 Terminal Box)
Water Cooling	20 l/min / 55°C Max Inlet Temperature
Coolant Connections	15L (M22 x 1.5)
Duty	S1 in 40°C Ambient, External Air Cooling
Weight	27 kg (60 lb), Aluminum Frame
Other	- Transit Inlet Adapter and End Cap - Compressor/Motor sub-assembly fully supported on AV Mounts - Internal thermostatic valve to oil cooler - Dual Over Temperature Switch fitted (110°C and 120°C) - Coolant to have suitable antifreeze and corrosion inhibitor Motor

PROTERRA

Driver's Area Layout

All controls for safe bus operation are in the driver's area.

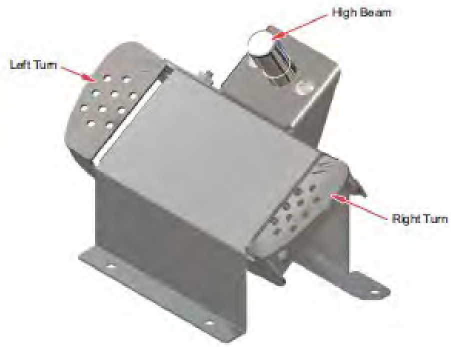




The right foot controls (either adjustable or non-adjustable) include the accelerator (far right) and the brakes. The left foot controls include the high beam (on/off) and the left and right turn signals. Optionally, the left foot controls may include a microphone switch.

The left turn signal and right turn signal foot controls are momentary switches and must be continuously pressed for them to operate through the turns.

PROTERRA



The high beam is activated by pushing the foot control once; push again to return to the low beam. The blue indicator will be illuminated on the dash. The high beam can only be activated during night mode.

NOTICE: Pedals and Left Foot Controls may differ based on customer requirements.

The dashboard contains the windshield wiper and mirror controls, switches, monitors, and warning or operating condition lamps for the bus.

Dashboard Indicator Lamps

The dashboard indicator lamps are used to show the status of the various standard bus systems such as the headlight high beams, turn signals, and parking brakes. There are also RED and AMBER warning indicators which will illuminate in the event of a fault in one of the bus operating systems. Some of these status or fault indications will also be shown on the driver's display. The driver should always be aware of any indication provided by these dashboard indicator lamps and the driver's display.

Digital Dash

Proterra is launching a new Digital Dash which will become our standard offering. The following page provides an overview of our new dash.

PROTERRA – Digital Dash
Continental MVP-12

Technical Specifications

- Super wide-view 12,3 inch color TFT-display with resolution of 1440 x 540 px in 8:3 format
- Programing and control of graphics, texts and animations via CGI Studio
- Functional programming and control of instrument and Human Machine Interface via KIBES® 32
- Software based on OSEK and Linux operating systems
- Several interfaces available: high-speed CAN, video, LIN, I/Os, Audio, Ethernet

Driver's Side Window

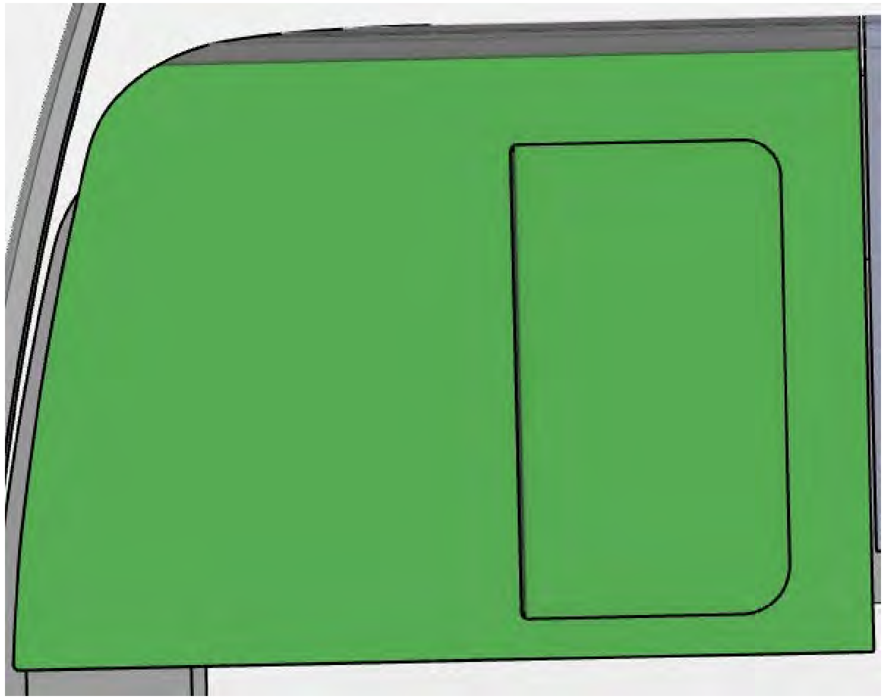
Rev A
1/21/2021
Michelle Benson

PROTERRA

Base Driver's Window

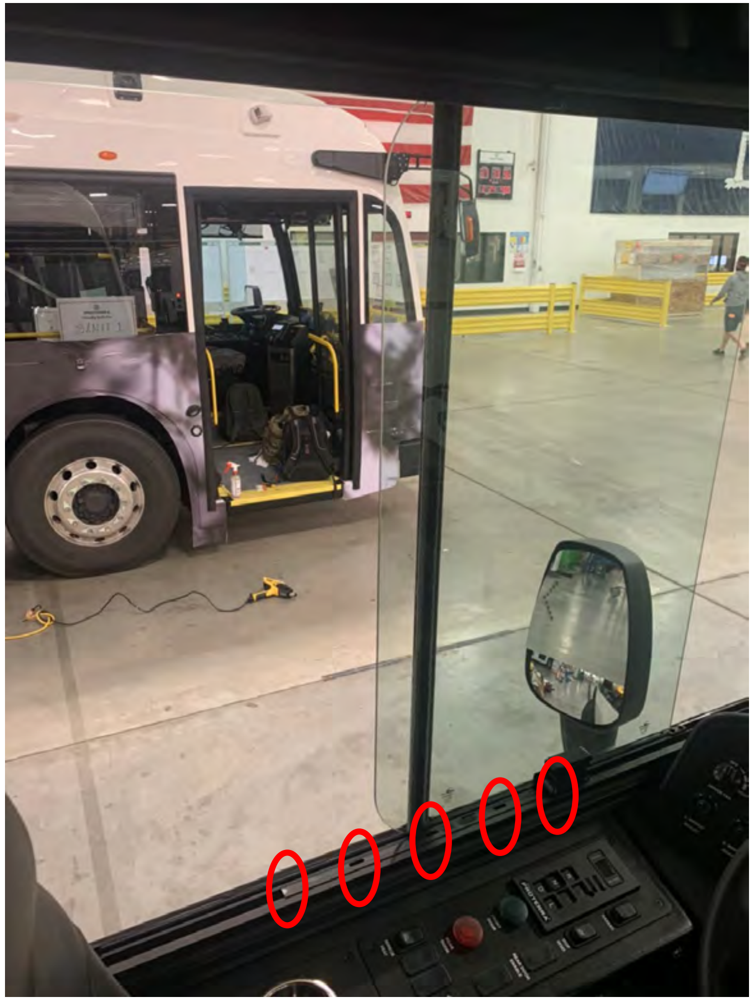
Driver's Window:

- Tinted green
- 75% light transmittance
- Tempered glass
- Hidden fasteners
- Single opening slider window with a rocker latch handle



Rocker Latch

- Rocker Latch will lock into 5 different positions. (shown in red)
- Window can be opened to in between locations, but it will not lock in



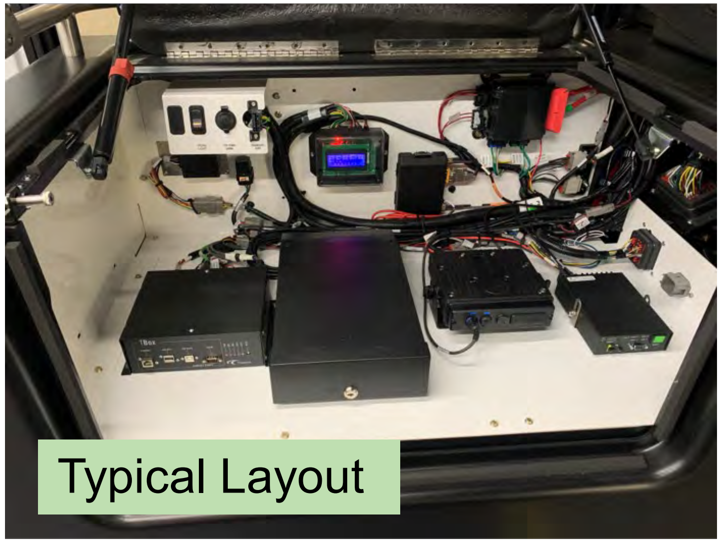
ITS & Customer Electronics

Rev A
1/21/2021
Michelle Benson

PROTERRA

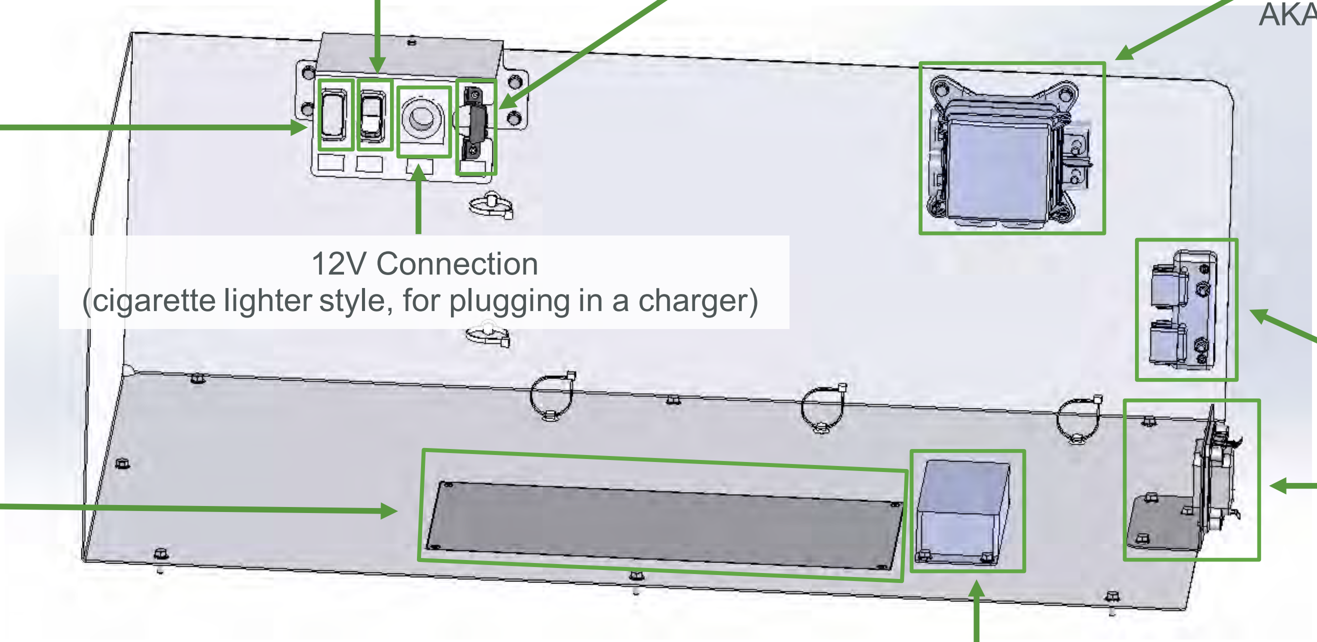
Electronic Cabinet Location

- ITS components, radios, WIFI, DVRs etc. Are installed in the street side wheel well box located behind the driver.

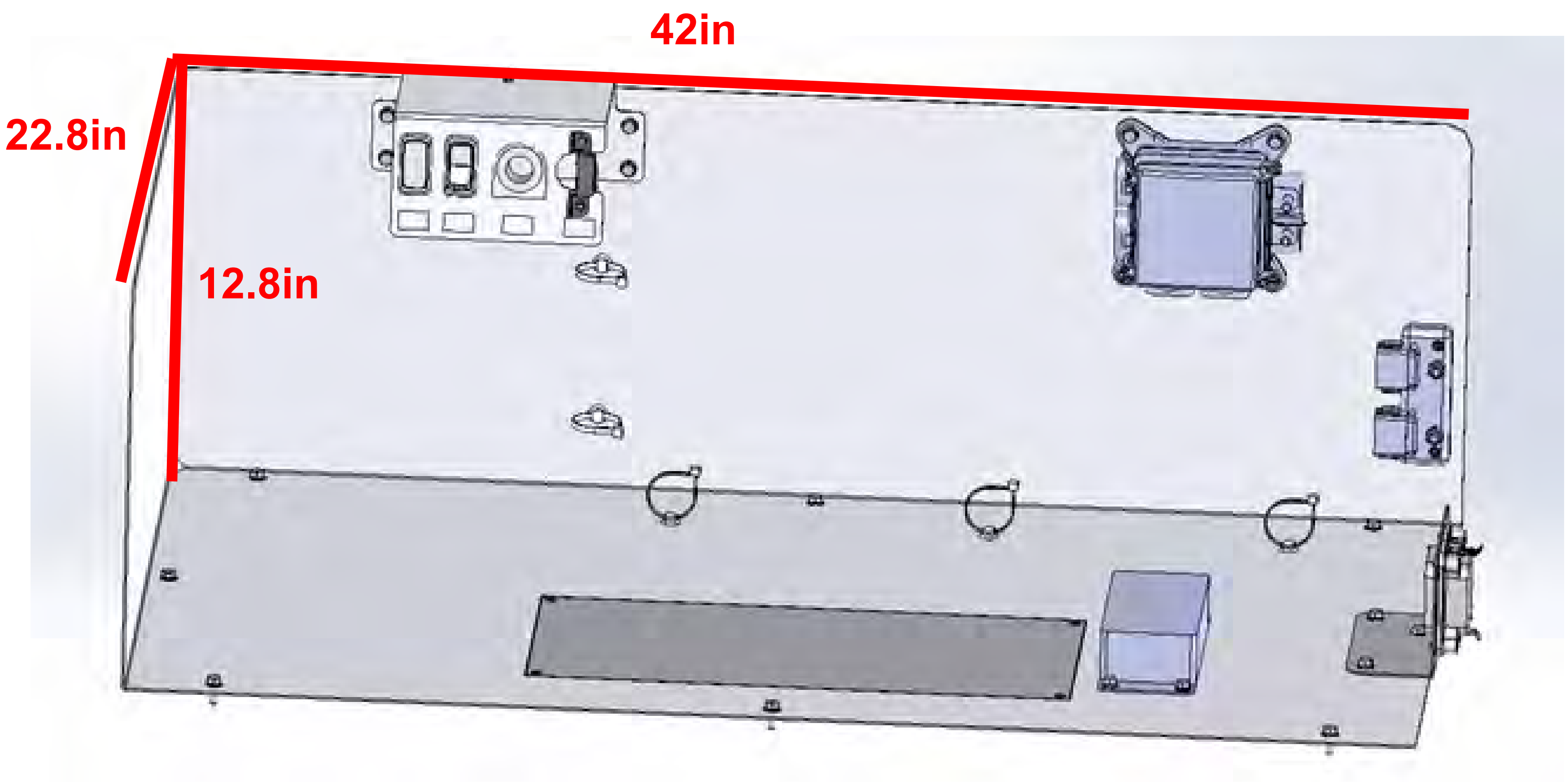


Typical Layout

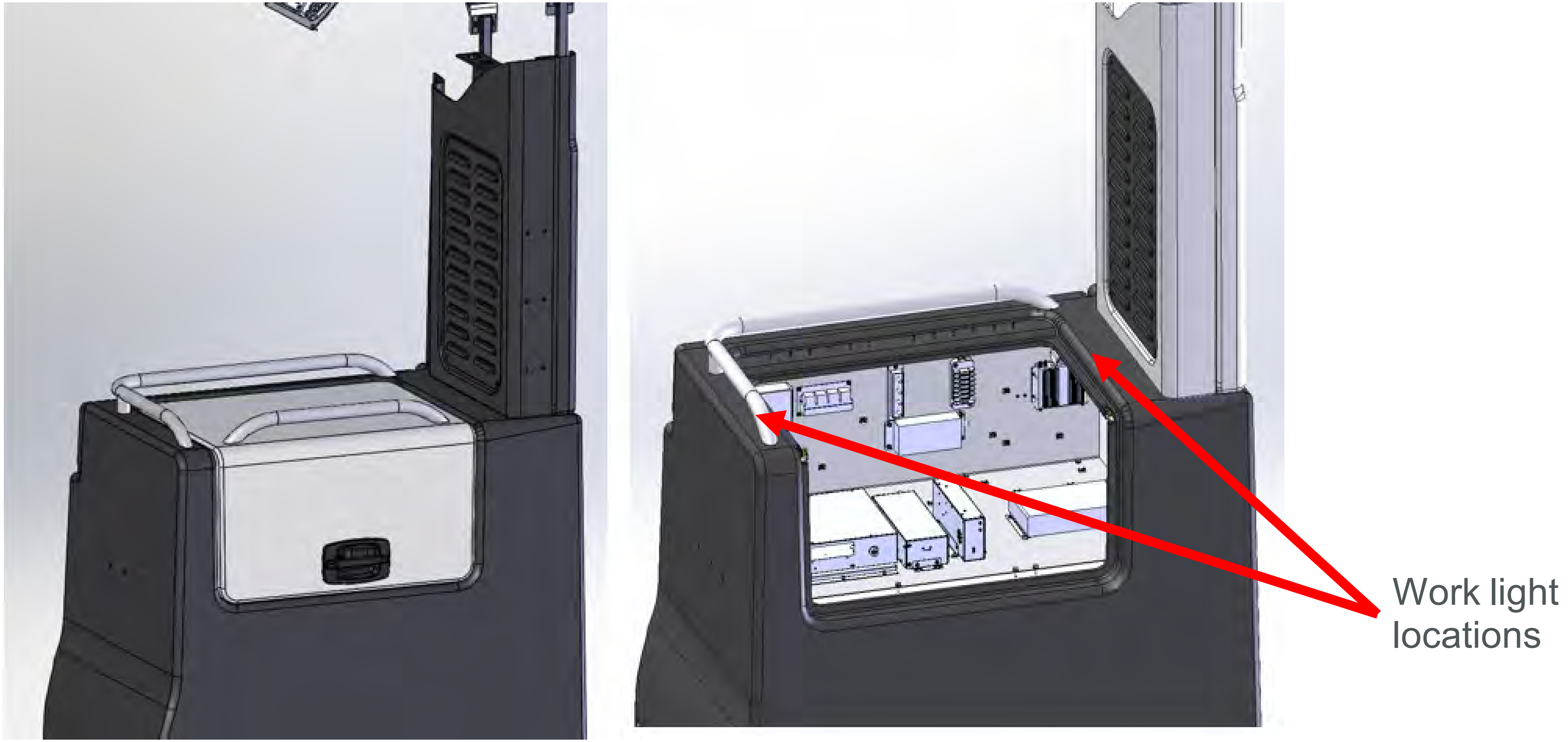
Base Customer Electronics Cabinet Configuration



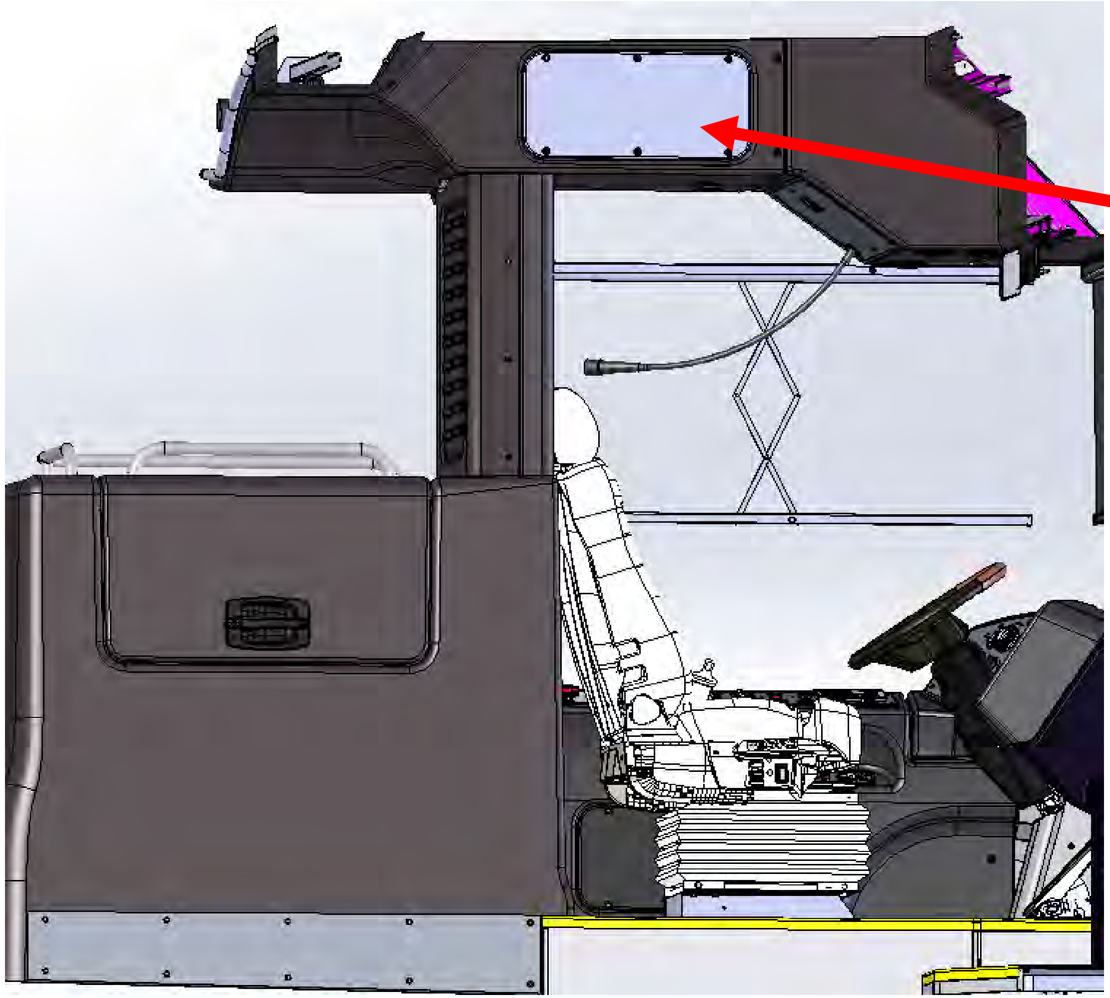
Dimensions

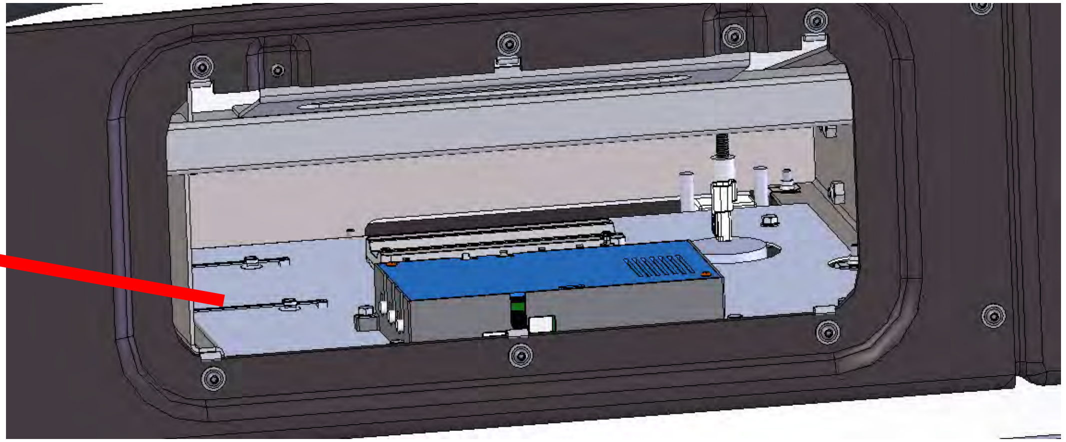


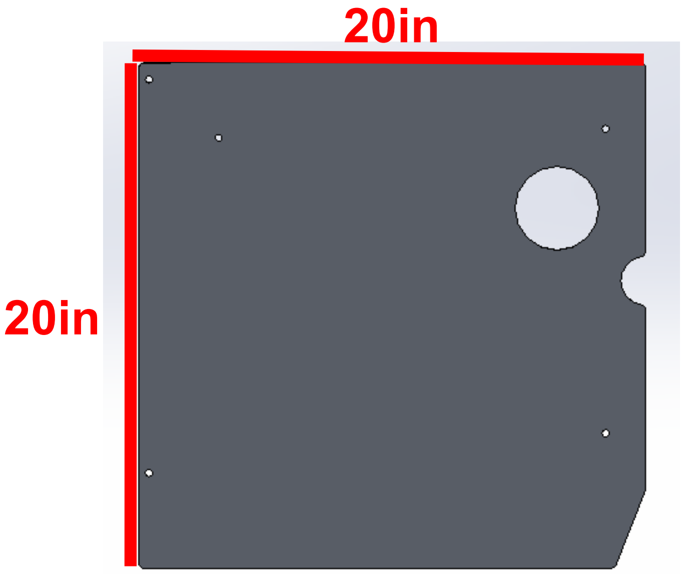
Work light locations



Additional ITS storage





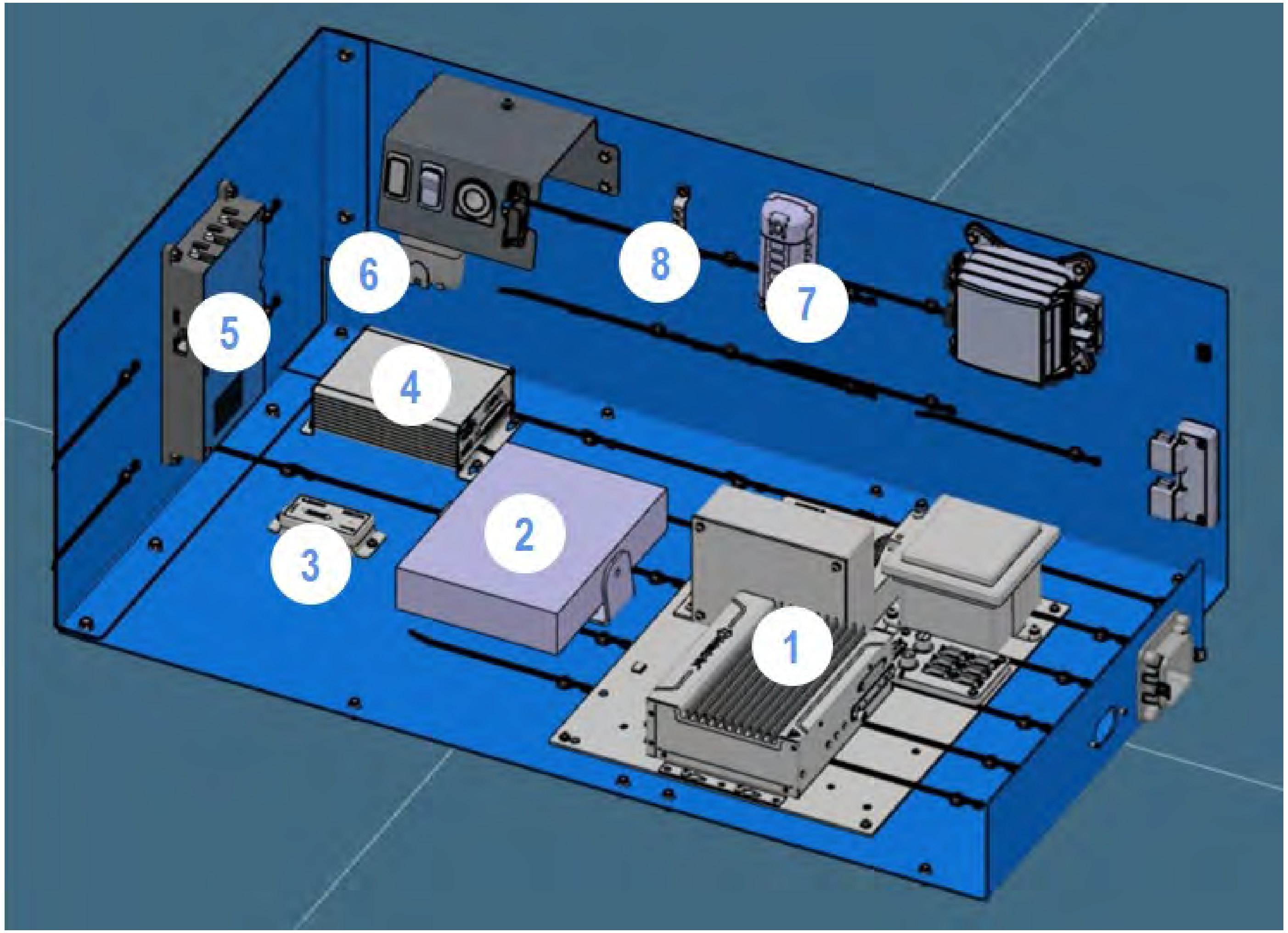


Mounting surface only installed when needed

Example of Average ITS Layout

PROTERRA

- 1. Avail Plate – ITS vendor component
- 2. APX6500 Radio – for communication with dispatch
- 3. G Force Sensor – Used to monitor significant g-force events
- 4. IVU3 – ITS vendor (Avail) component
- 5. Mobileye Shield Controller – collision avoidance system
- 6. Ituran Starlink Modem – collision avoidance system
- 7. Fuse Block – power distribution
- 8. Ground Bus Bar – power distribution



FAQ

PROTERRA

- What are some recommended ITS suppliers?
  - Clever, Trapeze, Avail, Syncromatics

- What prewire provisions can be accommodated?
  - Full installs are preferable so that the bus is ready to use upon delivery. If anything less than a full install is requested, details must be provided on the electronics template. The more precise requirements can be provided, the more successful the prewire provisions will be.

- What if there are additional ITS components mounted outside the wheel well box?
  - Please provide photos and information on how these components are mounted on other buses in your fleet. We will try to match the other vehicles in your fleet as closely as possible.

- Can Proterra install components provided by the customer?
  - Proterra prefers to purchase new components to install on new buses. This eliminates the potential to receive bad parts which can slow down production.

FAQ

- What validation can Proterra provide?
  - Proterra recommends validation coordinated with the vendor. Most vendors will come onsite to perform validation.

STORAGE BOX– CS FRONT

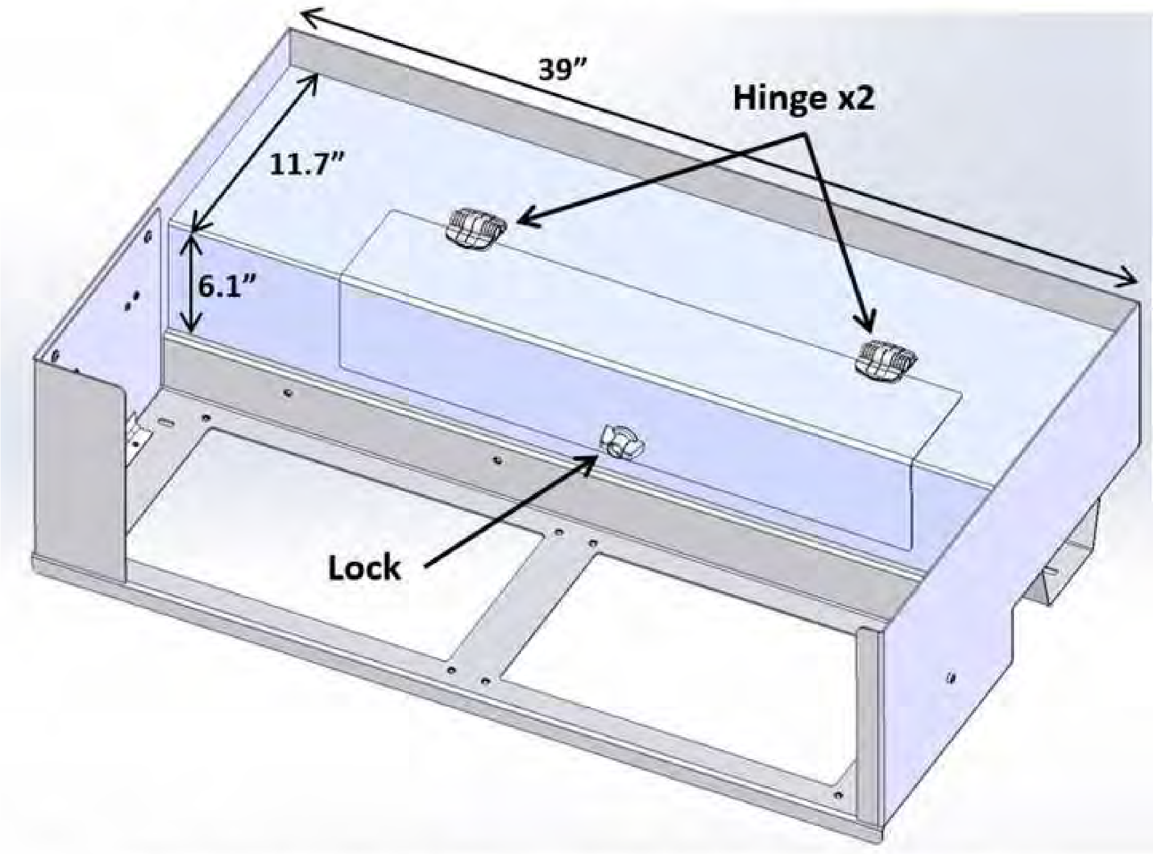
PROTERRA

PROTERRA

STORAGE BOX– CS FRONT

STORAGE BOX– CS FRONT

CS Wheel Well Box Storage Shelf – Heron



Operator Personal Storage Volume: 39x6.1x11.7 = 2,783 in^3

APTA Guideline: 2,750 in^3

PSTA

PROTERRA
1 Whitlee Court | Greenville, SC 29607

Pinellas Suncoast Transit Authority (35')
Proposed Seating Layout

Revision 00
September 3rd, 2021

[REFERENCE #: SDR66]
Platform: 35' ZX5

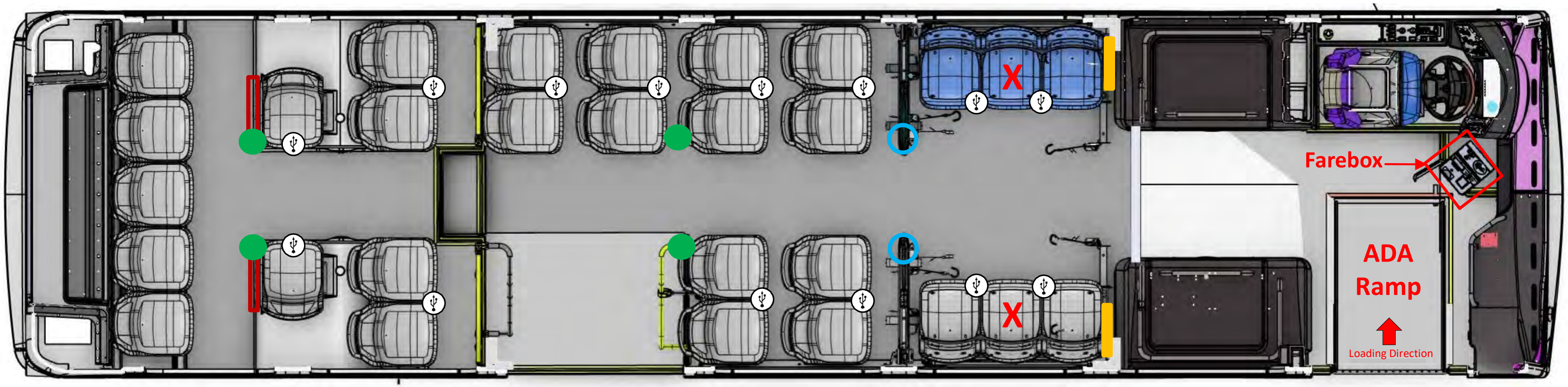
Agency Approval:

Name:

PSTA - Proposed Seating Layout (Proterra 35’ ZX5)

PROTERRA
1 Whitlee Court | Greenville, SC 29607

Rear | Top View | Front



- **Misc Options**

	Docket 90A:	No
▮ (yellow)	**Aisle Facing Flip Armrest:**	2
▯ (red)	**Aisle Facing Fixed Armrest:**	2 (To Be Determined)
● (green)	**Stanchion Cups:**	4
USB	**USB Hubs (optional)**	14

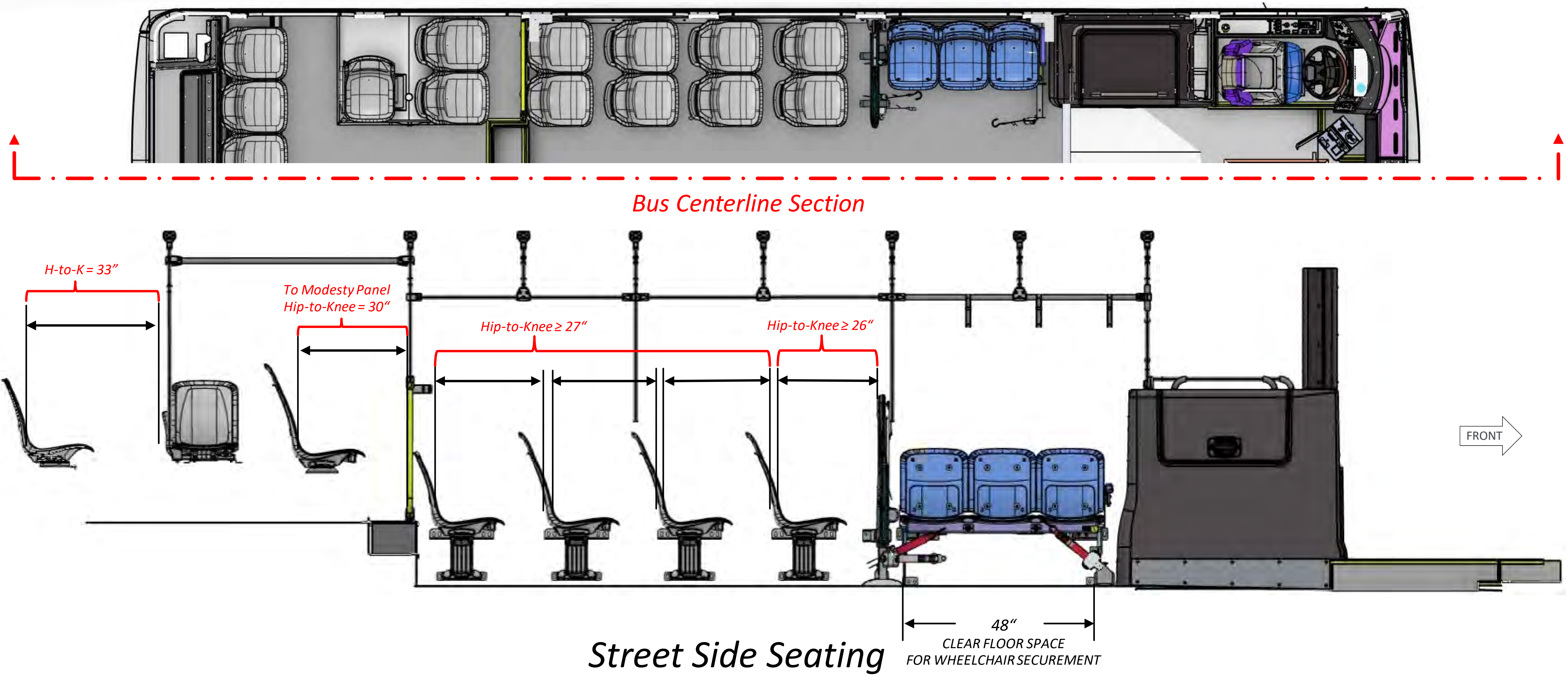
- **Special Instructions:** Single passenger rear longitudinal seats without clips
  ADA flip-up seat wiring harness routing “P-clamps”
- **Auxiliary Heating Clearance:** No

- **Restraint Options**
  - **C/S Type:** 4pt – Floor Mounted
  - **S/S Type:** 4pt – Floor Mounted
  - **Signaling Device:** Touch Pad (Indicated by X)
  - **Instruction Language:** English / Spanish
  - **Stanchion Cups:** 2 (x1 per barrier, indicated by O)

Passenger Seating
Model: *To Be Determined*
Number of Seats: 29

PSTA - Proposed Seating Layout (Proterra 35' ZX5)

PROTERRA
1 Whitlee Court | Greenville, SC 29607

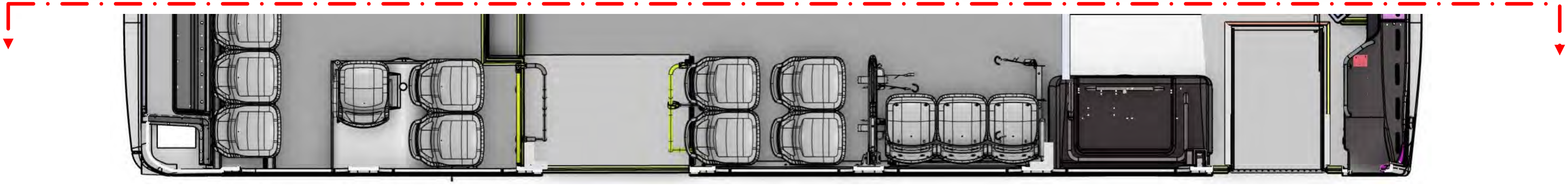


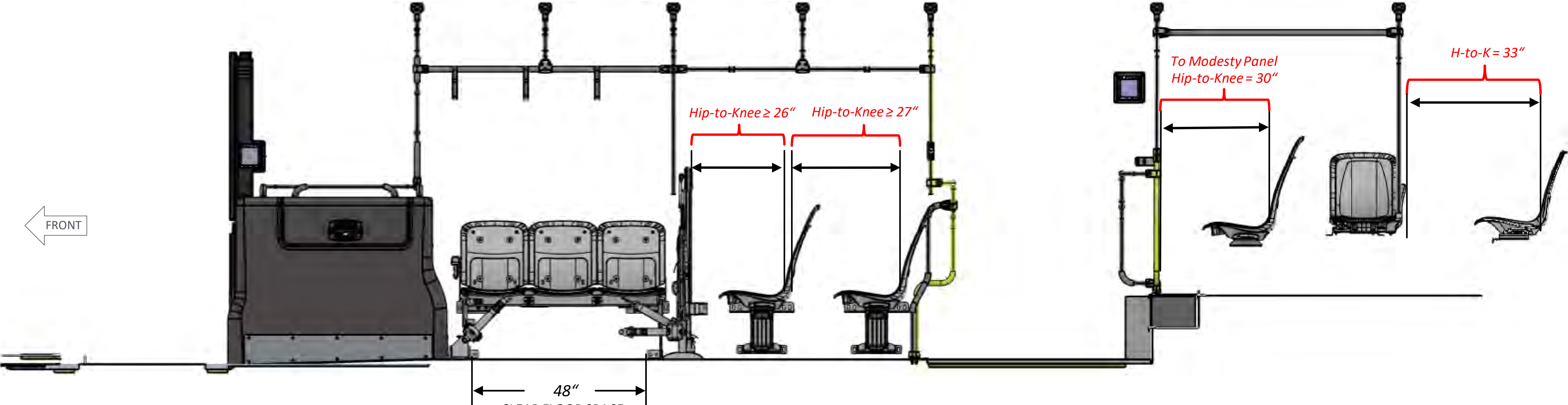
Street Side Seating

PSTA - PROPOSED SEATING LAYOUT (PROTERRA 35' ZX5)

PROTERRA
1 Whitlee Court | Greenville, SC 29607

Bus Centerline Section



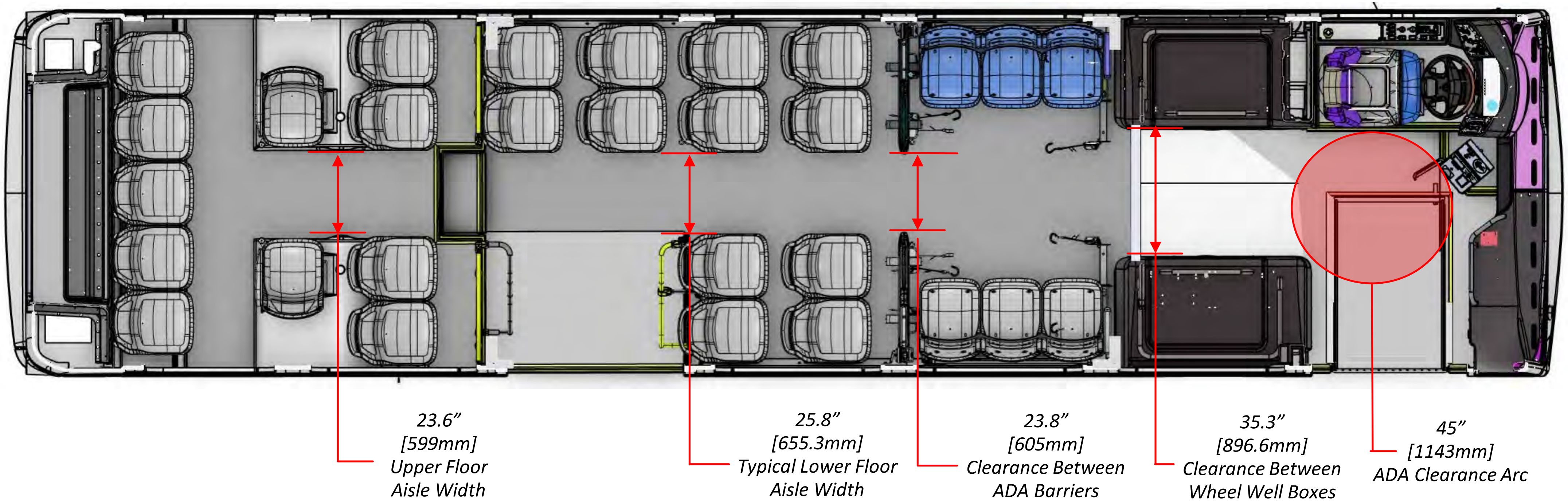


Curb Side Seating

(view rotated 180°)

PSTA - PROPOSED SEATING LAYOUT (PROTERRA 35' ZX5)

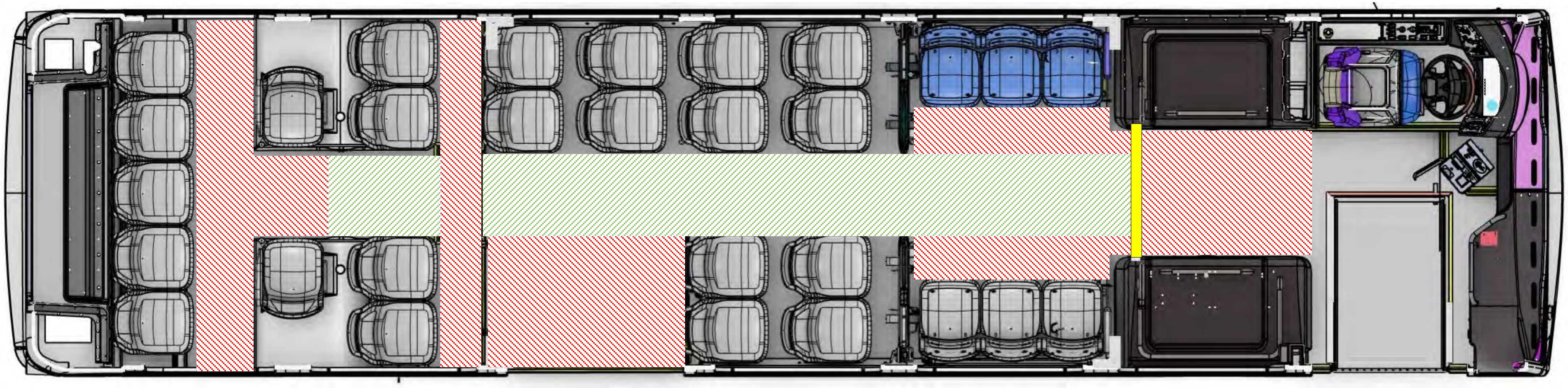
PROTERRA
1 Whitlee Court | Greenville, SC 29607



Interior Circulation Clearances

PSTA - Proposed Seating Layout (Proterra 35' ZX5)

PROTERRA
1 Whitlee Court | Greenville, SC 29607

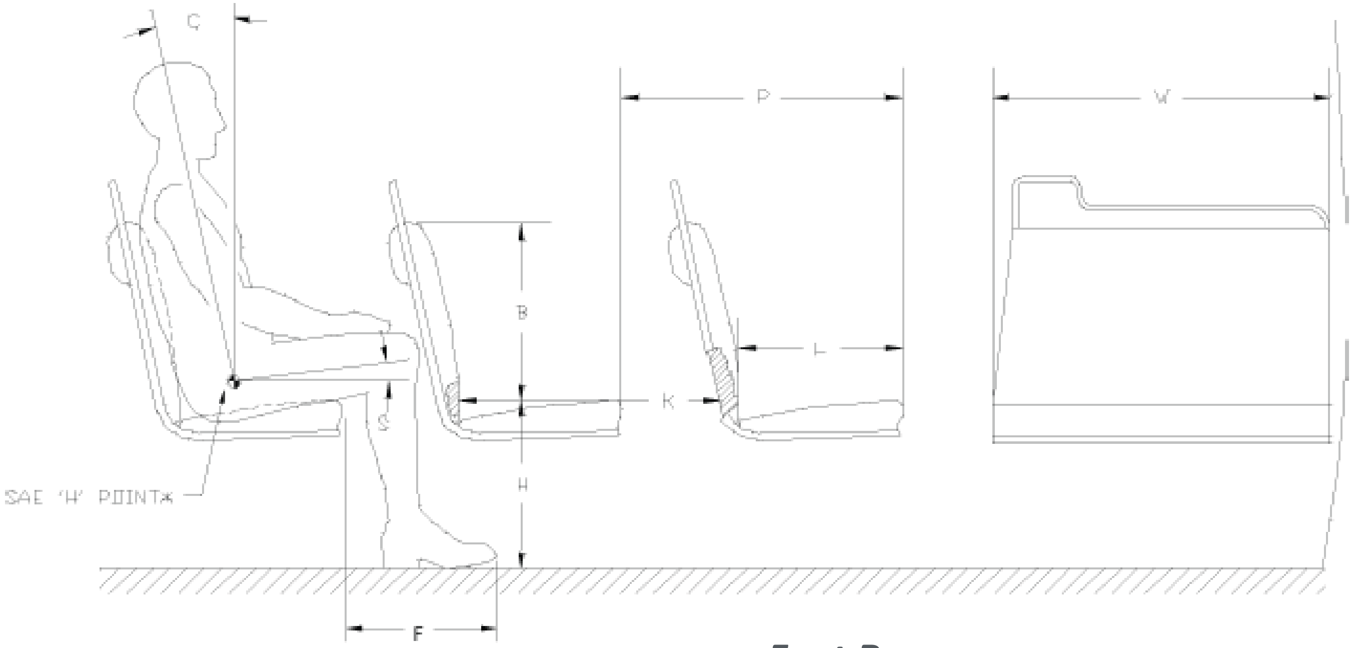


$3103400mm^2 = 3.1m^2 = 33.4ft^2/1.5 = 22$ passengers

Free Floor Space Calculation

PROTERRA
1 Whitlee Court | Greenville, SC 29607

Required Dimensions Per APTA (TS 78)



Aisle Width (per TS 78.10):
- → Between seats ≥ 20in
- → At 32in above floor ≥ 24in

Width:
- → W ≥ 35in

Length:
- → L = 17in +/- 1in

Seat Back Height:
- → B ≥ 15in

Seat Height:
- → H = 17in +/- 1in

Foot Room:
- → F ≥ 14in

Seat Cushion Slope:
- → S = 5° to 11°

Seat Back Slope:
- → C = 8° to 17°

Hip-to-Knee Room:
- → K ≥ 27" (seat-to-seat)
- → K ≥ 26" (to vertical surface)

PROTERRA
1 Whitlee Court | Greenville, SC 29607

REVISION HISTORY:

REV00…	Initial Release for RFP activity	9/3/2021

1 Whitlee Court | Greenville, SC 29607

Pinellas Suncoast Transit Authority (40')
Proposed Seating Layout

Revision 00
September 3rd, 2021

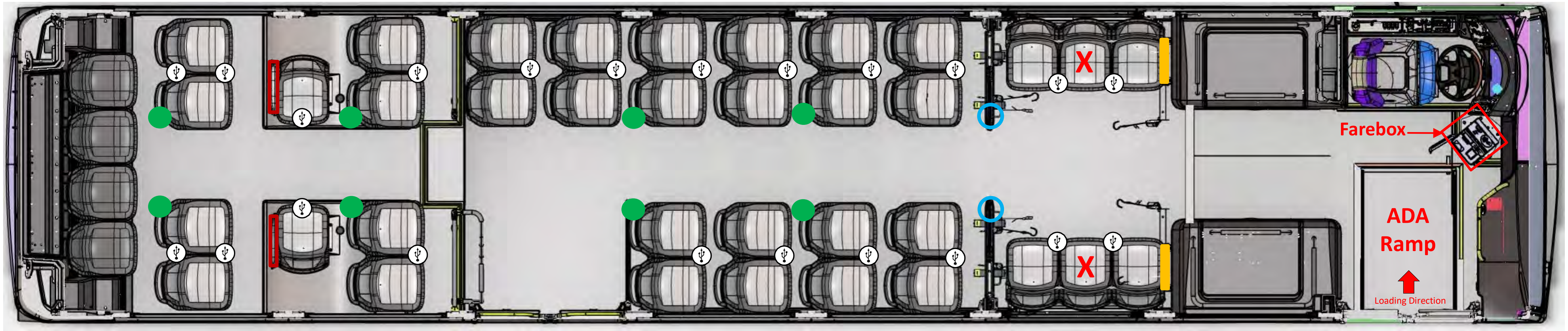
[REFERENCE #: SDR67]
Platform: 40' ZX5

Agency Approval:

Name:

PSTA - Proposed Seating Layout (Proterra 40' ZX5)

PROTERRA
1 Whitlee Court | Greenville, SC 29607



- **Misc Options**

	Docket 90A:	No
	Aisle Facing Flip Armrest:	2
	Aisle Facing Fixed Armrest:	2 (To Be Determined)
	Stanchion Cups:	8
	USB Hubs (optional)	22

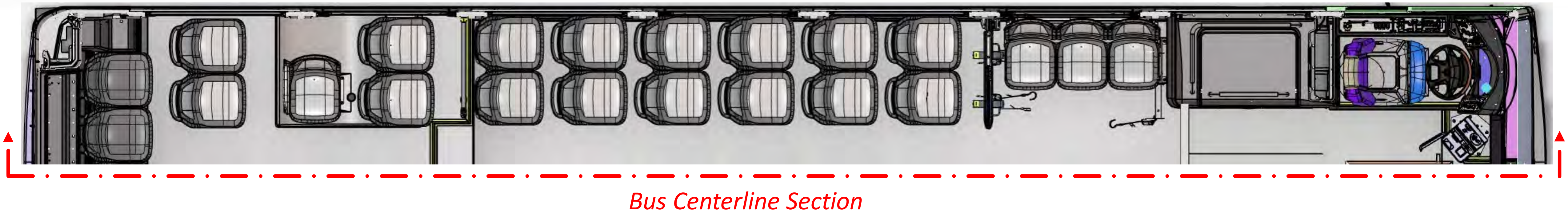
- **Special Instructions:** Three passenger rear longitudinal seats without clips
  ADA flip-up seat wiring harness routing "P-clamps"
- **Auxiliary Heating Clearance:** No

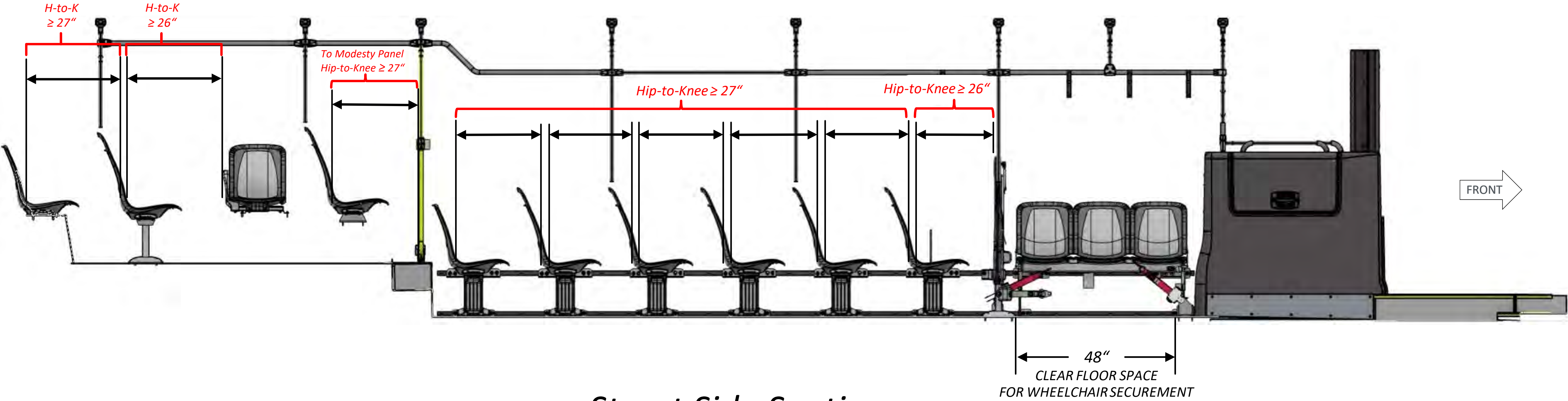
- **Restraint Options**
  - **C/S Type:** 4pt – Floor Mounted
  - **S/S Type:** 4pt – Floor Mounted
  - **Signaling Device:** Touch Pad (Indicated by X)
  - **Instruction Language:** English / Spanish
  - **Stanchion Cups:** 2 (x1 per barrier, indicated by O)

Passenger Seating
Model: *To Be Determined*
Number of Seats: 40

PSTA - PROPOSED SEATING LAYOUT (PROTERRA 40' ZX5)

PROTERRA
1 Whitlee Court | Greenville, SC 29607



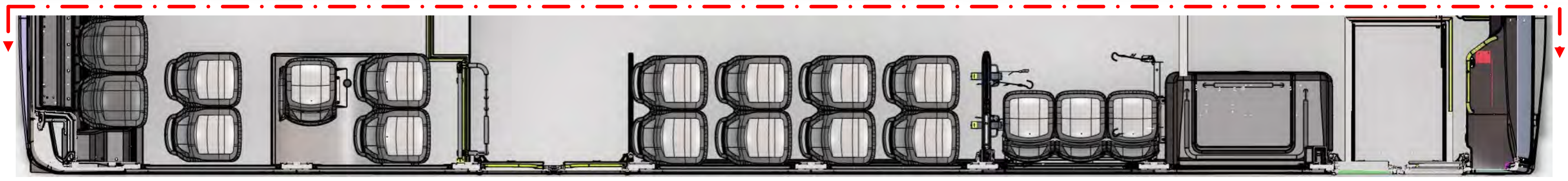


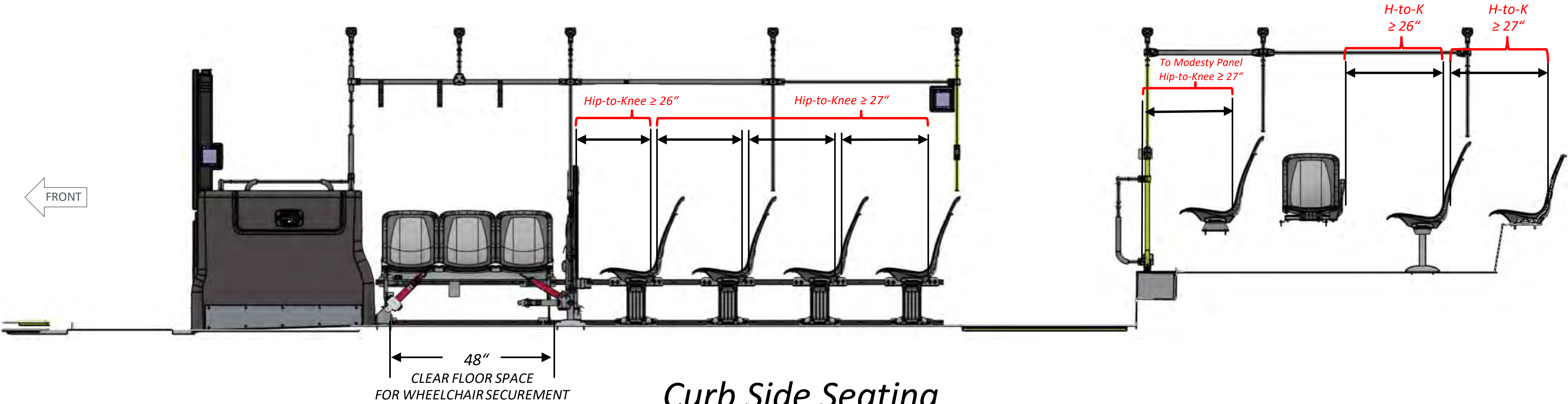
Street Side Seating

PSTA - Proposed Seating Layout (Proterra 40' ZX5)

PROTERRA
1 Whitlee Court | Greenville, SC 29607

Bus Centerline Section



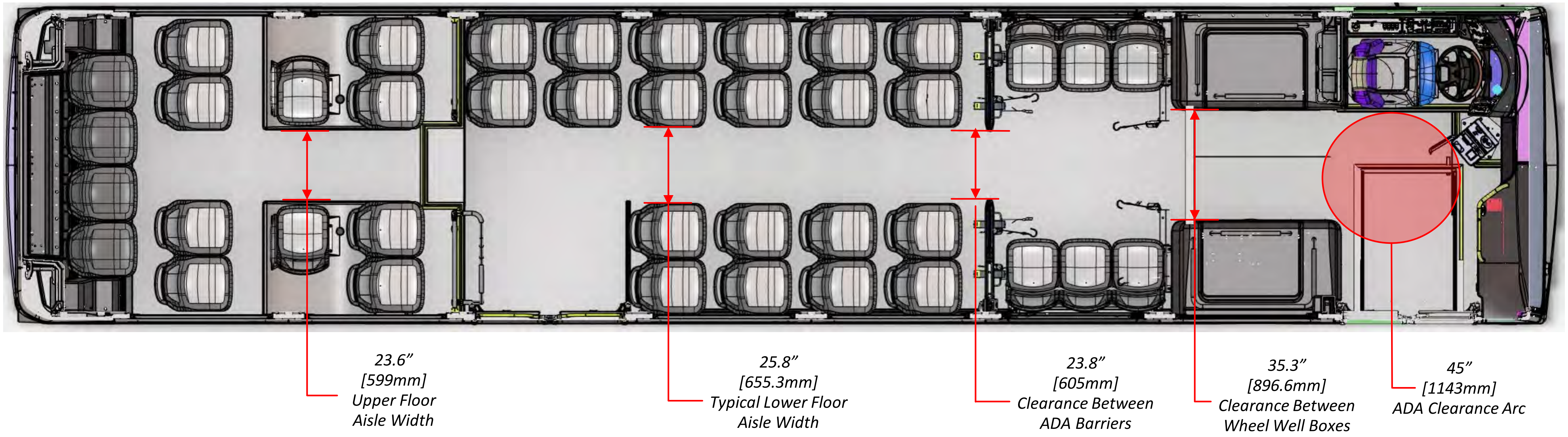


Curb Side Seating

(view rotated 180°)

PSTA - Proposed Seating Layout (Proterra 40' ZX5)

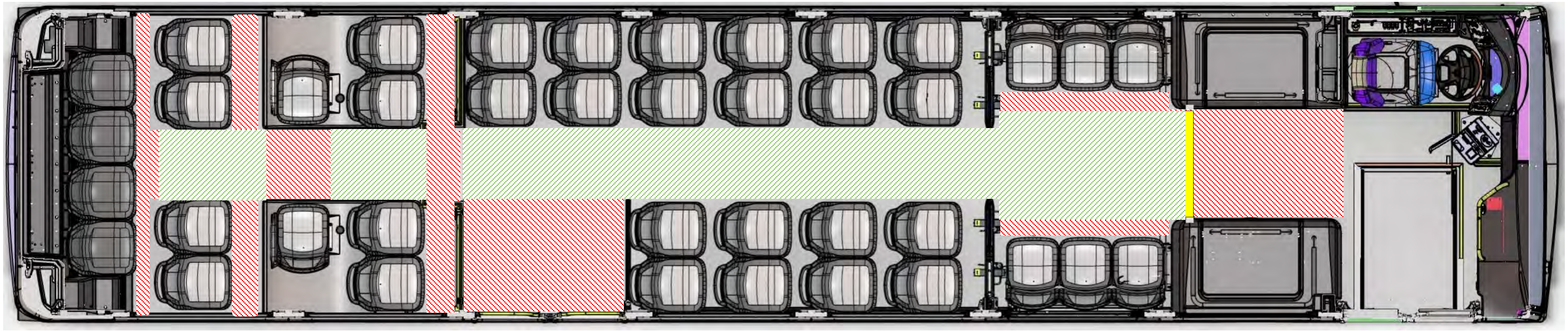
PROTERRA
1 Whitlee Court | Greenville, SC 29607



Interior Circulation Clearances

PSTA - Proposed Seating Layout (Proterra 40' ZX5)

PROTERRA
1 Whitlee Court | Greenville, SC 29607

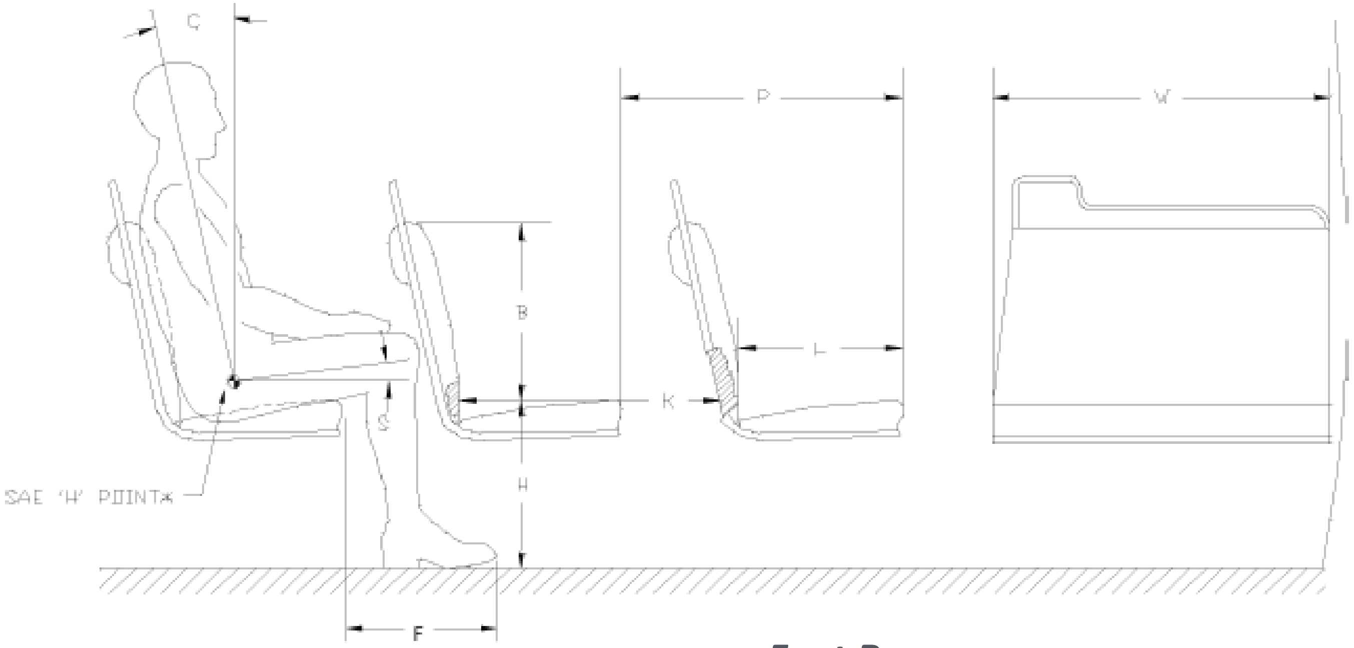


$4{,}394{,}301mm^2 = 4.39m^2 = 47.3ft^2/1.5 = 31$ standees

Free Floor Space Calculation

PROTERRA
1 Whitlee Court | Greenville, SC 29607

Required Dimensions Per APTA (TS 78)



Aisle Width (per TS 78.10):
- → Between seats ≥ 20in
- → At 32in above floor ≥ 24in

Width:
- → W ≥ 35in

Length:
- → L = 17in +/- 1in

Seat Back Height:
- → B ≥ 15in

Seat Height:
- → H = 17in +/- 1in

Foot Room:
- → F ≥ 14in

Seat Cushion Slope:
- → S = 5° to 11°

Seat Back Slope:
- → C = 8° to 17°

Hip-to-Knee Room:
- → K ≥ 27” (seat-to-seat)
- → K ≥ 26” (to vertical surface)

PSTA - Proposed Seating Layout (Proterra 40’ ZX5)

PROTERRA
1 Whitlee Court | Greenville, SC 29607

REVISION HISTORY:

REV00…	Initial Release for RFP activity	9/3/2021

PROTERRA

Towing Procedures

Towing procedures for Proterra's proposed ZX5 buses are included on the following pages.

PROTERRA

ZX5 TOWING GUIDE

CS_TOW_MT_HO001_2017

This towing guide has been prepared to provide you with the information necessary to tow this bus safely in most situations. To ensure vehicle safety, you must read and thoroughly understand the contents of this manual.

The specifications and information in this manual are the most current at the time of publications, and may be subject to change without notice. It is the responsibility of the transit agency to provide you with the necessary instructions when special equipment or changes to standard equipment are implemented.

This manual is not intended to provide all-encompassing towing instructions, nor does it attempt to teach towing skills, rules of the road, or regulations of the DOT, State, or transit agency.

Chapter 1: ZX5 Towing Guide

About Towing

The bus will need to be towed by the transit agency service vehicle if a total power failure occurs, or if the bus has accidentally driven off a paved surface, and is not able to return. The following procedures describe the method used to flat tow a Proterra bus. These procedures are also applicable to winching a bus onto a trailer.

Prior to towing the Catalyst vehicle, ask and answer the following questions to determine the appropriate procedure(s) to follow:

1. Does the bus have available high-voltage electrical power?
   - YES - Check the operational status of the air compressor.
   - NO - Cage the brakes.
2. Is the air compressor operational?
   - YES - Use the air compressor to release the brakes. Do not cage the brakes.
   - NO - Manually air the bus and listen for potential air leaks.
3. Is there an air leak preventing the brakes from being released?
   - YES - Cage the brakes.
   - NO - Manually air the bus and release the brakes.
     - The Brake Release knob on the left console can be used to supply air to the rear brakes, as needed.
4. Does the bus need to be repositioned for towing?
   - YES - See the *Positioning the Bus for Towing* section of this chapter.
   - NO - Continue with the towing procedure.
5. How far do you need to tow the bus?
   - Less than 1 mile - Do not remove the half shaft.
   - Greater than 1 mile - Remove the half shaft.

CAUTION

DO NOT flat tow the bus (drive wheels on the ground) over 1 mile at speeds above 20 MPH unless you have removed the half-shaft from the rear axle. **Severe damage to the transmission will occur if this caution is not heeded.**

To remove the half-shaft from the rear axle, reference the ZF AV-132 DROP CENTER AXLE Repair Manual.

NOTICE! Check and grease the o-ring on the half-shaft ring nut prior to re-installing the half-shaft. The M18 bolts will need to be cross-torqued to 440 Nm.

ZF AV-132 DROP CENTER AXLE Repair Manual

Figure 1-1. Rear Axle Half-Shaft

Vehicle Ride Height Preparation

1. Maximize ride height by pressing and holding the ride height button until maximum ride height is reached. Turn off the Master Switch at the Driver's workplace.

Figure 1-2. Maximize Ride Height and Turn OFF Master Switch

2. If you do not have power, have the tow truck driver manually air each of the four corners using the Schrader valves located behind the streetside lower rear access panel.

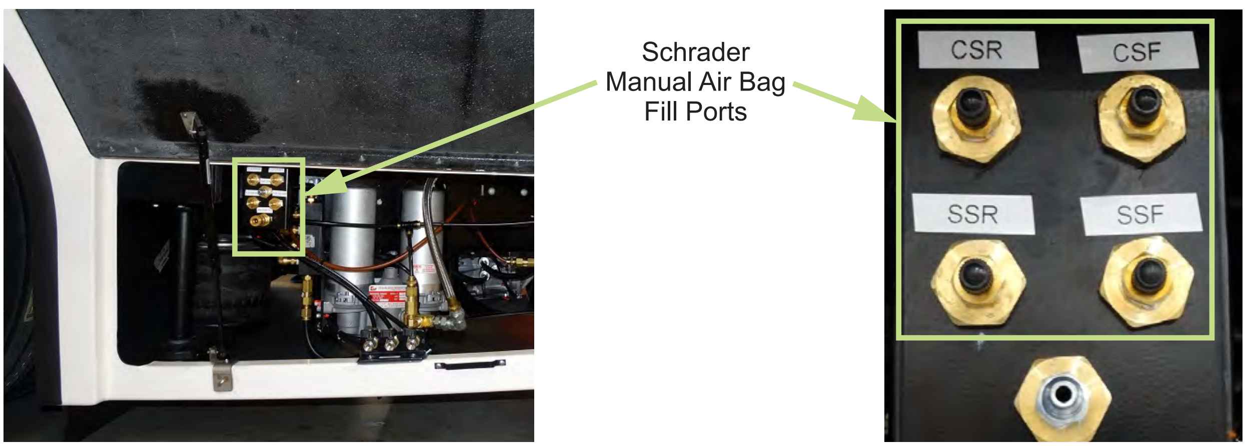


Figure 1-3. Schrader Valves

3. Open the rear deck access panel and remove the VEC locking cover to access the rear deck circuit breakers.

Figure 1-4. Opening the Rear Deck Access Covers

4. Turn off the ride height system by removing circuit breaker CB423. This is necessary to ensure the bus does not try to level itself while lifting and towing.

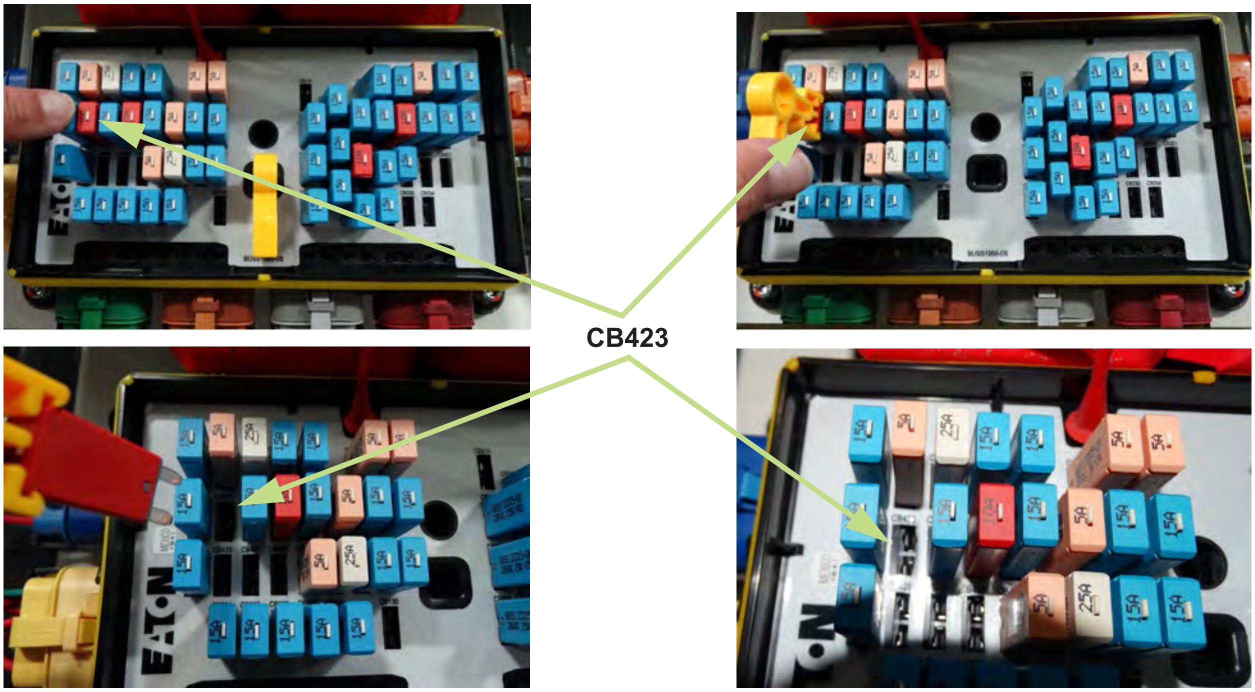


Figure 1-5. Rear Deck Circuit Breaker

Brake System Caging (Disconnect) Procedure

1. In order to cage or disconnect the rear brakes, you must remove the rear brake canister access plug on each rear wheel well.
   NOTE: You may need to remove seats to access this plug.

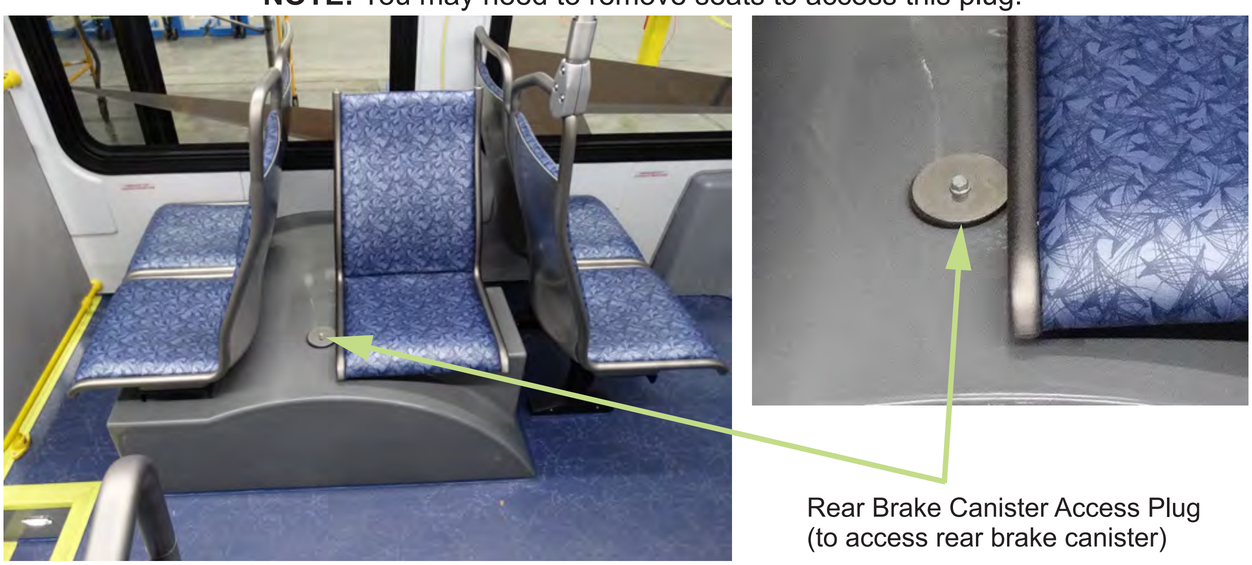


Figure 1-6. Rear Brake Access Plug

2. Using a ratchet with an extension, turn the brake caging bolt counter clockwise to disengage the rear brake. Repeat for both sides.

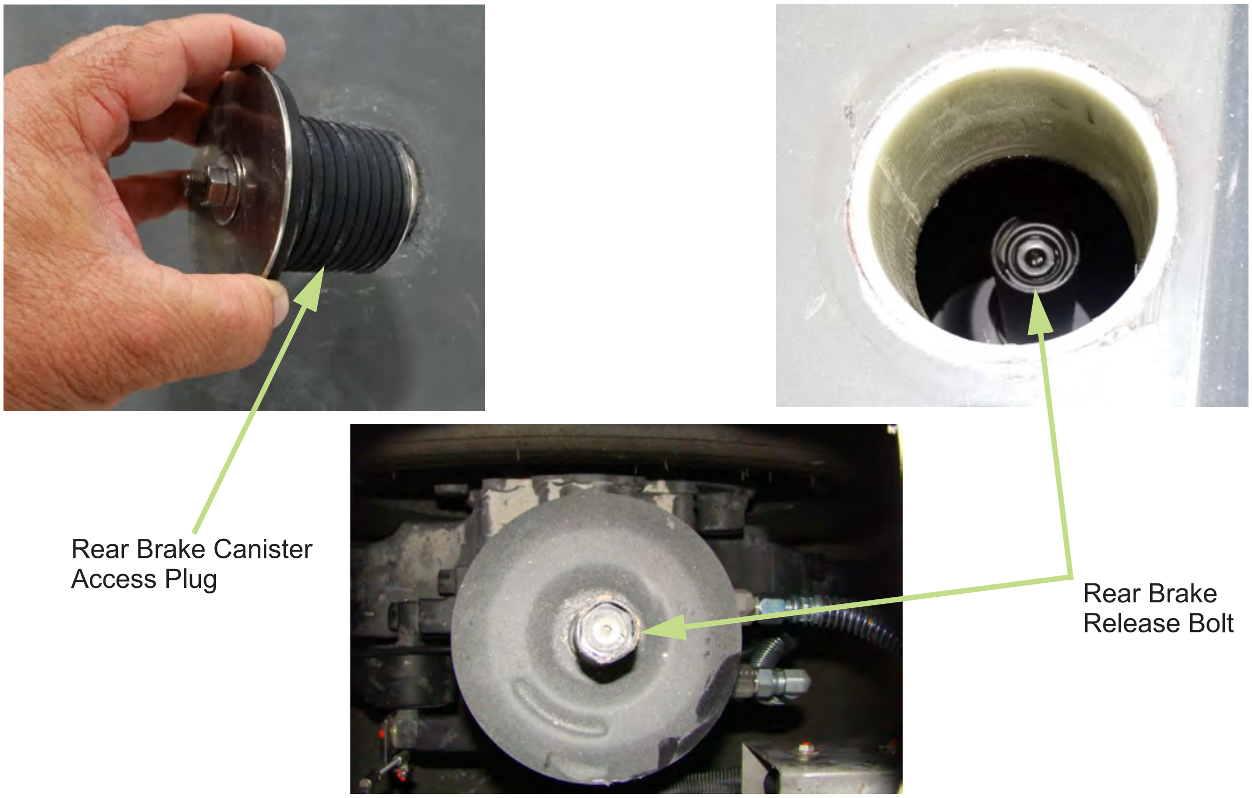


Figure 1-7. Brake Caging Access Panel

3. Follow the vendor recommended procedure for disconnecting the braking system. Reference Bendix Technical Bulletin TCH-002-006 for the Brake Actuator Caging Procedure.

Bendix Technical Bulletin TCH-002-006

Manually Airing the Bus for Towing

The following procedures should be performed if the bus has no power AND the air compressor is not operational.

1. If attaching air from the tow vehicle to the front of the bus, locate the air receptacle behind the front bumper on the curbside of the vehicle. Attach the air connection from the tow truck to the bus front air receptacle.

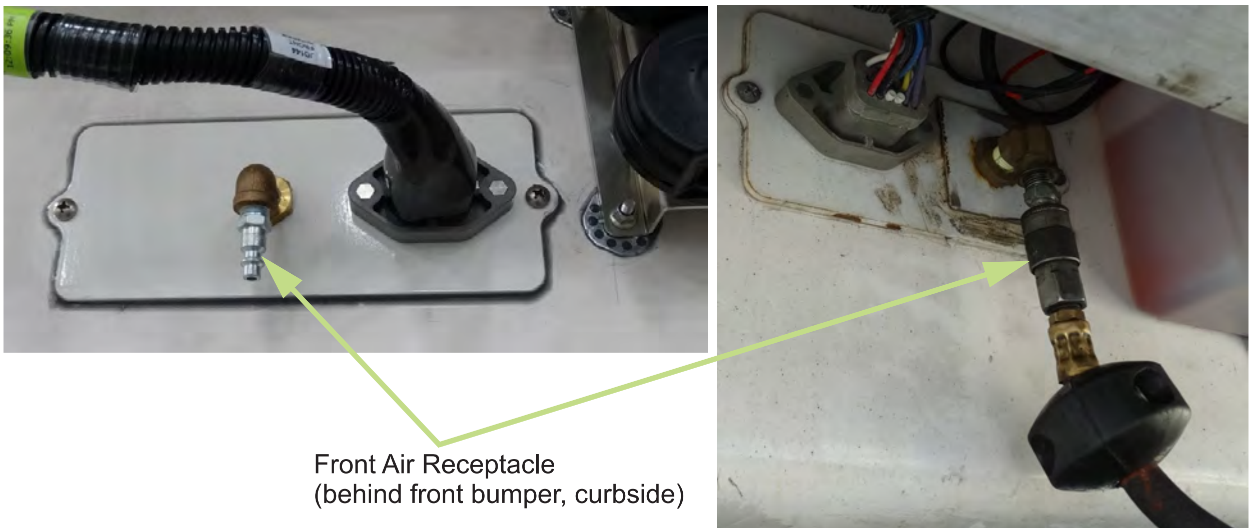


Figure 1-8. Front Air Receptacles

2. If the bus must be extracted by attaching to the **rear** of the bus, open the streetside rear lower access panel on the bus to access the rear air receptacle and attach the air connection from the tow truck to the rear air receptacle, shown in the following figure.

Figure 1-9. Rear Air Receptacle for Tow Truck Attachment

Positioning the Bus for Towing

CAUTION Do **NOT** attempt to tow or hoist the bus from any other location, except that depicted here.

Front Extraction or Winching Attachment Points

Front extraction or winching may be required to reposition a Proterra bus for towing. If rear extraction is necessary, reference the Rear Towing Attachment Points procedure and only rear tow the bus in order to position it for front towing.

1. For front extraction, route a tow strap through the tow pockets and use the tow truck to reposition the bus.

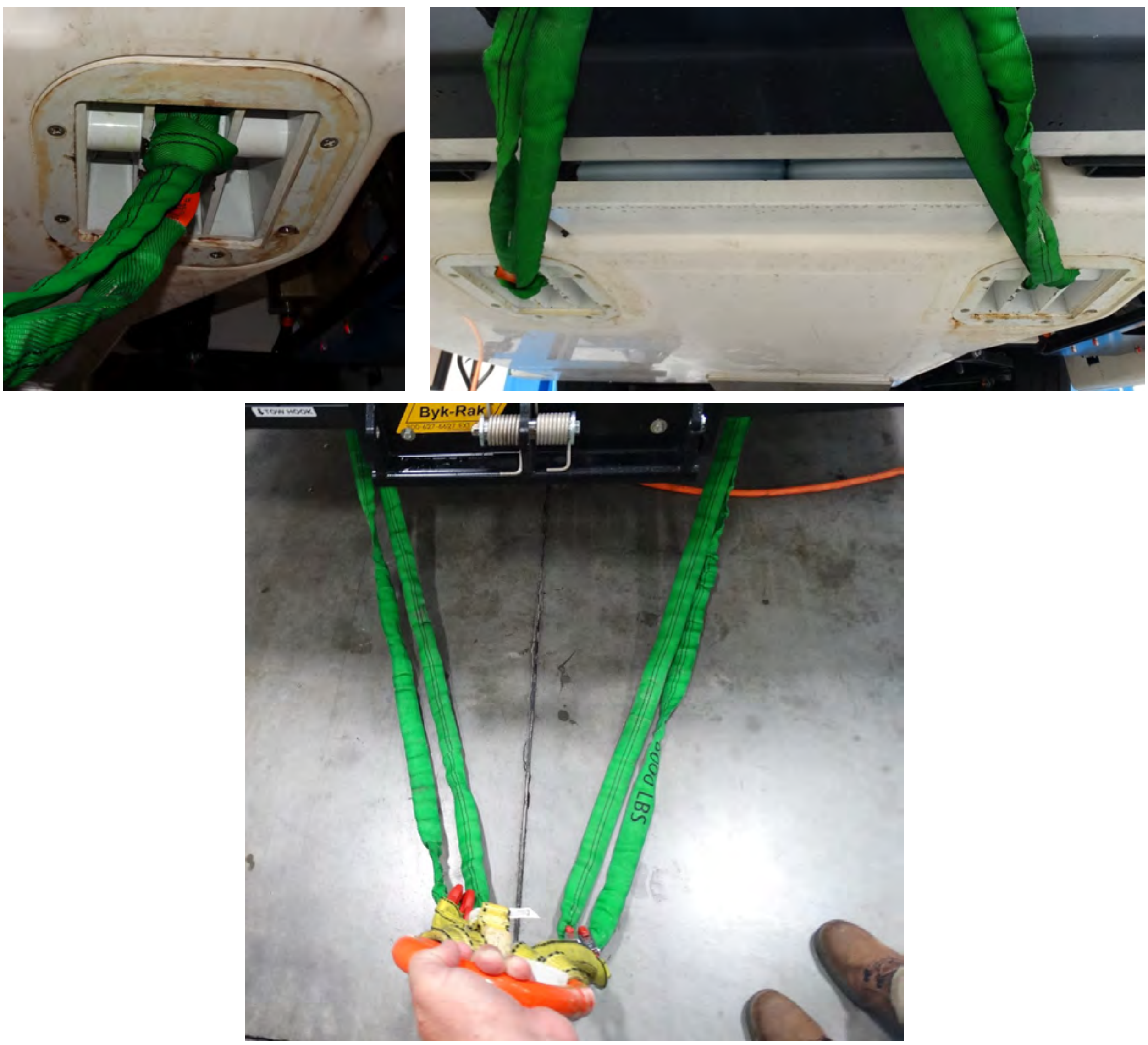


Figure 1-10. Front Extraction - Tow Pockets

Rear Towing Attachment Points

CAUTION Bus should be rear towed only in the event of an emergency or if bus is in a “nose-in” situation. When the front of the bus is cleared, the tow apparatus should be moved to attach to the front tow position.

1. If the bus must be rear-extracted, open the rear trunk and locate the rear extraction attachment points on the ProDrive frame.

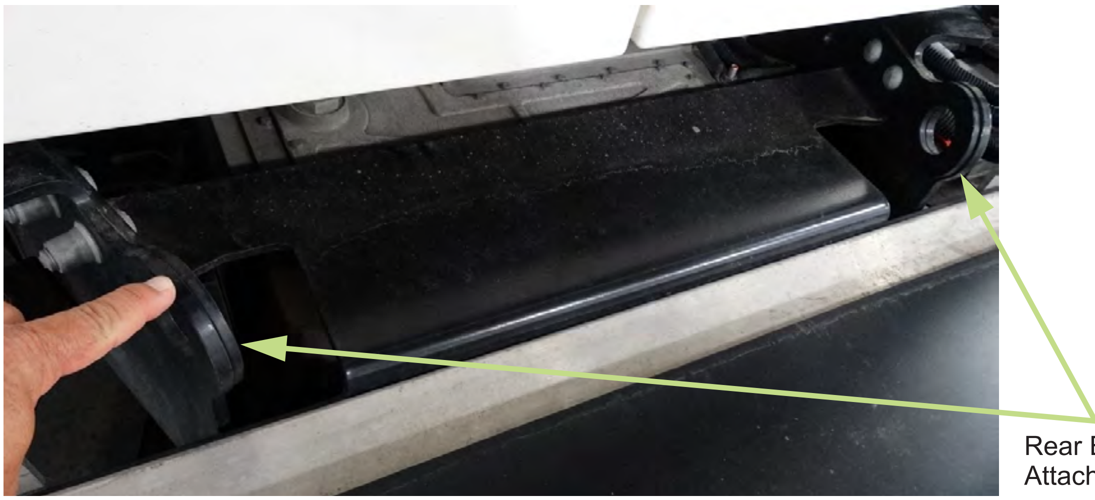


Figure 1-11. Rear Extraction Points on ProDrive Frame

2. Attach clevis hooks (with tow strap) to each of the rear attachment points.

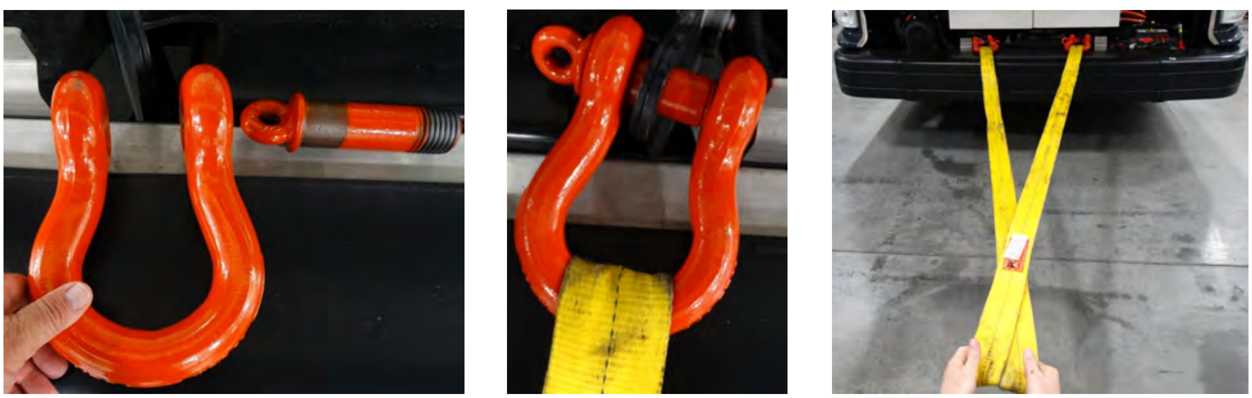


Figure 1-12. Rear Extraction - Clevis Hook Attachment

3. Use the tow truck to reposition the bus for front extraction or towing.

Front Towing Attachment

Front towing is the preferred method when transporting a Proterra bus.

1. Locate the tow truck to access the front of the vehicle.

Figure 1-13. Tow Truck Positioned for Front Extraction

2. The tow truck driver then lowers the stinger, positions it for lifting the front of the bus, and installs the lifting forks.

Figure 1-14. Positioning Stinger Under Front of Bus

3. Reposition the lifting forks to align with the front tow pockets.

Figure 1-15. Repositioning Tow Forks to Align with Tow Pockets

4. Carefully raise the stinger to mate the tow forks with the tow pockets and lift the front of the bus off the ground.

Figure 1-16. Lift the Bus

5. Wrap safety chains around each towing attachment point and secure.

Figure 1-17. Install Tow Fork Safety Chains

6. Install Safety Straps/Safety Chains between the tow pockets of the bus and the tow vehicle.

Figure 1-18. Install Tow Fork Safety Chains

7. Connect the tow vehicle wiring harness to the front of the bus to allow operation of the bus brake lights and turn signals.

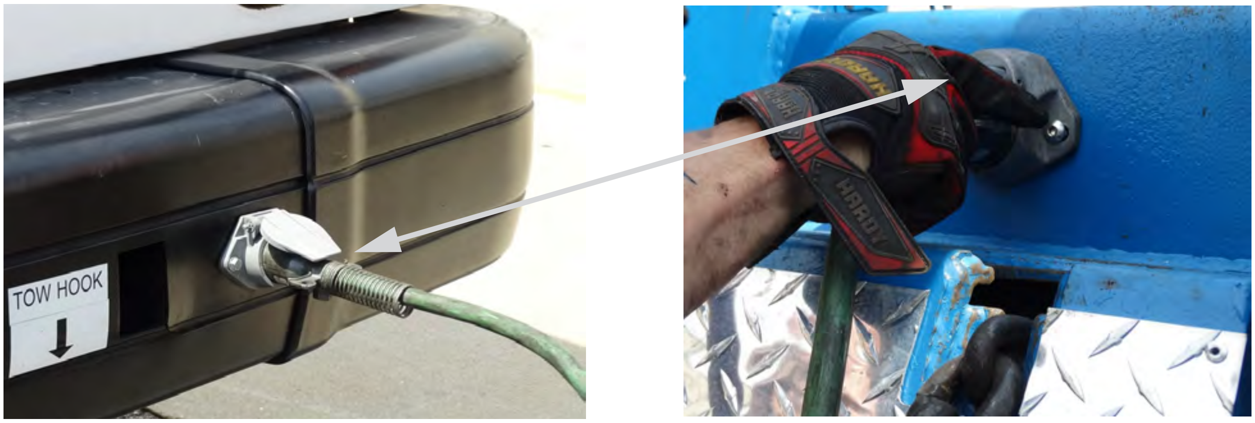


Figure 1-19. Bus Towing 7-Pin Wiring Connector

8. With the bus secured by the tow truck, remove the half shaft on the non-traffic side of the vehicle (streetside shown).

Figure 1-20. Removing the Half Shaft

CAUTION

DO NOT flat tow the bus (drive wheels on the ground) over 1 mile at speeds above 20 MPH unless you have removed the half-shaft from the rear axle or unless you have disconnected and removed the drive shaft. **Severe damage to the transmission will occur if this caution is not heeded.**

---

9. To remove the half-shaft from the rear axle, reference the ZF AV-132 DROP CENTER AXLE Repair Manual. To remove the drive shaft, reference the Proterra Repair Manual.

ZF AV-132 DROP CENTER AXLE Repair Manual

10. Tow or winch normally according to the appropriate Bus Towing Process (Power or No Power).

Bus Towing Process with No Power Available

CAUTION

DO NOT flat tow the bus (drive wheels on the ground) over 1 mile at speeds above 20 MPH unless you have removed the half-shaft from the rear axle or unless you have disconnected and removed the drive shaft. **Severe damage to the transmission will occur if this caution is not heeded.**

1. To gain temporary ride height clearance when no power is available, see the *Bus Ride Height Preparation* section of this chapter.
2. Release the parking brake by pressing firmly on the brake pedal and then pressing down on the yellow Parking Brake button located on the driver's armrest console.
3. Confirm the tow vehicle wiring harness is connected to the 7-pin wiring connector at the front of the bus to allow operation of the bus brake lights and turn signals.

NOTE: For the tow vehicle wiring harness to be operational, the main power switch should be in the ON position OR the interior light switch must be in one of the ON positions (dim or bright) for the 12/24 volt contactors to be powered, allowing the exterior lights to be operational.

4. Close the front door using the rocker switch in the streetside front access panel. If the bus does not have air to close and secure the doors, the doors will need to be manually closed and secured.
5. Tow or winch the bus normally.

CAUTION

If the bus does not have electrical power, it should be towed no faster than 10 mph, and for no longer than 10 miles. Failure to follow this rule could result in severe damage to the drive system.

Bus Towing Process with Power Available

CAUTION

DO NOT flat tow the bus (drive wheels on the ground) over 1 mile at speeds above 20 MPH unless you have removed the half-shaft from the rear axle or unless you have disconnected and removed the drive shaft. **Severe damage to the transmission will occur if this caution is not heeded.**

1. Ensure that the bus has adequate power to operate the air compressor, if not reference *Bus Towing Process with No Power Available*.
2. Determine if the bus can be towed from the front and reference the *Front Towing Attachment Points* section. If it cannot be towed from the front, reference the *Rear Towing Attachment Points* section in order to position the bus for front towing.
3. Turn the bus ON to enable the air compressor. The bus is turned ON by rotating the knob located on the lower left side of the dash one click to the right. The dash screen will light up to indicate the bus is on. This can take several seconds.

Figure 1-21. Turn ON Master Switch

4. Ensure that the bus is in Neutral, if not press down on the brake pedal and then press the “N” button located on the driver’s armrest console. The “N” light will flash.

Note: The power steering pump will continue to operate as long as the vehicle is moving. Should the power steering pump stop, repeat Step 4 above.

CAUTION

Failure to place the bus into Neutral position, prior to winching or towing will result in damage.

5. Release the parking brake by pressing firmly on the brake pedal and then pressing down on the yellow Parking Brake button located on the driver’s armrest console.

6. To gain temporary ride height clearance, see the *Bus Ride Height Preparation* section of this chapter.
7. Confirm the tow vehicle wiring harness is connected to the 7-pin wiring connector at the front of the bus to allow operation of the bus brake lights and turn signals.

NOTE: For the tow vehicle wiring harness to be operational, the main power switch should be in the ON position OR the interior light switch must be in one of the ON positions (dim or bright) for the 12/24 volt contactors to be powered, allowing the exterior lights to be operational.

8. Close the front door using the rocker switch in the streetside front access panel. If the bus does not have air to close and secure the doors, the doors will need to be manually closed and secured.
9. Tow or winch the bus normally.

! *CAUTION* If the bus is operational with electrical power, it can be towed no faster than 40 mph, and for no longer than 20 miles. Failure to follow this rule could result in severe damage to the drive system.

PROTERRA

Route Simulation and Operating Range Data

Efficiency is extremely important as it plays a vital role to determining operating range. Proterra, much like the other battery-electric bus OEMs, utilizes ~90% of the total energy stored on the vehicle as “usable” energy required to power the vehicle. This is done for a variety of reasons, but namely to extend the battery life cycle and protect against performance degradation over time.

Detailed simulation reports are provided on the attached pages for the base 35’ ZX5+ (450kWh) and 40’ ZX5+ (450kWh) as well as the optional 40’ ZX5 Max (675kWh).

PROTERRA

35’ ZX5+

Simulation Report

Simulated ZX5+ Energy Economy for PSTA

Prepared for the Pinellas Suncoast Transit Authority

Report Number: SIM-R2021-038A-PSTA

September 14, 2021

Headquarters
1815 Rollins Road, Burlingame, CA 94010

East Coast Manufacturing
1 Whitlee Court, Greenville, SC 29607

West Coast Manufacturing
393 Cheryl Lane, City of Industry, CA 91789

Simulation Information

Projected gradeability, acceleration, top speed, energy consumption, and range for PSTA

Abbreviations and Definitions

ADB	Advanced Design Bus drive cycle, also known as the Transit Coach Operating Duty Cycle and the Business-Arterial-Commuter (BAC) drive cycle. A composite of the ART, CBD, and COM drive cycles
Ambient Temperature	The temperature of surrounding air
ART	Arterial drive cycle
Attainable Gradeability	Gradeability when drivetrain is a maximum possible performance within normal operating limits, also referred to as peak performance
BOL	Beginning of battery life, 100% of maximum usable energy
BRTC	Larson Transportation Institute's Bus Research and Testing Center, located in Altoona, Pennsylvania, commonly referred to as Altoona
CBD	Central Business District drive cycle
COM	Commuter drive cycle. This report uses the commuter drive cycle previously utilized at the BRTC at Altoona, which has a top speed of 40 mph, not the commuter cycle as stated in SAE J1376, which has a top speed of 55 mph
Continuous Gradeability	Gradeability during sustained climb at high grade for a significant period of time when limitations are imposed on the motors due to thermals
CVW	Curb Vehicle Weight, unloaded vehicle weight assumed to be approximately 31020 lbs. Actual CVW will vary with configuration
Dash SOC	Dash State of Charge, state of charge as displayed to the driver
Drive Cycle	Time series speed data at a sampling rate of 1 Hz or greater
EOL	End of battery life
ft	Feet
Gradeability	The maximum speed that a vehicle can achieve for a specified grade
GVW	Gross Vehicle Weight, vehicle weight loaded with an assumed 51 passengers and a driver at 150 lbs per person. Actual GVW will vary with configuration
GVWR	Gross Vehicle Weight Rating, maximum vehicle load of 42000 lbs
hr	Hours
HVAC	Heating, Ventilation, and Air Conditioning
Jerk	Change in acceleration, $\Delta a / \Delta t$, where a is acceleration and t is time
kW	Kilowatt

kWh	Kilowatt-hour
lbs	Pounds
Michelin® X® InCity Energy Z	Michelin low rolling resistance coach tires, size 315/80R22.5
min	Minutes
MPGe	Diesel Miles Per Gallon Equivalent
mph	Miles per hour
PSTA	Pinellas Suncoast Transit Authority
SLW	Seated Load Weight, vehicle weight loaded with an assumed 29 passengers and a driver at 150 lbs per person. Actual SLW will vary with configuration
Usable Energy	Total amount of energy available for normal operation at any one time, measured in kWh
ZX5 Series	Proterra® fifth-generation battery electric bus series

Table of Contents

Tables and Figures

1 Objective

To predict the gradeability, acceleration, top speed, overall energy consumption, and achievable range of the 35 foot ZX5+[1] with single motor drivetrain for the conditions specified by the PSTA.

1.1 Top Speed Requirement

PSTA stipulated that the proposed vehicle shall be capable of a top speed of 65 mph on a straight, level road at GVWR with all accessories operating and with any variance between peak and sustained performance noted, per RFP TS 7.1 Top Speed[2].

1.2 Gradeability Requirement

PSTA stipulated that the proposed vehicle must be capable achieving and maintaining a speed of 40 mph on a 2.5% ascending grade and 10 mph on a 10% ascending grade continuous, per RFP TS 7.2 Gradeability[2]. Additionally, PSTA stipulated that that time to speed on flat ground, 5%, 7%, 10%, and maximum grade for the speeds of 5 mph, 10 mph, 15 mph, 25 mph, 35 mph at a 130% passenger load be simulated and provided, per TS 8.2 Design Operating Profile[2].

1.3 Acceleration Requirement

PSTA stipulated that the proposed vehicle must be capable of the acceleration requirements stipulated in Table 1-1 with all systems in operation and on straight, level, dry pavement and at GVWR, per RFP TS 7.3 Acceleration[2].

Table 1-1. Acceleration Requirement

Speed (mph)	Maximum Time (s)
10	5
20	10
30	18
40	30
50	60
Top Speed	

1.4 Operating Range Requirement

PSTA stipulated that the energy consumption and range of the proposed vehicle be provided, per TS 7.4 Operating Range[2] and TS 8. Range[2]. The energy economy and range are to be evaluated under two sets of conditions, Altoona Energy Consumption Tests and the PSTA defined Design Operating Profile.

1.4.1 Altoona Energy Consumption Test Requirement

PSTA stipulated that Altoona Energy Consumption and Range Test results be provided for the Transit Coach Operating Duty Cycle (ADB cycle), per TS 8.1 Altoona Energy Consumption Tests[2].

1.4.2 Design Operating Profile Requirement

PSTA stipulated that the proposed vehicle must be evaluated on with mathematical modeling, simulations, or empirical methods, per TS 8.2 Design Operating Profile[2]. Not drive cycle was provided in TS 8.2 Design Operating Profile[2], however, PSTA went on to clarify that the drive cycles utilized for the Design Operating Profile were to be the CBD, ART, and COM duty cycle in an addendum[3]. The conditions stipulated in the Design Operating Profile are as follows:

(a) Maximum auxiliary loads
(b) Results provided for EOL
(c) Starting at maximum operating state of charge
(d) Nominal Conditions
  i. Ambient temperature of 90°F
  ii. Vehicle loaded to SLW
(e) Worst-case Conditions
  i. Ambient temperature consistent with worst-case heating and cooling loads when operating in the State of Florida as defined by NOAA, or alternative website
  ii. Vehicle loaded to GVWR

PSTA further stipulated that any modeling, simulations, or empirical testing be validated against Altoona Energy Economy results utilizing ADB cycle data, per TS 8.2 Design Operating Profile[2].

2 Discussion

The general assumptions of the High-Fidelity simulation are:

(a) Michelin® X® InCity Energy Z tires
(b) Battery and cabin air are thermally preconditioned
(c) Windshield preconditioned (defrosted)
(d) Usable energy of 404 kWh for the ZX5+ at BOL
(e) Useable energy of 324 kWh of the ZX5+ at EOL per standard warranty
(f) Metabolic heat is based on passenger count
(g) No kneeling operation
(h) Range estimations are based on simulated values and are subject to change based on driver performance, configuration, and other factors
    i. Stated values are not guaranteed nor are provided as a warranty term
(i) Range estimations are based on full useable energy and do not consider any reserves that may be imposed by operators

3 Simulation Results

3.1 Top Speed Results

The ZX5+ has a governed top speed of 65 mph and can achieve this speed at loads up to GVWR according to simulations.

3.2 Gradeability Results

Under the stipulated conditions of dry pavement, at GVWR, and with all systems in operation, simulations indicate that the ZX5+ with single motor drivetrain is capable of achieving an attainable speed of 58.3 mph and a continuous speed of 53.1 mph on a 2.5% grade. On a 10% grade, the ZX5+ is capable of achieving an attainable speed of 23.3 mph and a continuous speed of 19.2 mph. Attainable gradeability refer to the gradeability over short periods, such as on a freeway onramp or short hill. Continuous gradeability is gradeability during a sustained climb at the specified grade when limitations are imposed on the motors due to thermals.

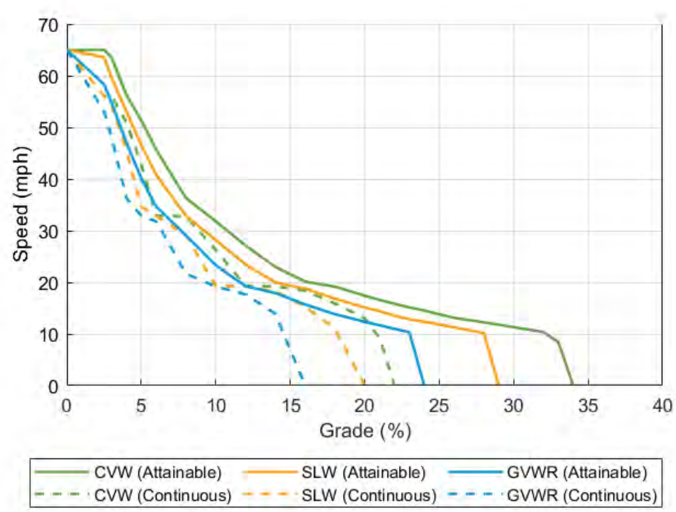


Figure 3-1. Simulated Gradeability at Varying Loads

In addition to the stipulated gradeability requirement, PSTA required simulations of vehicle performance at varying grades and speeds. The results of these simulations can be found in Table 3-1 and Table 3-2 below. The passenger load was stipulated to be 130% passenger load. No definition for 100% passenger load was provided so 100% passenger load was assumed to be GVW or 51 passengers, therefore, 130% passenger load is assumed to be 67 passengers.

Table 3-1. Simulated Performance at Varying Grades and Speeds at 130% Passenger Load (Attainable)

		Time to Speed (s)					Maximum for Grade	
		5 mph	10 mph	15 mph	25 mph	35 mph	Speed (mph)	Time to Speed (s)
Grade	0%	2.4	3.9	5.4	10.7	18.2	65.0	61.4
	5%	2.9	4.4	6.1	15.2	40.6	41.2	250.6
	7%	3.1	4.6	6.5	19.7	N/A	32.8	76.8
	10%	3.5	5.3	7.8	N/A	N/A	24.2	133.4
Maximum for Speed	Grade (%)	24.4	23.8	17.2	9.7	6.1		
	Time to Speed (s)	783.2	251.8	47.2	112.3	208.1		

Table 3-2. Simulated Performance at Varying Grades and Speeds at 130% Passenger Load (Continuous)

		Time to Speed (s)					Maximum for Grade	
		5 mph	10 mph	15 mph	25 mph	35 mph	Speed (mph)	Time to Speed (s)
Grade	0%	2.5	4.0	5.6	11.8	20.9	65.0	86.3
	5%	3.4	5.7	8.2	22.6	N/A	32.9	45.3
	7%	4.0	6.9	10.0	47.2	N/A	28.1	181.6
	10%	5.6	10.0	15.1	N/A	N/A	19.2	23.7
Maximum for Speed	Grade (%)	15.7	15.5	13.8	7.6	4.2		
	Time to Speed (s)	1077.2	318.5	93.9	209.3	545.5		

3.3 Acceleration Results

Under the stipulated conditions of GVWR on straight, level, dry pavement, simulations show that the ZX5+ can achieve the time to speed listed below in Table 3-3.

Table 3-3. ZX5+ Acceleration Results

Speed (mph)	Time (s)
10	3.9
20	7.3
30	13.6
40	22.7
50	33.7
65	62.9

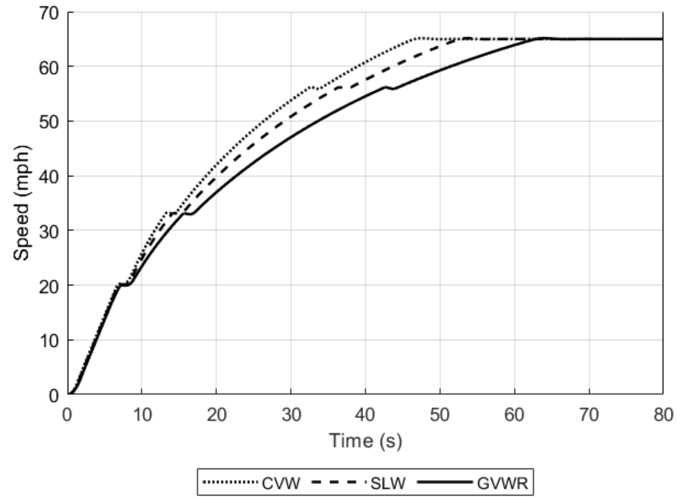


Figure 3-2. ZX5+ 0 mph to 65 mph Speed Profile

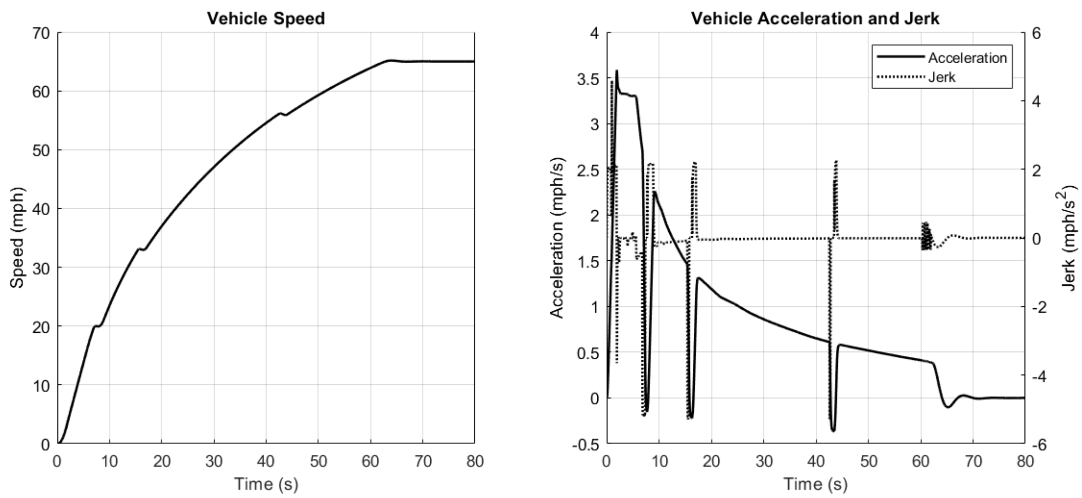


Figure 3-3. Vehicle Acceleration and Jerk for a 0 mph to 65 mph Speed Profile at GVWR

3.4 Altoona Energy Economy Results

The Bus Research and Testing Center at Altoona, PA, has yet to complete testing on the proposed vehicle configuration and the drive cycles stipulated by PSTA (CBD, ART, and COM) are no longer in use by the Bus Research and Testing Center at Altoona, PA, for 35ft and 40ft vehicles. As such, simulations were conducted using parameters intended to emulate the testing methodology used in Altoona Energy Economy Tests[4] and are summarized below.

(a) HVAC disabled
(b) At SLW
(c) Defroster disabled
(d) Windows and doors closed

It should be noted that the bus testing procedure used at Altoona does not stipulate an ambient temperature so an ambient temperature of 73°F from a previous report[5] was used.

Table 3-4. ZX5+ Simulated Altoona Energy Economy Range Tests

Cycle	Load	Ambient Temperature (°F)	Energy Economy (kWh/mi)	MPGe	Auxiliary Loads (kW)	BOL Range (mi)	EOL Range (mi)
ADB	SLW	73°F	1.74	21.7	2.7	232	186
CBD	SLW	73°F	1.71	22	2.8	236	189
ART	SLW	73°F	2.16	17.4	2.9	187	150
COM	SLW	73°F	1.34	28	1.9	300	241

3.5 Model Validation Results

As previously stated, the Bus Research and Testing Center at Altoona, PA, has not completed testing of the proposed configuration at the time of writing this report. As such, the model was validated against a previous Altoona report[5]. The configuration simulated for model validation and test by Altoona in the referenced report is not the proposed configuration and is for model validation purposes only. Note that without information concerning the specific ambient and coast down conditions at Altoona during the test, no model will be able to accurately and consistently emulate Altoona results with exact certainty.

Table 3-5. Simulation Validation Results

Cycle	Simulated		Altoona		Difference	
	Energy Economy (kWh/mi)	Maximum Range (mi)	Energy Economy (kWh/mi)	Maximum Range (mi)	Energy Economy Error (%)	Range Delta (mi)
MANN	2.167	34.1	2.100	32.7	3%	1.4
OCC	2.002	37.0	2.096	32.8	4%	4.2
HD-UDDS	1.874	39.5	2.074	32.0	10%	7.5

3.6 Operating Range Results

PSTA stipulated that range be evaluated on four operating profiles ADB cycle, the CBD cycle, the ART cycle, and the COM cycle. Simulations were conducted on the stipulated drive cycles with the following conditions and parameters.

(a) Initial maximum dash state of charge
(b) Defroster enabled
(c) HVAC enabled
    i. Setpoint of 73°F
(d) Door operation at every idle period of 12 seconds or longer
(e) Nominal Case
    i. Loaded to SLW
    ii. Ambient temperature of 90°F
(f) Worst Case
    i. Loaded to GVWR
        1. Loaded to GVW at 150 lbs per passenger and a thermally inert mass for the remainder
    ii. Ambient temperature consistent with environmental conditions in the State of Florida

1. Hot temperature case utilizes an hourly temperature profile for the 90th percentile July temperature for zip code 33716, averaged to be 91°F
2. Cold temperature case utilizes an hourly temperature profile for the 10th percentile January temperature for zip code 33716, averaged to be 54°F

(g) Solar loading estimated for US zip code 33716

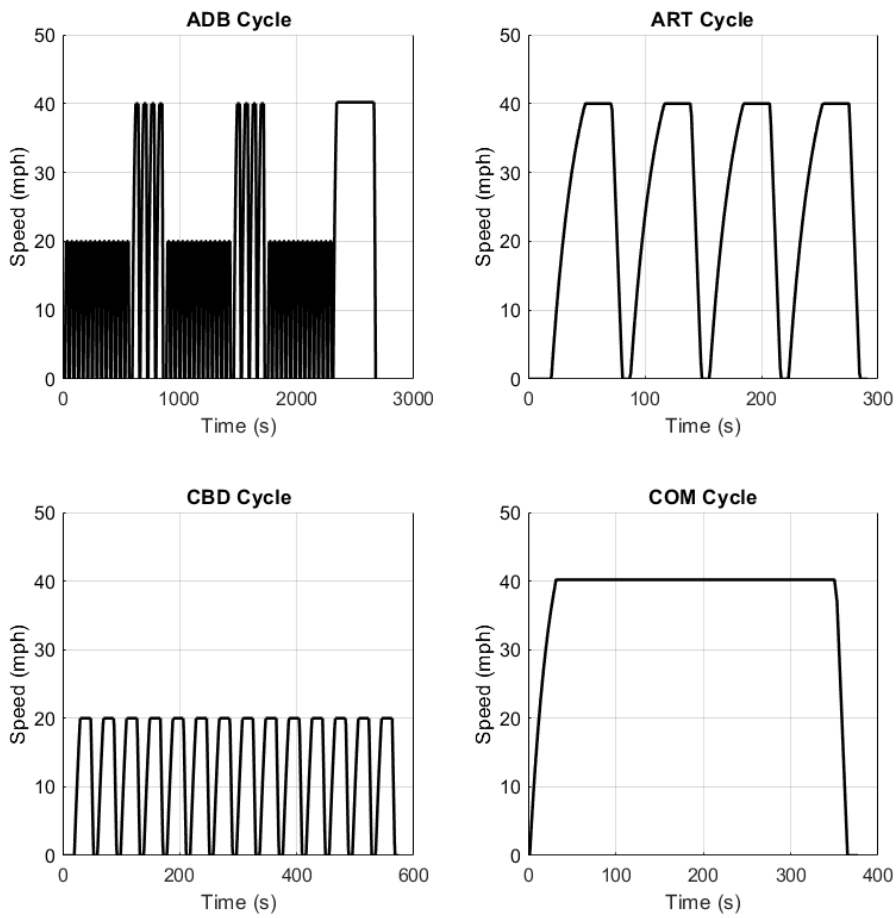


Figure 3-4. Standard Drive Cycles as Utilized in Altoona Energy Economy Testing

Table 3-6. Simulated Range Results

Cycle	Load	Ambient Temperature (°F)	Energy Economy (kWh/mi)	MPGe	Auxiliary Loads (kW)	BOL Range (mi)	EOL Range (mi)
ADB	SLW	90°F	2.09	18.0	3.2	193	155
	GVWR	91°F	2.41	15.6	3.4	167	134
	GVWR	54°F	2.20	17.1	3.6	183	147
CBD	SLW	90°F	2.23	16.9	3.3	181	145
	GVWR	91°F	2.59	14.5	3.5	156	125
	GVWR	54°F	2.26	16.6	3.7	178	143
ART	SLW	90°F	2.43	15.5	3.4	166	133
	GVWR	91°F	2.86	13.2	3.6	141	113
	GVWR	54°F	2.69	14.0	3.7	150	120
COM	SLW	90°F	1.51	24.9	2.4	267	214
	GVWR	91°F	1.68	22.4	2.4	240	192
	GVWR	54°F	1.61	23.4	3.2	250	200

4 References

Reference #	Report #	Title	Agency
1	SPEC_35_002_2020_Q4	Proterra ZX5 35 Foot Bus Platform Specifications	Proterra
2	RFP 21-980369	Florida Electric Transit Buses with Charging and Associated Equipment	PSTA
3	RFP 21980369, Addendum 4	Addendum of Solicitation	PSTA
4	-	Test Bus Procedure: Energy Economy Test	BRTC
5	LTI-BT-R1805-P	PROTERRA, INC. 35-Foot Catalyst FC	BRTC

PROTERRA

40’ ZX5+

Headquarters
1815 Rollins Road, Burlingame, CA 94010

East Coast Manufacturing
1 Whitlee Court, Greenville, SC 29607

West Coast Manufacturing
383 Cheryl Lane, City of Industry, CA 91789

www.proterra.com

Simulation Report

Simulated ZX5+ Energy Economy for PSTA

Prepared for the Pinellas Suncoast Transit Authority

Report Number: SIM-R2021-037A-PSTA

PROTERRA

September 14, 2021

Simulation Information

Projected gradeability, acceleration, top speed, energy consumption, and range for PSTA

Abbreviations and Definitions

ADB	Advanced Design Bus drive cycle, also known as the Transit Coach Operating Duty Cycle and the Business-Arterial-Commuter (BAC) drive cycle. A composite of the ART, CBD, and COM drive cycles
Ambient Temperature	The temperature of surrounding air
ART	Arterial drive cycle
Attainable Gradeability	Gradeability when drivetrain is a maximum possible performance within normal operating limits, also referred to as peak performance
BOL	Beginning of battery life, 100% of maximum usable energy
BRTC	Larson Transportation Institute's Bus Research and Testing Center, located in Altoona, Pennsylvania, commonly referred to as Altoona
CBD	Central Business District drive cycle
COM	Commuter drive cycle. This report uses the commuter drive cycle previously utilized at the BRTC at Altoona, which has a top speed of 40 mph, not the commuter cycle as stated in SAE J1376, which has a top speed of 55 mph
Continuous Gradeability	Gradeability during sustained climb at high grade for a significant period of time when limitations are imposed on the motors due to thermals
CVW	Curb Vehicle Weight, unloaded vehicle weight assumed to be approximately 30320 lbs. Actual CVW will vary with configuration
Dash SOC	Dash State of Charge, state of charge as displayed to the driver
Drive Cycle	Time series speed data at a sampling rate of 1 Hz or greater
EOL	End of battery life
ft	Feet
Gradeability	The maximum speed that a vehicle can achieve for a specified grade
GVW	Gross Vehicle Weight, vehicle weight loaded with an assumed 71 passengers and a driver at 150 lbs per person. Actual GVW will vary with configuration
GVWR	Gross Vehicle Weight Rating, maximum vehicle load of 43650 lbs
hr	Hours
HVAC	Heating, Ventilation, and Air Conditioning
Jerk	Change in acceleration, $\Delta a/\Delta t$, where a is acceleration and t is time
kW	Kilowatt

kWh	Kilowatt-hour
lbs	Pounds
Michelin® X® InCity Energy Z	Michelin low rolling resistance coach tires, size 315/80R22.5
min	Minutes
MPGe	Diesel Miles Per Gallon Equivalent
mph	Miles per hour
PSTA	Pinellas Suncoast Transit Authority
SLW	Seated Load Weight, vehicle weight loaded with an assumed 40 passengers and a driver at 150 lbs per person. Actual SLW will vary with configuration
Usable Energy	Total amount of energy available for normal operation at any one time, measured in kWh
ZX5 Series	Proterra® fifth-generation battery electric bus series

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Tables and Figures

1 Objective

To predict the gradeability, acceleration, top speed, overall energy consumption, and achievable range of the 40 foot ZX5+[1] with single motor drivetrain for the conditions specified by the PSTA.

1.1 Top Speed Requirement

PSTA stipulated that the proposed vehicle shall be capable of a top speed of 65 mph on a straight, level road at GVWR with all accessories operating and with any variance between peak and sustained performance noted, per RFP TS 7.1 Top Speed[2].

1.2 Gradeability Requirement

PSTA stipulated that the proposed vehicle must be capable achieving and maintaining a speed of 40 mph on a 2.5% ascending grade and 10 mph on a 10% ascending grade continuous, per RFP TS 7.2 Gradeability[2]. Additionally, PSTA stipulated that that time to speed on flat ground, 5%, 7%, 10%, and maximum grade for the speeds of 5 mph, 10 mph, 15 mph, 25 mph, 35 mph at a 130% passenger load be simulated and provided, per TS 8.2 Design Operating Profile[2].

1.3 Acceleration Requirement

PSTA stipulated that the proposed vehicle must be capable of the acceleration requirements stipulated in Table 1-1 with all systems in operation and on straight, level, dry pavement and at GVWR, per RFP TS 7.3 Acceleration[2].

Table 1-1. Acceleration Requirement

Speed (mph)	Maximum Time (s)
10	5
20	10
30	18
40	30
50	60
Top Speed	

1.4 Operating Range Requirement

PSTA stipulated that the energy consumption and range of the proposed vehicle be provided, per TS 7.4 Operating Range[2] and TS 8. Range[2]. The energy economy and range are to be evaluated under two sets of conditions, Altoona Energy Consumption Tests and the PSTA defined Design Operating Profile.

1.4.1 Altoona Energy Consumption Test Requirement

PSTA stipulated that Altoona Energy Consumption and Range Test results be provided for the Transit Coach Operating Duty Cycle (ADB cycle), per TS 8.1 Altoona Energy Consumption Tests[2].

1.4.2 Design Operating Profile Requirement

PSTA stipulated that the proposed vehicle must be evaluated on with mathematical modeling, simulations, or empirical methods, per TS 8.2 Design Operating Profile[2]. Not drive cycle was provided in TS 8.2 Design Operating Profile[2], however, PSTA went on to clarify that the drive cycles utilized for the Design Operating Profile were to be the CBD, ART, and COM duty cycle in an addendum[3]. The conditions stipulated in the Design Operating Profile are as follows:

(a) Maximum auxiliary loads
(b) Results provided for EOL
(c) Starting at maximum operating state of charge
(d) Nominal Conditions
  i. Ambient temperature of 90°F
  ii. Vehicle loaded to SLW
(e) Worst-case Conditions
  i. Ambient temperature consistent with worst-case heating and cooling loads when operating in the State of Florida as defined by NOAA, or alternative website
  ii. Vehicle loaded to GVWR

PSTA further stipulated that any modeling, simulations, or empirical testing be validated against Altoona Energy Economy results utilizing ADB cycle data, per TS 8.2 Design Operating Profile[2].

2 Discussion

The general assumptions of the High-Fidelity simulation are:

(a) Michelin® X® InCity Energy Z tires
(b) Battery and cabin air are thermally preconditioned
(c) Windshield preconditioned (defrosted)
(d) Usable energy of 404 kWh for the ZX5+ at BOL
(e) Useable energy of 324 kWh of the ZX5+ at EOL per standard warranty
(f) Metabolic heat is based on passenger count
(g) No kneeling operation
(h) Range estimations are based on simulated values and are subject to change based on driver performance, configuration, and other factors
   i. Stated values are not guaranteed nor are provided as a warranty term
(i) Range estimations are based on full useable energy and do not consider any reserves that may be imposed by operators

3 Simulation Results

3.1 Top Speed Results

The ZX5+ has a governed top speed of 65 mph and can achieve this speed at loads up to GVWR according to simulations.

3.2 Gradeability Results

Under the stipulated conditions of dry pavement, at GVWR, and with all systems in operation, simulations indicate that the ZX5+ with single motor drivetrain is capable of achieving an attainable speed of 56.9 mph and a continuous speed of 51.7 mph on a 2.5% grade. On a 10% grade, the ZX5+ is capable of achieving an attainable speed of 22.3 mph and a continuous speed of 19.2 mph. Attainable gradeability refer to the gradeability over short periods, such as on a freeway onramp or short hill. Continuous gradeability is gradeability during a sustained climb at the specified grade when limitations are imposed on the motors due to thermals.

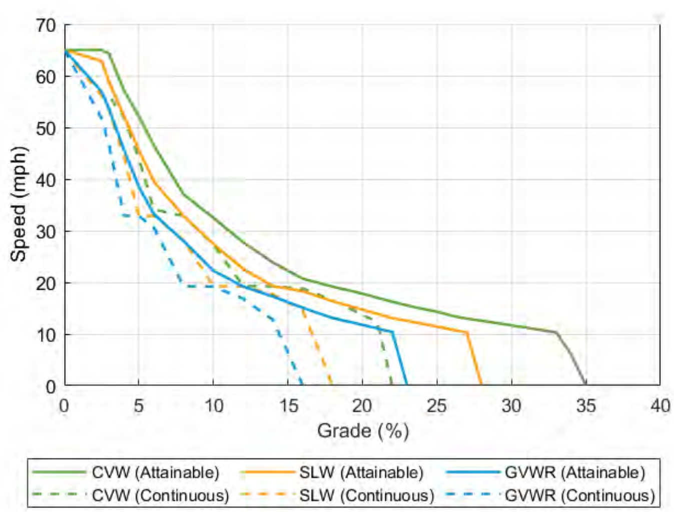

Figure 3-1. Simulated Gradeability at Varying Loads

In addition to the stipulated gradeability requirement, PSTA required simulations of vehicle performance at varying grades and speeds. The results of these simulations can be found in Table 3-1 below. The passenger load was stipulated to be 130% passenger load. No definition for 100% passenger load was provided so 100% passenger load was assumed to be GVW or 71 passengers, therefore, 130% passenger load is assumed to be 92 passengers. It should be noted that with the assumed CVW of 30320 lbs., which will vary with configuration, 130% passenger load will exceed the GVWR of 43650 lbs.

Table 3-1. Simulated Performance at Varying Grades and Speeds at 130% Passenger Load (Attainable)

		Time to Speed (s)					Maximum for Grade	
		5 mph	10 mph	15 mph	25 mph	35 mph	Speed (mph)	Time to Speed (s)
Grade	0%	2.5	4.0	5.5	11.0	19.0	65.0	66.4
	5%	3.0	4.5	6.3	16.6	52.0	38.2	204.5
	7%	3.3	4.9	7.0	23.0	N/A	31.0	138.9
	10%	3.8	5.8	8.7	N/A	N/A	22.0	81.7
Maximum for Speed	Grade (%)	22.6	22.0	15.9	9.0	5.6		
	Time to Speed (s)	600.7	176.8	48.1	117.8	217.5		

Table 3-2. Simulated Performance at Varying Grades and Speeds at 130% Passenger Load (Continuous)

		Time to Speed (s)					Maximum for Grade	
		5 mph	10 mph	15 mph	25 mph	35 mph	Speed (mph)	Time to Speed (s)
Grade	0%	2.6	4.2	6.0	12.5	22.3	65.0	95.4
	5%	3.7	6.3	9.0	26.4	N/A	32.8	61.1
	7%	4.5	7.7	11.3	167.1	N/A	25.0	263.8
	10%	3.8	5.8	8.7	N/A	N/A	19.2	63.8
Maximum for Speed	Grade (%)	14.6	14.3	12.8	7.0	3.8		
	Time to Speed (s)	1676.8	323.8	98.1	172.1	434.1		

3.3 Acceleration Results

Under the stipulated conditions of GVWR on straight, level, dry pavement, simulations show that the ZX5+ can achieve the time to speed listed below in Table 3-3.

Table 3-3. ZX5+ Acceleration Results

Speed (mph)	Time (s)
10	4.0
20	7.4
30	13.9
40	23.4
50	34.8
65	65.6

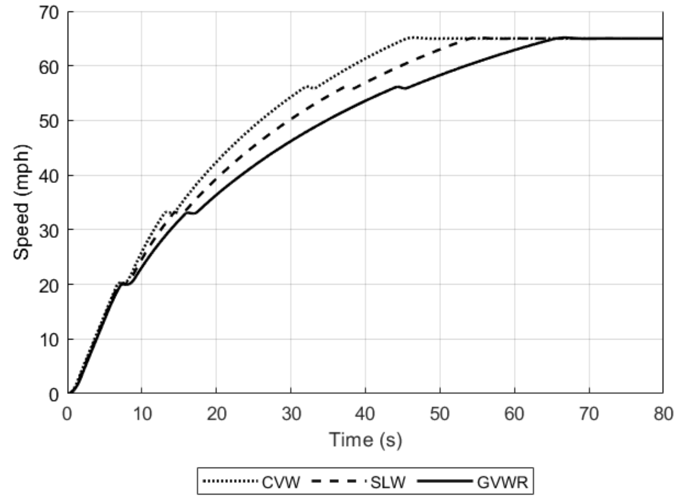

Figure 3-2. ZX5+ 0 mph to 65 mph Speed Profile

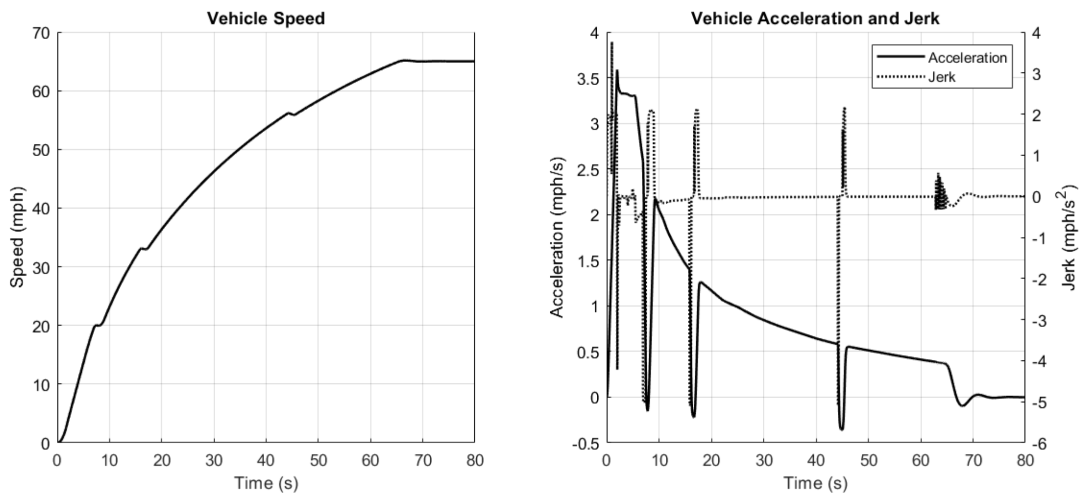

Figure 3-3. Vehicle Acceleration and Jerk for a 0 mph to 65 mph Speed Profile at GVWR

3.4 Altoona Energy Economy Results

The Bus Research and Testing Center at Altoona, PA, has yet to complete testing on the proposed vehicle configuration and the drive cycles stipulated by PSTA (CBD, ART, and COM) are no longer in use by the Bus Research and Testing Center at Altoona, PA, for 35ft and 40ft vehicles. As such, simulations were conducted using parameters intended to emulate the testing methodology used in Altoona Energy Economy Tests[4] and are summarized below.

(a) HVAC disabled
(b) At SLW
(c) Defroster disabled
(d) Windows and doors closed

It should be noted that the bus testing procedure used at Altoona does not stipulate an ambient temperature so an ambient temperature of 73°F from a previous report[5] was used.

Table 3-4. ZX5+ Simulated Altoona Energy Economy Range Tests

Cycle	Load	Ambient Temperature (°F)	Energy Economy (kWh/mi)	MPGe	Auxiliary Loads (kW)	BOL Range (mi)	EOL Range (mi)
ADB	SLW	73°F	1.78	21.2	2.8	227	182
CBD	SLW	73°F	1.75	21.5	2.9	231	185
ART	SLW	73°F	2.22	17	2.9	182	146
COM	SLW	73°F	1.37	27.5	1.9	295	237

3.5 Model Validation Results

As previously stated, the Bus Research and Testing Center at Altoona, PA, has not completed testing of the proposed configuration at the time of writing this report. As such, the model was validated against a previous Altoona report[5]. The configuration simulated for model validation and test by Altoona in the referenced report is not the proposed configuration and is for model validation purposes only. Note that without information concerning the specific ambient and coast down conditions at Altoona during the test, no model will be able to accurately and consistently emulate Altoona results with exact certainty.

Table 3-5. Simulation Validation Results

Cycle	Simulated		Altoona		Difference	
	Energy Economy (kWh/mi)	Maximum Range (mi)	Energy Economy (kWh/mi)	Maximum Range (mi)	Energy Economy Error (%)	Range Delta (mi)
MANN	2.167	34.1	2.100	32.7	3%	1.4
OCC	2.002	37.0	2.096	32.8	4%	4.2
HD-UDDS	1.874	39.5	2.074	32.0	10%	7.5

3.6 Operating Range Results

PSTA stipulated that range be evaluated on four operating profiles ADB cycle, the CBD cycle, the ART cycle, and the COM cycle. Simulations were conducted on the stipulated drive cycles with the following conditions and parameters.

(a) Initial maximum dash state of charge
(b) Defroster enabled
(c) HVAC enabled
  i. Setpoint of 73°F
(d) Door operation at every idle period of 12 seconds or longer
(e) Nominal Case
  i. Loaded to SLW
  ii. Ambient temperature of 90°F
(f) Worst Case
  i. Loaded to GVWR
    1. Loaded to GVW at 150 lbs per passenger and a thermally inert mass for the remainder
  ii. Ambient temperature consistent with environmental conditions in the State of Florida

1. Hot temperature case utilizes an hourly temperature profile for the 90th percentile July temperature for zip code 33716, averaged to be 91°F
2. Cold temperature case utilizes an hourly temperature profile for the 10th percentile January temperature for zip code 33716, averaged to be 54°F

(g) Solar loading estimated for US zip code 33716

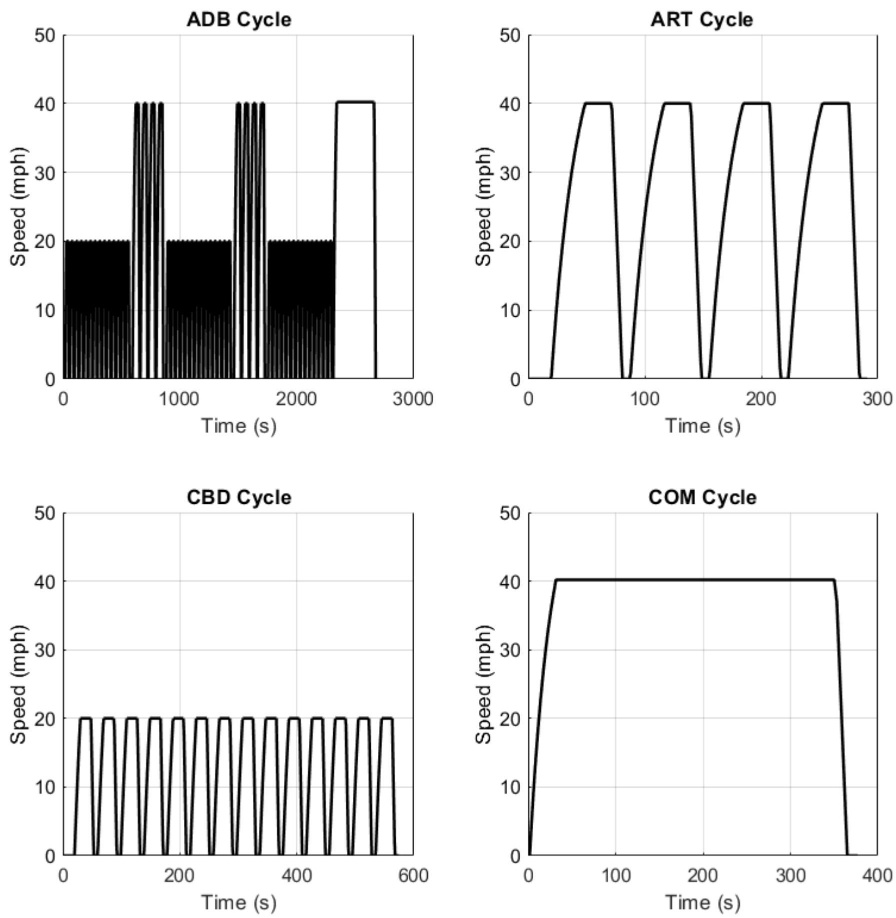

Figure 3-4. Standard Drive Cycles as Utilized in Altoona Energy Economy Testing

Table 3-6. Simulated Range Results

Cycle	Load	Ambient Temperature (°F)	Energy Economy (kWh/mi)	MPGe	Auxiliary Loads (kW)	BOL Range (mi)	EOL Range (mi)
ADB	SLW	90°F	2.14	17.6	3.2	188	151
	GVWR	91°F	2.52	15.0	3.4	160	128
	GVWR	54°F	2.30	16.3	3.6	175	140
CBD	SLW	90°F	2.29	16.4	3.3	176	141
	GVWR	91°F	2.71	13.9	3.6	149	119
	GVWR	54°F	2.38	15.8	3.8	169	135
ART	SLW	90°F	2.51	15.0	3.5	161	129
	GVWR	91°F	2.98	12.6	3.7	135	108
	GVWR	54°F	2.81	13.4	3.7	143	115
COM	SLW	90°F	1.54	24.5	2.4	262	210
	GVWR	91°F	1.73	21.8	2.4	233	187
	GVWR	54°F	1.64	23.0	2.2	247	198

4 References

Reference #	Report #	Title	Agency
1	SPEC_40_002_2021_Q2	Proterra ZX5 40 Foot Bus Platform Specifications	Proterra
2	RFP 21-980369	Florida Electric Transit Buses with Charging and Associated Equipment	PSTA
3	RFP 21980369, Addendum 4	Addendum of Solicitation	PSTA
4	-	Test Bus Procedure: Energy Economy Test	BRTC
5	LTI-BT-R1805-P	PROTERRA, INC. 35-Foot Catalyst FC	BRTC

PROTERRA

40’ ZX5 Max (optional)

Simulation Report

Simulated ZX5 MAX Energy Economy for PSTA

Prepared for the Pinellas Suncoast Transit Authority

Report Number: SIM-R2021-042A-PSTA

PROTERRA

September 20, 2021

Headquarters
1815 Rollins Road, Burlingame, CA 94010

East Coast Manufacturing
1 Whitlee Court, Greenville, SC 29607

West Coast Manufacturing
393 Cheryl Lane, City of Industry, CA 91789

Simulation Information

Projected gradeability, acceleration, top speed, energy consumption, and range for PSTA

Abbreviations and Definitions

ADB	Advanced Design Bus drive cycle, also known as the Transit Coach Operating Duty Cycle and the Business-Arterial-Commuter (BAC) drive cycle. A composite of the ART, CBD, and COM drive cycles
Ambient Temperature	The temperature of surrounding air
ART	Arterial drive cycle
Attainable Gradeability	Gradeability when drivetrain is a maximum possible performance within normal operating limits, also referred to as peak performance
BOL	Beginning of battery life, 100% of maximum usable energy
BRTC	Larson Transportation Institute's Bus Research and Testing Center, located in Altoona, Pennsylvania, commonly referred to as Altoona
CBD	Central Business District drive cycle
COM	Commuter drive cycle. This report uses the commuter drive cycle previously utilized at the BRTC at Altoona, which has a top speed of 40 mph, not the commuter cycle as stated in SAE J1376, which has a top speed of 55 mph
Continuous Gradeability	Gradeability during sustained climb at high grade for a significant period of time when limitations are imposed on the motors due to thermals
CVW	Curb Vehicle Weight, unloaded vehicle weight assumed to be approximately 33740 lbs. Actual CVW will vary with configuration
Dash SOC	Dash State of Charge, state of charge as displayed to the driver
Drive Cycle	Time series speed data at a sampling rate of 1 Hz or greater
EOL	End of battery life
ft	Feet
Gradeability	The maximum speed that a vehicle can achieve for a specified grade
GVW	Gross Vehicle Weight, vehicle weight loaded with an assumed 71 passengers and a driver at 150 lbs per person. Actual GVW will vary with configuration
GVWR	Gross Vehicle Weight Rating, maximum vehicle load of 43650 lbs
hr	Hours
HVAC	Heating, Ventilation, and Air Conditioning
Jerk	Change in acceleration, $\Delta a / \Delta t$, where a is acceleration and t is time
kW	Kilowatt

kWh	Kilowatt-hour
lbs	Pounds
Michelin® X® InCity Energy Z	Michelin low rolling resistance coach tires, size 315/80R22.5
min	Minutes
MPGe	Diesel Miles Per Gallon Equivalent
mph	Miles per hour
PSTA	Pinellas Suncoast Transit Authority
SLW	Seated Load Weight, vehicle weight loaded with an assumed 40 passengers and a driver at 150 lbs per person. Actual SLW will vary with configuration
Usable Energy	Total amount of energy available for normal operation at any one time, measured in kWh
ZX5 Series	Proterra® fifth-generation battery electric bus series

Table of Contents

Tables and Figures

1 Objective

To predict the gradeability, acceleration, top speed, overall energy consumption, and achievable range of the 40 foot ZX5 MAX[1] with single motor drivetrain for the conditions specified by the PSTA.

1.1 Top Speed Requirement

PSTA stipulated that the proposed vehicle shall be capable of a top speed of 65 mph on a straight, level road at GVWR with all accessories operating and with any variance between peak and sustained performance noted, per RFP TS 7.1 Top Speed[2].

1.2 Gradeability Requirement

PSTA stipulated that the proposed vehicle must be capable achieving and maintaining a speed of 40 mph on a 2.5% ascending grade and 10 mph on a 10% ascending grade continuous, per RFP TS 7.2 Gradeability[2]. Additionally, PSTA stipulated that that time to speed on flat ground, 5%, 7%, 10%, and maximum grade for the speeds of 5 mph, 10 mph, 15 mph, 25 mph, 35 mph at a 130% passenger load be simulated and provided, per TS 8.2 Design Operating Profile[2].

1.3 Acceleration Requirement

PSTA stipulated that the proposed vehicle must be capable of the acceleration requirements stipulated in Table 1-1 with all systems in operation and on straight, level, dry pavement and at GVWR, per RFP TS 7.3 Acceleration[2].

Table 1-1. Acceleration Requirement

Speed (mph)	Maximum Time (s)
10	5
20	10
30	18
40	30
50	60
Top Speed	

1.4 Operating Range Requirement

PSTA stipulated that the energy consumption and range of the proposed vehicle be provided, per TS 7.4 Operating Range[2] and TS 8. Range[2]. The energy economy and range are to be evaluated under two sets of conditions, Altoona Energy Consumption Tests and the PSTA defined Design Operating Profile.

1.4.1 Altoona Energy Consumption Test Requirement

PSTA stipulated that Altoona Energy Consumption and Range Test results be provided for the Transit Coach Operating Duty Cycle (ADB cycle), per TS 8.1 Altoona Energy Consumption Tests[2].

1.4.2 Design Operating Profile Requirement

PSTA stipulated that the proposed vehicle must be evaluated on with mathematical modeling, simulations, or empirical methods, per TS 8.2 Design Operating Profile[2]. Not drive cycle was provided in TS 8.2 Design Operating Profile[2], however, PSTA went on to clarify that the drive cycles utilized for the Design Operating Profile were to be the CBD, ART, and COM duty cycle in an addendum[3]. The conditions stipulated in the Design Operating Profile are as follows:

(a) Maximum auxiliary loads
(b) Results provided for EOL
(c) Starting at maximum operating state of charge
(d) Nominal Conditions
    i. Ambient temperature of 90°F
    ii. Vehicle loaded to SLW
(e) Worst-case Conditions
    i. Ambient temperature consistent with worst-case heating and cooling loads when operating in the State of Florida as defined by NOAA, or alternative website
    ii. Vehicle loaded to GVWR

PSTA further stipulated that any modeling, simulations, or empirical testing be validated against Altoona Energy Economy results utilizing ADB cycle data, per TS 8.2 Design Operating Profile[2].

2 Discussion

The general assumptions of the High-Fidelity simulation are:

(a) Michelin® X® InCity Energy Z tires
(b) Battery and cabin air are thermally preconditioned
(c) Windshield preconditioned (defrosted)
(d) Usable energy of 606 kWh for the ZX5 MAX at BOL
(e) Useable energy of 486 kWh of the ZX5 MAX at EOL per standard warranty
(f) Metabolic heat is based on passenger count
(g) No kneeling operation
(h) Range estimations are based on simulated values and are subject to change based on driver performance, configuration, and other factors
    i. Stated values are not guaranteed nor are provided as a warranty term
(i) Range estimations are based on full useable energy and do not consider any reserves that may be imposed by operators

3 Simulation Results

3.1 Top Speed Results

The ZX5 MAX has a governed top speed of 65 mph and can achieve this speed at loads up to GVWR according to simulations.

3.2 Gradeability Results

Under the stipulated conditions of dry pavement, at GVWR, and with all systems in operation, simulations indicate that the ZX5 MAX with single motor drivetrain is capable of achieving an attainable speed of 56.9 mph and a continuous speed of 51.7 mph on a 2.5% grade. On a 10% grade, the ZX5 MAX is capable of achieving an attainable speed of 22.3 mph and a continuous speed of 19.2 mph. Attainable gradeability refer to the gradeability over short periods, such as on a freeway onramp or short hill. Continuous gradeability is gradeability during a sustained climb at the specified grade when limitations are imposed on the motors due to thermals.

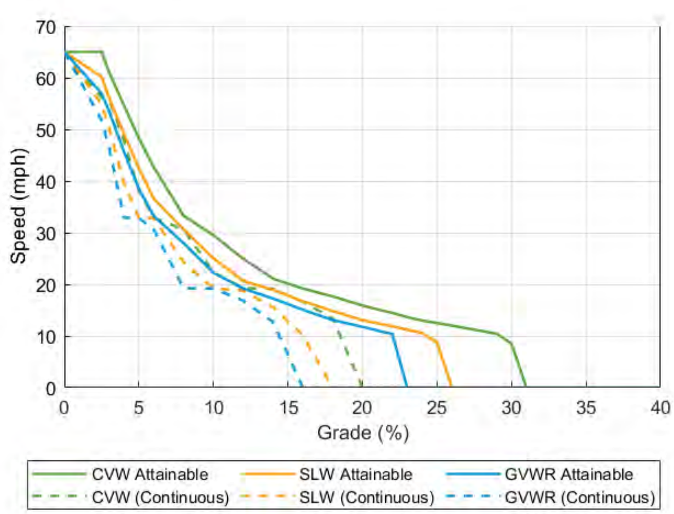

Figure 3-1. Simulated Gradeability at Varying Loads

In addition to the stipulated gradeability requirement, PSTA required simulations of vehicle performance at varying grades and speeds. The results of these simulations can be found in Table 3-1 below. The passenger load was stipulated to be 130% passenger load. No definition for 100% passenger load was provided so 100% passenger load was assumed to be GVW or 71 passengers, therefore, 130% passenger load is assumed to be 92 passengers. It should be noted that with the assumed CVW of 33740 lbs., which will vary with configuration, 130% passenger load will exceed the GVWR of 43650 lbs.

Table 3-1. Simulated Performance at Varying Grades and Speeds at 130% Passenger Load (Attainable)

		Time to Speed (s)					Maximum for Grade	
		5 mph	10 mph	15 mph	25 mph	35 mph	Speed (mph)	Time to Speed (s)
Grade	0%	2.5	4.0	5.6	11.5	20.0	65.0	72.3
	5%	3.1	4.7	6.7	18.5	85.8	35.9	301.0
	7%	3.5	5.3	7.7	28.4		29.0	235.8
	10%	4.1	6.4	10.0			20.4	117.7
Maximum for Speed	Grade (%)	20.8	20.3	14.7	8.2	5.2		
	Time to Speed (s)	568.6	213.4	53.5	97.7	215.4		

Table 3-2. Simulated Performance at Varying Grades and Speeds at 130% Passenger Load (Continuous)

		Time to Speed (s)					Maximum for Grade	
		5 mph	10 mph	15 mph	25 mph	35 mph	Speed (mph)	Time to Speed (s)
Grade	0%	2.7	4.5	6.4	13.3	23.9	65.0	106.4
	5%	4.0	6.9	10.0	32.0		32.8	229.0
	7%	5.0	8.8	13.1			21.5	325.6
	10%	8.4	15.6	24.8			18.6	102.8
Maximum for Speed	Grade (%)	13.4	13.2	11.8	6.4	3.5		
	Time to Speed (s)	875.3	321.7	110.7	179.0	691.5		

3.3 Acceleration Results

Under the stipulated conditions of GVWR on straight, level, dry pavement, simulations show that the ZX5 MAX can achieve the time to speed listed below in Table 3-3.

Table 3-3. ZX5 MAX Acceleration Results

Speed (mph)	Time (s)
10	4.0
20	7.4
30	13.9
40	23.4
50	34.8
65	65.6

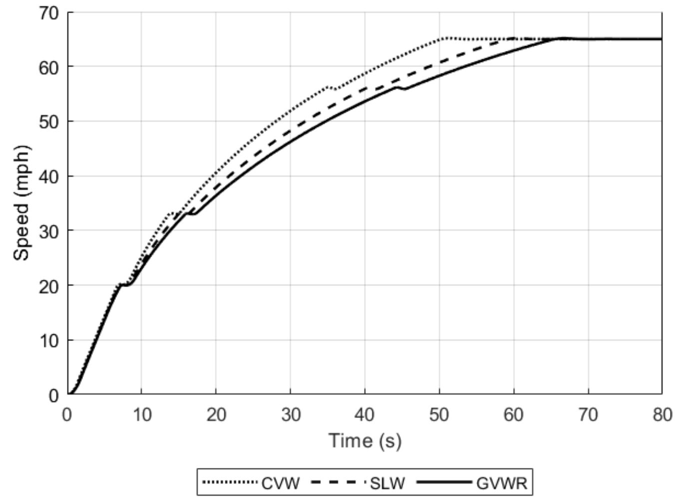

Figure 3-2. ZX5 MAX 0 mph to 65 mph Speed Profile

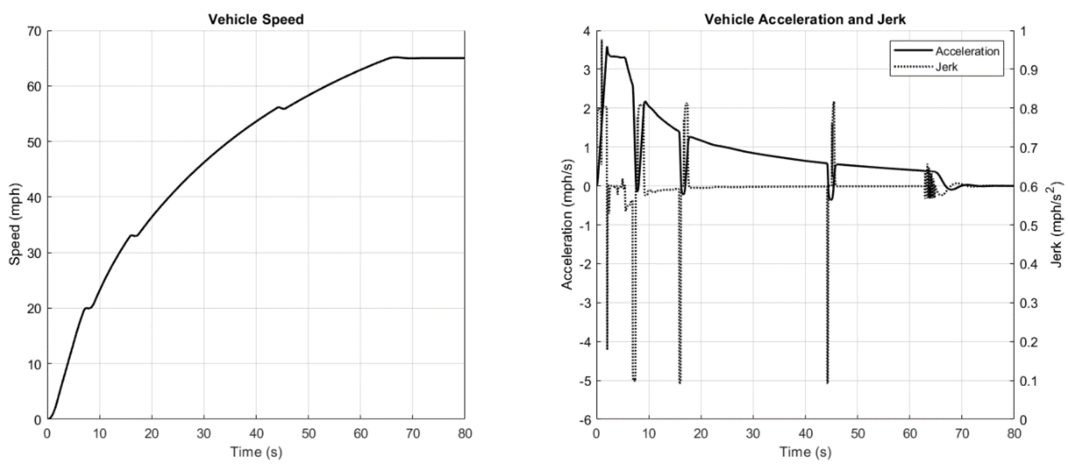

Figure 3-3. Vehicle Acceleration and Jerk for a 0 mph to 65 mph Speed Profile at GVWR

3.4 Altoona Energy Economy Results

The Bus Research and Testing Center at Altoona, PA, has yet to complete testing on the proposed vehicle configuration and the drive cycles stipulated by PSTA (CBD, ART, and COM) are no longer in use by the Bus Research and Testing Center at Altoona, PA, for 35ft and 40ft vehicles. As such, simulations were conducted using parameters intended to emulate the testing methodology used in Altoona Energy Economy Tests[4] and are summarized below.

(a) HVAC disabled
(b) At SLW
(c) Defroster disabled
(d) Windows and doors closed

It should be noted that the bus testing procedure used at Altoona does not stipulate an ambient temperature so an ambient temperature of 73°F from a previous report[5] was used.

Table 3-4. ZX5 MAX Simulated Altoona Energy Economy Range Tests

Cycle	Load	Ambient Temperature (°F)	Energy Economy (kWh/mi)	MPGe	Auxiliary Loads (kW)	BOL Range (mi)	EOL Range (mi)
ADB	SLW	73°F	1.93	19.5	2.9	314	252
CBD	SLW	73°F	1.91	19.7	3.0	317	254
ART	SLW	73°F	2.42	15.6	3.0	250	201
COM	SLW	73°F	1.45	26.0	1.9	419	336

3.5 Model Validation Results

As previously stated, the Bus Research and Testing Center at Altoona, PA, has not completed testing of the proposed configuration at the time of writing this report. As such, the model was validated against a previous Altoona report[5]. The configuration simulated for model validation and test by Altoona in the referenced report is not the proposed configuration and is for model validation purposes only. Note that without information concerning the specific ambient and coast down conditions at Altoona during the test, no model will be able to accurately and consistently emulate Altoona results with exact certainty.

Table 3-5. Simulation Validation Results

Cycle	Simulated		Altoona		Difference	
	Energy Economy (kWh/mi)	Maximum Range (mi)	Energy Economy (kWh/mi)	Maximum Range (mi)	Energy Economy Error (%)	Range Delta (mi)
MANN	2.167	34.1	2.100	32.7	3%	1.4
OCC	2.002	37.0	2.096	32.8	4%	4.2
HD-UDDS	1.874	39.5	2.074	32.0	10%	7.5

3.6 Operating Range Results

PSTA stipulated that range be evaluated on four operating profiles ADB cycle, the CBD cycle, the ART cycle, and the COM cycle. Simulations were conducted on the stipulated drive cycles with the following conditions and parameters.

(a) Initial maximum dash state of charge
(b) Defroster enabled
(c) HVAC enabled
    i. Setpoint of 73°F
(d) Door operation at every idle period of 12 seconds or longer
(e) Nominal Case
    i. Loaded to SLW
    ii. Ambient temperature of 90°F
(f) Worst Case
    i. Loaded to GVWR
        1. Loaded to GVW at 150 lbs per passenger and a thermally inert mass for the remainder
    ii. Ambient temperature consistent with environmental conditions in the State of Florida

1. Hot temperature case utilizes an hourly temperature profile for the 90th percentile July temperature for zip code 33716, averaged to be 91°F
2. Cold temperature case utilizes an hourly temperature profile for the 10th percentile January temperature for zip code 33716, averaged to be 54°F

(g) Solar loading estimated for US zip code 33716

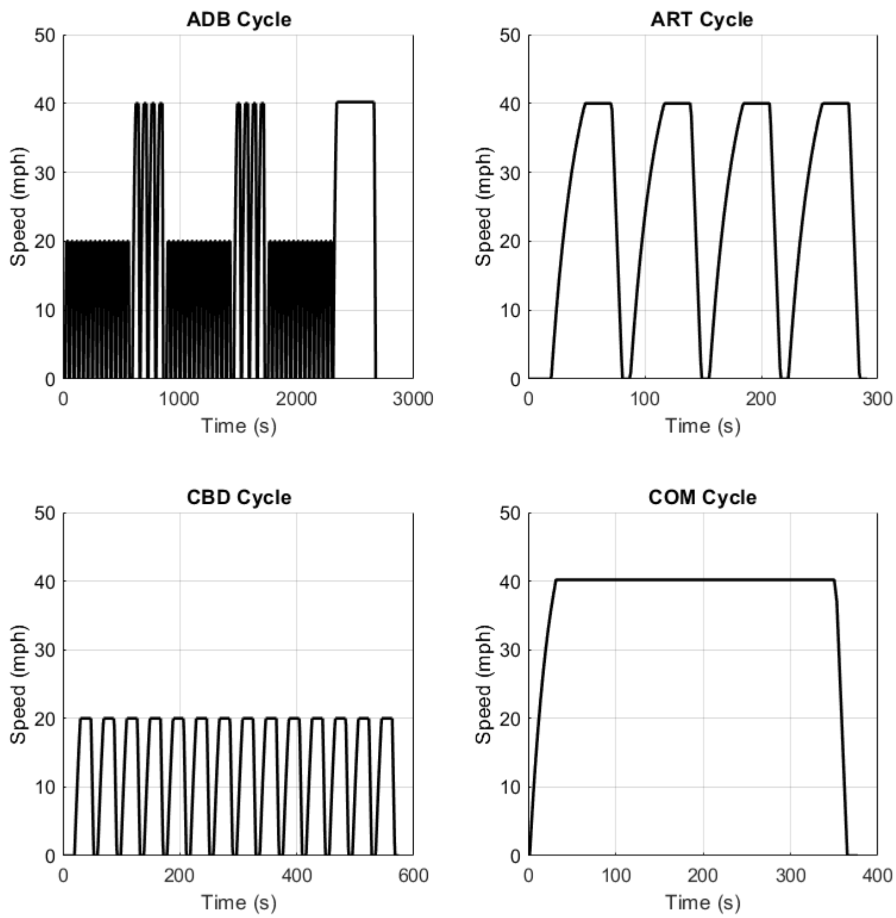

Figure 3-4. Standard Drive Cycles as Utilized in Altoona Energy Economy Testing

Table 3-6. Simulated Range Results

Cycle	Load	Ambient Temperature (°F)	Energy Economy (kWh/mi)	MPGe	Auxiliary Loads (kW)	BOL Range (mi)	EOL Range (mi)
ADB	SLW	90°F	2.29	16.4	3.3	264	212
	GVWR	91°F	2.51	15.0	3.4	241	193
	GVWR	54°F	2.31	16.3	3.9	262	210
CBD	SLW	90°F	2.45	15.4	3.4	247	198
	GVWR	91°F	2.71	13.9	3.6	223	179
	GVWR	54°F	2.40	15.7	4.0	253	202
ART	SLW	90°F	2.70	14.0	3.5	224	180
	GVWR	91°F	2.97	12.7	3.6	204	163
	GVWR	54°F	2.81	13.4	4.0	215	172
COM	SLW	90°F	1.62	23.2	2.4	374	300
	GVWR	91°F	1.73	21.7	2.5	349	280
	GVWR	54°F	1.68	22.4	3.8	361	289

4 References

Reference #	Report #	Title	Agency
1	SPEC_40_002_2021_Q2	Proterra ZX5 40 Foot Bus Platform Specifications	Proterra
2	RFP 21-980369	Florida Electric Transit Buses with Charging and Associated Equipment	PSTA
3	RFP 21980369, Addendum 4	Addendum of Solicitation	PSTA
4	-	Test Bus Procedure: Energy Economy Test	BRTC
5	LTI-BT-R1805-P	PROTERRA, INC. 35-Foot Catalyst FC	BRTC

PROTERRA

Warranty Documentation

Proterra’s standard and extended warranty policies are included on the following pages, for the base buses as well as the High Voltage Batteries / Energy Storage System (ESS). Note: Proterra’s proposal is compliant with PSTA’s required 6-year warranty for the High Voltage Batteries (ESS), Traction Motors, Inverters, Depot Chargers and On Route Chargers.

PROTERRA

Base Warranty Documentation

PROTERRA TRANSIT BUS COMPLETE VEHICLE LIMITED WARRANTY

Proterra, Inc. ("**Proterra**") warrants to the original purchaser/lessee ("**Customer**") that its Proterra ZX5 / ZX5+ / ZX5 Max - Series Battery Electric Transit Bus will be free from defects in material and workmanship under normal use and when properly serviced. Proterra agrees to repair or replace defective parts with either new, or re-certified parts when available, subject to the terms and conditions set forth herein.

NOTE: This Warranty does not include Proterra High Voltage Battery Packs. Please refer to the Battery Pack Limited Warranty section.

The final determination of required repairs or parts replacement shall be the sole discretion of Proterra. This Proterra Transit Bus Complete Vehicle Limited Warranty ("**Warranty**") is a limited warranty subject to the terms and conditions stated in the sections below.

EXCEPT FOR THE OBLIGATIONS, WARRANTIES AND REPRESENTATIONS SPECIFIED HEREIN, PROTERRA MAKES NO REPRESENTATIONS OR WARRANTIES, EXPRESS OR IMPLIED, AND SPECIFICALLY DISCLAIMS ANY REPRESENTATION OR WARRANTY OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, TITLE OR NON-INFRINGEMENT, AND SPECIFICALLY DISCLAIMS ANY WARRANTY ARISING BY USAGE OF TRADE OR BY COURSE OF DEALING.

This Warranty is comprised of two sections; Section **A** applies to the Complete Vehicle, Vehicle Structural Warranty, and Body Warranty. **Section B** applies to the Major Components listed below.

Proterra will reimburse the customer for the parts and labor as published in the Proterra Standard Repair Time Guide ("**SRT**") and shall follow local ordinances as necessary and if applicable in accordance with the terms of this warranty and the purchase/lease agreement, along with associated freight costs to provide required replacement parts during the warranty time period identified below.

Warranty repairs may be performed by the Customer, an authorized warranty provider, or Proterra only and must adhere to the terms and conditions outlined in the following statement of warranty. All components replaced under the warranty are exclusive property of Proterra Inc. and must be returned following the procedures set forth in the "Part Return" section of the warranty manual.

Proterra, at its sole discretion or as part of a Proterra Service Plan, may perform warranty repairs at the Customer location. Costs associated with these repairs will be at the expense of Proterra during standard operating hours. Emergency afterhours warranty support may be performed at the request of the Customer for a fee.

At Proterra, safety is of the utmost importance for our customers and our employees. Therefore, we require our customers to have and maintain the necessary safety equipment, in accordance with state and local OSHA regulations, for the use of any Proterra employee, or authorized provider, that may be performing or assisting with repairs at the Customer's location. This includes but is not limited to, fall restraints, proper lifting equipment and jack stands. Proterra employees will not be permitted to perform any repairs without the necessary safety equipment being provided.

PROTERRA

WARRANTY TERMS SECTION A – PROTERRA TRANSIT BUS – STANDARD BASE WARRANTY COVERAGE

This section includes manufactured or assembled components and systems, including some purchased assemblies listed below.

Proterra Complete Vehicle Limited Warranty **1 Year / 50,000 Miles, whichever occurs first.** (1 Year / 80,467 Kilometers, whichever occurs first).	Coverage includes all components and workmanship that were provided with the Complete Vehicle from the factory. **Excludes:** • Normal maintenance items or wearable items including, but not limited to, brake pads, filters, light bulbs, fuses, circuit breakers, bushings, or any consumable items that are the sole responsibility of the Customer • Provided Customer Equipment, including but not limited to, cameras, fare boxes, counters, and ITS components. • Adjustments, Alignments and/or loose hardware after the first 90 days following vehicle acceptance.
Vehicle Structural Warranty **3 Year / 150,000 Miles, whichever occurs first.** (3 Year / 241,401 Kilometers, whichever occurs first).	Includes the structural elements of the following: Suspension, Front & Rear, Powertrain Cradle, Including Support Members. **Excludes:** • Physically damaged components due to accidents or other impacts. • Modified/Repaired components that were damaged and repaired after collision.
Body Warranty (Monocoque Assembly) **12 Year / 500,000 Miles, whichever occurs first.** (12 Year / 804,672 Kilometers, whichever occurs first).	This applies to any structural and/or workmanship defects discovered in the Monocoque structure. **Excludes:** • Non-structural members.

WARRANTY TERMS SECTION B - PROTERRA TRANSIT BUS – STANDARD MAJOR COMPONENT COVERAGE – 2YR/100K

This section includes major components purchased and installed by Proterra and listed below and is guided by the manufacture warranty. Each item listed in Section B is covered for 2 years or 100,000 miles (160,934 Kilometers), whichever occurs first.

Propulsion System Warranty	System Components including but not limited to; Traction Motor, Traction Motor Inverter, Transmission, Drive Shaft, Output Flange, Differential, Gearboxes, Planetary Sets, and Axle shafts, Oil pump(s), and all internally lubricated parts. **Excludes:** Lack of maintenance and/or physically damaged components
HV Power Electronics and HV Cooling Warranty	System Components including but not limited to, VFD, DC-DC, HV Junction Box, Radiator, and Battery Coolant Pump(s), Contactors, Shunts and Buss Bars. **Excludes:** Lack of maintenance and/or physically damaged components
HVAC Warranty	System Components including but not limited to, Condenser, Compressor, Controller, HVAC Inverter, Evaporator, Receiver/Drier, Blower Fan, Ducting, Thermostat/Thermistor, VFD, and related Sensors and Switches. **Excludes:** • Maintenance items/filters • Debris from external sources (e.g. leaves, dust/dirt) • Routine Recharge/System Tests • Lack of maintenance • Physically damaged components
Control Systems & Driver Convenience Warranty	System Components including but not limited to, ZR Vehicle Controller, Multiplex, Powertrain Controller, D-MUX, Charge Controller, WCCM (Pantograph), Factory Telemetry/Data Logger, Ride Height Controller, Body Controller, Defroster and Blower Motor, Driver Workplace Controls and Switches, **Excludes:** • Modifications to system architecture • Physically damaged components
Chassis System Warranty	System Components including but not limited to, ABS Controller, Air Bags/Shocks, Ride Height Linkage/Sensors, Ride Height Controller, Ride Height Manifold, Air Compressor, Air Dryer, Brake Calipers, Wheel Speed Sensors, Power Steering Motor and Pump, Steering Linkage and Gear. **Excludes:** • Air Compressor Filter & Oil Separator Maintenance • Lack of maintenance • Physically damaged components
Auxiliary Heater Warranty	System Components limited to added components within the Auxiliary Heating Option if selected by the Customer. This includes, Auxiliary Heating Unit, Aux. Heat Fuel System Components, Aux. Blower Motor(s), Aux. Ducting, Aux. Thermistor(s), and Aux. Control(s) as equipped per specification. **Excludes:** • Maintenance items/filters • Debris from external sources (e.g. leaves, dust/dirt) • Lack of maintenance • Physically damaged components

Configuration Package Warranty	Subsystem Components including but not limited to, Wheelchair Access Ramp(s), Wheelchair Securement System(s), Door System(s), Windows, Destination Signs, Fire Suppression System, and Seating. This includes associated components within each system ordered and identified by the Sales Contract. This is contract-specific coverage based on Customer's selected Options. **Excludes:** • Glass breakage, wear and tear • Refilling and/or certification of fire suppression bottles • Seat Covers and Upholstery • Physically damaged components

WHAT IS NOT COVERED:

The following conditions are not covered by this Warranty:

- Alteration or modification of any part of the Product with any third-party item,
- Misuse or negligent use of the bus, including but not limited to Customer's, or a third-party's, failure to follow Proterra's Operating Manual,
- Intentional or accidental collision and/or other physical damage.
- Acts of Nature,
- Neglect or Failure to perform the Preventative Maintenance as outlined in the maintenance documentation for the Product,
- Unauthorized use or operation outside of the terms and conditions of the applicable lease contract,
- Improper maintenance and repair, or
- Intentional acts of destruction, tampering or vandalism.
- Adjustments and Alignments past the first 90 days after the bus is delivered to the Customer'ssite.
- Normal maintenance items or wearable items including, but not limited to, brake pads, filters, light bulbs, fuses, circuit breakers, bushings, or any consumable items.
- Oil, coolant, refrigerant and other fluids are not covered except when used in conjunction with a covered repair as identified in the Proterra Service Manual.
- Any physical damage to Product while in transit to Customer site. This includes shipping damage by carrier delivering a bus. Any damage incurred while in transit will require a claim being filed to the transportation company.
- Body paint and/or vehicle wraps are not covered by this Warranty. Speak to a Proterra representative regarding paint and/or vehicle wrap warranty.

LOW VOLTAGE 12/24 BATTERY POLICY

Proterra warrants the original 12/24V low voltage batteries during the first 90-day period upon delivery of the Proterra Bus and is not extendable. No claims for these batteries will be accepted after the original 90-day period.

For approved low voltage battery replacements during the Warranty period, Customer shall acquire battery at their local vendor and submit for reimbursement through the Warranty Claim submission process outlined within this manual. Customer is advised to contact their local battery vendor for replacement low voltage batteries when required. Proterra will not sell nor ship low voltage batteries through its Service Parts Operation.

Any subsequent battery failures will be subject to the warranty terms provided from the local battery vendor.

PROTERRA

ACTIVATION OF WARRANTY

The Warranty term starts on the Date of Acceptance for each Product in accordance with the terms of the applicable purchasing contract.

Proterra administers the warranty process, and all warranty claim approvals are at the sole and absolute discretion of Proterra.

In connection with any claim brought under this Warranty, the Customer must submit a completed Proterra Warranty Claim Form along with a copy of their internal work order, showing technician punch times, and any additional applicable documentation. Customer is required to retain any parts related to a Warranty transaction for thirty (30) days from the date that the claim has been approved. Proterra reserves the right to request any removed parts be returned at any time during the 30-day period.

Customer also has thirty (30) days to return any parts that are identified as “Core” parts or will be charged the applicable “Core Charge”. Proterra may perform an inspection of the failed component and supporting documentation to make a claim determination. Proterra will not provide any compensation, labor, repairs, or replacement part to the Customer without the above documentation.

Proterra reserves the right to adjust the approved amount to align with the current published SRT guide if excess amounts are claimed without prior authorization from Proterra.

NOTE: Towing coverage is only reimbursed during the initial ***Transit Bus Complete Vehicle Limited Warranty*** for 1 Year/ 50,000 miles, whichever occurs first. All towing claims must be accompanied the warranty repair order and the towing invoice from the provider. Proterra will not pay mark-up on any sublet claims.

For assistance with any warranty claim transactions, please email warranty@proterra.com for support. Please include vehicle VIN, current odometer, unit number, claim number and/or invoice in your correspondence.

DELAYED WARRANTY STARTS

A Delayed Warranty Start may be granted for the Customer to ready the Product for revenue service. This Delayed Warranty Start period shall not exceed 30 days after the Date of Acceptance for each Product and must be approved in writing by Proterra.

This period will allow for Customer to install any necessary equipment, have graphics applied, or any other service readiness activities.

For Delayed Warranty Start approval, the Customer must apply for this added time as part of the Purchase Agreement for the Product, or by submitting the Delayed Warranty Start Application included in the Forms Section of the Appendix.

PLEASE SEE THE PROTERRA TRANSIT WARRANTY MANUAL FOR ALL SERVICE, PARTS AND WARRANTY POLICIES AND PROCEDURES

2170 BATTERY PACK LIMITED WARRANTY

Subject to the terms, conditions and limitations set forth in this Battery Pack Limited Warranty (the "Warranty"), including, without limitation, the Approved Use Conditions, Proterra, Inc. ("Proterra") warrants to the original purchaser or lessee (individually or collectively, the "Customer") that its high voltage battery pack (the "Battery Pack") for the Proterra ZX5 / ZX5+ /ZX5 Max - series battery-electric bus will be free from defects in materials and workmanship.

This Warranty covers the parts, labor (if applicable and in accordance with the terms of this Warranty and/or any purchase or lease agreement), and freight costs incurred during the Warranty Period.

The Battery Pack may not be serviced by the Customer, or any third-party maintenance provider, without having completed the proper factory training and have successfully been certified by Proterra to service the Battery Pack. Any servicing of the Battery Pack by the Customer, or any third-party maintenance provider, without having become Proterra-Certified will void the Warranty. Proterra, or a Proterra-Certified technician, will perform all necessary repairs to the Battery Pack.

2170 BATTERY PACK LIMITED WARRANTY TERMS

As it pertains to this section, the following terms are defined:

"Gross Discharge Throughput" means the total energy discharged through the Battery Pack during its life, including energy from external chargers and energy recuperated from regenerative braking. The Gross Discharge Throughput will be tracked by the BMS at the Battery Pack level and reported through the onboard vehicle telemetry system.

"Nameplate Energy" means the amount of energy stated in the specifications, bid proposal, and/or contract, divided by the number of Battery Packs (e.g., 4 Battery Packs at 400 kWh would have 100 kWh nameplate energy per Battery Pack).

"Available Energy" means the amount of energy available between 0% state of charge ("SOC") and 100% SOC - This information can be obtained using the Proterra diagnostic tool and a snapshot thereof must accompany any battery claims.

Battery Pack Material and Workmanship Warranty **6 Years / Unlimited Mileage**	Coverage to include all materials, components and workmanship of the Battery Pack to be free of defects.
Battery Packs with Nameplate energy of 112.5 kWh **6 Years / 200 MWh**	For Battery Packs with 112.5 kWh of Nameplate Energy and the Available Energy of 101 kWh in new condition, Proterra warrants Available Energy of 81 kWh per Battery Pack for 6 years, or 200 MWh of Gross Discharge Throughput per Battery Pack, whichever comes first.

COMPONENTS INCLUDED IN BATTERY PACK LIMITED WARRANTY

This Warranty includes the following Battery Pack components:

- Battery Modules
- Battery Management System (BMS)
- Battery Cooling System
- Battery Pack Enclosure
- Electrical, Mechanical, and Thermal Interfaces
- Manual Service Disconnect (MSD)

WHAT IS NOT COVERED

The following conditions are not covered by the Battery Pack Limited Warranty:

- Battery Packs that have been serviced by a non-Proterra-Certified technician without prior authorization by Proterra.
- Alteration or modification of any part of the Product with any third-party item
- Misuse or negligent use of the bus, including but not limited to Customer's, or a third-party's, failure to follow Proterra's Operating Manual
- Intentional or accidental collision and/or other physical damage
- Acts of Nature
- Neglect or Failure to perform the Preventative Maintenance as outlined in the maintenance documentation for the Product
- Unauthorized use or operation outside of the terms and conditions of the applicable lease contract,
- Improper maintenance and repair
- Intentional acts of destruction, tampering or vandalism

PROTERRA

Extended Warranty Documentation

Note: We are offering an optional 12-year extended warranty for the high voltage batteries (ESS) as priced on the Pricing Schedule, in accordance with the battery pack limited extended warranty documentation provided on the following pages.

2170 BATTERY PACK LIMITED EXTENDED WARRANTY

Subject to the terms, conditions and limitations set forth in this Battery Pack Limited Warranty (the "Warranty"), including, without limitation, the Approved Use Conditions, Proterra, Inc. ("Proterra") warrants to the original purchaser or lessee (individually or collectively, the "Customer") that its high voltage battery pack (the "Battery Pack") for the Proterra ZX5 / ZX5+ /ZX5 Max - series battery-electric bus will be free from defects in materials and workmanship.

This Warranty covers the parts, labor (if applicable and in accordance with the terms of this Warranty and/or any purchase or lease agreement), and freight costs incurred during the Warranty Period.

The Battery Pack may not be serviced by the Customer, or any third-party maintenance provider, without having completed the proper factory training and have successfully been certified by Proterra to service the Battery Pack. Any servicing of the Battery Pack by the Customer, or any third-party maintenance provider, without having become Proterra-Certified will void the Warranty. Proterra, or a Proterra-Certified technician, will perform all necessary repairs to the Battery Pack.

2170 BATTERY PACK LIMITED EXTENDED WARRANTY TERMS

As it pertains to this section, the following terms are defined:

"Gross Discharge Throughput" means the total energy discharged through the Battery Pack during its life, including energy from external chargers and energy recuperated from regenerative braking. The Gross Discharge Throughput will be tracked by the BMS at the Battery Pack level and reported through the onboard vehicle telemetry system.

"Nameplate Energy" means the amount of energy stated in the specifications, bid proposal, and/or contract, divided by the number of Battery Packs (e.g., 4 Battery Packs at 400 kWh would have 100 kWh nameplate energy per Battery Pack).

"Available Energy" means the amount of energy available between 0% state of charge ("SOC") and 100% SOC - This information can be obtained using the Proterra diagnostic tool and a snapshot thereof must accompany any battery claims.

Battery Pack Material and Workmanship Warranty **12 Years / Unlimited Mileage**	Coverage to include all materials, components and workmanship of the Battery Pack to be free of defects.
Battery Packs with Nameplate energy of 112.5 kWh **12 Years / 400 MWh**	For Battery Packs with 112.5 kWh of Nameplate Energy and the Available Energy of 101 kWh in new condition, Proterra warrants Available Energy of 81 kWh per Battery Pack for 12 years, or 400 MWh of Gross Discharge Throughput per Battery Pack, whichever comes first.

COMPONENTS INCLUDED IN BATTERY PACK LIMITED WARRANTY

This Warranty includes the following Battery Pack components:

- Battery Modules
- Battery Management System (BMS)
- Battery Cooling System
- Battery Pack Enclosure
- Electrical, Mechanical, and Thermal Interfaces
- Manual Service Disconnect (MSD)

WHAT IS NOT COVERED

The following conditions are not covered by the Battery Pack Limited Warranty:

- Battery Packs that have been serviced by a non-Proterra-Certified technician without prior authorization by Proterra.
- Alteration or modification of any part of the Product with any third-party item
- Misuse or negligent use of the bus, including but not limited to Customer's, or a third-party's, failure to follow Proterra's Operating Manual
- Intentional or accidental collision and/or other physical damage
- Acts of Nature
- Neglect or Failure to perform the Preventative Maintenance as outlined in the maintenance documentation for the Product
- Unauthorized use or operation outside of the terms and conditions of the applicable lease contract,
- Improper maintenance and repair
- Intentional acts of destruction, tampering or vandalism

Altoona Status

Proterra BEBs have been tested at Altoona on nine (9) different occasions, including three distinct full STURRA tests. The proposed ZX5 buses recently completed the Altoona pass/fail testing after a lengthy shutdown due to the COVID-19 pandemic. The full Altoona Test Report for the 40' ZX5 with DuoPower (identified as CAT40DP) is included on the following pages.

The additional partial test for the ZX5 Max (675kWh), which shows the longest documented range of any 40' electric bus ever tested at Altoona, is available upon request.

PROTERRA

40’ Complete Test
September 2020
Report Number: LTI-BT-R1906

FEDERAL TRANSIT BUS TEST

Performed for the Federal Transit Administration U.S. DOT
In accordance with 49 CFR, Part 665

Manufacturer: Proterra
Model: CAT40DP

Tested in Service-Life Category
12 Year / 500,000 Miles

September 2020

Report Number: LTI-BT-R1906

The Thomas D. Larson
Pennsylvania Transportation Institute
201 Transportation Research Building
The Pennsylvania State University
University Park, PA 16802
(814) 865-1891

Bus Testing and Research Center
2237 Plank Road
Duncansville, PA 16635
(814) 695-3404

PennState
College of Engineering

LTI BUS RESEARCH
AND TESTING CENTER

FEDERAL TRANSIT BUS TEST

Performed for the Federal Transit Administration, U.S. DOT
1200 New Jersey Avenue, SE
Washington, DC 20590

In accordance with 49 CFR Part, 665

Manufacturer: Proterra
Manufacturer's address: 1815 Rollins Road
Burlingame, CA 94010

Model: CAT40DP

Tested in Service-Life Category
12 Year / 500,000 Miles

Report Number: LTI-BT-R1906

ACCREDITED
Mechanical Testing Certificate 3172.01

David Klinikowski	Director, Bus Research and Testing Center	09/23/2020
Quality Authorization	Title	Date

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EXECUTIVE SUMMARY

TEST HIGHLIGHTS

The information in this report pertains only to this specific bus, as received from the manufacturer for testing.

The Check-In section of the report provides a description of the bus and specifies its major components. The following table gives the salient specifications.

Manufacturer	Proterra
Model	CAT40DP
Chassis Make/Model	Proterra / Catalyst
Chassis Modified	No
Length	42 feet, 5 inches
Fuel	Battery Electric
Service Life	12 Years / 500,000 miles
Number of Seats (including driver)	39 or 33 and 2 wheelchairs
Manufacturer-Designated Standing Passenger Capacity	38
Gross Vehicle Weight used for testing	43,640
Gross Vehicle Weight Rating	43,650 (Manufacturer Specified)
Mileage at Delivery	2,330
Test Start Date	March 28, 2019
Test Completion Date	September 10, 2020*

***Due to the COVID-19 pandemic, all bus testing activities were suspended during the period of March 26, 2020 through July 16, 2020.**

The measured curb weight was 14,490 lb. for the front axle and 18,870 lb. for the rear axle. These combined weights provided a total measured curb weight of 33,360 lb. There are 39 seats including the driver and free floor space for 49 standing passengers bringing the potential total passenger capacity to 88. However, a placard limits the maximum number of standing passengers to 29. Therefore, the gross load represents 39 seated passengers and 29 standees for a total of 68 passengers. Gross load is calculated as 150 lb. x 68 = 10,200 lb. At full declared capacity, the measured gross vehicle weight was 43,640 lb. There is a potential to overload this bus with the available floor space for standing passengers.

For the Performance and Energy Economy Tests, ballast weight equivalent of the roof mount battery packs was removed to represent the four-pack battery configuration per the Federal Transit Administration determination letter. Therefore, the seated load weight used was 36,960 lbs. for those tests.

During the Structural Durability testing the bus experienced periodic instances of mileage loss by the odometer. The issues appeared to be resolved after a software update. Mileage accumulation was tracked secondarily on a hub-odometer to ensure accuracy. Late in the test, the bus developed an intermittent shifting problem in the rear axle. The manufacturer traced a contributor to the problem to be contamination in the air line actuating the pneumatic shift valves. The manufacturer stated that the contamination was caused by a degradation of the grease used during the shifter mechanism assembly and the issue would be resolved in the production process.

BUS TESTING BACKGROUND

On August 1, 2016, FTA announced a final rule for bus testing for improving the process of ensuring the safety and reliability of new transit buses. The rule satisfies requirements in MAP-21 to establish minimum performance standards, a standardized scoring system, and a pass-fail threshold based on the score.

FTA's Bus Testing Program (often referred to as "Altoona Testing" due to the location of the main testing center) tests new transit bus models for:

- Maintainability
- Reliability
- Safety
- Performance (including Braking Performance)
- Structural Integrity (including Structural Durability)
- Fuel Economy (Energy Efficiency and Range, for electric buses)
- Noise
- Emissions

Bus models that fail to meet one or more minimum performance standards will "fail" their test and thus be ineligible for purchase with FTA funds until the failures are resolved and validated through further testing. FTA will use this authority to make sure defects are corrected before a bus model can be acquired with FTA funding.

In each application to FTA for the purchase or lease of any new bus model, or any bus model with a major change in configuration or components to be acquired or leased with funds obligated by the FTA, the recipient shall certify that it has received the appropriate full Bus Testing Report and any applicable partial testing report(s) before final acceptance of the first vehicle. In dealing with a bus manufacturer or dealer, the recipient shall be responsible for determining whether a vehicle to be acquired requires full testing or partial testing or has already satisfied the requirements of this part. A bus manufacturer or recipient may request guidance from FTA in making these determinations.

The purpose of the testing is intended set a "Pass/Fail" standard and grade the performance of the buses in order to provide performance information to the transit authorities that can be used in their purchase or lease decisions. The intent of this report is to provide the grantee a relative measure of the performance of a particular model of transit bus against a standard of performance. The passing of this test should ensure a vehicle has a high probability of meeting its service life in the category it was tested.

The data included in this test report and other applicable reports should be reviewed to choose the most suitable bus for a grantee's operation. A higher scoring bus is not necessarily the best bus for a given application. For example, a bus with a powerful engine may score well because of its performance and gradeability, but another bus with a smaller and more fuel-efficient engine could be a better choice for applications in mostly flat areas. It is the responsibility of the grantee to ensure the proper test report or applicable partial report is in their possession and has been thoroughly reviewed.

The score sheet for the subject vehicle of this test report is provided below. **This bus passed the Altoona test, with an aggregate score of 79.9**

Bus 1906 Proterra

Test category		Standard	Base Pts.	Bonus Pts.	Range	Range	Test Data	Score	FAIL
1. Maintainability	Unscheduled maint.	< 125 hours	2	14	0	125	94.6	5.40	
2. Reliability	# Class 2 failures	< 2 Uncorrected	2	6	0	2	0	8.00	
3. Safety	Hazards	No uncorrected Class 1	10	0	P	F	P	10.00	
	Stability	Lane change, 45 mph?	2.5	0	P	F	P	2.50	
		< 158 feet at 45mph	0.5	2	80	158	139.3	0.98	
	Braking	Holds Lane, Split coeffient	2.5	0	P	F	P	2.50	
		Parking brake, 20% grade	2.5	0	P	F	P	2.50	
4. Performance	Acceleration 0-30 mph	less than 30 sec	1.5	0	P	F	P	1.50	
	Gradeability 2.5%	more than 40 mph	1.5	0	P	F	P	1.50	
	Gradeability 10%	more than 10 mph	2	0	P	F	P	2.00	
5. Structural Integrity	Distortion	Exits are operational	1	0	P	F	P	1.00	
	Static Towing	No significant deformation	1	0	P	F	P	1.00	
	Dynamic Towing	Towable with std. wrecker	1	0	P	F	P	1.00	
	Jacking	Liftable with std. jack	1	0	P	F	P	1.00	
	Hoisting	Stable on jacks	1	0	P	F	P	1.00	
	Durability-Structural	No uncorrected failures	13	0	P	F	P	13.00	
	Durability-Powertrain	No uncorrected failures	12	0	P	F	P	12.00	
6. Fuel Economy	Liquid fuels	1-13mpg	1	6	1	13	NA	0.00	
	CNG	10-50 scf/mi			10	50	NA	0.00	
	Hydrogen	15-98 cf/mi			15	98	NA	0.00	
	Electric	1-3 kWh/mi			1	3	2.23	3.31	
7. Noise	Int. Noise (0-35 mph)	less than 80 db	0.5	3	30	80	74	0.86	
	Ext. Noise (0-35 mph)	less than 83 db	0.5	3	50	83	68.6	1.81	
8. Emissions	CO_2	0-4000 g/mi	1	4	0	4000	0	5.00	
	CO	0-20 g/mi		0.4	0	20	0	0.40	
	Total hydrocarbon	0-3 g/mi		0.4	0	3	0	0.40	
	NMHC	0-3 g/mi		0.4	0	3	0	0.40	
	Nitrogen oxides	0-3 g/mi		0.4	0	2	0	0.40	
	Particulates	0-0.1 g/m		0.4	0	0.1	0	0.40	
Total			60	40				79.9	

Note: The use of the scoring system is not mandatory for procurement. It is only necessary that the bus being procured has received a passing score.

ABBREVIATIONS AND ACRONYMS

ABS - anti-skid braking system
ABTC - Altoona Bus Test Center
A/C - air conditioner, or air conditioning
AC - alternating current
ADA - American Disability Act
CDCTS - chassis dynamometer test control system
CVS - constant volume sampling
CW - curb weight (bus weight including maximum fuel, oil, and coolant; but without passengers or driver)
dB(A) - decibels with reference to 0.0002 microbar as measured on the "A" scale
DC - direct current
DIR - test director
DR - bus driver
EPA - Environmental Protection Agency
GAWR – gross axle weight rating
GVL - gross vehicle load (150 lb. for every designed passenger seating position, for the driver, and for each 1.5 sq ft of free floor space)
GVW - gross vehicle weight (curb weight plus gross vehicle load)
GVWR - gross vehicle weight rating
HD-UDDS – Heavy Duty-Urban Dynamometer Driving Schedule
LTI - Larson Transportation Institute
mpg - miles per gallon
mph - miles per hour
PM - Preventive maintenance
PSTT - Penn State Test Track
rpm - revolutions per minute
SAE - Society of Automotive Engineers
SCF - Standard cubic foot
SCH - test scheduler
SA - staff assistant
SLW - seated load weight (curb weight plus 150 lb. for every designed passenger seating position and for the driver)
TD - test driver
TECH - test technician
TM - track manager
TP - test personnel
Wh - Watt hour

TEST BUS CHECK-IN

I. OBJECTIVE

The objective of this task is to log in the test bus, assign a bus number, complete the vehicle data form, and perform a safety check.

II. TEST DESCRIPTION

The test consisted of assigning a bus test number to the bus, cleaning the bus, completing the vehicle data form, obtaining any special information and tools from the manufacturer, determining a testing schedule, performing an initial safety check, and performing the manufacturer's recommended preventive maintenance. The bus manufacturer certified that the bus meets all Federal regulations.

III. DISCUSSION

The check-in procedure is used to identify in detail the major components and configuration of the bus.

The test bus consisted of a Proterra CAT40DP bus model. The bus has a front passenger door with a fold out Ricon ADA accessible ramp forward of the front axle, and a rear passenger door forward of the rear axle. Power is provided by a battery electric, Proterra DuoPower Control System and a pair of Parker GVM310-125 traction motors.

The measured curb weight was 14,490 lb. for the front axle and 18,870 lb. for the rear axle. These combined weights provided a total measured curb weight of 33,360 lb. There are 39 seats including the driver and free floor space for 49 standing passengers bringing the potential total passenger capacity to 88. However, a placard limits the maximum number of standing passengers to 29. Therefore, the gross load represents 39 seated passengers and 29 standees for a total of 68 passengers. Gross load is calculated as 150 lb. x 68 = 10,200 lb. At full declared capacity, the measured gross vehicle weight was 43,640 lb. There is a potential to overload this bus with the available floor space for standing passengers.

VEHICLE DATA FORM

Bus Number: 1906	Date of Check-In: 03/28/19
Bus Manufacturer: Proterra	Vehicle Identification Number (VIN): 1M9TH16J0JS816351
Model Number: CAT40DP	Chassis Mfr./Mod. #: Proterra / Catalyst
Personnel: T.S., E.D., E.L. & S.R.	Starting Odometer Reading: 2330

WEIGHT:

Individual Wheel Reactions:

Weights (lb.)	Front Axle		Middle Axle		Rear Axle	
	Curb	Street	Curb	Street	Curb	Street
CW	7,230	7,260	N/A	N/A	9,370	9,500
SLW	8,450	8,410	N/A	N/A	10,950	11,740
GVW	9,050	9,010	N/A	N/A	12,550	13,030

Total Weight Details:

Weight (lb.)	CW	SLW	GVW	GAWR
Front Axle	14,490	16,860	18,060	18,078
Middle Axle	N/A	N/A	N/A	N/A
Rear Axle	18,870	22,690	25,580	28,660
Total	33,360	39,550	43,640	Manufacturer Specified GVWR: 43,650

Dimensions:

Length (ft/in)	42/5 (+ 5 ½" for bike rack mount brackets)
Width (in)	102
Height (in)	126 ¾
Front Overhang (in)	102 ¼
Rear Overhang (in)	110 ½
Wheelbase (in)	296 ¼
Wheel Track (in)	Front: 86.1
	Middle: N/A
	Rear: 76.2

VEHICLE DATA FORM

Bus Number: 1906	Date: 03/28/19

CLEARANCES:

Lowest Point Outside Front Axle	Location: skid plate	Clearance(in): 6.3
Lowest Point Outside Rear Axle	Location: door	Clearance(in): 9.0
Lowest Point between Axles	Location: frame	Clearance(in): 8.7
Ground Clearance at the center (in)	8.7	
Front Approach Angle (deg)*	8.5	
Rear Approach Angle (deg)*	9.2	
Ramp Clearance Angle (deg)	3.3	
Aisle Width (in)	Front: 24	Rear: 22.2
Inside Standing Height at Center Aisle (in)	Front: 90.7	Rear: 73.9

*measurements used to calculate approach and departure angles are taken from the centerline of the axles.

BODY DETAILS:

Body Structural Type	Monocoque		
Frame Material	Composite / Laminate Construction		
Body Material	Composite / Laminate Construction		
Floor Material	Composite / Laminate Construction		
Roof Material	Composite / Laminate Construction		
Windows Type	■ Fixed	☐ Movable	
Window Mfg./Model No.	Arow / AS3 DOT 411		
Number of Doors	1 Front	1 Rear	
Mfr. / Model No.	Front: Ventura / IGE 1100	Rear: Ventura / PSE 1250	
Dimension of Each Door (in)	Front: 75.3 x 33.8	Rear: 76.9 x 43.3	
Passenger Seat Type	■ Cantilever (Front)	■ Pedestal (Rear)	☐ Other
Driver Seat Type	■ Air	☐ Spring	☐ Other (explain)
Mfr. / Model No.	Recaro / Ergo Metro (AM80)		
Number of Seats (including Driver)	39 or 33 & 2 wheelchair positions		

Bus Number: 1906	Date: 03/28/19

BODY DETAILS (Contd.)

Free Floor Space (ft^2)	76.4				
Height of Each Step at Normal Position (in)	Front	1. 15.2	2. N/A	3. N/A	4. N/A
	Middle	1. N/A	2. N/A	3. N/A	4. N/A
	Rear	1. 17.2	2. N/A	3. N/A	4. N/A
Step Elevation Change - Kneeling (in)	Front: 2.1	Rear: 0.4			

ENGINE

Type	☐ C.I.	☐ Alternate Fuel	
	☐ S.I.	■ Other (Battery Electric)	
Air Compressor Mfr. / Model No.	Hydrovane / 0009-0010-07		
Maximum Capacity (ft^3 / min)	8.96		
Starter Type – N/A	☐ Electrical	☐ Pneumatic	☐ Other (explain)
Starter Mfr. / Model No.	N/A		

BATTERY SYSTEM

Maximum Rated Capacity (kWh)	440
Usable Capacity (kWh)	391
Nominal Voltage (Vdc)	326

PROPULSION CONTROL SYSTEM (Rear Axle)

Propulsion Control System Mfr. / Model No.	Proterra / DuoPower Control System
Traction Motor - Mfr. / Model No.	Parker / GVM310-125
Traction Motor Power rating (kW)	190 kW per motor / 2 motors within DuoPower Axle

OTHERS

DCDC Converter Mfr. / Model No.	TDI Power / T100103677-LF
HV Distribution Box Mfr. / Model No.	Proterra / 034640
PTC Mfr./ Model No.	ThermaTech / 074020004

Bus Number: 1906	Date: 03/28/19

SUSPENSION

Number of Axles	2		
Front Axle Type	■ Independent	☐ Beam Axle	
Mfr. / Model No.	ZF / RL75EC		
Axle Ratio (if driven)	N/A		
Suspension Type	■ Air	☐ Spring	☐ Other (explain)
No. of Shock Absorbers	2		
Mfr. / Model No.	Sachs / 481700004723 (Start of Test) Replaced with: Koni / 5414 (June 13, 2019)		
Middle Axle Type	☐ Independent	☐ Beam Axle	
Mfr. / Model No.	N/A		
Axle Ratio (if driven)	N/A		
Suspension Type	☐ Air	☐ Spring	☐ Other (explain)
No. of Shock Absorbers	N/A		
Mfr. / Model No.	N/A		
Rear Axle Type	☐ Independent	■ Beam Axle	
Mfr. / Model No.	Proterra / DuoPower		
Axle Ratio (if driven)	3.31:1		
Suspension Type	■ Air	☐ Spring	☐ Other (explain)
No. of Shock Absorbers	4		
Mfr. / Model No.	Sachs / 47 1700 006 149 (Start of Test) Replaced with: Koni / 5415 (June 13, 2019)		

Bus Number: 1906	Date: 03/28/19

WHEELS & TIRES

Front	Wheel Mfr./ Model No.	Alcoa / LVLone 22.5 x 9.00-176
	Tire Mfr./ Model No.	Michelin / XIncity 315/80R22.5
Rear	Wheel Mfr./ Model No.	Alcoa / LVLone 22.5 x 9.00-176
	Tire Mfr./ Model No.	Michelin / XIncity 315/80R22.5

BRAKES

Front Axle Brakes Type	☐ Cam	■ Disc	☐ Other (explain)
Mfr. / Model No.	Knorr / SN7		
Middle Axle Brakes Type	☐ Cam	☐ Disc	☐ Other
Mfr. / Model No.	N/A		
Rear Axle Brakes Type	☐ Cam	■ Disc	☐ Other (explain)
Mfr. / Model No.	Knorr / SB7		

HVAC

Heating System Type	☐ Air	☐Water	☐ Other
Capacity (Btu/hr.)	54,594		
Mfr. / Model No.	Eberspaecher / AC136 model 88-50-26-00755-00		
Air Conditioner	■ Yes	☐ No	
Location	Roof		
Capacity (Btu/hr.)	102,363		
A/C Compressor Mfr. / Model No.	Eberspaecher / HGX34e / 380-4SA (Boch / GEA compressor)		

STEERING

Steering Gear Box Type	Hydraulic gear		
Mfr. / Model No.	Ross / TRW model TAS85		
Steering Wheel Diameter	19.9		
Number of turns (lock to lock)	4 ½		
Control Type	☐ Electric	■ Hydraulic	☐ Other (explain)

Bus Number: 1906	Date: 03/28/19

OTHERS

Wheelchair Ramps	Location: Front	Type: Fold out
Wheelchair Lifts	Location: N/A	Type: N/A
Mfr. / Model No.	Ricon / RISSR-OC27301B00	
Emergency Exit	Location: Window Door Roof hatch	Number: 4 2 2

CAPACITIES

Fuel Tank Capacity	N/A
Engine Crankcase Capacity	N/A
Transmission Capacity	4.5 L per Transmission / 2 Transmissions within DuoPower axle
Differential Capacity	2.8 L per wheel end / 2 wheel ends within DuoPower axle
Cooling System Capacity	Battery Thermal Loop: 12.8 g Power Electronics Thermal Loop: 11.8 g
Power Steering Fluid Capacity	11 quarts

VEHICLE DATA FORM
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Bus Number: 1906	Date: 03/28/19

List all spare parts, tools and manuals delivered with the bus.

Part Number	Description	Qty.
None noted.		

COMPONENT/SUBSYSTEM INSPECTION FORM

Page 1 of 1

Bus Number: 1906	Date: 03/28/19

Subsystem	Checked	Initials	Comments
Air Conditioning Heating and Ventilation	✓	E.D.	None noted.
Body and Sheet Metal	✓	E.D.	None noted.
Frame	✓	E.D.	None noted.
Steering	✓	E.D.	None noted.
Suspension	✓	E.D.	None noted.
Interior/Seating	✓	E.D.	None noted.
Axles	✓	E.D.	None noted.
Brakes	✓	E.D.	None noted.
Tires/Wheels	✓	E.D.	None noted.
Exhaust	N/A	E.D.	None noted.
Fuel System	✓	E.D.	Battery Electric
Power Plant	✓	E.D.	Battery Electric
Accessories	✓	E.D.	None noted.
ADA Accessible Lift System	N/A	E.D.	None noted.
ADA Accessible Ramp System	✓	E.D.	None noted.
Interior Fasteners	✓	E.D.	None noted.
Batteries	✓	E.D.	None noted.

CHECK - IN

PROTERRA
CAT40DP

CHECK - IN CONT.

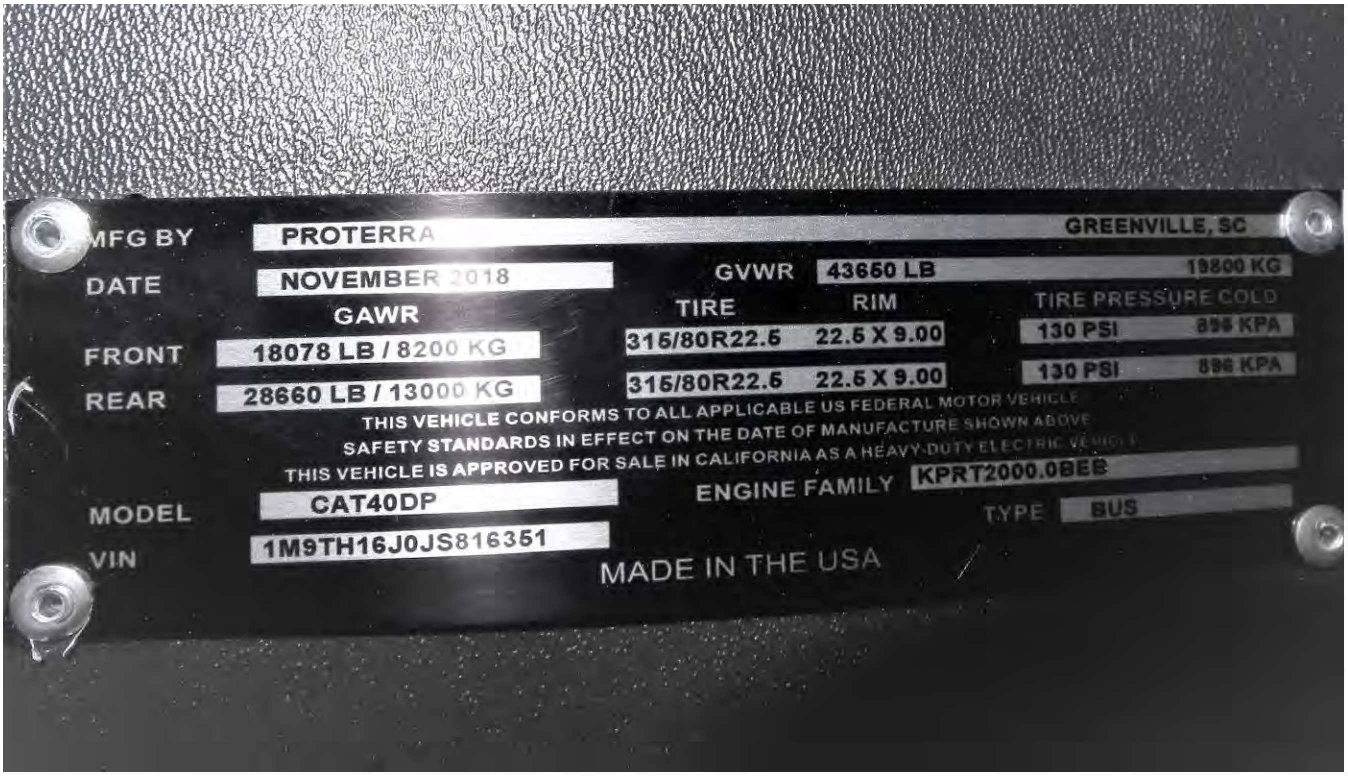
PROTERRA
CAT40DP

CHECK - IN CONT.

OPERATOR'S AREA

INTERIOR FROM FRONT

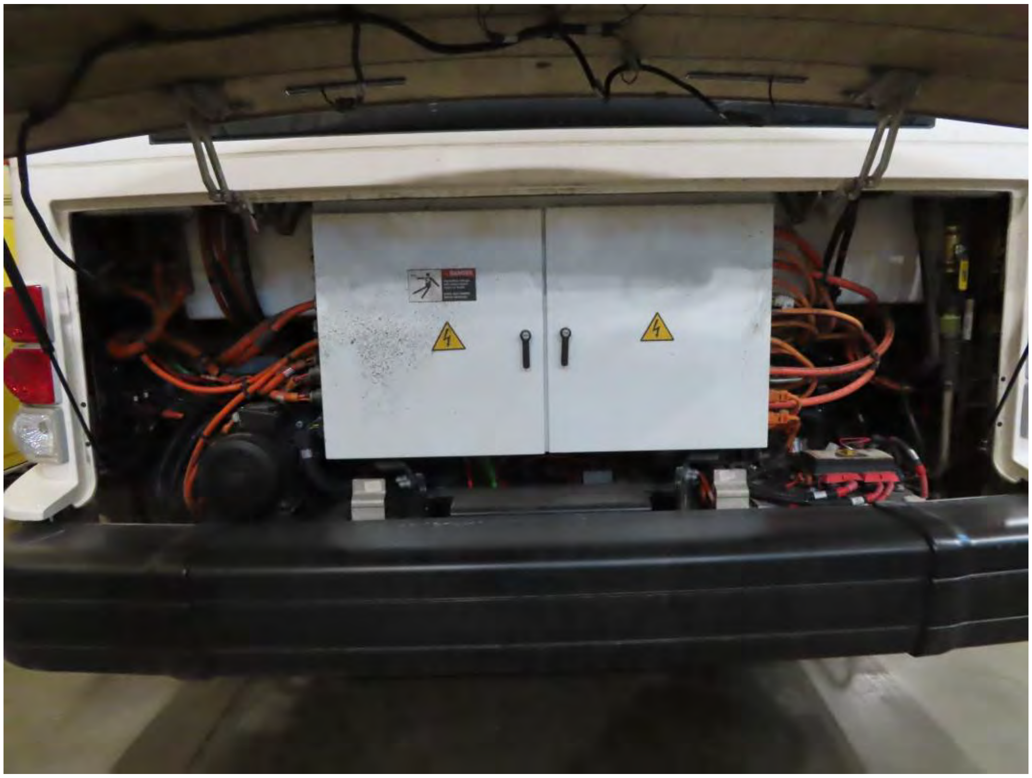
CHECK - IN CONT.



VIN TAG

PLACARD SHOWING MAXIMUM STANDEES

CHECK - IN CONT.



REAR COMPARTMENT

1. MAINTAINABILITY

1.1 ACCESSIBILITY OF COMPONENTS AND SUBSYSTEMS

1.1-I. TEST OBJECTIVE

The objective of this test is to check the accessibility of components and subsystems.

1.1-II. TEST DESCRIPTION

Accessibility of components and subsystems was checked, and where accessibility was restricted the subsystem was noted along with the reason for the restriction.

1.1-III. DISCUSSION

Accessibility, in general, was adequate. Components covered in Section 1.3 (repair and/or replacement of selected subsystems), along with all other components encountered during testing, were found to be readily accessible and no restrictions were noted, with the exception of the windshield wiper motor. Both dash panels inside the bus needed to be removed to access this component.

ACCESSIBILITY DATA FORM

Bus Number: 1906	Date: 08/20/2020

Component	Checked	Comments
ENGINE:		
Oil Dipstick	N/A	N/A
Oil Filler Hole	N/A	N/A
Oil Drain Plug	N/A	N/A
Oil Filter	N/A	N/A
Fuel Filter	N/A	N/A
Air Filter	N/A	N/A
Belts	N/A	N/A
Coolant Level	✓	Drive Motors
Coolant Filler Hole	✓	Drive Motors
Coolant Drain	✓	Drive Motors
Spark / Glow Plugs	N/A	N/A
Alternator	N/A	N/A
Diagnostic Interface Connector	✓	None noted.
TRANSMISSION:		
Fluid Dipstick	N/A	N/A
Filler Hole	N/A	N/A
Drain Plug	N/A	N/A
SUSPENSION:		
Bushings	✓	None noted.
Shock Absorbers	✓	None noted.
Air Springs	✓	None noted.
Leveling Valves	✓	None noted.
Grease Fittings	✓	None noted.

ACCESSIBILITY DATA FORM

Bus Number: 1906	Date: 08/20/2020

Component	Checked	Comments
HVAC:		
A/C Compressor	✓	None noted.
Filters	✓	None noted.
Fans	✓	None noted.
ELECTRICAL SYSTEM:		
Fuses	✓	None noted.
Batteries	✓	None noted.
Voltage regulator	✓	None noted.
Voltage Converters	✓	None noted.
Lighting	✓	None noted.
MISCELLANEOUS:		
Brakes	✓	None noted.
ADA Accessible Lifts/Ramps	✓	None noted.
Instruments	✓	None noted.
Axles	✓	None noted.
Exhaust	N/A	N/A
Fuel System	N/A	Battery Electric
OTHERS:		
Wiper Motor	✓	Both dash pieces need to be removed to access motor

1.1 ACCESSIBILITY OF COMPONENTS AND SUBSYSTEMS

DASH PIECES REMOVED TO ACCESS WIPER MOTOR

1.2 SERVICING, PREVENTIVE MAINTENANCE, AND REPAIR AND MAINTENANCE DURING TESTING

1.2-I. TEST OBJECTIVE

The objective of this test is to collect maintenance data about the servicing, preventive maintenance, and repair.

1.2.-II. TEST DESCRIPTION

The test was conducted by operating the bus and collecting the following data on work order forms and a driver log.

1. Scheduled Maintenance
   a. Bus number
   b. Date
   c. Mileage
   d. Results of scheduled inspections
   e. Description of malfunction (if any)
   f. Repair action and parts used (if any)
   g. Man-hours required

2. Unscheduled Maintenance
   a. Bus number
   b. Date
   c. Mileage
   d. Description of malfunction
   e. Place and time of malfunction (e.g., in service or undergoing inspection)
   f. Repair action and parts used
   g. Man-hours required

The bus was operated in accelerated durability service. While typical items are given below, the specific service schedule was that specified by the manufacturer.

A. Service
   1. Fueling
   2. Consumable checks
   3. Interior cleaning

B. Preventive Maintenance
   1. Brake adjustments
   2. Lubrication
   3. 3,000 mi (or manufacturer recommended) inspection

4. Oil and filter change inspection
5. Major inspection
6. Tune-up

C. Periodic Repairs

1. Brake reline*
2. Transmission change
3. Engine change*
4. Windshield wiper motor change
5. Stoplight bulb change*
6. Towing operations
7. Hoisting operations

*These items are attended to if found necessary, while the others in the list are removed/replaced/tested for all buses undergoing a full test.

1.2-III. DISCUSSION

Servicing and preventive maintenance were performed at manufacturer-specified intervals. The following Scheduled Maintenance Form lists the mileage, items serviced, the service interval, and amount of time required to perform the maintenance.

The Unscheduled Maintenance List along with related photographs is included in Section 5.7, Structural Durability. This list supplies information related to failures that occurred during the durability portion of testing. The Unscheduled Maintenance List includes the date and mileage at which the malfunction was detected, a description of the malfunction and repair, and the time required to perform the repair.

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SCHEDULED MAINTENANCE
Proterra Bus# 1906

DATE	TEST MILES	SERVICE	ACTIVITY	DOWN TIME	LABOR HOURS
05/17/19	1,220	P.M./Inspection	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	4.00	4.00
06/24/19	2,711	P.M./Inspection	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	4.00	4.00
07/31/19	3,910	P.M./Inspection	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	4.00	4.00
08/04/19	4,094	P.M./Inspection	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	4.00	4.00
08/15/19	4,532	P.M./Inspection	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	4.00	4.00
10/13/19	7,851	P.M./Inspection	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	4.00	4.00

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SCHEDULED MAINTENANCE

Proterra Bus# 1906

DATE	TEST MILES	SERVICE	ACTIVITY	DOWN TIME	LABOR HOURS
11/05/19	8,976	P.M./Inspection	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	4.00	4.00
11/26/19	10,163	P.M./Inspection	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	4.00	4.00
12/17/19	11,573	P.M./Inspection	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	4.00	4.00
02/08/20	14,388	P.M./Inspection Energy Economy Prep	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	8.00	8.00
02/20/20	14,584	P.M./Inspection	Steering linkages and tie rods, all checked; all fluids checked. Inspected frame, body and suspension.	4.00	4.00

1.3 REPLACEMENT AND/OR REPAIR OF SELECTED SUBSYSTEMS

1.3-I. TEST OBJECTIVE

The objective of this test is to establish the time required to replace and/or repair selected subsystems.

1.3-II. TEST DESCRIPTION

The test involved components that may be expected to fail or require replacement during the service life of the bus. In addition, any component that failed during testing of the bus was added to this list. Components to be included are:

1. Transmission
2. Alternator
3. Starter
4. Batteries
5. Windshield wiper motor

1.3-III. DISCUSSION

At the end of the test, the items on the list were removed and replaced. The DuoPower axle assembly took 4.00 labor-hours (2 persons @ 2.00 hrs.) to remove and replace. The time required for repair/replacement of the other four components is given on the following Repair and/or Replacement Form.

REPLACEMENT AND/OR REPAIR FORM

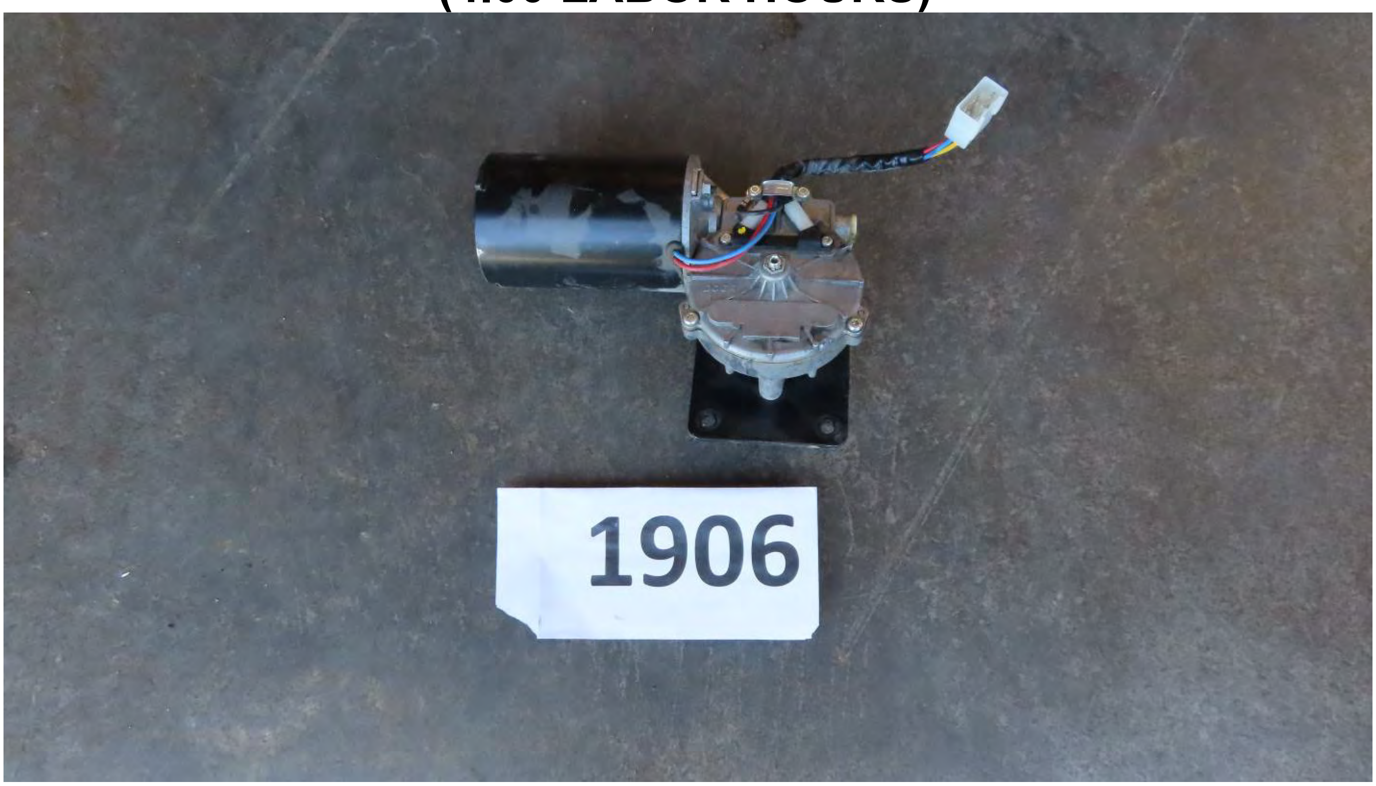
Subsystem	Replacement Time
DuoPower Axle	4.00 labor hours
Wiper Motor	2.00 labor hours
DC-DC Converter	1.00 labor hours
ESS Battery Pack (Streetside)	2.00 labor hours
Batteries (12 volt)	1.00 labor hours

During removal and replacement of the windshield wiper motor, it is noted that the dash of the bus had to be removed to access the motor.

During the test, additional components were removed for repair or replacement and the details are available in Section 5.7 in Unscheduled Maintenance.

1.3 REPLACEMENT AND/OR REPAIR OF SELECTED SUBSYSTEMS

DUOPOWER AXLE REMOVAL AND REPLACEMENT
(4.00 LABOR HOURS)



WIPER MOTOR REMOVAL AND REPLACEMENT
(2.00 LABOR HOURS)

1.3 REPLACEMENT AND/OR REPAIR OF SELECTED SUBSYSTEMS CONT.

DC-DC CONVERTER REMOVAL AND REPLACEMENT (1.00 LABOR HOURS)

HIGH VOLTAGE ESS BATTERY PACK REMOVAL AND REPLACEMENT (2.00 LABOR HOURS)

2. RELIABILITY - DOCUMENTATION OF BREAKDOWN AND REPAIR TIMES DURING TESTING

2-I. TEST OBJECTIVE

The objective of this test is to document unscheduled breakdowns, repairs, down time, and repair time that occur during testing.

2-II. TEST DESCRIPTION

Using the driver log and unscheduled work order forms, all significant breakdowns, repairs, labor-hours to repair, and hours out of service were recorded on the Reliability Data Form.

CLASS OF FAILURES

Classes of failures are described below:

(a) Class 1: Physical Safety. A failure that could lead directly to Injury, a crash and/or significant physical damage.

(b) Class 2: Road Call. A failure resulting in an en-route interruption of revenue service. Service is discontinued until the bus is replaced or repaired at the point of failure.

(c) Class 3: Bus Change. A failure that requires removal of the bus from service during its assignments. The bus is operable to a rendezvous point with a replacement bus.

(d) Class 4: Bad Order. A failure that does not require removal of the bus from service during its assignments but does degrade coach operation. The failure shall be reported by driver, inspector, or hostler.

2-III. DISCUSSION

A listing of breakdowns and unscheduled repairs was accumulated during the Structural Durability Test. The following Reliability Data Form lists all unscheduled repairs under classes as defined above.

The classification of repairs according to subsystem is intended to emphasize those systems which had persistent minor or more serious problems. There was a total of 80 failures throughout various subsystems. There was one Class One failure that affected the ADA Ramp. There were six Class Two failures, 67 Class Three failures and six Class Four failures. These failures are available for review in the Unscheduled Maintenance List, located in Section 5.7 Structural Durability.

This bus passed the Structural and Powertrain Durability sections of the test.

RELIABILITY DATA FORMS

Bus Number: 1906	Date: 09/22/2020
Personnel: B.L. & D.K.	

	Failure Type					
	Class 4 Bad Order	Class 3 Bus Change	Class 2 Road Call	Class 1 Physical Safety		
Subsystems	Mileage	Mileage	Mileage	Mileage	Labor Hours	Down Time
Electrical			239		1.25	1.25
		381			1.00	1.00
		992			1.00	1.00
			1,087		2.50	2.50
		1,517			0.75	0.75
		1,652			1.00	1.00
		1,744			1.50	1.50
		2,049			0.08	0.08
		2,049			1.00	1.00
		2,359			0.50	0.50
		2,669			2.00	2.00
		2,957			0.50	0.50
		3,682			0.25	0.25
		3,874			0.25	0.25
		4,292			0.50	0.50
		4,529			0.10	0.10
		5,581			0.08	0.08
		6,446			0.50	0.50
		6,511			0.20	0.20
			6,615		2.85	2.85
	9,461				---	---
		10,783			0.08	0.08

RELIABILITY DATA FORMS

Bus Number: 1906	Date: 09/22/2020
Personnel: B.L. & D.K.	

Subsystems	Failure Type: Class 4 Bad Order Mileage	Class 3 Bus Change Mileage	Class 2 Road Call Mileage	Class 1 Physical Safety Mileage	Labor Hours	Down Time
Electrical (Cont.)		10,783			1.25	1.25
	11,595				---	---
		12,044			0.25	0.25
		12,999			0.50	0.50
		12,999			1.00	1.00
		13,267			0.25	0.25
		14,930			1.00	1.00
Body		381			0.50	0.50
		681			0.25	0.25
		681			0.75	0.75
		1,220			1.00	1.00
		1,648			2.50	2.50
	1,744				0.08	0.08
		2,593			1.00	1.00
		3,437			0.50	0.50
		4,094			0.25	0.25
		4,592			0.20	0.20
		5,581			0.08	0.08
		6,446			3.25	3.25
		6,446			1.00	1.00
		8,754			0.25	0.25
		9,098			0.75	0.75

RELIABILITY DATA FORMS

Bus Number: 1906	Date: 09/22/2020
Personnel: B.L. & D.K.	

Subsystems	Failure Type: Class 4 Bad Order Mileage	Class 3 Bus Change Mileage	Class 2 Road Call Mileage	Class 1 Physical Safety Mileage	Labor Hours	Down Time
Body (Cont.)		10,510			0.08	0.08
		10,783			0.50	0.50
		11,803			2.50	2.50
		12,598			2.50	2.50
		12,999			7.50	7.50
		13,267			0.25	0.25
	14,587				0.25	0.25
		14,782			1.50	1.50
Coolant (Motor & Battery)		381			0.25	0.25
		12,044			0.50	0.50
Software/Electrical			381		0.25	0.25
		7,132			2.00	2.00
		10,103			0.25	0.25
Electrical/Body		681			2.50	2.50
			2,285		1.00	1.00
			9,334		3.00	3.00
Drivetrain		755			2.00	2.00
		992			4.50	4.50
		2,085			2.00	2.00
		3,612			0.50	0.50
		6,911			0.50	0.50

RELIABILITY DATA FORMS

Bus Number: 1906	Date: 09/22/2020
Personnel: B.L. & D.K.	

Subsystems	Class 4 Bad Order Mileage	Class 3 Bus Change Mileage	Class 2 Road Call Mileage	Class 1 Physical Safety Mileage	Labor Hours	Down Time
Drivetrain (Cont.)		12,999			---	---
Suspension		1,220			0.50	0.50
		2,285			0.50	0.50
		2,285			0.50	0.50
		2,302			0.50	0.50
		2,421			1.00	1.00
		7,302			0.50	0.50
		9,398			12.00	12.00
Hardware		1,231			4.00	4.00
HVAC	2,757				2.00	2.00
Electrical / Motor and Battery Cooling		3,437			0.75	0.75
Coach Air Compressor	5,180				1.00	1.00
Software		6,265			0.10	0.10
Compressed Air System		6,511			0.25	0.25
Door		12,999			1.00	1.00
ADA Ramp				13,644	1.25	1.25

3.1 SAFETY - A DOUBLE-LANE CHANGE (OBSTACLE AVOIDANCE)

3.1-I. TEST OBJECTIVE

The objective of this test is to determine handling and stability of the bus by measuring speed through a double lane change test.

3.1-II. TEST DESCRIPTION

The Safety Test consisted of an obstacle avoidance maneuver to evaluate the handling and stability of the bus. The test was conducted at the LTI test track on the vehicle dynamics pad. The bus was driven through a double-lane change course at increasing speeds until the test was determined to be unsafe or a speed of 45 mph is reached. The test is determined unsafe if vehicle handling becomes unstable or if any of the tires lose contact with the pavement.

The layout of the test course was defined by placing pylons along painted guidelines that delineated the course. The guidelines marked off two 12-foot center-to-center lanes. Each lane had two 100 foot long gates with a spacing distance of 100 feet between them. The bus entered the test course in one lane, crossed over to the other lane within the 100 foot gate, traveled for 100 feet, and then returned back into the original lane within the next 100 foot gate. This maneuver was repeated from 20 mph with speed increasing in increments of 5 mph. The test was performed starting from both the right and left lanes.

A test run is considered valid if the bus is able to perform the maneuver at a constant speed without deviating from the test course or striking pylons. If the bus is not able to successfully complete the maneuver due to vehicle instability, the test will be terminated. The highest speed at which the maneuver can be successfully performed up to a maximum speed of 45 mph is recorded on the Safety Data Form.

3.1-III. DISCUSSION

The double-lane change was performed in both right-hand and left-hand directions. The bus was able to safely negotiate the test course in both the right-hand and left-hand directions up to the maximum test speed of 45 mph, and therefore, passed this portion of the test.

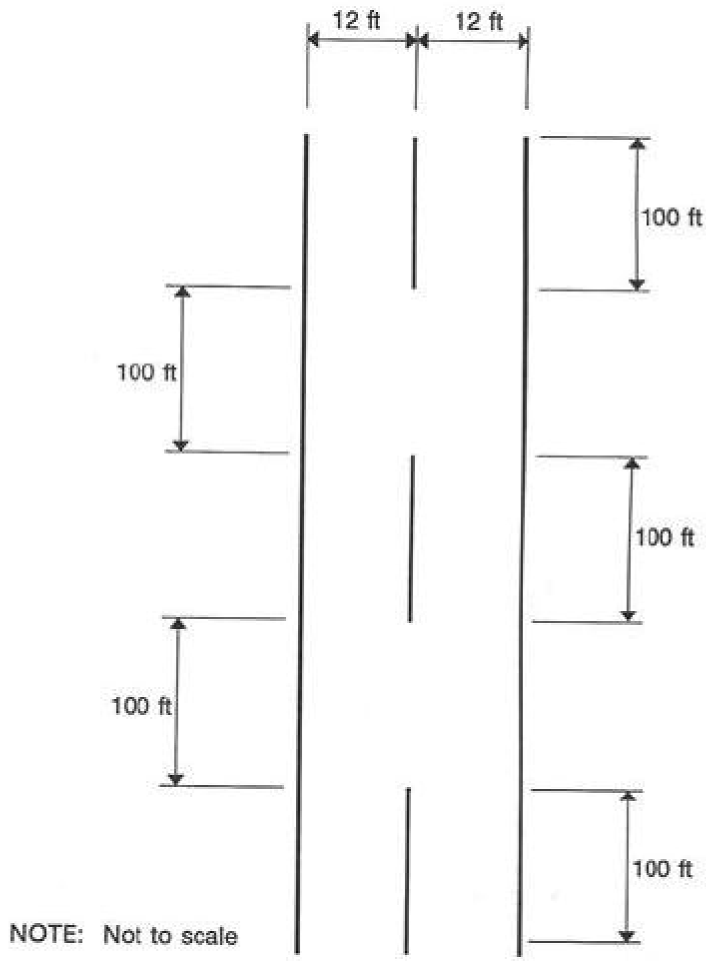


Figure 3.1. Double lane change test course

SAFETY DATA FORM

Page 1 of 1

Bus Number: 1906	Date: 08/30/19
Personnel: E.D., E.L., S.R. & J.S.	

Temperature (°F): 73	Humidity (%): 65
Wind Direction: SW	Wind Speed (mph): Steady at 3, gusts to 10
Barometric Pressure (inHg): 30.06	

SAFETY TEST: DOUBLE LANE CHANGE	
Maximum safe speed tested for double-lane change to left	45 mph
Maximum safe speed tested for double-lane change to right	45 mph
Comments of the position of the bus during the lane change:	
The bus maintained a safe profile through all portions of testing.	
Comments of the tire/ground contact patch:	
The bus maintained the tire/ground patch throughout the test.	

3.1 SAFETY

RIGHT - HAND APPROACH

LEFT - HAND APPROACH

3.2 Safety - Braking

3.2 I. TEST OBJECTIVE

The objective of this test is to provide, for comparison purposes, braking performance data on transit buses produced by different manufacturers.

3.2 II. TEST DESCRIPTION

The testing was conducted at the LTI Test Track skid pad area. Brake tests were conducted after completion of the GVW portion of the vehicle durability test. At this point in testing the brakes have been subjected to a large number of braking snubs and will be considered well burnished. For buses that have not completed Durability Testing, the brakes will be burnished according to the test procedure. Testing was performed when the bus was fully loaded at its GVW. All tires on each bus were representative of the tires on the production model vehicle and inflated to the bus manufacturer's specified pressures.

The brake testing procedure is comprised of three phases:

1. Stopping distance tests
    - i. Dry surface (high-friction, Skid Number within the range of 70-76)
    - ii. Wet surface (low-friction, Skid Number within the range of 30-36)
2. Stability tests
3. Parking brake test

3.2-III. DISCUSSION

The results of the Stopping Distance phase of the Brake Test are available in table 3.2-2. There was no deviation from the test lane during the performance of the Stopping Distance phase. The bus passed this portion of the test.

During the Stability phase of Brake Testing the test bus experienced no deviation from the test lane during both approaches to the Split Friction Road surface.

The Parking Brake phase was completed with the test bus maintaining the parked position for the full five-minute period with no slip or roll observed in both the uphill and downhill positions.

This bus passed all three phases of the Safety –Braking Test.

Table 3.2-1. Braking Test Data Forms

Page 1 of 3

Bus Number: 1906	Date: 04/29/19
Personnel: S.R., T.S. & E.D.	
Amb. Temperature (°F): 56	Wind Speed (mph): 9
Wind Direction: SE	Pavement Temp (°F) Start:79 End: 86

TIRE INFLATION PRESSURE (psi): Tire Type: Front and Rear: Michelin X Incity				
	Left Tire(s)		Right Tire(s)	
Front	130		130	
	Inner	Outer	Inner	Outer
Middle	N/A	N/A	N/A	N/A
Rear	130	130	130	130

AXLE LOADS (lb.)		
	Left	Right
Front	9,010	9,050
Middle	N/A	N/A
Rear	13,030	12,550

Table 3.2-2. Stopping Distance Test Results Form
(longest stopping distance in each test condition in bold)

Stopping Distance (ft)					
Vehicle Direction	CW	CW	CCW	CCW	
Speed (mph)	Stop 1	Stop 2	Stop 3	Stop 4	**Average**
20 (dry)	29.22	26.40	**29.88**	28.20	28.42
30 (dry)	**60.94**	60.64	57.59	53.85	58.25
40 (dry)	101.84	**112.86**	104.14	102.33	105.29
45 (dry)	145.07	**148.94**	133.10	130.05	139.29
20 (wet)	28.33	27.28	**33.65**	27.84	29.27

Table 3.2-3. Stability Test Results Form

Stability Test Results (Split Friction Road surface)			
Vehicle Direction	Attempt	Did test bus stay in 12' lane? (Yes/No)	Comments
Driver side on high friction	1	Yes	None noted.
	2	Yes	None noted.
Driver side on low friction	1	Yes	None noted.
	2	Yes	None noted.

Table 3.2-4. Parking Brake Test Form

PARKING BRAKE (GVW) – GRADE HOLDING						
Vehicle Direction	Attempt	Hold Time (min)	Slide (in)	Roll (in)	Did Hold	No Hold
Front up	1	5:00	0	0	✓	
	2	N/A	N/A	N/A	N/A	N/A
	3	N/A	N/A	N/A	N/A	N/A
Front down	1	5:00	0	0	✓	
	2	N/A	N/A	N/A	N/A	N/A
	3	N/A	N/A	N/A	N/A	N/A

Table 3.2-5. Record of All Braking System Faults/Repairs.

Date	Fault/Repair	Description
04/29/19	None noted.	None noted.

3.2 Safety - Bus Braking

PARKING BRAKE TEST
PARKING BRAKE HELD FOR 5 MINUTES IN
BOTH 20% UP AND 20% DOWN POSITIONS

4. PERFORMANCE - AN ACCELERATION, GRADEABILITY, AND TOP SPEED TEST

4-I. TEST OBJECTIVE

The objective of this test is to determine the acceleration, gradeability, and top speed capabilities of the bus.

4-II. TEST DESCRIPTION

In this test, the bus was operated at SLW on a chassis dynamometer. The procedure dictates that the test bus be accelerated to a maximum "power-limited"/"governed" or maximum "safe" speed not exceeding 80 mph. The maximum power-limited/governed speed, if applicable, is the top speed as limited by the engine control system. The maximum safe speed is defined as the maximum speed that the dynamometer, the tires or other bus components are limited to. The test vehicle speed was measured using a speed encoder built in the chassis dynamometer. The time intervals between 10 mph increments were recorded using a Data Acquisitions System. Time-speed data and the top speed attained were recorded on the Performance Data Form. The recorded data was used to generate a percent grade versus speed table and a speed versus time curve. All the above are available in the following pages.

4-III. DISCUSSION

This test consisted of three runs from standstill to full throttle on the chassis dynamometer. Speed versus time data was obtained for each run and results are averaged to minimize test variability. The test was performed up to a maximum safe speed of 64.2 mph. The calculated gradeability results are attached. The average time to reach 30 mph was 4.2 seconds. The maximum gradeablity at 10 mph was 45.3% and at 40 mph was 10.4%. This bus passed this section of the test.

For the Performance test, ballast weight equivalent of the roof mount battery packs was removed to represent the four-pack battery configuration per the Federal Transit Administration determination letter. Therefore, the seated load weight used was 36,960 lbs. for this Performance tests.

PERFORMANCE DATA FORM

Page 1 of 1

Bus Number: 1906	Date: 09/10/2020
Personnel: J.S. & S.I.	

Temperature (°F): 75.7	Humidity (%): 85
Barometric Pressure (inHg): 29.0	

		INITIALS:
Air Conditioning - OFF	✓Checked	J.S.
Ventilation fans - ON HIGH	N/A	N/A
Heater pump motor - OFF	N/A	N/A
Defroster - OFF	✓ Checked	J.S.
Exterior and interior lights - ON	✓ Checked	J.S.
Windows and doors - CLOSED	✓ Checked	J.S.

ACCELERATION, GRADEABILITY, TOP SPEED

Recorded Interval Times			
Speed	Run 1	Run 2	Run 3
10 mph	1.9	0.9	2.2
20 mph	2.7	1.7	3.1
30 mph	4.3	3.3	4.7
40 mph	9.4	8.4	7.7
50 mph	15.9	15.0	16.2
60 mph	25.9	25.0	26.4
70 mph	N/A	N/A	N/A

Maximum Speed (mph): 64.2 (maximum governed speed reached)

PERFORMANCE SUMMARY SHEET

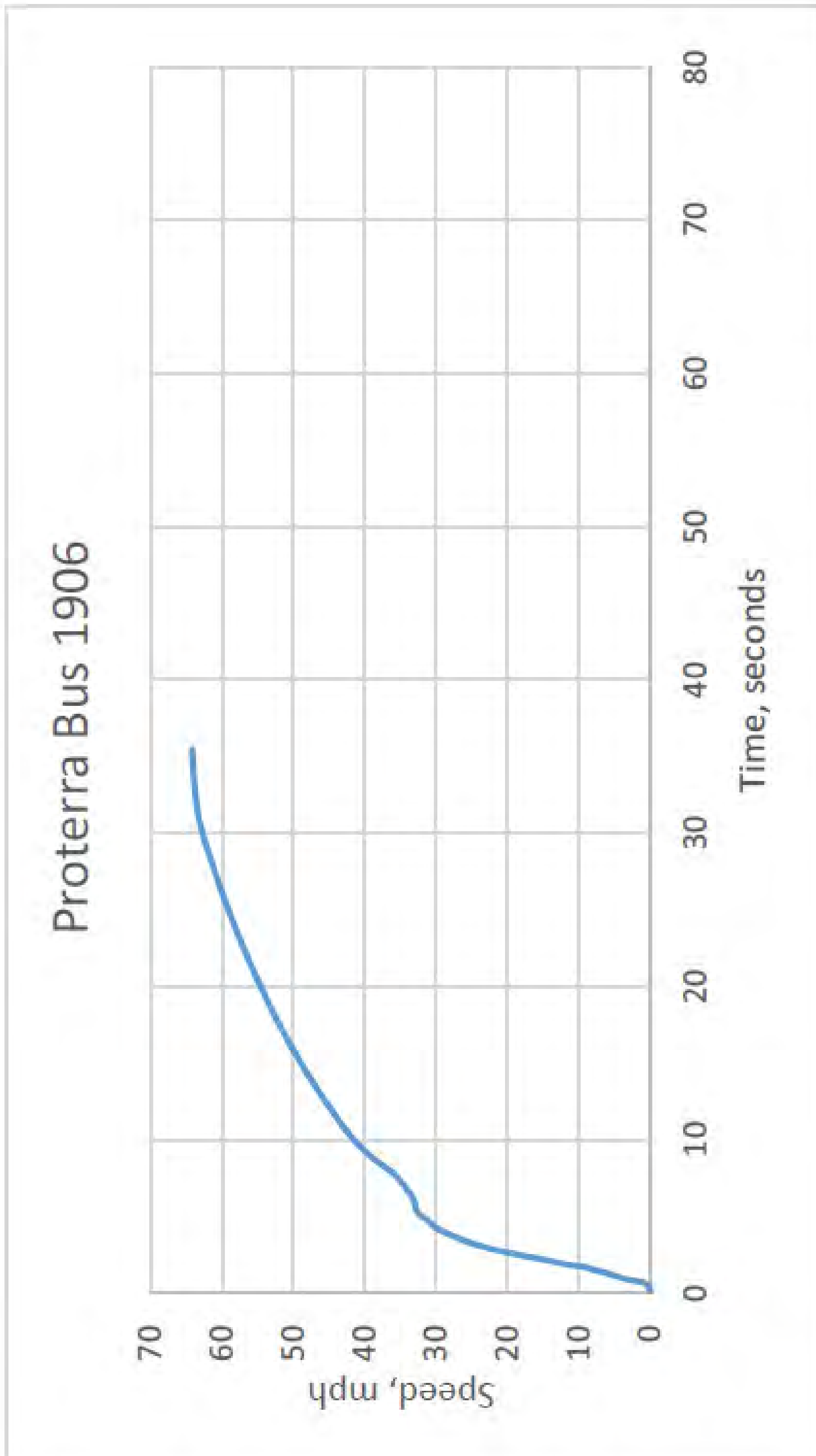
Bus Number: 1906	Date: 09/10/2020
Personnel: J.S. & S.I.	

Test Conditions:

Temperature (°F): 75.7	Humidity (%): 85
Barometric Pressure (inHg): 29.0	

Test Results:

Vehicle Speed (MPH)	Time (SEC)	Acceleration (FT/SEC^2)	Max. Grade (%)
1.0	0.6	7.57	23.5
5.0	1.1	11.57	35.9
10.0	1.7	14.60	45.3
15.0	2.1	15.17	47.1
20.0	2.6	13.61	42.3
25.0	3.2	9.92	30.8
30.0	4.2	5.09	15.8
35.0	7.2	2.86	8.9
40.0	9.2	3.35	10.4
45.0	12.1	2.18	6.8
50.0	15.8	1.79	5.6
55.0	20.3	1.44	4.5
60.0	26.0	1.14	3.4
64.2	35.5	Maximum Speed	


Proterra Bus 1906
Speed, mph
Time, seconds
0
10
20
30
40
50
60
70
80

5.2 STRUCTURAL STRENGTH AND DISTORTION TESTS - STRUCTURAL DISTORTION

5.2-I. TEST OBJECTIVE

The objective of this test is to observe the operation of the bus subsystems when the bus is placed in a longitudinal twist simulating operation over a curb or through a pothole.

5.2-II. TEST DESCRIPTION

With the bus loaded to GVW, each wheel of the bus was raised (one at a time) to simulate operation over a curb and the following were inspected:

1. Body
2. Windows
3. Doors
4. Roof vents
5. Special seating
6. Undercarriage
7. Engine
8. Service doors
9. Escape hatches
10. Steering mechanism

Each wheel was then lowered (one at a time) to simulate operation through a pothole and the same items inspected.

5.2-III. DISCUSSION

The test sequence was repeated ten times. The first and last test is with all wheels level. The other eight tests are with each wheel 6 inches higher and 6 inches lower than the other three wheels.

All doors, windows, escape mechanisms, engine, steering and ADA accessible devices operated normally throughout the test. The undercarriage and body indicated no deficiencies. No water leakage was observed during the test. The results of this test are indicated on the following data forms. This bus passed this section of the test.

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Bus Number: 1906	Date: 04/15/19
Personnel: S.R., T.S., E.D., E.L. & P.D.	Temperature(°F): 50

Wheel Position: (check one)		
All wheels level	■ before	□ after
Left front	□ 6 in higher	□ 6 in lower
Right front	□ 6 in higher	□ 6 in lower
Right rear	□ 6 in higher	□ 6 in lower
Left rear	□ 6 in higher	□ 6 in lower
Right center	□ 6 in higher	□ 6 in lower
Left center	□ 6 in higher	□ 6 in lower

	Comments
Windows	No Deficiencies.
Front Doors	No Deficiencies.
Rear Doors	No Deficiencies.
Escape Mechanisms/ Roof Vents	No Deficiencies.
Engine	No Deficiencies.
ADA Accessible/ Special Seating	No Deficiencies.
Undercarriage	No Deficiencies.
Service Doors	No Deficiencies.
Body	No Deficiencies.
Windows/ Body Leakage	No Deficiencies.
Steering Mechanism	No Deficiencies.

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Bus Number: 1906	Date: 04/15/19
Personnel: S.R., T.S., E.D., E.L. & P.D.	Temperature(°F): 50

Wheel Position: (check one)		
All wheels level	☐ before	☐ after
Left front	■ 6 in higher	☐ 6 in lower
Right front	☐ 6 in higher	☐ 6 in lower
Right rear	☐ 6 in higher	☐ 6 in lower
Left rear	☐ 6 in higher	☐ 6 in lower
Right center	☐ 6 in higher	☐ 6 in lower
Left center	☐ 6 in higher	☐ 6 in lower

	Comments
Windows	No Deficiencies.
Front Doors	No Deficiencies.
Rear Doors	No Deficiencies.
Escape Mechanisms/ Roof Vents	No Deficiencies.
Engine	No Deficiencies.
ADA Accessible/ Special Seating	No Deficiencies.
Undercarriage	No Deficiencies.
Service Doors	No Deficiencies.
Body	No Deficiencies.
Windows/ Body Leakage	No Deficiencies.
Steering Mechanism	No Deficiencies.

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Bus Number: 1906	Date: 04/15/19
Personnel: S.R., T.S., E.D., E.L. & P.D.	Temperature(°F): 50

Wheel Position: (check one)		
All wheels level	☐ before	☐ after
Left front	☐ 6 in higher	☐ 6 in lower
Right front	■ 6 in higher	☐ 6 in lower
Right rear	☐ 6 in higher	☐ 6 in lower
Left rear	☐ 6 in higher	☐ 6 in lower
Right center	☐ 6 in higher	☐ 6 in lower
Left center	☐ 6 in higher	☐ 6 in lower

	Comments
Windows	No Deficiencies.
Front Doors	No Deficiencies.
Rear Doors	No Deficiencies.
Escape Mechanisms/ Roof Vents	No Deficiencies.
Engine	No Deficiencies.
ADA Accessible/ Special Seating	No Deficiencies.
Undercarriage	No Deficiencies.
Service Doors	No Deficiencies.
Body	No Deficiencies.
Windows/ Body Leakage	No Deficiencies.
Steering Mechanism	No Deficiencies.

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Page 4 of 10

Bus Number: 1906	Date: 04/15/19
Personnel: S.R., T.S., E.D., E.L. & P.D.	Temperature(°F): 50

Wheel Position: (check one)		
All wheels level	☐ before	☐ after
Left front	☐ 6 in higher	☐ 6 in lower
Right front	☐ 6 in higher	☐ 6 in lower
Right rear	■ 6 in higher	☐ 6 in lower
Left rear	☐ 6 in higher	☐ 6 in lower
Right center	☐ 6 in higher	☐ 6 in lower
Left center	☐ 6 in higher	☐ 6 in lower

	Comments
Windows	No Deficiencies.
Front Doors	No Deficiencies.
Rear Doors	No Deficiencies.
Escape Mechanisms/ Roof Vents	No Deficiencies.
Engine	No Deficiencies.
ADA Accessible/ Special Seating	No Deficiencies.
Undercarriage	No Deficiencies.
Service Doors	No Deficiencies.
Body	No Deficiencies.
Windows/ Body Leakage	No Deficiencies.
Steering Mechanism	No Deficiencies.

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Bus Number: 1906	Date: 04/15/19
Personnel: S.R., T.S., E.D., E.L. & P.D.	Temperature(°F): 50

Wheel Position: (check one)		
All wheels level	☐ before	☐ after
Left front	☐ 6 in higher	☐ 6 in lower
Right front	☐ 6 in higher	☐ 6 in lower
Right rear	☐ 6 in higher	☐ 6 in lower
Left rear	■ 6 in higher	☐ 6 in lower
Right center	☐ 6 in higher	☐ 6 in lower
Left center	☐ 6 in higher	☐ 6 in lower

	Comments
Windows	No Deficiencies.
Front Doors	No Deficiencies.
Rear Doors	No Deficiencies.
Escape Mechanisms/ Roof Vents	No Deficiencies.
Engine	No Deficiencies.
ADA Accessible/ Special Seating	No Deficiencies.
Undercarriage	No Deficiencies.
Service Doors	No Deficiencies.
Body	No Deficiencies.
Windows/ Body Leakage	No Deficiencies.
Steering Mechanism	No Deficiencies.

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Bus Number: 1906	Date: 04/15/19
Personnel: S.R., T.S., E.D., E.L. & P.D.	Temperature(°F): 50

Wheel Position: (check one)		
All wheels level	☐ before	☐ after
Left front	☐ 6 in higher	■ 6 in lower
Right front	☐ 6 in higher	☐ 6 in lower
Right rear	☐ 6 in higher	☐ 6 in lower
Left rear	☐ 6 in higher	☐ 6 in lower
Right center	☐ 6 in higher	☐ 6 in lower
Left center	☐ 6 in higher	☐ 6 in lower

	Comments
Windows	No Deficiencies.
Front Doors	No Deficiencies.
Rear Doors	No Deficiencies.
Escape Mechanisms/ Roof Vents	No Deficiencies.
Engine	No Deficiencies.
ADA Accessible/ Special Seating	No Deficiencies.
Undercarriage	No Deficiencies.
Service Doors	No Deficiencies.
Body	No Deficiencies.
Windows/ Body Leakage	No Deficiencies.
Steering Mechanism	No Deficiencies.

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Bus Number: 1906	Date: 04/15/19
Personnel: S.R., T.S., E.D., E.L. & P.D.	Temperature(°F): 50

Wheel Position: (check one)		
All wheels level	☐ before	☐ after
Left front	☐ 6 in higher	☐ 6 in lower
Right front	☐ 6 in higher	■ 6 in lower
Right rear	☐ 6 in higher	☐ 6 in lower
Left rear	☐ 6 in higher	☐ 6 in lower
Right center	☐ 6 in higher	☐ 6 in lower
Left center	☐ 6 in higher	☐ 6 in lower

	Comments
Windows	No Deficiencies.
Front Doors	No Deficiencies.
Rear Doors	No Deficiencies.
Escape Mechanisms/ Roof Vents	No Deficiencies.
Engine	No Deficiencies.
ADA Accessible/ Special Seating	No Deficiencies.
Undercarriage	No Deficiencies.
Service Doors	No Deficiencies.
Body	No Deficiencies.
Windows/ Body Leakage	No Deficiencies.
Steering Mechanism	No Deficiencies.

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Bus Number: 1906	Date: 04/15/19
Personnel: S.R., T.S., E.D., E.L. & P.D.	Temperature(°F): 50

Wheel Position: (check one)		
All wheels level	☐ before	☐ after
Left front	☐ 6 in higher	☐ 6 in lower
Right front	☐ 6 in higher	☐ 6 in lower
Right rear	☐ 6 in higher	■ 6 in lower
Left rear	☐ 6 in higher	☐ 6 in lower
Right center	☐ 6 in higher	☐ 6 in lower
Left center	☐ 6 in higher	☐ 6 in lower

	Comments
Windows	No Deficiencies.
Front Doors	No Deficiencies.
Rear Doors	No Deficiencies.
Escape Mechanisms/ Roof Vents	No Deficiencies.
Engine	No Deficiencies.
ADA Accessible/ Special Seating	No Deficiencies.
Undercarriage	No Deficiencies.
Service Doors	No Deficiencies.
Body	No Deficiencies.
Windows/ Body Leakage	No Deficiencies.
Steering Mechanism	No Deficiencies.

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Bus Number: 1906	Date: 04/15/19
Personnel: S.R., T.S., E.D., E.L. & P.D.	Temperature(°F): 50

Wheel Position: (check one)		
All wheels level	☐ before	☐ after
Left front	☐ 6 in higher	☐ 6 in lower
Right front	☐ 6 in higher	☐ 6 in lower
Right rear	☐ 6 in higher	☐ 6 in lower
Left rear	☐ 6 in higher	■ 6 in lower
Right center	☐ 6 in higher	☐ 6 in lower
Left center	☐ 6 in higher	☐ 6 in lower

	Comments
Windows	No Deficiencies.
Front Doors	No Deficiencies.
Rear Doors	No Deficiencies.
Escape Mechanisms/ Roof Vents	No Deficiencies.
Engine	No Deficiencies.
ADA Accessible/ Special Seating	No Deficiencies.
Undercarriage	No Deficiencies.
Service Doors	No Deficiencies.
Body	No Deficiencies.
Windows/ Body Leakage	No Deficiencies.
Steering Mechanism	No Deficiencies.

DISTORTION TEST INSPECTION FORM

(Note: Ten copies of this data sheet are required)

Bus Number: 1906	Date: 04/15/19
Personnel: S.R., T.S., E.D., E.L. & P.D.	Temperature(°F): 50

Wheel Position: (check one)		
All wheels level	☐ before	■ after
Left front	☐ 6 in higher	☐ 6 in lower
Right front	☐ 6 in higher	☐ 6 in lower
Right rear	☐ 6 in higher	☐ 6 in lower
Left rear	☐ 6 in higher	☐ 6 in lower
Right center	☐ 6 in higher	☐ 6 in lower
Left center	☐ 6 in higher	☐ 6 in lower

	Comments
Windows	No Deficiencies.
Front Doors	No Deficiencies.
Rear Doors	No Deficiencies.
Escape Mechanisms/ Roof Vents	No Deficiencies.
Engine	No Deficiencies.
ADA Accessible/ Special Seating	No Deficiencies.
Undercarriage	No Deficiencies.
Service Doors	No Deficiencies.
Body	No Deficiencies.
Windows/ Body Leakage	No Deficiencies.
Steering Mechanism	No Deficiencies.

5.2 STRUCTURAL DISTORTION TEST

RIGHT REAR WHEEL SIX INCHES HIGHER

LEFT FRONT WHEEL SIX INCHES LOWER

5.3 STRUCTURAL STRENGTH AND DISTORTION TESTS - STATIC TOWING TEST

5.3-I. TEST OBJECTIVE

The objective of this test is to determine the characteristics of the bus towing mechanisms under static loading conditions.

5.3-II. TEST DESCRIPTION

Utilizing a load-distributing yoke, a hydraulic cylinder was used to apply a static tension load equal to 1.2 times the bus curb weight. The load was applied to both the front and rear, if applicable, towing fixtures at an angle of 20 degrees with the longitudinal axis of the bus, first to one side then the other in the horizontal plane, and then upward and downward in the vertical plane. Any permanent deformation or damage to the tow eyes or adjoining structure was recorded.

5.3-III. DISCUSSION

The load-distributing yoke was incorporated as the interface between the Static Tow apparatus and the test bus tow hook/eyes. The test was performed to the full target test weight of 40,032 lb. (1.2 x 33,360 lb. CW). No damage or deformation was observed during all four pulls of the test.

STATIC TOWING TEST DATA FORM

Page 1 of 1

Bus Number: 1906	Date: 08/14/2020
Personnel: S.R., E.L. & P.D.	Temperature (°F): 84

Inspect right front tow eye and adjoining structure.
Comments: No damage or deformation.
Check the torque of all bolts attaching tow eye and surrounding structure.
Comments: None noted.
Inspect left front tow eye and adjoining structure.
Comments: No damage or deformation.
Check the torque of all bolts attaching tow eye and surrounding structure.
Comments: None noted.
Inspect right rear tow eye and adjoining structure.
Comments: N/A
Check the torque of all bolts attaching tow eye and surrounding structure.
Comments: N/A
Inspect left rear tow eye and adjoining structure.
Comments: N/A
Check the torque of all bolts attaching tow eye and surrounding structure.
Comments: N/A
General comments of any other structure deformation or failure:
Per manufacturer's recommendation no rear pull was performed.
No damage, deformation or failure noted at any point during each of the four, front pulls.

5.3 STATIC TOWING TEST

20^{0} UPWARD PULL

20^{0} DOWNWARD PULL

5.4 STRUCTURAL STRENGTH AND DISTORTION TESTS - DYNAMIC TOWING TEST

5.4-I. TEST OBJECTIVE

The objective of this test is to verify the integrity of the towing fixtures and determine the feasibility of towing the bus under manufacturer specified procedures.

5.4-II. TEST DESCRIPTION

This test required the bus to be towed at curb weight using the specified equipment and instructions provided by the manufacturer and a heavy-duty wrecker. The bus was towed for 5 miles at a speed of 20 mph for each recommended towing configuration. After releasing the bus from the wrecker, the bus was visually inspected for any structural damage or permanent deformation. All doors, windows and passenger escape mechanisms were inspected for proper operation.

5.4-III. DISCUSSION

The bus was towed using a heavy-duty wrecker. The towing interface was accomplished by incorporating a hydraulic under-lift. A front lift tow was performed. No problems, deformation, or damage was noted during testing. This bus passed this section of the test.

DYNAMIC TOWING TEST DATA FORM

Page 1 of 1

Bus Number: 1906	Date: 10/30/19
Personnel: T.S. & E.D.	

Temperature (°F): 60	
Wind Direction: calm	Wind Speed (mph): 0

Inspect tow equipment-bus interface.
Comments: No problems encountered.
Inspect tow equipment-wrecker interface.
Comments: No problems encountered.
Towing Comments: The towing test was performed successfully using a
Hydraulic underlift wrecker.
Description and location of any structural damage:
None noted.
General Comments:
None noted.

5.4 DYNAMIC TOWING TEST

TOWING INTERFACE

TEST BUS IN TOW

5.5 STRUCTURAL STRENGTH AND DISTORTION TESTS – JACKING TEST

5.5-I. TEST OBJECTIVE

The objective of this test is to inspect for damage due to the deflated tire and determine the feasibility of jacking the bus with a portable hydraulic jack to a height sufficient to replace a deflated tire.

5.5-II. TEST DESCRIPTION

With the bus at curb weight, the tire(s) at one corner of the bus were replaced with deflated tire(s) of the appropriate type. A portable hydraulic floor jack was then positioned in a manner and location specified by the manufacturer and used to raise the bus to a height sufficient to provide 3-in clearance between the floor and an inflated tire. The deflated tire(s) were replaced with the original tire(s) and the jack was lowered. Any structural damage or permanent deformation was recorded on the test data sheet. This procedure was repeated for each corner of the bus.

5.5-III. DISCUSSION

With the tires deflated during the test, the jacking point clearances ranged from 4.0 inches to 9.2 inches. No deformation or damage was observed during testing. A complete listing of jacking point clearances is provided in the Jacking Test Data Form. This bus passed this section of the test.

JACKING CLEARANCE SUMMARY

Condition	Frame Point Clearance
Front axle – one tire flat	5.3
Rear axle – one tire flat	8.2
Rear axle – two tires flat	5.1

JACKING TEST DATA FORM

Bus Number: 1906	Date: 04/11/19
Personnel: E.D., E.L. & S.R.	Temperature (°F):

Record any permanent deformation or damage to bus as well as any difficulty encountered during jacking procedure.

I= Inflated D= Deflated

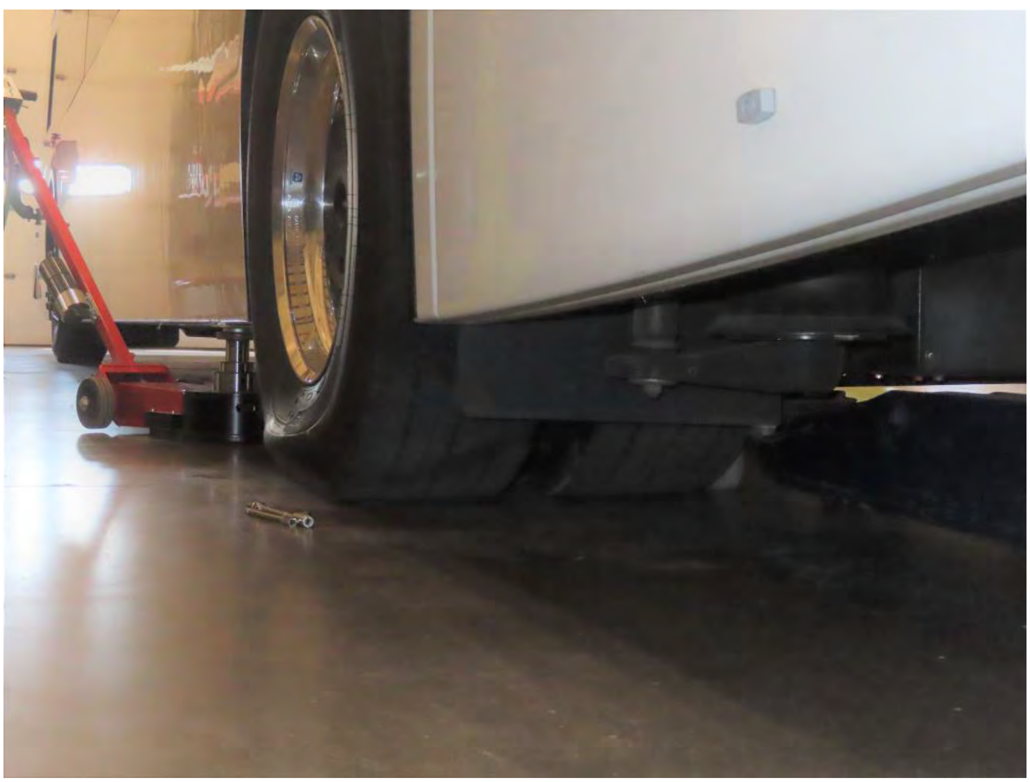
Deflated Tire	Jacking Pad Clearance Body/Frame (in)	Jacking Pad Clearance Axle/Suspension (in)	Comments
Right front	8.2“I 5.5“D	8.7“I 4.0” D	Body & Suspension
Left front	8.8“I 5.3“D	7.3“I 4.9“D	Body & Suspension
Right rear—outside	8.9“I 8.4“D	9.8“I 9.2“D	Body & Suspension
Right rear—both	8.9“I 5.1“D	9.8“I 5.6“D	Body & Suspension
Left rear—outside	9.0“I 8.2“D	9.9“I 9.1“D	Body & Suspension
Left rear—both	9.0“I 5.2“D	9.9“I 5.6“D	Body & Suspension
Right middle or tag—outside	N/A	N/A	N/A
Right middle or tag—both	N/A	N/A	N/A
Left middle or tag—outside	N/A	N/A	N/A
Left middle or tag—both	N/A	N/A	N/A

Additional comments of any deformation or difficulty during jacking:

None noted.

5.5 JACKING TEST

JACK IN PLACE – FRONT



JACK IN PLACE – REAR

5.6 STRUCTURAL STRENGTH AND DISTORTION TESTS - HOISTING TEST

5.6-I. TEST OBJECTIVE

The objective of this test is to determine possible damage or deformation caused by the jack/stands.

5.6-II. TEST DESCRIPTION

With the bus at curb weight, the front end of the bus was raised to a height sufficient to allow manufacturer-specified placement of jack stands under the axles or jacking pads independent of the hoist system. The bus was checked for stability on the jack stands and for any damage to the jacking pads or bulkheads. The procedure was repeated for the tag/middle axles (if equipped), and rear end of the bus. The procedure was then repeated for the front, tag/middle (if equipped) axles, and rear simultaneously.

5.6-III. DISCUSSION

The test was conducted using four posts of a six-post electric lift and 19-inch jack stands. The bus was hoisted from the front wheels and then from the rear wheels, and then from the front and rear wheels simultaneously and placed on jack stands.

The bus accommodated the placement of the vehicle lifts and jack stands and the procedure was performed without any instability noted. This bus passed this section of the test.

HOISTING TEST DATA FORM

Page 1 of 1

Bus Number: 1906	Date: 04/11/19
Personnel: E.D. & S.R.	Temperature (°F): 70

Comments of any structural damage to the jacking pads or axles while both the front wheels are supported by the jack stands:
None noted.
Comments of any structural damage to the jacking pads or axles while both the rear wheels are supported by the jack stands:
None noted.
Comments of any structural damage to the jacking pads or axles while both the tag axle wheels are supported by the jack stands:
N/A
Comments of any structural damage to the jacking pads or axles while the front, tag axle and rear wheels are supported by the jack stands:
None noted.
Comments of any problems or interference placing wheel hoists under wheels:
None noted.

5.6 HOISTING TEST

REAR JACK STANDS IN PLACE

FRONT AND REAR JACK STANDS IN PLACE

5.7 STRUCTURAL DURABILITY TEST

5.7-I. TEST OBJECTIVE

The objective of this test is to perform an accelerated durability test that approximates 25 percent of the service life of the vehicle.

5.7-II. TEST DESCRIPTION

The test vehicle was driven a total of 15,069 miles; approximately 12,500 miles on the LTI Durability Test Track and approximately 2,500 miscellaneous other miles. The test was conducted with the bus operated under three different loading conditions. The first segment consisted of approximately 6,250 miles with the bus operated at GVW. The second segment consisted of approximately 2,500 miles with the bus operated at SLW. The remainder of the test, approximately 6,250 miles, was conducted with the bus loaded to CW. The loads on both axles and GVW were within their ratings with the bus loaded as specified by the manufacturer. All subsystems were running during these tests in their normal operating modes. All manufacturer-recommended servicing was followed and noted on the vehicle maintainability log. Servicing items accelerated by the durability tests were compressed by 10:1; all others were done on a 1:1 mi/mi basis. Unscheduled breakdowns and repairs were recorded on the same log as are any unusual occurrences as noted by the driver. Once a week the test vehicle was washed down and thoroughly inspected for any signs of failure.

5.7-III. DISCUSSION

The Structural Durability Test was started on April 16, 2019 and was conducted until August 03, 2020. The first 6,250 miles were performed at a GVW of 43,640 lb. and completed on August 28, 2019. The next 2,500-mile SLW segment was performed at 39,550 lb. and completed on October 28, 2019 and the final 6,250-mile segment was performed at a CW of 33,360 lb. and completed on August 03, 2020.

The following mileage summary presents the accumulation of miles during the Structural Durability Test. The driving schedule is included, showing the operating duty cycle. A detailed plan view of the LTI Test Track Facility and Durability Test Track are attached for reference. Also, a durability element profile detail shows all the measurements of the different conditions. Finally, photographs illustrating some of the failures that were encountered during the Structural Durability Test are included. This bus passed this section of the test, as there were no uncorrected Class 1 or Class 2 failures and the unscheduled maintenance of 94.6 hours was less than 125 hours.

During the Structural Durability testing the bus experienced periodic instances of mileage loss by the odometer. The issues appeared to be resolved after a software update. Mileage accumulation was tracked secondarily on a hub-odometer to ensure accuracy. Late in the test, the bus developed an intermittent shifting problem in the rear axle. The manufacturer traced a contributor to the problem to be contamination in the air line actuating the pneumatic shift valves. The manufacturer stated that the contamination was caused by a degradation of the grease used during the shifter mechanism assembly and the issue would be resolved in the production process.

Proterra Bus # 1906

MILEAGE DRIVEN/RECORDED FROM DRIVER'S LOGS

DATE	TOTAL DURABILITY TRACK	TOTAL OTHER MILES	TOTAL
04/15/19 TO 04/21/19	179.00	60.00	239.00
04/22/19 TO 04/28/19	136.00	6.00	142.00
04/29/19 TO 05/05/19	262.00	41.00	303.00
05/06/19 TO 05/12/19	292.00	16.00	308.00
05/13/19 TO 05/19/19	218.00	10.00	228.00
05/20/19 TO 05/26/19	113.00	5.00	118.00
05/27/19 TO 06/02/19 TO	297.00	13.00	310.00
06/03/19 TO 06/09/19	197.00	14.00	211.00
06/10/19 TO 06/16/19	319.00	16.00	335.00
06/17/19 TO 06/23/19	450.00	25.00	475.00
06/24/19 TO 06/30/19	294.00	14.00	308.00
07/01/19 TO 07/07/19	438.00	22.00	460.00
07/08/19 TO 07/14/19	0.00	0.00	0.00
07/15/19 TO 07/21/19	0.00	0.00	0.00
07/22/19 TO 07/28/19	222.00	11.00	233.00

Proterra Bus # 1906

MILEAGE DRIVEN/RECORDED FROM DRIVER'S LOGS

DATE	TOTAL DURABILITY TRACK	TOTAL OTHER MILES	TOTAL
07/29/19 TO 08/04/19	406.00	18.00	424.00
08/05/19 TO 08/11/19	257.00	11.00	268.00
08/12/19 TO 08/18/19	526.00	26.00	552.00
08/19/19 TO 08/25/19	640.00	27.00	667.00
08/26/19 TO 09/01/19	344.00	42.00	386.00
09/02/19 TO 09/08/19	369.00	110.00	479.00
09/09/19 TO 09/15/19	161.00	8.00	169.00
09/16/19 TO 09/22/19	284.00	12.00	296.00
09/23/19 TO 09/29/19	376.00	685.00	1061.00
09/30/19 TO 10/06/19	15.00	62.00	77.00
10/07/19 TO 10/13/19	0.00	0.00	0.00
10/14/19 TO 10/20/19	127.00	11.00	138.00
10/21/19 TO 10/27/19	328.00	68.00	396.00
10/28/19 TO 11/03/19	437.00	122.00	559.00
11/04/19 TO 11/10/19	185.00	7.00	192.00

Proterra Bus # 1906

MILEAGE DRIVEN/RECORDED FROM DRIVER'S LOGS

DATE	TOTAL DURABILITY TRACK	TOTAL OTHER MILES	TOTAL
11/11/19 TO 11/17/19	61.00	3.00	64.00
11/18/19 TO 11/24/19	676.00	29.00	705.00
11/25/19 TO 12/01/19	390.00	17.00	407.00
12/02/19 TO 12/08/19	487.00	23.00	510.00
12/09/19 TO 12/15/19	551.00	24.00	575.00
12/16/2019 TO 12/22/19	429.00	20.00	449.00
12/23/19 TO 12/29/19	0.00	0.00	0.00
12/30/19 TO 01/05/20	0.00	0.00	0.00
01/06/20 TO 01/12/20	252.00	12.00	264.00
01/13/20 TO 01/19/20	558.00	26.00	584.00
01/20/20 TO 01/26/20	102.00	15.00	117.00
01/27/20 TO 02/02/20	518.00	25.00	543.00
02/03/20 TO 02/09/20	604.00	430.00	1034.00
02/10/20 TO 02/16/20	0.00	196.00	196.00
02/17/20 TO 02/23/20	0.00	0.00	0.00

Proterra Bus # 1906

MILEAGE DRIVEN/RECORDED FROM DRIVER'S LOGS

DATE	TOTAL DURABILITY TRACK	TOTAL OTHER MILES	TOTAL
02/24/20 TO 03/01/20	0.00	0.00	0.00
03/02/20 TO 03/08/20	0.00	31.00	31.00
03/09/20 TO 03/15/20	0.00	0.00	0.00
03/16/20 TO 03/22/20	0.00	117.00	117.00
ALL TESTING AT THE ALTOONA BUS TESTING CENTER WAS SUSPENDED FROM 03/26/20 TO 07/21/20 DUE TO THE COVID-19 PANDEMIC			
07/20/20 TO 07/26/20	0.00	0.00	0.00
07/27/20 TO 08/02/20	0.00	54.00	54.00
08/03/20 TO 08/09/20	0.00	85.00	85.00
Total	**12500.00**	**2569.00**	**15069.00**

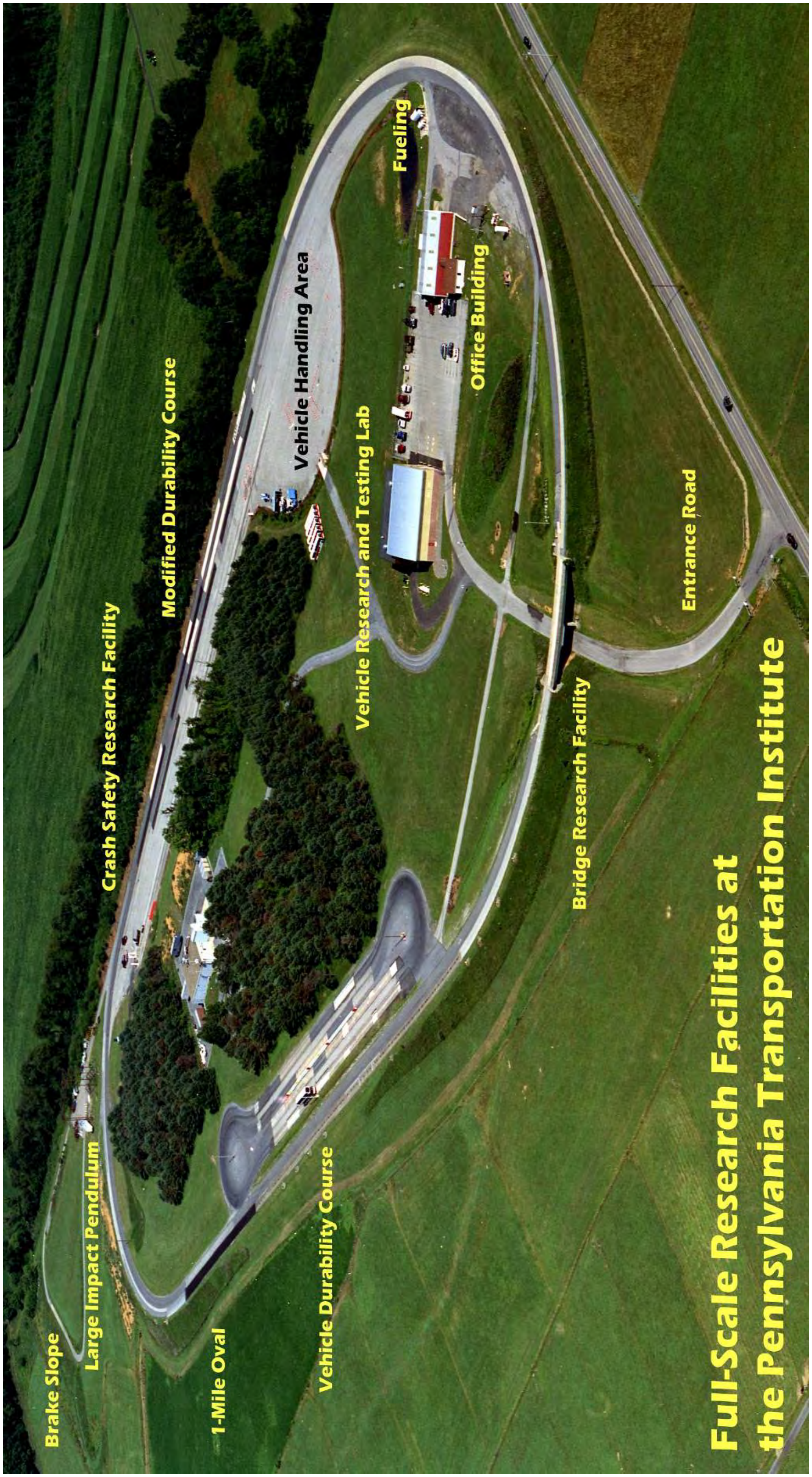
Driving Schedule for Bus Operation on the Durability Test Track.

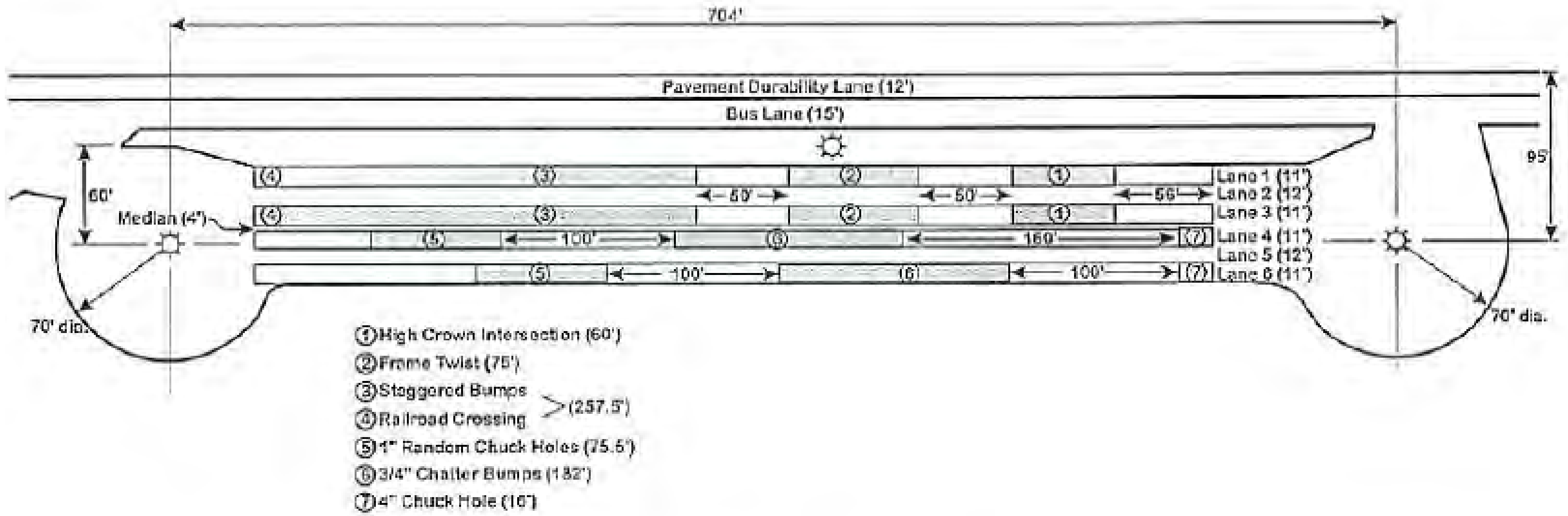
STANDARD OPERATING SCHEDULE

Monday through Friday

	HOUR	ACTION
Shift 1	midnight	D
	1:40 am	C
	1:50 am	B
	2:00 am	D
	3:35 am	C
	3:45 am	B
	4:05 am	D
	5:40 am	C
	5:50 am	B
	6:00 am	D
	7:40 am	C
	7:50 am	F
Shift 2	8:00 am	D
	9:40 am	C
	9:50 am	B
	10:00 am	D
	11:35 am	C
	11:45 am	B
	12:05 pm	D
	1:40 pm	C
	1:50 pm	B
	2:00 pm	D
	3:40 pm	C
	3:50 pm	F
Shift 3	4:00 pm	D
	5:40 pm	C
	5:50 pm	B
	6:00 pm	D
	7:40 pm	C
	7:50 pm	B
	8:05 pm	D
	9:40 pm	C
	9:50 pm	B
	10:00 pm	D
	11:40 pm	C
	11:50 pm	F

B—Break
C—Cycle all systems five times, visual inspection, driver's log entries
D—Drive bus as specified by procedure
F—Fuel bus, complete driver's log shift entries


Full-Scale Research Facilities at
the Pennsylvania Transportation Institute
Brake Slope
Large Impact Pendulum
1-Mile Oval
Vehicle Durability Course
Crash Safety Research Facility
Modified Durability Course
Vehicle Handling Area
Vehicle Research and Testing Lab
Fueling
Office Building
Bridge Research Facility
Entrance Road



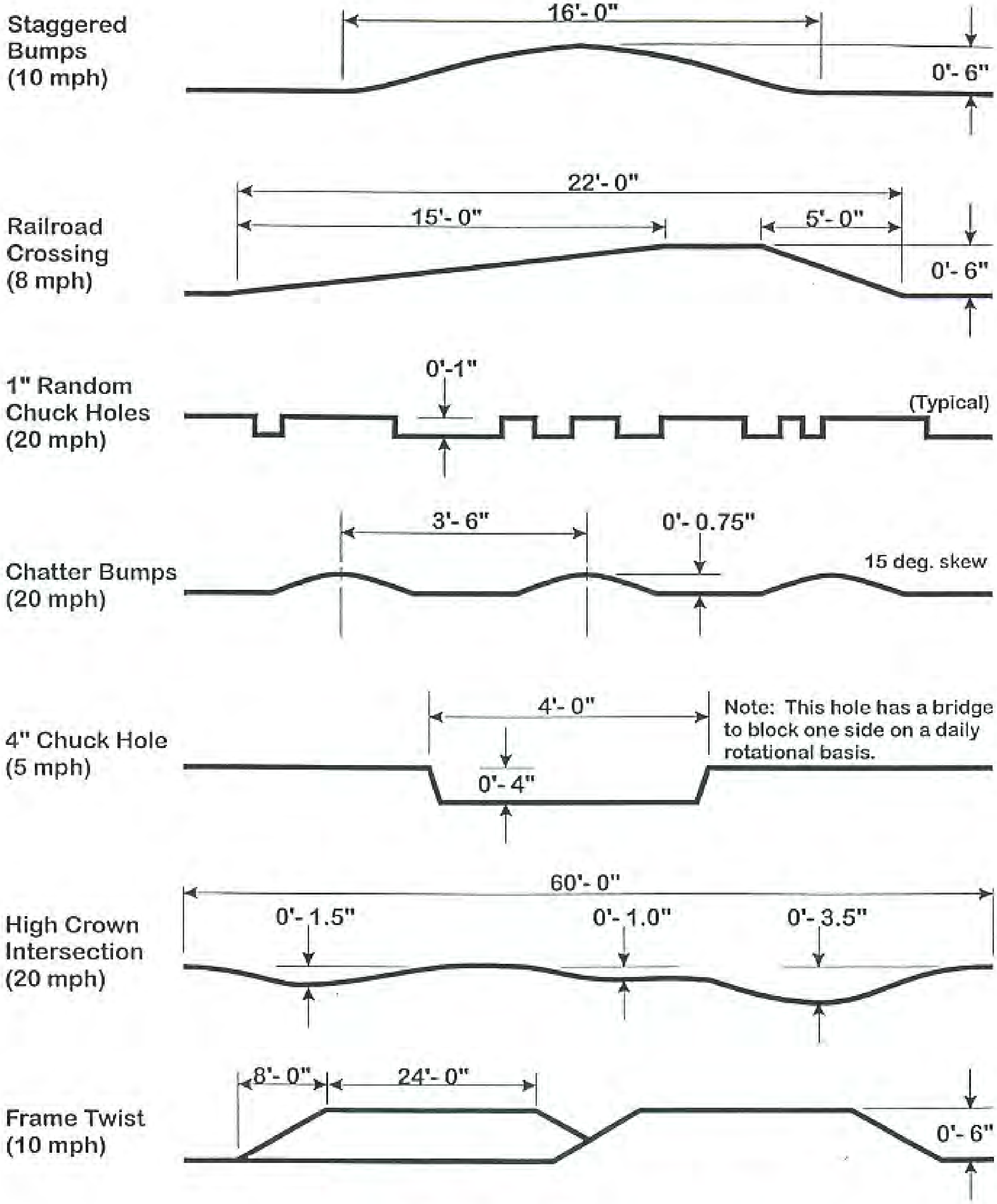
Plan View

Vehicle Durability Test Track

Track 1 (Track 2 has similar layout)

The Larson Transportation Institute

Penn State



Durability Element Profiles

The Pennsylvania Transportation Institute
Penn State

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 1 of 11)

Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
04/17/19	239	Bus stopped/shut down on durability track. Red "stop" light came on. Cycled 24V batteries. Bus will start to boot up but powers off as soon as boot up is complete. Bus is stopped on the track.	Ground wire repair included powertrain cover removal, wiring troubleshooting, wire repair/zip tie addition, systems check and power train cover installation.	1.25	Electrical	2
04/25/19	381	Trunk latch is broken.	Trunk latch was replaced and bracket was adjusted.	0.50	Body	3
04/25/19	381	Coolant is leaking from bus.	Replaced coolant line clamps on DCDC unit.	0.25	Coolant (Motor and Battery)	3
04/25/19	381	Bus stalled during brake testing and had to be towed from point of failure.	New software installed. This software improved the ability to interpret sensor data under certain fault conditions.	0.25	Software/ Electrical	2
04/26/19	381	Fault code from bus stalling during brake test did not clear after update and low voltage power reset.	Further investigation found water in the Vehicle Electrical Center (VEC) at the rear of the bus. A small leak path was found in one of the plugs. The original VEC was removed and a new VEC was installed.	1.00	Electrical	3
05/02/19	681	Worn air compressor isolator bolt found during inspection.	A new air compressor isolator bolt was installed.	0.25	Body	3
05/03/19	681	The low voltage (LV) battery tray slides broken due to loose retaining bolt.	A new LV battery tray and slides were installed.	2.50	Electrical / Body	3
05/03/19	681	Curbside mirror bolts loose. Mirror broke at pivot arm.	A new mirror was installed.	0.75	Body	3

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 2 of 11)

Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
05/06/19 To 05/15/19	755 To 1,087	Loose cover on rear axle. Rear, streetside bulkhead cover for rear drive motors is broken. The welds broke on both ends of rear front cover crossmember.	Drivetrain covers were removed and replaced with modified 2-piece covers.	2.00	Drivetrain	3
05/10/19	992	Oil pump bolts are loose. Original oil pump installation did not have isolators installed.	The rear inspection cover and skid plate were removed and wire harness and hoses were disassembled. The oil pump was removed and reinstalled with new bolts and isolators. Reconnection of wiring harness and hoses and reinstallation of rear inspection covers and skid plate.	4.50	Drivetrain	3
05/10/15	992	While on the durability course the driver noted that the speedometer and odometer were no longer working and that a yellow light had illuminated.	Tachograph mounting bracket found loose. Replaced tachograph.	1.00	Electrical	3
05/15/19 To 07/05/19	1,087	After crossing the chatter bumps, the bus had a red gear symbol light come on and it lost drive power. The batteries were cycled and the bus restarted but shut down again as it exited the chatter bumps. Bus would not restart and had to be towed to garage.	Inspected drivetrain harness and found broken wire. Repaired drivetrain harness assembly and installed updated harness securements.	2.50	Electrical	2
05/20/19	1,220	The drivers noted that the front destination sign was making noise.	Destination sign bracket bolts were loose. Tightened bolts.	1.00	Body	3
05/20/19	1,220	Bus will not level and is leaning to the streetside. Bus hitting on 10 mph frame twists.	Worn shocks causing rear streetside leveling sensor linkage to invert. Corrected linkage. Shocks were replaced as part of scheduled maintenance.	0.50	Suspension	3

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 3 of 11)

Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
05/22/19	1,231	Drivetrain oil pump manifold bolts broken.	The bolt and isolator combination installed on May 10 was modified with the addition of a larger bushing and additional snub washer. The bolt class was also changed from a 12.9 to a 10.9.	4.00	Hardware	3
05/29/19 To 05/30/19	1,517 To 1,609	Bus shut off on durability track. Had a symbol of bus with a slash through it. A yellow caution light and a red gear light also came on.	Tightened grounding strap for drive axle.	0.75	Electrical	3
06/03/19	1,648	Air compressor bracket is broken.	Missing bolt on air compressor vertical support bracket caused the isolator bracket to fatigue and crack. Replaced bolt and air compressor bracket.	2.50	Body	3
06/05/19	1,652	Curbside transmission thermistor is unresponsive.	Replaced curbside transmission thermistor.	1.00	Electrical	3
06/06/19	1,744	Red caution light and red “gear” light came on on dash.	Fixed two shift position sensor connectors.	1.50	Electrical	3
06/06/19	1,744	Curbside mirror is loose and will not stay adjusted.	Mirror bolts were tightened.	0.08	Body	4
06/11/19	2,049	Bus had yellow caution light and yellow gear symbol light on.	Bus manufacturer’s representative looked at the codes, cycled 24V batteries and cleared codes.	0.08	Electrical	3
06/11/19	2,049	Yellow caution and yellow temperature light came on to indicate that there is an issue with the power electronics coolant loop temperature sensor.	Discovered broken wires at sensor. Drained coolant, replaced sensor refilled coolant	1.00	Electrical	3

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 4 of 11)

Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
06/12/19	2,085	The hub seal on the rear, streetside wheel was found to be leaking.	The vendor arrived on site to investigate and fix the issue. The root cause was found to be loose mounting hardware for the interior gearset. A new hub seal was installed. The vendor is working to correct the issue for future axles.	2.00	Drivetrain	3
06/17/19	2,285	Bus is leaning hard to the curbside and will not level.	The curbside, rear leveling arm was found inverted. The inverted linkage was corrected.	0.50	Suspension	3
06/17/19	2,285	Bus is leaning hard to the curbside and will not level.	The curbside, rear leveling arm was found inverted. The inverted linkage was corrected.	0.50	Suspension	3
06/17/19	2,285	The rear door is coming open while on the durability track, causing the bus to stop.	Rear door hardware is worn out. Hardware was replaced.	1.00	Electrical/ Body	2
06/18/19	2,302	Bus is leaning hard to the curbside and will not level.	The curbside, rear leveling arm was found inverted. The inverted linkage was corrected. Recalibration of ride height.	0.50	Suspension	3
06/18/19	2,359	Bus stopped running on durability track two times. Symbol of bus on hill came on. Red caution light came on.	The CAN-H wire to the inverter was found to be broken and intermittently connecting. This was driving a red level fault on the vehicle that required a reset. The wire was corrected with a splice.	0.50	Electrical	3
06/19/19	2,421	The streetside, rear of bus is making contact on frame twist obstacle.	Rear leveling arm found inverted. Corrected linkage length/alignment to be within specification. Recalibrated ride height.	1.00	Suspension	3
06/21/19	2,593	The wheel well box on the curbside is coming loose.	The mounting screws were tightened and the wheel well box was reinstalled.	1.00	Body	3

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 5 of 11)

Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
06/21/19	2,669	Bus will not charge.	DC cable going to the DuoPower rear axle was damaged at the support clamp where it is secured to the top of the axle. Power cable and cable support clamps were replaced.	2.00	Electrical	3
07/02/19	2,957	Yellow "air compressor" light on dash.	Replaced air compressor thermistor.	0.50	Electrical	3
06/26/19 To 10/18/19	2,757 To 8,187	HVAC not working.	The root cause was found to be that the high-pressure refrigerant line had cracked/failed. On 10/18/19 the HVAC vendor installed updated flex line which is an implemented design change.	2.00	HVAC	4
07/08/19 T0 07/19/19	3,437	Coolant was leaking under rear, streetside of bus. Checked coolant level, but could not see coolant in one sight glass.	Replaced both power electronic coolant pumps.	0.75	Electrical / Motor & Battery Cooling	3
07/19/19	3,437	Rear hatch hinge and rear hatch latch are broken.	Replaced rear hatch hinge and rear latch with new assembly.	0.50	Body	3
07/25/19	3,612	Bolts are loose on axle cover.	Cover was redesigned to split the support bar in the middle so that it did not span the width of the axle. Added thread locking compound on bolts for inspection plate cover.	0.50	Drivetrain	3
07/29/19	3,682	Vehicle will not charge on Port A.	The root cause was a broken wire with a ring terminal. The ring terminal was replaced and additional securement added to the new wire.	0.25	Electrical	3
08/02/19	4,094	Rear passenger door keeps opening while running durability.	Adjusted rear door actuator. Tightened door actuator joint in order to prevent movement causing door to trigger an "open" sensor.	0.25	Body	3

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 6 of 11)

Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
07/31/19 To 08/05/19	3,874 To 4,130	Battery tray retaining bar and left side battery hold down mount is broken.	Installed a new restraining bracket on the LV battery tray box.	0.25	Electrical	3
08/06/19 To 08/12/19	4,292 To 4,392	Red caution light and red gear symbol light came on and bus lost throttle. When bus was restarted lights would go out and bus would run. This happened multiple times.	Drivetrain LV harness had an improperly installed zip tie which caused a connector to unlock. This cause an intermittent connection in the harness. Zip tie was moved.	0.50	Electrical	3
08/13/19	4,529	Curbside mirror is loose.	Mirror was tightened.	0.20	Body	3
08/13/19 To 08/15/19	4,529 To 4,730	Caution light and HV light flashing.	Turned bus off and back on from driver's area. Lights went out.	0.10	Electrical	3
08/20/19	5,180	Air filter support mount on air compressor is broken.	Repaired broken air filter support mount on air compressor.	1.00	Coach Air Compressor	4
08/23/19	5,581	Red caution light and red gear symbol came on and bus lost throttle.	Cycled batteries.	0.08	Electrical	3
09/04/19	6,265	Incorrect mileage on odometer.	Bus manufacturer's representative updated software to correct odometer mileage. Continued monitoring vehicle to determine root cause.	0.10	Software	3
09/06/19 To 09/10/19	6,446 To 6,494	Fiberglass is starting to delaminate at two different points above the front door.	The area was repaired by installing a new mounting bracket.	3.25	Body	3

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 7 of 11)

Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
09/06/19 To 09/10/19	6,446 To 6,494	ADA ramp is non-functioning. One of the mounting brackets has become de-bonded.	The ADA ramp bracket was re-bonded to the vehicle.	1.00	Body	3
09/06/19 To 09/10/19	6,446	ADA ramp is non-functioning.	ADA ramp controller ground wire found chaffed on interior panel screw. Replaced instrument panel harness.	0.50	Electrical	3
09/11/19	6,511	Rear door is intermittently tripping its circuit breaker.	Low voltage wiring to door found damaged due to contact with door actuator. Repaired wiring and routed harness properly.	0.20	Electrical	3
09/11/19	6,511	Drivers noted that there was an air leak.	Leaking airline for front door found chaffing on interior panel screw. Air line replaced and routed to prevent reoccurrence	0.25	Compressed Air System	3
09/12/19	6,615	Red caution light came on after disconnecting from charger and would not engage into gear. The bus displayed yellow faults on dash.	Power cables for DuoPower axle were chaffing where they were secured. Damaged cables were replaced. At the location of damage, water was able to leak into the drivetrain inverter.	2.85	Electrical	2
09/20/19	6,911	Rear axle inspection cover under rear of bus is loose and rattling due to missing bolts.	Bolts were replaced and tightened.	0.50	Drivetrain	3
09/24/19 To 10/16/19	7,132 To 8,187	Yellow caution and "gear" symbols came on dashboard. On 09/30/19, the red caution light came on and throttle went into de-rate. Once the bus slowed to below 15 mph the throttle started working again.	Motor resolver had intermittent connection. Bracket added to prevent intermittent wiring connection with inverter.	2.00	Software/ Electrical	3
09/25/19 To 09/26/19	7,302 To 7,527	Bus leaned hard to the curbside and the bus would not relevel. Bus lost ride height, all airbags.	Inverted leveling arm was corrected and ride height sensor was adjusted.	0.50	Suspension	3

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 8 of 11)

Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
10/29/19	8,754	Red "Door" light and caution light came on while running durability. Used interlock override to drive bus back to the garage.	Rear door actuator hardware became loose causing actuation mechanism to disconnect. Repositioned bracket and tightened hardware.	0.25	Body	3
10/31/19 To 11/06/19	9,098 To 9,305	Rear door is coming open while running durability.	Rear door actuator hardware became loose causing actuation mechanism to disconnect. Additional bolt was added and mechanism was replaced to prevent problem.	0.75	Body	3
11/07/19	9,334	While exiting the 4" pothole, the 24V battery box broke and fell onto the track.	Per the manufacturer, the root cause was determined to be an improper torque spec and hardware combination which lead to a loss of clamp load on the fasteners. Battery box was reinstalled with updated hardware.	3.00	Electrical/ Body	2
11/15/19	9,398	The bushings in the front suspension upper arms are worn out.	Both front-upper arm assemblies were replaced. Both front air bags had wear from contacting the inner wheel well. Both air bags replaced.	12.00	Suspension	3
11/18/19	9,461	Yellow caution light and "gear" light came on in 1" chatter bump area of the durability track.	Intermittent electrical issue. Not resolved. Will continue to monitor problem.	---	Electrical	4
11/18/19 to 12/05/19	10,103 To 10,901	Yellow caution light and "gear" light came on in 1" chatter bump area of the durability track. Had to stop multiple times to reset regenerative braking.	Issue was monitored until software update. Bus manufacturer's representative updated SOC software on 12/05/19. Software update to address earlier issues with caution lights, "gear" lights, regen and SOC.	0.25	Software/ Electrical	3
11/27/19	10,510	Streetside mirror will not stay adjusted.	Bolts were tightened.	0.08	Body	3

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 9 of 11)

Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
12/04/19	10,783	Symbol of yellow bus and up and down arrows and yellow caution lights are coming on.	Cycled bus, but lights are still on. Fault was cleared. Will continue to monitor.	0.08	Electrical	3
12/04/19	10,783	Side mount for the air compressor and power steering variable frequency drive (VFD) was broken.	Repaired broken mount.	1.25	Electrical	3
12/04/19	10,783	The two latches retaining the rear hatch on the bus are worn.	Replaced broken latches.	0.50	Body	3
12/13/19 To 01/30/20	11,595 To 13,267	The "drive" and "neutral" indicator lights are not working in the driver's gear selection.	Situation being monitored. See repairs on 01/30/2020.	---	Electrical	4
12/17/19	11,803	The bracket isolating the air compressor from the frame of the vehicle was found to have fractures.	The air compressor bracket was replaced.	2.50	Body	3
01/02/20	12,044	Red caution light came on.	Faulty lock motor on the Port-A charge port failed. Replaced lock motor.	0.25	Electrical	3
01/08/20	12,044	The Battery Thermal Management System (BTMS) pump #2 stopped functioning.	Replaced pump and worn isolators.	0.50	Battery Coolant	3
01/15/20	12,598	Air compressor bracket is cracked.	Replaced air compressor and air compressor bracket.	2.50	Body	3
01/20/20	12,999	Transmission is not shifting properly. Bus is losing power to a drive motor when exceeding 25 mph in second gear.	This is being monitored. See repair on 01/23/2020.	---	Drivetrain	3
01/20/20 To 01/22/20	12,999	Rear door interlock light came on. Driver had to use interlock override to drive bus back to the garage.	Rear door actuator bracket found worn. Replaced component.	1.00	Door	3

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 10 of 11)

Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
01/20/20	12,999	Loss of CAN communication to power electronics coolant loop (PECL) #2.	Replaced power electronics coolant loop pump.	0.50	Electrical	3
01/22/20 To 01/28/20	12,999 To 13,079	Cracks and delamination were noticed around rear door and rear door mounting bracket.	Rear door mounting bracket area was repaired and rear door mounting bracket was replaced and re-bonded to vehicle.	7.50	Body	3
01/23/20	12,999	Drivers noted that the transmission caution light showed on the dash when the vehicle shifted from 2nd to 1st gear.	The curbside shift solenoid was found with contamination in the exhaust ports and corrosion on electrical connections. Solenoid was replaced.	1.00	Electrical	3
01/30/20	13,267	The latch for the rear hatch was found broken.	Replaced latch.	0.25	Body	3
01/30/20	13,267	Front passenger entry door will not open/close when using door switch in driver's area.	Wire connection to the door request button found broken. Wires for gear selection button lights also found broken. Wires were repaired. Replaced all buttons.	0.25	Electrical	3
02/03/20	13,644	The ADA ramp became unsecured from the vehicle on the durability course.	The root cause was determined to be missing hardware which secures the ADA ramp assembly to the vehicle brackets. Some mounting bolts came loose and some were sheared off. Required thread locking compound was not used in the ADA ramp repair performed on 09/10. The ramp was reinstalled per installation procedure.	1.25	ADA Ramp	1
02/07/20 To 08/03/20	14,587 To 15,151	Front passenger entry door will not open. Driver must enter and exit through the rear door.	Missing screw in air sweep causing door to jam when opening. Screw was replaced.	0.25	Body	4
02/10/20	14,782	Left side of 12/24V battery box and left side flange for the battery box is broken.	Battery box was replaced.	1.50	Body	3

Unscheduled Maintenance
Bus Proterra Bus# 1906
(Page 11 of 11)

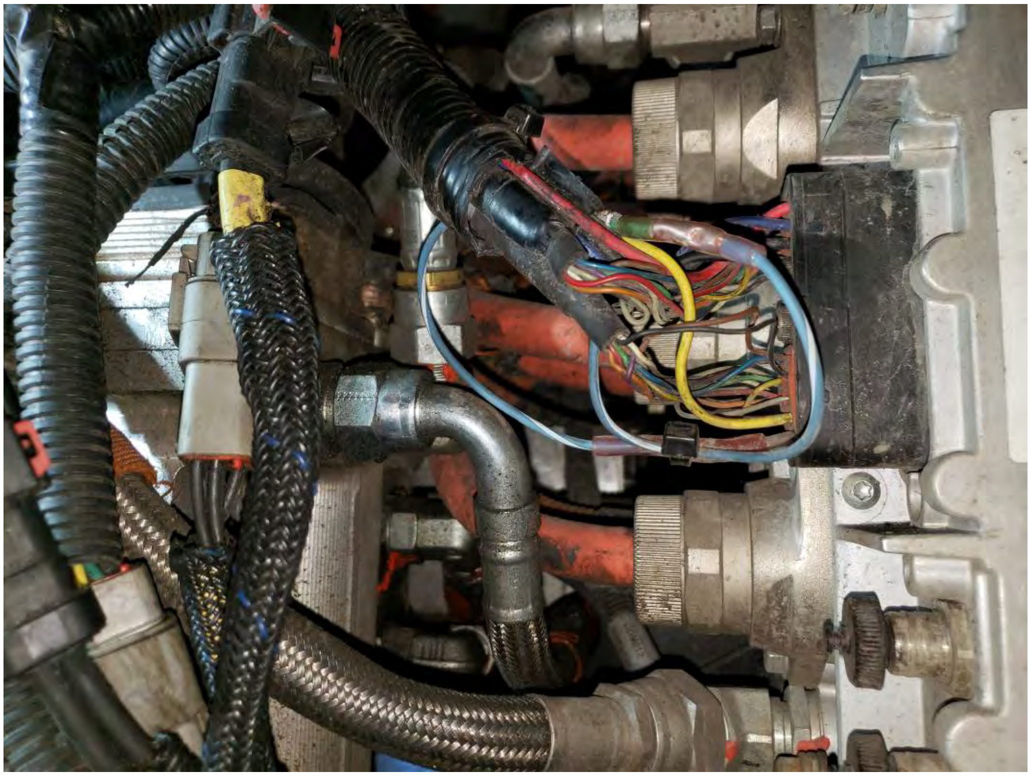
Date	Test Miles	Issue	Action	Labor Hours	Sub-system	Class
ALL TESTING AT THE ALTOONA BUS TESTING CENTER WAS SUSPENDED FROM 03/26/20 TO 07/16/20 DUE TO THE COVID-19 PANDEMIC						
07/21/20	14,930	Transmission is not shifting properly.	Replaced both the streetside and curbside shift solenoids.	1.00	Electrical	3

UNSCHEDULED MAINTENANCE

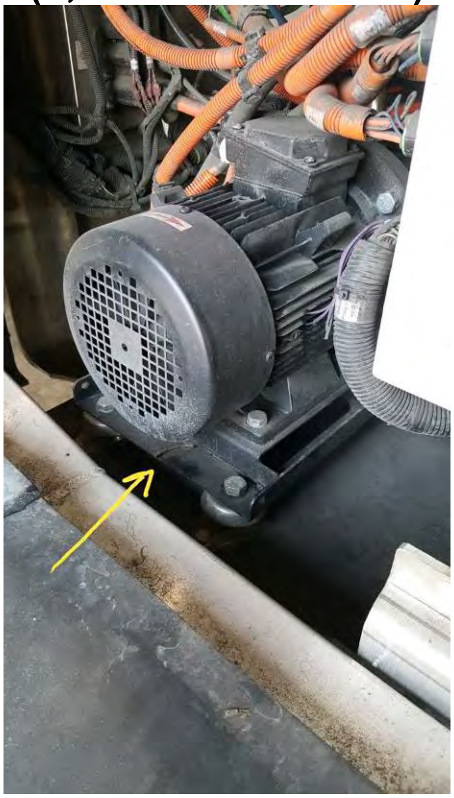
CURBSIDE MIRROR ARM SNAPPED
(681 TEST MILES)

BOLTS LOOSE ON REAR AXLE COVER
(755 TEST MILES)

UNSCHEDULED MAINTENANCE CONT.



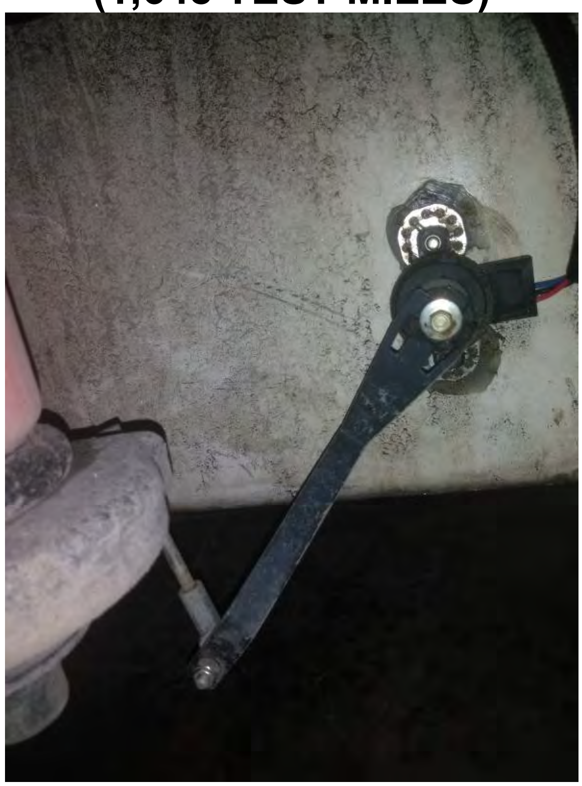
CAN-L WIRE TO DUOPOWER INVERTER IS BROKEN (1,087 TEST MILES)



AIR COMPRESSOR BRACKET IS BROKEN (1,648 TEST MILES)

UNSCHEDULED MAINTENANCE CONT.

SHIFT POSITION SENSOR WIRE IS BROKEN
(1,648 TEST MILES)



CURBSIDE REAR LEVELING ARM IS INVERTED
(2,285 TEST MILES)

DAMAGED DC CABLE GOING TO DUOPOWER AXLE (2,669 TEST MILES)

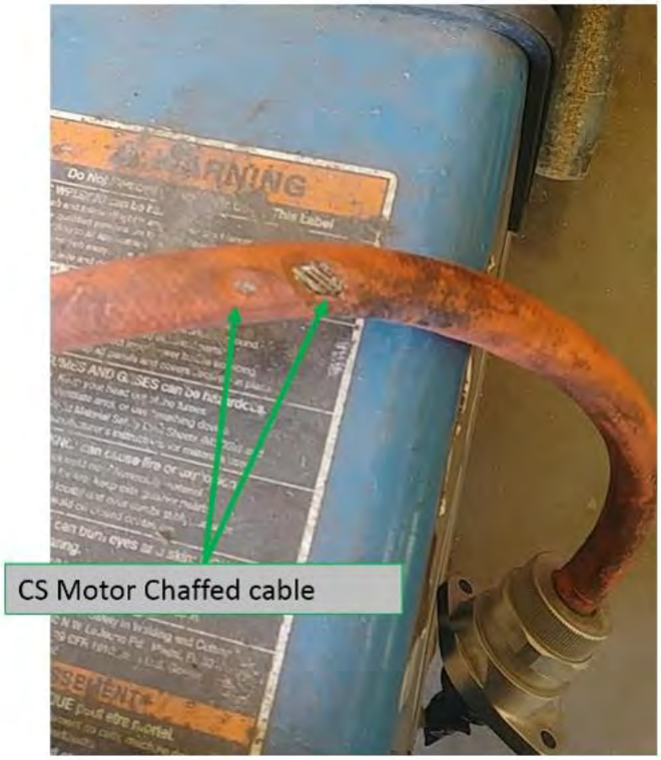
DAMAGED FRONT DOOR HAT BRACKET (6,494 TEST MILES)

FRONT DOOR HAT BRACKET REPAIR
(6,494 TEST MILES)

WIRES BEHIND DASH FOR ADA RAMP ARE WORN
(6,494 TEST MILES)

UNSCHEDULED MAINTENANCE CONT.

REAR DOOR LOW VOLTAGE HARNESS IS CHAFFING (6,511 TEST MILES)



PHASE CABLE FOR CURBSIDE MOTOR IS CHAFFING (6,615 TEST MILES)

UNSCHEDULED MAINTENANCE CONT.

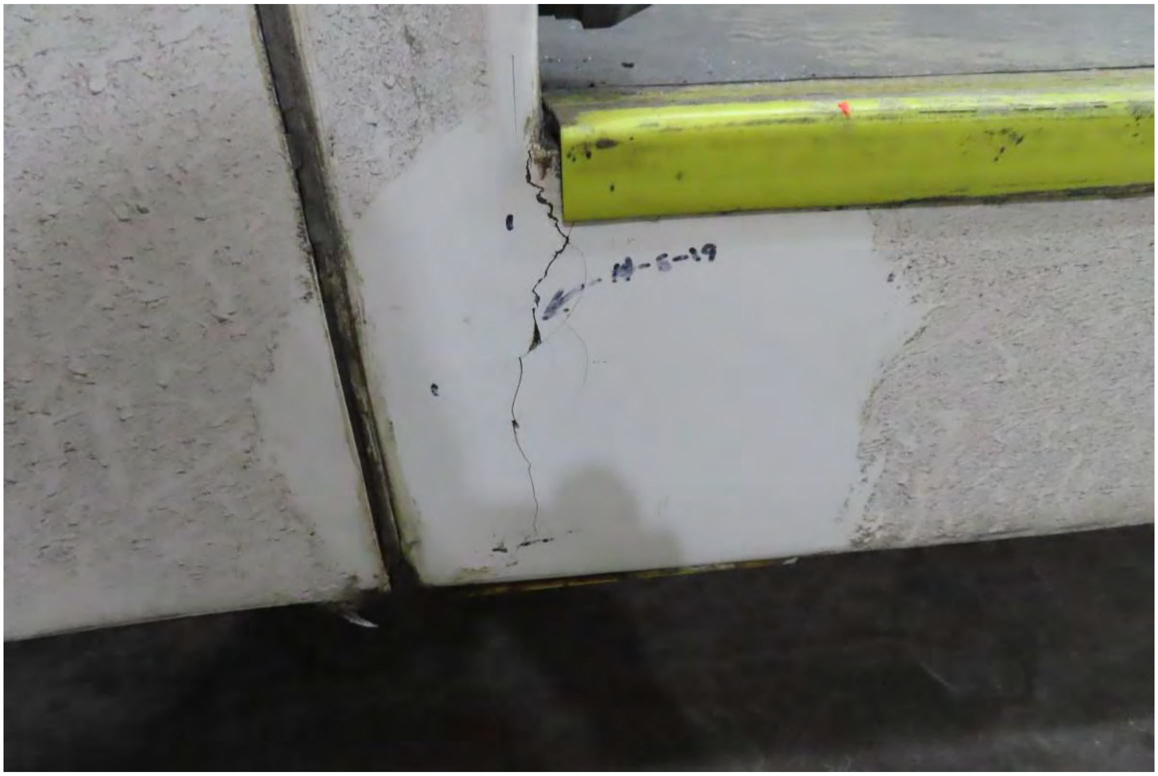
24 VOLT BATTERY BOX FELL OUT
(9,334 TEST MILES)

AIR COMPRESSOR BRACKET IS CRACKED
(12,598 TEST MILES)

CRACKS AROUND REAR DOOR
(12,999 TEST MILES)

CRACKS AROUND REAR DOOR
(12,999 TEST MILES)

UNSCHEDULED MAINTENANCE CONT.



ADDITIONAL CRACKS AROUND REAR DOOR (12,999 TEST MILES)

REAR DOOR HAT BRACKET REPAIR (12,999 TEST MILES)

ADA RAMP BECAME UNSECURED FROM BUS
(13,644 TEST MILES)

ADA RAMP BECAME UNSECURED FROM BUS
(13,644 TEST MILES)

6. ENERGY ECONOMY AND RANGE TEST – AN ENERGY CONSUMPTION AND RANGE TEST FOR BATTERY ELECTRIC BUSES USING APPROPRIATE OPERATING CYCLES

6-I. TEST OBJECTIVE

The objective of this test is to provide accurate comparable energy consumption data on battery electric transit buses produced by different manufacturers. This energy economy test bears no relation to the calculations done by the Environmental Protection Agency (EPA) to determine levels for the Corporate Average Fuel Economy Program. EPA's calculations are based on tests conducted under laboratory conditions intended to simulate city and highway driving. This energy economy test, as designated here, is a measurement of the energy consumed by a vehicle traveling a specified test operating profile, under specified operating conditions that are typical of transit bus operation. The results of this test will not represent actual energy usage but will provide data that can be used by FTA Grantees to compare buses tested using this procedure.

6-II. TEST DESCRIPTION

This test is performed in the emissions bay of the LTI Vehicle Testing Laboratory. The Laboratory is equipped with a Schenk Pegasus 300 HP, large-roll (72 inch diameter) chassis dynamometer suitable for heavy-vehicle emissions testing. The driving cycles are the Manhattan cycle, a low average speed, highly transient urban cycle (Figure 1), the Orange County Bus Cycle which consists of urban and highway driving segments (Figure 2), and the EPA HD-UDDS Cycle (Figure 3). This test is conducted at seated load weight.

This test is conducted generally as per the methods described in the SAE standard J 1634-2017. The light-duty test cycles specified in this standard are replaced by transit bus test cycles mentioned above.

The Multi-Cycle test (MCT) procedure is adopted for this bus. The end of test is determined when the bus cannot keep up with the speed trace of the test cycle, as recommended by the bus manufacturer. The battery system is recharged to full SOC at the end of the test, following procedures specified in SAE J 1634-2017. During the recharge, the DC energy (into the battery system) and the AC energy (into the charger) are recorded. From these data, the average AC energy consumption, the charger efficiency (DC Energy, kWh/AC Energy, kWh) and range (miles) for each test cycle is calculated.

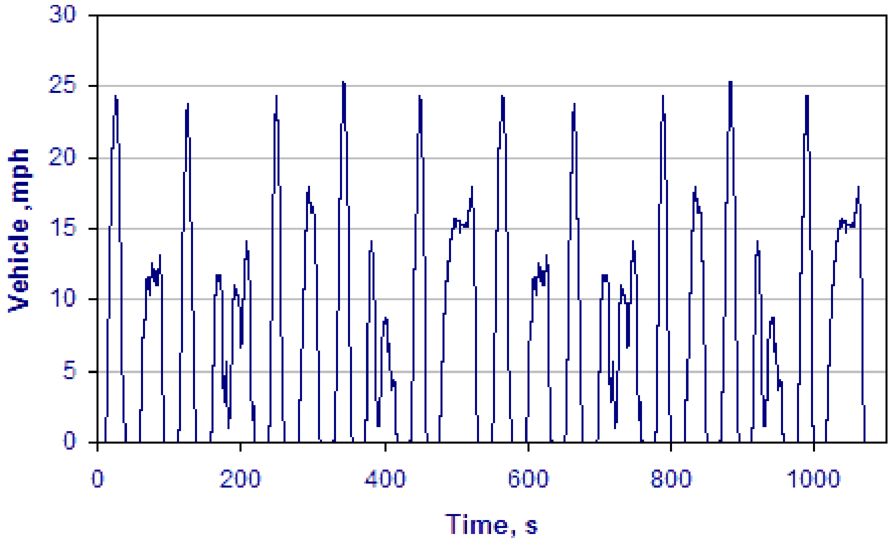


Figure 1. Manhattan Driving Cycle (duration 1089 sec, Maximum speed 25.4 mph, average speed 6.8 mph)

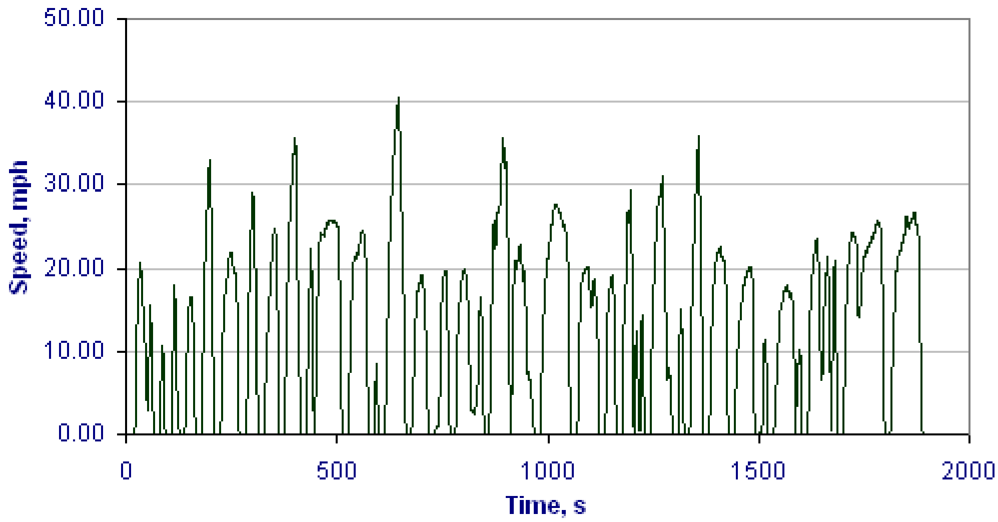


Figure 2. Orange County Bus Cycle (Duration 1909 Sec, Maximum Speed 41 mph, Average Speed 12 mph).

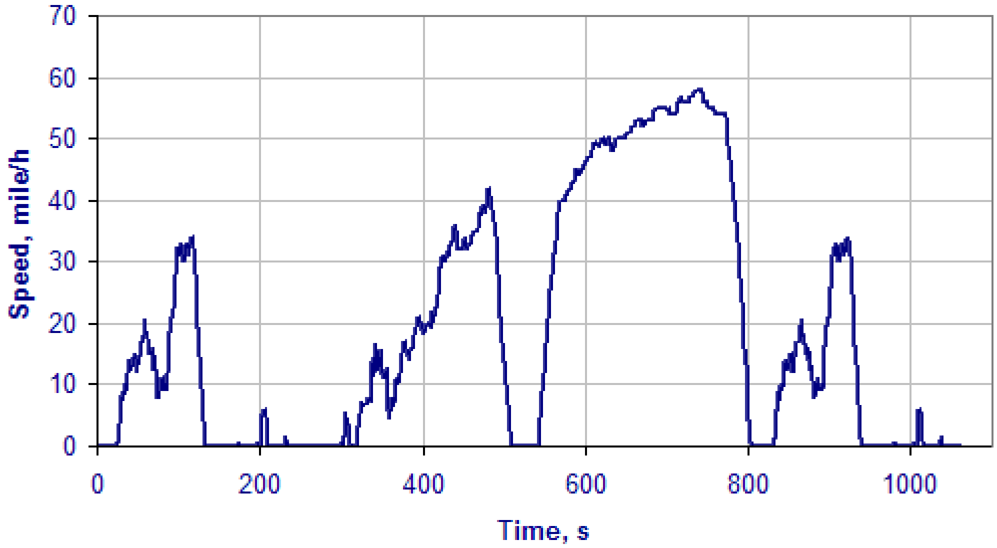


Figure 3. HD-UDDS Cycle (duration 1060 seconds, Maximum Speed 58 mph, Average Speed 18.86 mph).

6-III. DISCUSSION

The driving cycle consists of three simulated transit driving cycles: Manhattan, Orange County Bus Cycle and the HD-UDDS, as described in 6-II.

An extensive pretest maintenance check is conducted including the replacement of all lubrication fluids, if applicable. The details of the pretest maintenance are given in the first three Pretest Maintenance Forms. The fourth sheet shows the Pretest Inspection Form. Finally, the summary sheet provides the average energy consumption and range of bus for the three test cycles. The test was conducted at a seated load weight of 36,960 lbs. The average AC energy consumption for the Manhattan, OCBC and the HD-UDDS were 2,582 Wh/mile, 2,155 Wh/mile and 1,955 Wh/mile respectively. The average DC energy consumption for the Manhattan, OCBC and the HD-UDDS were 2,217 Wh/mile, 1,850 Wh/mile and 1,678 Wh/mile respectively. The range for the three driving cycles were 142 miles, 170 miles and 187 miles respectively.

This bus was tested using the Manhattan, Orange County and UDDS driving cycles. The energy economy and range results for buses tested using these cycles are not directly comparable to buses tested under the earlier protocol that uses the CBD, Arterial and Commuter driving cycles.

For the Energy Economy Tests, ballast weight equivalent of the roof mount battery packs was removed to represent the four-pack battery configuration per the Federal Transit Administration determination letter. Therefore, the seated load weight used was 36,960 lbs. for this Fuel Economy test.

ENERGY ECONOMY PRE-TEST MAINTENANCE FORM

Page 1 of 3

Bus Number: 1906	Date: 02/08/2020	SLW (lb.): 36,960
Personnel: T.S., S.R. & E.D.		

ENERGY SYSTEM	OK
Install fuel measurement system	✓
Remarks: None noted.	
BRAKES/TIRES	OK
Inspect hoses	✓
Inspect brakes	✓
Check tire inflation pressures (mfg. specs.)	✓
Check tire wear (less than 50%)	✓
Remarks: None noted.	
BATTERY COOLING SYSTEM	OK
Check hoses and connections	✓
Check system for coolant leaks	✓
Remarks: None noted.	

ENERGY ECONOMY PRE-TEST MAINTENANCE FORM

Page 2 of 3

Bus Number: 1906	Date: 02/08/2020
Personnel: T.S., S.R. & E.D.	

ELECTRICAL SYSTEM	OK
Check battery	✓
Inspect wiring	✓
Inspect terminals	✓
Check lighting	✓
Remarks: None noted.	
DRIVE SYSTEM	OK
Drain transmission fluid – Drive Motor	✓
Replace filter/gasket	Done by MFG
Check hoses and connections	✓
Replace transmission fluid	Done by MFG
Check for fluid leaks	✓
Remarks: Done by manufacturer to specs	
LUBRICATION	OK
Lube all chassis grease fittings	✓
Lube universal joints	✓
Replace differential lube including axles	N/A
Remarks: None noted.	

ENERGY ECONOMY PRE-TEST MAINTENANCE FORM

Page 3 of 3

Bus Number: 1906	Date: 02/08/2020
Personnel: T.S., S.R. & E.D.	

OTHER ITEMS	OK
Replace air filter	N/A
Inspect air compressor and air system	✓
Inspect vacuum system, if applicable	N/A
Check and adjust all drive belts	N/A
Remarks: None noted	
STEERING SYSTEM	OK
Check power steering hoses and connectors	✓
Service fluid level	✓
Check power steering operation	✓
Remarks: None noted	
	OK
Ballast bus to seated load weight*	✓
*see note on weight in discussion	
TEST DRIVE	OK
Check brake operation	✓
Check transmission operation – Drive Motor	✓
Remarks: None noted.	

ENERGY ECONOMY PRE-TEST INSPECTION FORM
Page 1 of 1

Bus Number: 1906	Date: 02/08/2020
Personnel: T.S., S.R. & E.D.	

PRE-WARM-UP	If OK, Initial
Energy Economy Pre-Test Maintenance Form is complete	E.D.
Cold tire pressure (psi): Front 130 Middle N/A Rear 130	E.D.
Energy economy instrumentation installed and working properly.	T.S.
Bus is loaded to SLW during coast down	E.D.
WARM-UP	**If OK, Initial**
Interior and exterior lights on	J.S.
Air conditioner off	J.S.
Defroster off	J.S.
Windows and doors closed	J.S.
Do not drive with left foot on brake	J.S.

ENERGY ECONOMY DATA FORM
(Battery Electric Buses)

Page 1 of 1

Bus Number: 1906	Manufacturer: Proterra	Date: 09/10/2020
Fuel Type: Electric	Personnel: J.S. & S.I.	
Temperature (°F): 84.9	Humidity (%): 84.8	Barometric Pressure (inHg): 29.0
SLW (lb.): 36,960	Charger: Proterra 60kW	

	Manhattan	**Orange County**	**UDDS**
DC Energy (Wh/mile)	2,217	1,850	1,678
AC Energy (Wh/mile)	2,582	2,155	1,955
Range (miles)	142	170	187

Comments: Bus lost drive to one wheel motor twice during the test. Manufacturer's
representative resolved the problem and the test continued.

ENERGY ECONOMY TEST CONT.

BUS TESTED ON CHASSIS DYNAMOMETER FOR PERFORMANCE AND ENERGY ECONOMY

7. NOISE

7.1 INTERIOR NOISE AND VIBRATION TESTS

7.1-I. TEST OBJECTIVE

The objective of these tests is to measure and record interior noise levels and check for audible vibration under various operating conditions.

7.1-II. TEST DESCRIPTION

During this series of tests, the interior noise level was measured at several locations with the bus operating under the following three conditions:

1. With the bus stationary, a white noise generating system provided a uniform sound pressure level equal to 80 dB(A) on the left, exterior side of the bus. The engine and all accessories were switched off and all openings including doors and windows were closed. This test was performed at the LTI Test Track Facility.

2. The bus was accelerated at full throttle from a standing start to 35 mph on a level pavement. All openings were closed and all accessories were operating during the test. This test was performed on the track at the LTI Test Track Facility.

3. The bus was operated at various speeds from 0 to 55 mph with and without the air conditioning and accessories on. Any audible vibration or rattles were noted. This test was performed on the test segment between the LTI Test Track and the Bus Testing Center.

All tests were performed in an area free from extraneous sound-making sources or reflecting surfaces. The ambient sound level as well as the surrounding weather conditions were recorded in the test data.

7.1-III. DISCUSSION

For the first part, the overall average of the six measurements was 49.4 dB(A); ranging from 48.6 dB(A) in line with the front speaker to 50.2 dB(A) in line with the rear speaker. The interior ambient noise level for this test was less than 30 dB(A).

For the second part, the interior noise level ranged from 71.1 dB(A) at the driver's seat to 74.0 dB(A) at the middle passenger seats. The overall average was 72.6 dB(A). The interior ambient noise level for this test was less than 30 dB(A).

No vibrations or rattles were noted during the third part of this test. This bus passed this section of the test.

INTERIOR NOISE TEST DATA FORM
Test Condition 1: 80 dB(A) Stationary White Noise

Bus Number: 1906	Date: 10/29/19
Personnel: T.S. & E.D.	
Temperature (°F): 58	Humidity (%): 72
Wind Speed (mph): 6	Wind Direction: S
Barometric Pressure (inHg): 30.24	
Interior Ambient Noise Level dB(A): less than 30	Exterior Ambient Noise Level dB(A): 43.1
Microphone Height During Testing (in): 46.4	

Reading Location	Measured Sound Level dB(A)
Driver's Seat	49.4
Front Passenger Seats	49.1
In Line with Front Speaker	48.6
In Line with Middle Speaker	48.8
In Line with Rear Speaker	50.2
Rear Passenger Seats	50.0

Comments: None noted.

INTERIOR NOISE TEST DATA FORM
Test Condition 2: 0 to 35 mph Acceleration Test
Page 2 of 3

Bus Number: 1906	Date: 08/30/19
Personnel: S.R., E.D., E.L. & J.S.	
Temperature (°F): 75	Humidity (%): 64
Wind Speed (mph): Steady at 6; gust to 11	Wind Direction: SW
Barometric Pressure (inHg): 30.01	
Interior Ambient Noise Level dB(A): less than 30	Exterior Ambient Noise Level dB(A): 42.6
Microphone Height During Testing (in): 46.4	

Reading Location	Measured Sound Level dB(A)
Driver's Seat	71.1
Front Passenger Seats	71.8
Middle Passenger Seats	74.0
Rear Passenger Seats	73.4

Comments: None noted.

INTERIOR NOISE TEST DATA FORM
Test Condition 3: Audible Vibration Test
Page 3 of 3

Bus Number: 1906	Date: 09/03/19
Personnel: T.S., E.L. & M.R.	
Temperature (°F): 75	

Describe the following possible sources of noise and give the relative location on the bus.

Source of Noise	Location	Description of Noise
Engine and Accessories	N/A	N/A
Windows and Doors	None noted.	None noted.
Seats and Wheelchair lifts	None noted.	None noted.
Other	None noted.	None noted.

Comment on any other vibration or noise source which may have occurred that is not described above: None noted.

Comments: None noted.

7.1 INTERIOR NOISE TEST

TEST BUS SET-UP FOR 80 dB(A)
INTERIOR NOISE TEST

7.2 EXTERIOR NOISE TESTS

7.2-I. TEST OBJECTIVE

The objective of this test is to record exterior noise levels when a bus is operated under various conditions.

7.2-II. TEST DESCRIPTION

In the exterior noise tests, the bus was operated at a SLW in three different conditions using a smooth, straight and level roadway:

1. Accelerating at full throttle from a constant speed starting from 35 mph.

2. Accelerating at full throttle from standstill.

3. Stationary, with the engine at low idle, high idle, and wide-open throttle, where applicable. In addition, the bus was tested with and without the air conditioning operating.

The test site is at the Larson Transportation Institute Test Track and the test procedures were performed in accordance with SAE Standards SAE J366b, Exterior Sound Level for Heavy Trucks and Buses. The test site is an open space free of large reflecting surfaces. A noise meter placed at a specified location outside the bus was used to measure the noise level.

During the test, special attention was paid to:

1. The test site characteristics regarding parked vehicles, signboards, buildings, or other sound-reflecting surfaces
2. Proper usage of all test equipment including set-up and calibration
3. The ambient sound level

7.2-III. DISCUSSION

The Exterior Noise Test determines the noise level generated by the vehicle under different driving conditions, and at stationary with and without air conditioning and accessories operating. The test site is a large, level, bituminous paved area with no reflecting surfaces nearby.

With an outside ambient noise level of 49.2 dB(A), the average of the two highest readings obtained while accelerating from a constant speed was 70.0 dB(A) on the right side and 69.0 dB(A) on the left side.

When accelerating from a standstill with an exterior ambient noise level of 49.2 dB(A), the average of the two highest readings obtained were 68.2 dB(A) on the right side and 68.6 dB(A) on the left side.

With the vehicle stationary and the engine, accessories, and air conditioning on, the measurements averaged 50.2 dB(A). With the accessories and air conditioning off, the readings averaged 49.0 dB(A). The exterior ambient noise level measured during this test was 49.2 dB(A). This bus passed this section of the test.

EXTERIOR NOISE TEST DATA FORM
Accelerating from Constant Speed

Bus Number: 1906	Date: 09/03/19
Personnel: T.S., E.L. & E.D.	
Temperature (°F): 68	Humidity (%): 76
Wind Speed (mph): 0	Wind Direction: Calm
Barometric Pressure (inHg): 30	

Verify that microphone height is 4 feet, wind speed is less than 12 mph and ambient temperature is between 30°F and 90°F: ✓

Initial Sound Level Meter Calibration: 94.0 dB(A)

Exterior Ambient Noise Level: 49.2 dB(A)

Accelerating from Constant Speed Curb (Right) Side		Accelerating from Constant Speed Street (Left) Side	
Run #	Measured Noise Level dB(A)	Run #	Measured Noise Level dB(A)
1	70.6	1	69.9
2	67.7	2	67.0
3	69.4	3	68.0
4	68.5	4	68.0
5	69.1	5	68.1
6	N/A	6	N/A
7	N/A	7	N/A
8	N/A	8	N/A
9	N/A	9	N/A
10	N/A	10	N/A
Average of two highest actual noise levels = 70.0 dB(A)		Average of two highest actual noise levels = 69.0 dB(A)	

Final Sound Level Meter Calibration Check: 94.0 dB(A)

Comments: None noted.

EXTERIOR NOISE TEST DATA FORM
Accelerating from Standstill

Bus Number: 1906	Date: 09/03/19
Personnel: E.D. & E.L.	
Temperature (°F): 73	Humidity (%): 65
Wind Speed (mph): 0	Wind Direction: calm
Barometric Pressure (inHg):	

Verify that microphone height is 4 feet, wind speed is less than 12 mph and ambient temperature is between 30°F and 90°F: ✓

Initial Sound Level Meter Calibration: 94.0 dB(A)

Exterior Ambient Noise Level: 49.2 dB(A)

Accelerating from Standstill Curb (Right) Side		Accelerating from Standstill Street (Left) Side	
Run #	Measured Noise Level dB(A)	Run #	Measured Noise Level dB(A)
1	68.1	1	67.9
2	67.8	2	67.0
3	68.2	3	67.8
4	67.9	4	69.2
5	67.9	5	66.9
6	N/A	6	N/A
7	N/A	7	N/A
8	N/A	8	N/A
9	N/A	9	N/A
10	N/A	10	N/A
Average of two highest actual noise levels = 68.2 dB(A)		Average of two highest actual noise levels = 68.6 dB(A)	

Final Sound Level Meter Calibration Check: 94.0 dB(A)

Comments: None noted.

EXTERIOR NOISE TEST DATA FORM
Stationary
Page 3 of 3

Bus Number: 1906	Date: 09/03/19
Personnel: E.D. & E.L.	
Temperature (°F): 73	Humidity (%): 65
Wind Speed (mph): 0	Wind Direction: Calm
Barometric Pressure (inHg): 30.10	
Initial Sound Level Meter Calibration: 94.0 dB(A)	
Exterior Ambient Noise Level: 49.2 dB(A)	

Air Conditioning ON

Throttle Position	Engine RPM	Curb (Right) Side dB(A)	Street (Left) Side db(A)
		Measured	Measured
Low Idle	N/A	49.3	51.1
High Idle	N/A	N/A	N/A
Wide Open Throttle	N/A	N/A	N/A

Air Conditioning OFF

Throttle Position	Engine RPM	Curb (Right) Side dB(A)	Street (Left) Side db(A)
		Measured	Measured
Low Idle	N/A	48.1	49.8
High Idle	N/A	N/A	N/A
Wide Open Throttle	N/A	N/A	N/A

Final Sound Level Meter Calibration Check: 94.0 dB(A)

Comments: Electric bus – no high idle or full throttle

7.2 EXTERIOR NOISE TESTS

TEST BUS UNDERGOING EXTERIOR NOISE TESTING

PROTERRA

Depot Charging Equipment

PROTERRA
ENERGY

PROTERRA®
CHARGING SYSTEMS

RELIABLE DC FAST CHARGING FOR FLEETS

INDUSTRIAL SERIES

The Proterra Industrial Series charging system is designed explicitly for fleet applications.

Available in 60kW, 90kW, 120kW, 150kW and 180kW configurations.

Charge up to 4 vehicles from the same charger with automated, multi-dispenser configurations, including up to 4 single-cable dispensers or 2 dual-cable dispensers.

Dispensers can be sited separately (up to 500 feet away) from the charging cabinet, enabling greater flexibility in design and configuration for fleets.

Remote monitoring, intelligent diagnostics and a modular design allows for quick issue resolution and efficient field service.

Broad voltage range (up to 1000VDC) ensures compatibility with both today's and next generation electric vehicles.

- **OCPP compliant and 4G enabled**
- **Small footprint**
- **Multi-dispenser option**
- **Supports CCS1 and pantograph options**
- **3 Year Standard Warranty with extensions available**

PROTERRA

Proterra charging systems are compliant with Federal DOT Buy America requirements.

PROTERRA ENERGY

PROTERRA® CHARGING SYSTEMS

MODEL	PC-060-PI	PC-090-PI	PC-120-PI	PC-150-PI	PC-180-PI
ELECTRICAL OUTPUT					
Continuous DC Output Power	60 kW	90 kW	120 kW	150 kW	180 kW
DC Output Voltage	150-1000 VDC				
Continuous DC Output Current	200 A, 500 A Pantograph (Optional)			300 A, 500 A Pantograph (Optional)	
ELECTRICAL INPUT					
AC Input Power	63 kVA	95 kVA	126 kVA	158 kVA	189 kVA
AC Input Current	76 A	114 A	152 A	190 A	227 A
AC Input Voltage	480V +/- 10%				
AC Input Topology	5-wire WYE (3ph + N + GND)				
AC Input Frequency	60 Hz				
Current THD% at full power	<3%				
Power Factor	>0.99				
Efficiency	95%				
MECHANICAL					
Cooling	Integrated air cooling				
Weight	825 lbs	880 lbs	935 lbs	990 lbs	1056 lbs
Dimensions (D x W x H)	31.2 in x 39.6 in x 79.2 in | 80 cm x 100 cm x 200 cm				
Required side doork clearance	None				
Required Front and Rear Clearance	1000 mm				
ENVIRONMENTAL					
Environmental Rating	NEMA 3R				
Maximum Altitude	3000m | 9800 ft (power derates above 2000m | 6500 ft)				
Operating temperature	-22°F to 122°F | -30°C to 50°C				
Operating Humidity	4-95%				
MISC					
Approved charger-to-vehicle interfaces	CCS1 Industrial dispenser J3105-1 Infrastructure-Down Pantograph				
Approved number of dispensers per power cabinet	Up to 2 Dual Cable Dispensers or Up to 4 Single Cable Dispensers				
Sequential Charging Capabilities	1 @ 60 kW	1 @ 90 kW	1 @ 120 kW	1 @ 150 kW	1 @ 180 kW
Simultaneous Charging Capabilities	-	-	2 @ 60 kW	-	3 @ 60 kW
Power Cabinet to dispenser or pantograph control box communications	Modbus TCP via fiber optic				
Max Distance between Power Cabinet and Dispenser	500 ft | 152.4 m (fiber optics)				
Management Communications	OCPP 1.6 control via 4G Cellular (standard) Supports WiFi, Ethernet (optional)				
Certifications	UL 2231, UL 2202 (pending)				
Warranty	3 year standard, 5 year extended warranty (optional)				

SPEC_CHG SYS_NBc_Q3_2021

PROTERRA
ENERGY™
FLEET SOLUTIONS

120 kW PROTERRA® CHARGING SYSTEM

PURPOSE-BUILT CHARGING HARDWARE

Compliant with SAE universal standards, the Proterra 120 kW Charging System offers plug-in charging at a higher power rate, and also has the added flexibility to be configured as an overhead charger. This charging system can charge one vehicle at a time at 120 kW or two vehicles simultaneously at 60 kW, and can be paired with up to 4 dispensers. With high power, fast charging capabilities, the Proterra 120 kW Charging System can fully charge a Proterra ZX5+ electric transit bus in less than 3 hours*.

- **Standardized and Interoperable**
- **Modular and Scalable**
- **Multi-dispenser Capable**
- **Intelligent and Automated**

Open source communications protocol

Smart grid ready

Telematics-enabled

PROTERRA

POWER ELECTRONICS

Developed in partnership with Power Electronics, Proterra charging systems build on Proterra's experience delivering charging infrastructure while leveraging Power Electronics' 30+ years of experience in solar, energy storage, and electric mobility.

*Subject to change based on operating, environmental and other conditions.

120 kW PROTERRA® CHARGING SYSTEM

PROTERRA ENERGY™
FLEET SOLUTIONS

ELECTRICAL OUTPUT	
Continuous DC Output Power	120 kW
DC Output Voltage	150-1000 VDC
Continuous DC Output Current	160A
ELECTRICAL INPUT	
AC Input Power	160 kW
AC Input Current	152A
AC Input Voltage	480V +/- 10%
AC Input Topology	5-wire WYE (3ph + N + GND)
AC Input Frequency	60 Hz
Current THD% at full power	<3%
Power Factor	>0.99
Efficiency	94%
MECHANICAL	
Cooling	Integrated air cooling
Weight	1336 lb | 606 kg
Dimensions (D x W x H)	27.6 in x 39.4 in x 74.8 in | 70 cm x 100 cm x 190 cm
Required side and back clearance	None
Required Door Clearance	1000 mm
ENVIRONMENTAL	
Environmental Rating	NEMA 3R
Maximum Altitude	3000m | 9800 ft (power derates above 2000m | 6500 ft)
Operating temperature	-13°F to 122°F | -25°C to 50°C (standard) -22°F to 122°F | -30°C to 50°C (optional)
Operating Humidity	4-95%
MISC	
Approved charger-to-vehicle interfaces	CCS1 Industrial dispenser J3105-1 Infrastructure-Down Pantograph
Approved number of dispensers per power cabinet	Supports simultaneous charging with up to 2 dispensers, and sequential charging with up to 4 vehicles.
Approved number of pantograph interfaces per power cabinet	1
Power Cabinet to dispenser or pantograph control box communications	Modbus TCP via Ethernet (standard) Modbus TCP via fiber optic (optional)
Max Distance between Power Cabinet and Dispenser	300 ft | 91.4 m (ethernet) 500 ft | 152.4 m (fiber optics)
Management Communications	OCPP 1.6 control via 4G Cellular (standard) Supports WiFi, Ethernet (optional)
Certifications	UL 2231, UL 2202 (pending)
Warranty	3 year standard, 5 year extended warranty options available

STANDARDIZED TECHNOLOGY

Proterra® charging systems utilize industry-standard charging technology so your heavy-duty electric vehicles, utility vehicles, and cars can share the same standardized chargers.

COMPATIBLE CONNECTIONS

UNIVERSAL PLUG-IN

PANTOGRAPH

Proterra charging systems are compliant with Federal DOT Buy America requirements.

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SPEC_CHG SYS_120_2021_Q1

PROTERRA
ENERGY™
FLEET SOLUTIONS

180 kW PROTERRA® CHARGING SYSTEM

PURPOSE-BUILT CHARGING HARDWARE

Compliant with SAE universal standards, the Proterra 180 kW Charging System offers plug-in charging at a higher power rate, and also has the added flexibility to be configured as an overhead charger. With high power, fast charging capabilities, the Proterra 180 kW Charging System can fully charge a Proterra ZX5+ electric transit bus in less than 3 hours*.

- **Standardized and Interoperable**
- **Modular and Scalable**
- **Multi-dispenser Capable**
- **Intelligent and Automated**

Open source communications protocol

Smart grid ready

Telematics-enabled

PROTERRA

POWER ELECTRONICS

Developed in partnership with Power Electronics, Proterra charging systems build on Proterra's experience delivering charging infrastructure while leveraging Power Electronics' 30+ years of experience in solar, energy storage, and electric mobility.

*Subject to change based on operating, environmental and other conditions.

180 kW PROTERRA® CHARGING SYSTEM

PROTERRA ENERGY™
FLEET SOLUTIONS

ELECTRICAL OUTPUT	
Continuous DC Output Power	180 kW
DC Output Voltage	150-1000 VDC
Continuous DC Output Current	240A (May be vehicle interface limited)
ELECTRICAL INPUT	
AC Input Power	189 kW
AC Input Current	232A
AC Input Voltage	480V +/- 10%
AC Input Topology	5-wire WYE (3ph + N + GND)
AC Input Frequency	60 Hz
Current THD% at full power	<3%
Power Factor	>0.99
Efficiency	94%
MECHANICAL	
Cooling	Integrated air cooling
Weight	1336 lb | 606 kg
Dimensions (D x W x H)	31.5 in x 59.1 in x 78.7 in | 80 cm x 150 cm x 200 cm
Required side and back clearance	None
Required Door Clearance	1000 mm
ENVIRONMENTAL	
Environmental Rating	NEMA 3R
Maximum Altitude	3000m | 9800 ft (power derates above 2000m | 6500 ft)
Operating temperature	-13°F to 122°F | -25°C to 50°C (standard) -22°F to 122°F | -30°C to 50°C (optional)
Operating Humidity	4-95%
MISC	
Approved charger-to-vehicle interfaces	CCS1 Industrial dispenser J3105-1 Infrastructure-Down Pantograph
Approved number of dispensers per power cabinet	Supports simultaneous charging with up to 3 dispensers at 60 kW each, and sequential charging at 180 kW each with up to 4 vehicles.
Approved number of pantograph interfaces per power cabinet	3
Power Cabinet to dispenser or pantograph control box communications	Modbus TCP via Ethernet (standard) Modbus TCP via fiber optic (optional)
Max Distance between Power Cabinet and Dispenser	300 ft | 91.4 m (ethernet) 500 ft | 152.4 m (fiber optics)
Management Communications	OCPP 1.6 control via 4G Cellular (standard) Supports WiFi, Ethernet (optional)
Certifications	UL 2231, UL 2202 (pending)
Warranty	3 year standard, 5 year extended warranty options available

STANDARDIZED TECHNOLOGY

Proterra® charging systems utilize industry-standard charging technology so your heavy-duty electric vehicles, utility vehicles, and cars can share the same standardized chargers.

COMPATIBLE CONNECTIONS

UNIVERSAL PLUG-IN

PANTOGRAPH

Proterra charging systems are compliant with Federal DOT Buy America requirements.

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SPEC_CHG SYS_180_2021_Q1

PROTERRA ENERGY™ FLEET SOLUTIONS

1.5 MW PROTERRA® CHARGING SYSTEM

PURPOSE-BUILT CHARGING HARDWARE

Designed with large-scale electric vehicle fleets in mind, the Proterra 1.5 MW Charging System is customizable and can be configured to charge up to 40 vehicles. With high voltage capabilities, this system can connect directly to the grid and avoid the need for separate installation of a transformer, resulting in significant space savings and cost reduction.

POWER ELECTRONICS

Developed in partnership with Power Electronics, Proterra charging systems build on Proterra's experience delivering charging infrastructure while leveraging Power Electronics' 30+ years of experience in solar, energy storage, and electric mobility.

PROTERRA

proterra.com/energy-services

COMPATIBLE CONNECTIONS

UNIVERSAL PLUG-IN

PANTOGRAPH

Proterra® charging systems utilize industry-standard charging technology so your heavy-duty electric vehicles, utility vehicles, and cars can share the same standardized chargers.

1.5 MW PROTERRA® CHARGING SYSTEM

PROTERRA ENERGY™ FLEET SOLUTIONS

ELECTRICAL OUTPUT	1.5 MW System - 480V	1.5 MW System - MV
Charger Continuous DC Output Power	1500 kW	
DC Output Voltage	150-1000 VDC	
Continuous DC Output Current per dispenser	300A (May be vehicle interface limited)	
Continuous DC Output Current per Pantograph	1000A (May be vehicle interface limited)	
Max number of simultaneous DC outputs	20	
Continuous DC Output Power per Pantograph	up to 750 kW	
ELECTRICAL INPUT		
AC Input Power	1613 kW	
AC Input Current	2,156A	*dependent on MV value
AC Input Voltage	480V +/- 10%	4.16kV to 34.5kV
AC Input Topology	4-wire WYE (3ph + GND)	4-wire WYE (3ph + GND)
AC Input Frequency	60 Hz	
Current THD% at full power	<3%	
Power Factor	>0.99	
Efficiency	93%	
MECHANICAL		
Cooling	Integrated air cooling	
Weight	17,857 lbs | 8100 kg	32,187 lbs | 14,600 kg
Dimensions (D x W x H)	219.7 in x 89 in x 79.5 in | 558 cm x 226 cm x 202 cm	335.4 in x 89 in x 79.5 in | 852 cm x 226 cm x 202 cm
Wall Clearance (front, back)	48 in | 120cm	
Wall Clearance (sides)	60 in | 150 cm	63 in | 160 cm
ENVIRONMENTAL		
Environmental Rating	NEMA 3R	
Maximum Altitude	3000m | 9800 ft (power derates above 2000m | 6500 ft)	
Operating temperature	-13°F to 122°F | -25°C to 50°C (standard) -22°F to 122°F | -30°C to 50°C (optional)	
Operating Humidity	4-95%	
MISC		
Approved charger-to-vehicle interfaces	CCS1 Industrial dispenser J3105-1 Infrastructure-down Pantograph	
Max number of dispensers per 1.5MW Charger	Supports simultaneous charging with 20 dispensers. Optionally supports charging up to 40 vehicles with two CCS1 cables per dispenser charging sequentially.	
Max number of pantographs per 1.5MW Charger	Supports simultaneous charging on 2 pantographs (standard) Can support 2x pantographs or 1x pantograph and up to 10 dispensers	
1.5MW Charger to dispenser or pantograph control box communications	Modbus TCP via Ethernet (standard) Modbus TCP via fiber optic (optional)	
Max Distance between 1.5MW Charger and Dispenser	300 ft | 91.4 m (ethernet) 500 ft | 152.4 m (fiber optics)	
V2G Capable	Yes (optional)	
Management Communications	OCPP 1.6 control via 4G Cellular (standard) Supports WiFi, Ethernet (optional)	
Certifications	UL 2231, UL 2202, UL 1741SA, IEEE 1547 (pending)	
Warranty	3 year standard, 5 year extended warranty options available	

Proterra charging systems are compliant with Federal DOT Buy America requirements.

PCS_SPEC_1.5_2020_Q4

PROTERRA ENERGY

PROTERRA®
CHARGING SYSTEMS

RELIABLE DC FAST CHARGING FOR FLEETS

The Proterra Industrial dispenser is designed explicitly for fleet applications.

Charge up to 4 vehicles from the same charger with automated, multi-dispenser configurations, including up to 4 single-cable dispensers or 2 dual-cable dispensers.

Dispensers can be sited separately (up to 500 feet away) from the charging cabinet, enabling greater flexibility in design and configuration for fleets.

Remote monitoring, intelligent diagnostics and a modular design allows for quick issue resolution and efficient field service.

Broad voltage range (up to 1000VDC) ensures compatibility with both today's and next generation electric vehicles.

- **OCPP compliant and 4G enabled**
- **200A and 300A cables available**
- **Supports CCS1**
- **3 Year Standard Warranty with extensions available.**

INDUSTRIAL SERIES

PROTERRA

Proterra charging systems are compliant with Federal DOT Buy America requirements.

PROTERRA ENERGY

PROTERRA®
CHARGING SYSTEMS

MODEL	PD-200-1-PI	PD-300-1-PI
ELECTRICAL OUTPUT		
DC Output Voltage	150-1000 VDC	
Max Continuous DC Output Current	200A	300A
MECHANICAL		
Cooling	Integrated air cooling	
Weight w/o pedestal (wall mounted)	130 lbs | 59 kg	
Weight with pedestal	183 lbs | 83 kg	
Dimensions w/o pedestal (wall mounted) (D x W x H)	12 in x 24 in x 31.5 in | 30.5 cm x 61 cm x 80 cm	
Dimensions w pedestal (D x W x H)	12 in x 24 in x 56.7 in | 30.5 cm x 61 cm x 145 cm	
Required side clearance	40 in | 1 m	
Required back clearance	None	
Required door Clearance	24 in | 61 cm	
ENVIRONMENTAL		
Environmental Rating	NEMA 3R	
Maximum Altitude	3000m, power derates above 2000m	
Operating temperature	-22°F to 122°F | -30°C to 50°C	
Operating Humidity	4-95%	
MISC		
Approved charger-to-vehicle interfaces	J1772 CCS Type 1 Universal Plug-in	
CCS Cable Lengths	18, 25 ft (optional)	
Number of CCS output cables per industrial dispenser	1 CCS1 Cable (standard) 2 CCS1 Cables (optional, sequential operation) 2 CCS1 Cables (optional, simultaneous operation)	
Approved number of dispensers per power cabinet	single dispensers or 2 double dispensers, 4 operating sequentially	
Power Cabinet to dispenser or pantograph control box communications	Modbus TCP via fiber optic	
Max Distance between Power Cabinet and Dispenser	500 ft | 152.4 m (fiber optics)	
V2G Capable	Yes (optional)	
Management Communications	OCPP 1.6 control via 4G Cellular (standard) Supports WiFi, Ethernet (optional)	
User Interface	Stop session button, Emergency stop button, Status LED	
Certifications	UL 2231, UL 2202, UL 1741SA, IEEE 1547 (pending)	
Warranty	3 year standard, 5 year extended warranty options available	

SPEC_CHG SYS DISP_NBi_Q3_2021

PROTERRA

On Route Charging Equipment
Note: Spec Sheets provided are preliminary and subject to change

Headquarters
1815 Rollins Road, Burlingame, CA 94010

East Coast Manufacturing
1 Whitlee Court, Greenville, SC 29607

West Coast Manufacturing
383 Cheryl Lane, City of Industry, CA 91789

www.proterra.com

PROTERRA
ENERGY™
FLEET SOLUTIONS

240 kW PROTERRA® CHARGING SYSTEM

PURPOSE-BUILT CHARGING HARDWARE

The Proterra 240 kW Charging System is designed for fleets requiring faster charge times, and is only available for overhead or plug-in charging. This high-power charging system is modular and allows for simplified scalability as your electric fleet grows. The Proterra 240 kW Charging System can charge a Proterra ZX5+ electric transit bus in approximately 2 hours*.

- **Standardized and Interoperable**
- **Modular and Scalable**
- **Intelligent and Automated**
- **High Reliability**

Open source communications protocol

V2G Bi-directional V2G capability

Smart grid ready

Telematics-enabled

PROTERRA

POWER ELECTRONICS

Developed in partnership with Power Electronics, Proterra charging systems build on Proterra's experience delivering charging infrastructure while leveraging Power Electronics' 30+ years of experience in solar, energy storage, and electric mobility.

*Subject to change based on operating, environmental and other conditions.

240 kW PROTERRA® CHARGING SYSTEM

PROTERRA ENERGY™
FLEET SOLUTIONS

ELECTRICAL OUTPUT	
Continuous DC Output Power	240 kW
DC Output Voltage	150-1000 VDC
Continuous DC Output Current	750A (May be vehicle interface limited)
ELECTRICAL INPUT	
AC Input Power	266 kW
AC Input Current	355A
AC Input Voltage	480V +/- 10%
AC Input Topology	5-wire WYE (3ph + N + GND)
AC Input Frequency	60 Hz
Current THD% at full power	<3%
Power Factor	>0.99
Efficiency	95%
MECHANICAL	
Cooling	Integrated air cooling
Weight	2094 lb | 950 kg
Dimensions (D x W x H)	31.5 in x 63 in x 78.7 in | 80 cm x 160 cm x 200 cm
Required side and back clearance	None
Required Door Clearance	1600 mm
ENVIRONMENTAL	
Environmental Rating	NEMA 3R
Maximum Altitude	3000m | 9800 ft (power derates above 2000m | 6500 ft)
Operating temperature	-13°F to 122°F | -25°C to 50°C (standard) -22°F to 122°F | -30°C to 50°C (optional)
Operating Humidity	4-95%
MISC	
Approved charger-to-vehicle interfaces	J3105-1 Infrastructure-Down Pantograph, CCS1 Industrial Dispenser
Approved number of dispensers per power cabinet	Supports simultaneous charging with up to 3 dispensers, and sequential charging with up to 6 vehicles
Approved number of pantograph interfaces per power cabinet	1
Power Cabinet to dispenser or pantograph control box communications	Modbus TCP via Ethernet (standard) Modbus TCP via fiber optic (optional)
Max Distance between Power Cabinet and Dispenser	300 ft | 91.4 m (ethernet) 500 ft | 152.4 m (fiber optics)
V2G Capable	Yes (optional)
Management Communications	OCPP 1.6 control via 4G Cellular (standard) Supports WiFi, Ethernet (optional)
Certifications	UL 2231, UL 2202, UL 1741SA, IEEE 1547 (pending)
Warranty	3 year standard, 5 year extended warranty options available

STANDARDIZED TECHNOLOGY

Proterra® charging systems utilize industry-standard charging technology so your heavy-duty electric vehicles, utility vehicles, and cars can share the same standardized chargers.

COMPATIBLE CONNECTIONS

UNIVERSAL PLUG-IN

PANTOGRAPH

Proterra charging systems are compliant with Federal DOT Buy America requirements.

proterra.com/energy-services

PCS_SPEC_250_2020_Q4

PROTERRA ENERGY™ FLEET SOLUTIONS

480 kW PROTERRA® CHARGING SYSTEM

PURPOSE-BUILT CHARGING HARDWARE

The Proterra 480 kW Charging System is designed for fleets requiring faster charge times and is available for over-head or plug-in charging. This high-power charging system is modular and allows for simplified scalability as your electric fleet grows. Suitable for depot charging or on-route charging, the Proterra 480 kW Charging System can replenish enough energy in just 10 minutes to provide approximately 33 miles* of range for a Proterra ZX5+ transit bus, or can be configured to fully chargea ZX5+ in 2 hours*.

- **Standardized and Interoperable**
- **Modular and Scalable**
- **Intelligent and Automated**
- **High Reliability**

Open source communications protocol

V2G Bi-directional V2G capability

Smart grid ready

Telematics-enabled

PROTERRA

*Subject to change based on operating, environmental and other conditions.

POWER ELECTRONICS

Developed in partnership with Power Electronics, Proterra charging systems build on Proterra's experience delivering charging infrastructure while leveraging Power Electronics' 30+ years of experience in solar, energy storage, and electric mobility.

480 kW PROTERRA® CHARGING SYSTEM

PROTERRA ENERGY™
FLEET SOLUTIONS

ELECTRICAL OUTPUT	
Continuous DC Output Power	500 kW
DC Output Voltage	150-1000 VDC
Continuous DC Output Current	1000A (May be vehicle interface limited)
ELECTRICAL INPUT	
AC Input Power	532 kW
AC Input Current	710A
AC Input Voltage	480V +/- 10%
AC Input Topology	5-wire WYE (3ph + N + GND)
AC Input Frequency	60 Hz
Current THD% at full power	<3%
Power Factor	>0.99
Efficiency	94%
MECHANICAL	
Cooling	Integrated air cooling
Weight	4188 lb | 1900 kg
Dimensions (D x W x H)	31.5 in x 126 in x 78.7 in | 80 cm x 320 cm x 200 cm
Required side and back clearance	None
Required Door Clearance	1600 mm
ENVIRONMENTAL	
Environmental Rating	NEMA 3R
Maximum Altitude	3000m | 9800 ft (power derates above 2000m | 6500 ft)
Operating temperature	-13°F to 122°F | -25°C to 50°C (standard) -22°F to 122°F | -30°C to 50°C (optional)
Operating Humidity	4-95%
MISC	
Approved charger-to-vehicle interfaces	J3105-1 Infrastructure-Down Pantograph, CCS1 Industrial Dispenser
Approved number of dispensers per power cabinet	Supports simultaneous charging with up to 6 dispensers, and sequential charging with up to 12 vehicles
Approved number of pantograph interfaces per power cabinet	1
Power Cabinet to dispenser or pantograph control box communications	Modbus TCP via Ethernet (standard) Modbus TCP via fiber optic (optional)
Max Distance between Power Cabinet and Dispenser	300 ft | 91.4 m (ethernet) 500 ft | 152.4 m (fiber optics)
V2G Capable	Yes (optional)
Management Communications	OCPP 1.6 control via 4G Cellular (standard) Supports WiFi, Ethernet (optional)
Certifications	UL 2231, UL 2202, UL 1741SA, IEEE 1547 (pending)
Warranty	3 year standard, 5 year extended warranty options available

STANDARDIZED TECHNOLOGY

Proterra® charging systems utilize industry-standard charging technology so your heavy-duty electric vehicles, utility vehicles, and cars can share the same standardized chargers.

COMPATIBLE CONNECTIONS

UNIVERSAL PLUG-IN

PANTOGRAPH

Proterra charging systems are compliant with Federal DOT Buy America requirements.

proterra.com/energy-services

PCS_SPEC_500_2020_Q4

PROTERRA

Performance Reporting (TS 89.3)

Proterra's fleet management software has several options for vehicle and charger monitoring. A standard monitoring subscription is included with Proterra vehicles. This includes the ability to access information about vehicle and charger performance such as status and current activity. More advanced reporting capabilities are available at a higher subscription level to provide insights into charging sessions, energy usage, alerts and diagnostics, and operational efficiencies. If an agency is interested in advanced reporting capabilities, Proterra would be happy to provide pricing on an annual subscription basis.

PROTERRA

Exportable Power Supply (TS 90)

Proterra has done preliminary work with our vehicles to prepare them to be capable of discharging power from the bus when it is stationary. In addition, Proterra has developed advanced vehicle-to-grid (V2G) and vehicle-to-building (V2B) capabilities with our chargers and fleet integration software to allow energy from Proterra batteries in vehicles to be accessed in the future. However, the international communications protocol standard, ISO 15118-20, that governs vehicle to grid communication for bi-directional charging/discharging of electric vehicles, has not yet been finalized. This standard, which applies to charging software within the bus, is planned to be completed in late 2021 or 2022. Proterra expects to be able to more broadly support these types of capabilities once changes in this new standard are fully incorporated. These features will be optional and not standard on the vehicle and additional pricing will apply. Proterra can work with the Agency during the contracting period to incorporate these types of features if/when the communications standard is finalized, and a timeline is available.

3. Acknowledgment of Addenda

CER 3. Acknowledgement of Addenda

Failure to acknowledge receipt of all addenda may cause the Proposal to be considered nonresponsive to the Solicitation. Acknowledged receipt of each addendum must be clearly established and included with the Proposal.

The undersigned acknowledges receipt of the following addenda to the documents:

Addendum No.:	1	Dated:	7/29/2021	Addendum No.:	5	Date:	9/1/2021
Addendum No.:	2	Dated:	8/5/2021	Addendum No.:	6	Date:	9/10/2021
Addendum No.:	3	Dated:	8/17/2021	Addendum No.:	7	Date:	9/15/2021
Addendum No.:	4	Dated:	8/30/2021	Addendum No.:	8	Date:	9/20/2021

Proposer: Proterra Operating Company, Inc.
Name: Devin Ikenberry
Title: Sr. Business Engagement Manager
Phone: (256) 499-5696
Street address: 1815 Rollins Rd.
City, state, ZIP: Burlingame, CA 94010

DocuSigned by:
John Walsh
190E3CD36916412...

September 20, 2021

Authorized signature — Date

Pinellas Suncoast Transit Authority

4. Contractor Service & Parts Support Data

CER 4. Contractor Service and Parts Support Data

Location of nearest Technical Service Representative to Agency

Name:	Ian Sherman	Jeremy Clemens	William Bramley
Address:	Miami, FL	Orlando, FL	Fort Lauderdale, FL
Telephone:	(864) 438-0000		

Describe technical services readily available from said representative:
Ian, Jeremy, and William will provide full technical support to ensure successful product launch and operation. They will also have access to Proterra's complete Customer Service Team as needed.

Location of nearest Parts Distribution Center to Agency:

Name: Proterra Operating Company, Inc.
Address: 1 Whitlee Ct. Greenville, SC 29607
Telephone: (864) 438-0000
Describe the extent of parts available at said center:
This Proterra location is where the buses for Pinellas Suncoast Transit Authority will be manufactured, and will house all parts required to maintain and support Proterra buses.

Policy for delivery of parts and components to be purchased for service and maintenance:

Regular method of shipment: UPS / FedEx ground for normal circumstances; Priority Shipping can be arranged as needed
Cost to Agency: During warranty period, all shipping is covered by Proterra. After warranty period, cost will vary based on actual shipping cost due to size, weight and shipping method

PROTERRA

Pinellas Suncoast Transit Authority

5. Form for Proposal Deviation

CER 5. Form for Proposal Deviation

This form shall be completed for each condition, exception, reservation or understanding (i.e., Deviation) in the Proposal according to "Conditions, Exceptions, Reservations or Understandings." One copy without any price/cost information is to be placed in the Technical Proposal as specified in "Technical Proposal Requirements," and a separate copy with any price/cost information placed in the Price Proposal as specified in "Price Proposal Requirements."

PSTA
[RFP 21-980369]

Deviation No.:	**Contractor:**	**RFP section:**	**Page:**
Complete description of Deviation: None			
Rationale (pros and cons):			

PROTERRA

Pinellas Suncoast Transit Authority

6. Vehicle Questionnaire

RFP 21-980369

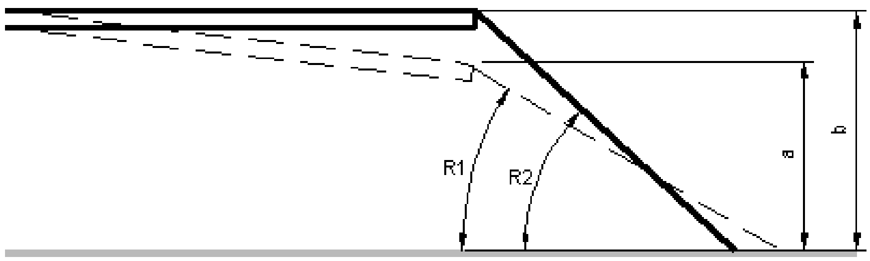
CER 10. Vehicle Technical Information

This form must be completed and included in the Technical Proposal. NOTE—one form must be completed for each type of bus submitted in response to this RFP

GENERAL COACH DATA SHEET						
Bus manufacturer:	Proterra Inc					
Bus model:	ZX5					
Understructure manufacturer:	Proterra Inc					
Model number:	ZX5+					
Size/Type of Bus	35' Transit Bus					
Basic Body Construction						
Type:	Composite Monocoque					
Tubing or frame member thickness and dimensions						
Overstructure	N/A					
Understructure	N/A					
Skin thickness and material						
Roof	1.38 inch, Composite Laminate					
Sidewall	0.94 inch, Composite Laminate					
Skirt panel	1.00 inch, Composite Laminate					
Front end	1.30 inch, Composite Laminate					
Rear end	0.90 inch, Composite Laminate					
Dimensions						
Overall length	Over bumpers	36	ft	11	in.	
	Over body	35	ft	10	in.	
Overall width	Over body excluding mirrors	8	ft	6	in.	
	Over body including mirrors–driving position	10	ft	0	in.	
	Over tires front axles	8	ft	3	in.	
	Over tires center axle	N/A	ft	N/A	in.	
	Over tires rear axles	8	ft	3	in.	
Overall height (maximum)		10	ft	9	in.	
Overall height (main roof line)		10	ft	9	in.	
Angle of approach	9.3	deg				
Breakover angle	9.4	deg				
Breakover angle (rear)	N/A	deg				
Angle of departure	9.3	deg				

Doorway Dimensions	Front		Rear	
Width between door posts	43.2	in.	49.1	in.
Door width between panels	33.2	in.	49.1	in.
Clear door width	33.2	in.	39	in.
Doorway height	75	in.	75	in.
Knuckle clearance	1.625	in.	1.625	in.

Step height from ground measured at center of doorway



	Front doorway, empty			Ramp angle			Rear Doorway, empty		
Kneeled	a.	13	in.	R1	10	deg	a.	14.4	in.
Unkneeled	b.	15.7	in.	R2	15	deg	b.	17.1	in.

Interior head room (center of aisle)

Front axle location	90	in.
Center axle location	N/A	in.
Rear axle location	75	in.

Aisle width between transverse seats	25.8	in.

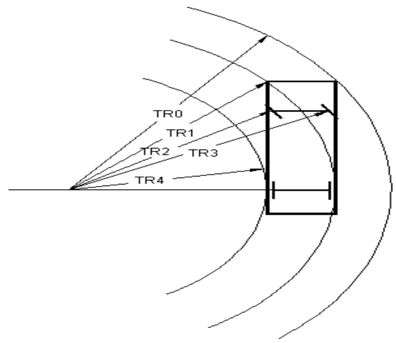
Floor height above ground (centerline of bus)

At front door	17.1	in.
At front axle	18.1	in.
At drive axle	34.1	in.
At rear door	18.1	in.

Minimum ground clearance (between bus and ground, with bus unkneeled)

Excluding axles	9	in.
Including axles	6	in.

Horizontal turning envelope (see diagram below)				
Outside body turning radius, TR0 (including bumper)	38	ft	7.2	in.
Front inner corner radius, TR1	33	ft	8.4	in.
Front wheel inner turning radius, TR2	27	ft	0	in.
Front wheel outer turning radius, TR3	33	ft	3.6	in.
Inside Body Turning Radius innermost point, TR4 (including bumper)	17	ft	9.6	in.



Wheel base

Front	20.2	ft.
Rear	N/A	ft.

Overhang, centerline of axle over bumper

Front	8.58	in.
Rear	7.9	in.

Floor

Interior length	32	ft	0	in.
Interior width (excluding coving)	7	ft	9	in.
Total standee area (approximately)	33.4	sq ft		
Minimum distance between wheelhouses:	Front		35.3	in.
	Rear		23.6	in.
	Center		N/A	in.
Maximum interior floor slope (from horizontal)	1.5	deg		

Passenger capacity provided

Total maximum seating	29	
Standee capacity	22	
Minimum hip to knee room	26	in.
Minimum foot room	14	in.

Weight

	No. of people	Front axle			Center axle			Rear axle			Total bus
		Left	Right	Total	Left	Right	Total	Left	Right	Total	

Empty bus, full fuel and farebox	0	6,680	6,680	13,360	N/A	N/A	N/A	8,625	8,625	17,250	30,610
Fully seated, full fuel and farebox	30	7,467	7,468	14,935	N/A	N/A	N/A	10,087	10,088	20,175	35,110
Fully loaded standee and fully seated, full fuel and farebox	52	8,292	8,293	16,585	N/A	N/A	N/A	10,912	10,913	21,825	38,410
Crush load (1.5x fully loaded)	78	9,267	9,268	18,535	N/A	N/A	N/A	11,887	11,888	23,775	42,310
GVWR	-	-	-	-	N/A	N/A	N/A	-	-	-	43,650
GAWR	-	-	-	18,078	N/A	N/A	N/A	-	-	28,660	

Energy Storage

Batteries – low voltage

Manufacturer	X2Power	
Type	Group 31 AGM	
Model number	SLI31AGMDPM	
Cold Cranking Amps	1150	Amps

Cranking Amps	-	Amps
Reserve Capacity	-	Amps

Batteries – high voltage

Manufacturer	Proterra
Type	Lithium Ion
Model Number	Proterra HV Pack
Total Battery Capacity (kWh)	452
Standard Charge Time	2 hrs (overhead), 2.9 hrs (plug-in)
Charging Capacity	TBD
Operating Temperature Range	-4 to 131 deg F
Cooling/Heating System	Valeo

Performance

Fuel Economy (w/full passenger load, HVAC, and all electric accessories in use)	**	kWh	*****Please refer to simulation report (SIM-R2021-038A-PSTA)***
Fuel Economy (w/full passenger load, HVAC, and all electric accessories in use)	**	MPGE	*****Please refer to simulation report (SIM-R2021-038A-PSTA)***
Max Gradeability	34	%	
Top Speed	65	MPH	
Battery Range	**	Miles	*****Please refer to simulation report (SIM-R2021-038A-PSTA)***
Acceleration (20 MPH)	7.3	Seconds	
Acceleration (40 MPH)	22.7	Seconds	
Top Speed (stated above)	62.9	Seconds	

Performance information/graphs to be attached with this form:

Energy consumption vs. Vehicle speed

Vehicle speed vs. time (both loaded and unloaded)

Vehicle speed vs. grade (both loaded and unloaded)

Acceleration vs. time

Change of acceleration vs. time

*****Please refer to simulation report (SIM-R2021-038A-PSTA) for performance graphs***

Traction Motor/Drive Motor

Manufacturer	Parker			
Type	GVM310			
Speeds	6,000 RPM max			
Traction motor horsepower rating	N/A			
Type ventilation/cooling	Glycol/water 50/50%			
Gear ratios	Forward:	Competition Sensitive	Reverse:	Competition Sensitive

Voltage Equalizer

Manufacturer	Vanner
Model	70-60 CAN

Auxiliary Inverter (120/240)

Manufacturer	Lenze
Model	EMDDAG23003303U00000
Inverter Technology	TBD
Output Voltage	220 V

Traction/Drive Motor		
Manufacturer	Parker	
Type	Brushless, permanent magnet synchronous motor	
Model	GVM310	
Quantity	1	
Torque Rating	850 N-m @ 3000 rpm	
kWh Rating	240 kW @ 3000 rpm	
Air compressor		
Manufacturer	Hydrovane	
Type	Rotary Vane	
Rated capacity	8.96	CFM
Capacity at idle (approximately)	N/A	CFM
Capacity at maximum speed (engine)	N/A	CFM
Maximum warranted speed	2800	rpm
Speed idle	Electric	rpm
Drive type	N/A	
Governor:		
Cut-in pressure	110	psi
Cut-out pressure	130	psi
Axles		
First		
Manufacturer	ZF	
Type	Independent, double A-arm	
Model number	RL-82EC	
Gross axle weight rating	18,078	lb
Axle load	17,067	lb
Second		
Manufacturer	ZF	
Type	Drop Portal	
Model number	AV-133/90	
Gross axle weight rating	28,660	lb
Axle load	22,135	lb
Third		
Manufacturer	N/A	
Type	N/A	
Model number	N/A	
Gross axle weight rating	N/A	lb

Axle load	N/A	lb	
Axle ratio	TBD		
Suspension system			
Manufacturer	ZF		
Type:	First:	Heavy-duty Independent Front Suspension (IFS), Model RL-82EC	
	Second:	H-Frame Beam Rear, Model AV-133/90	
	Third:	N/A	
Springs:	First:	Firestone, Model 1T1SL-4	
	Second:	Firestone, Model 1T1SL-4	
	Third:	N/A	
Joint			
Manufacturer	N/A		
Type	N/A		
Model number	N/A		
Wheels and tires			
Wheels			
Make	Alcoa		
Size	22.5 x 9"		
Capacity	9,090 lbs		
Material	Aluminum		
Tires			
Manufacturer	TBD		
Type	Leased		
Size	Leased		
Load range/air pressure	TBD	psi	
Steering, power			
Pump			
Manufacturer and model number	Eaton, Vickers V10		
Type	Hydraulic Vane Pump		
Relief pressure	2100	psi	
Booster/gear box			
Manufacturer and model number	TRW, TAS85153A		
Type	Fully integral, recirculating ball		
Ratio	21:1		
Power steering fluid capacity	2	gal	
Maximum effort at steering wheel	20	lb (unloaded stationary coach on dry asphalt pavement)	
Steering wheel diameter	18	in.	

Brakes			
Make of fundamental brake system	Knorr-Bremse		
Brake chambers vendor size and part number:	First:	Type 24	
	Second:	Type 24/24	
	Third:	N/A	
Brake operation effort	75 lbs		
Slack adjuster's vendor's type and part numbers			
First:	Right:	N/A	
	Left:	N/A	
Second:	Right:	N/A	
	Left:	N/A	
Third:	Right:	N/A	
	Left:	N/A	
Length:	First take-up:	N/A	
	Second take-up:	N/A	
	Third take-up:	N/A	
Brake _____Drums __X__Discs (Place X denoting type)			
First:	Manufacturer	Knorr-Bremse	
	Part number	0501.316.953	
	Diameter	17	in.
Second:	Manufacturer	Knorr-Bremse	
	Part number	0501.316.953	
	Diameter	17	in.
Third:	Manufacturer	N/A	
	Part number	N/A	
	Diameter	N/A	in.
Brake lining/pad manufacturer	MAT Holdings		
Type	Premium Long Life		
Brake lining/pad identification			
First:	Forward	MAT 6900	
	Reverse	MAT 6900	
Second:	Forward	MAT 6900	
	Reverse	MAT 6900	
Third:	Forward	N/A	
	Reverse	N/A	
Brake linings per shoe			

First	N/A			
Second	N/A			
Third	N/A			
Brake lining widths				
First	3.23	in.		
Second	3.23	in.		
Third	N/A	in.		
Brake lining/pad lengths				
First	4.72	in.		
Second	4.72	in.		
Third	N/A	in.		
Brake lining thickness/pad	0.83	in.		
Brake lining/pad per axle				
First	61	sq. in.		
Second	61	sq. in.		
Third	N/A	sq. in.		
Cooling system				
Radiator				
Manufacturer	Modine			
Type	Liquid to air heat exchanger			
Model number	1A021657000			
Number of tubes	88			
Tubes outer diameter	0.75	in./	N/A	in.
Fins per inch	88	fins		
Fin thickness	0.004	in.		
Total cooling and heating system capacity	*	gal	*12 gal in power electronics loop; 13 gal in battery loop*	
Radiator fan speed control	Electric			
Surge tank capacity	14.8	qt		
Thermostat temperature setting:	Initial opening (fully closed)	N/A	°F	
	Fully open	N/A	°F	
Overheat alarm temperature sending unit setting	320	°F		
Shutdown temperature setting	221	°F		
Air reservoir capacity				
Supply reservoir	18.30	cu in.		
Primary reservoir	1,848	cu in.		
Secondary reservoir	1,848	cu in.		

Packing reservoir	577.5	cu in.
Accessory reservoir	2x 1,848	cu in.
Other reservoir type	N/A	cu in.

Heating, ventilation and air conditioning equipment

Heating system capacity	68,000	BTU/hr
Air conditioning capacity	102,000	BTU
Ventilating capacity	4,000*	CFM *(recirc, 10% of which is fresh air option)

Compressor

Manufacturer	Sanyo	
Model	C-SWS225H00A	
Number of cylinders	N/A	
Drive ratio	Direct	
Maximum warranted speed	5,400	rpm
Operating speed	5,400	rpm (recommended)
Weight	99	lb

Oil capacity	Dry	0.42	gal		
	Wet	TBD	gal		
Refrigerant:	Type	R407C			lb

Condenser

Manufacturer	Kayer	
Model	TBD	
Number of fins/in.	14	
Outer diameter of tube	3/8	in.
Fin thickness	0.008	in.

Condenser fan

Manufacturer	Spal	
Model	TBD	
Fan diameter	12	in.
Speed maximum	4100	rpm
Flow rate (maximum)	2200	CFM

Receiver

Manufacturer	Valeo Supply	
Model	TBD	
Capacity	0.5 approx.	lb

Condenser fan drive motors

Manufacturer	Spal

Model	TBD	
Type	Centrifugal	
Horsepower	2	hp
Operating speed	TBD	rpm
Evaporator fan drive motors		
Manufacturer	Spal	
Model	TBD	
Type	Centrifugal	
Horsepower	2	hp
Operating speed	TBD	rpm
Evaporator(s)		
Manufacturer	Kayer	
Model	TBD	
Number of rows	4	
Number of fins/in.	14	
Outer diameter of tube	3/8	in.
Fin thickness	0.008	in.
Number of evaporators	2	
Expansion valve		
Manufacturer	Danfoss	
Model	TBD	
Filter-drier		
Manufacturer	Valeo, integrated with receiver	
Model	TBD	
Heater cores		
Manufacturer	PTC Heater	
Model	TBD	
Capacity	68,000	Btu/hr
Number of rows	N/A	
Number of fins/in.	N/A	
Outer diameter of tube	N/A	in.
Fin thickness	N/A	in.
Number of heater cores	N/A	
Floor heater blowers		
Front	N/A	
Rear	N/A	

Controls		
Manufacturer	Valeo	
Model	SC600, CAN Controlled	
Driver's heater		
Manufacturer	TBD	
Model	TBD	
Capacity	TBD	Btu/hr
Ventilation system		
Type	In HVAC	
Coolant heater		
Make	TBD	
Model	TBD	
Capacity	TBD	Btu

Interior lighting		
Manufacturer	Pretoria	
Type	LED	
Number of fixtures	N/A	Lights are built into the overhead system with covers)
Size of fixtures	N/A	
Power pack	TBD	

Doors	
Front	
Manufacturer of operating equipment	Ventura
Type of door	In-swinging
Type of operating equipment	Pneumatic
Rear	
Manufacturer of operating equipment	Ventura
Type of door	In-swinging
Type of operating equipment	Pneumatic

Passenger windows			
Front			
Manufacturer	Arow		
Model	Storm-Tite		
Type	Flush-mount, Fixed		
Number:	Side	13	

	Rear	1		
Sizes:	(13) 46" x 39"		(1) 50.45" x 20.32"	
Glazing:	Type	Tempered		
	Thickness	5 mm		
	Color of tint	Gray		
	Light transmission	13%		

Mirrors

	Size	Type	Manufacturer	Part no.	Model no.
Right side exterior	9 x 13"	Cast Steel	SafeFleet	M15CS001-TS	M15CS001-TS
Left side exterior	9 x 13"	Cast Steel	SafeFleet	PR01024-TS	PR01024-TS
Center rearview	16" x 8-14"	Flat	Hadley	A1706-1	A1706-1
Front entrance area	N/A	N/A	N/A	N/A	N/A
Upper-right corner	Ø 8.5"	Flat	Hadley	A1708NF	A1708NF
Rear exit area	Ø 12"	Convex	Hadley	A1712NF-1	A1712NF-1

Seats

Passenger

Manufacturer	USSC
Model	Gemini
Type	Cantilever

Operator

Manufacturer	Recaro
Model and part number	Ergo Metro M384
Type	Pneumatic Suspension

Paint

Manufacturer	TBD
Type	TBD

Wheelchair ramp equipment

Manufacturer	Lift-U
Model number	LU18

Capacity	1,000	lb
Width of platform	30	in.
Length of platform	48	in.
System fluid capacity	N/A	qt
Type of fluid used	N/A	
Operating hydraulic pressure	N/A	psi

Hydraulic cylinders:	Size	N/A	

	Number	N/A	

Wheelchair securement equipment

Manufacturer	Q'Straint
Model number	4pt - Floor Mounted

Destination signs

Manufacturer	Luminator
Type	Smart Series III

Character length		
Front destination	160	in.
Front route	N/A	in.
Curbside destination	112	in.
Rear route	48	in.
Character height		
Front destination	16	in.
Front route	N/A	in.
Curbside destination	14	in.
Rear route	16	in.
Number of characters		
Front destination	TBD	
Front route	TBD	
Curbside destination	TBD	
Rear route	TBD	
Message width		
Front destination	16 x 160"	in.
Front route	N/A	in.
Curbside destination	14 x 112"	in.
Rear route	16 x 48"	in.

Electrical

Multiplex system	
Manufacturer	Continental
Model number	ZR32-B
Batteries	
Manufacturer	X2Power
Model number	SLI31AGMDPM

Type	Group 31 AGM		
Communication system			
GPS			
Manufacturer	TBD		
Model number	TBD		
PA system			
	Manufacturer	**Model number**	**Number**
Amplifier	TBD	TBD	TBD
Microphone	TBD	TBD	TBD
Internal speakers	TBD	TBD	TBD
External speaker	TBD	TBD	TBD
Energy storage			
Type	Lithium Ion		
Number of cells	3.6	V	
Battery pack voltage	648	V	
Weight	1587*	lb	*weight per pack
Security camera system			
Manufacturer	TBD		
Model number	TBD		
Number of cameras	TBD		
Storage capacity	TBD		
Bike racks			
Manufacturer	TBD		
Model number	TBD		
Fire detection system			
Manufacturer	Amerex		
Model number	V25		
Fire detectors	350F Detection Sensors		
Type (thermal or optical)	Thermal		
Number of detectors	4		
Automatic voice annunciator system			
Manufacturer	TBD		
Model and part number	TBD		

Annunciator LED sign		
Number of signs	TBD	
Housing dimensions	TBD	
Character length	TBD	in.
Character height	TBD	in.
Character width	TBD	in.
GPS antenna		
Manufacturer	TBD	
Model and part number	TBD	
Automatic passenger counter		
Manufacturer		TBD
Model and part number	a.	TBD
	b.	TBD
	c.	TBD
Sensor type		TBD

Real-time bus arrival prediction system

	Manufacturer	**Model number**
Router	TBD	TBD
Cellular modem	TBD	TBD
Charge protection	TBD	TBD

NOTE: All information above is accurate to the timeframe upon submission. The Agency reserves the right to update above data if changes occur, upon consultation with the customer.

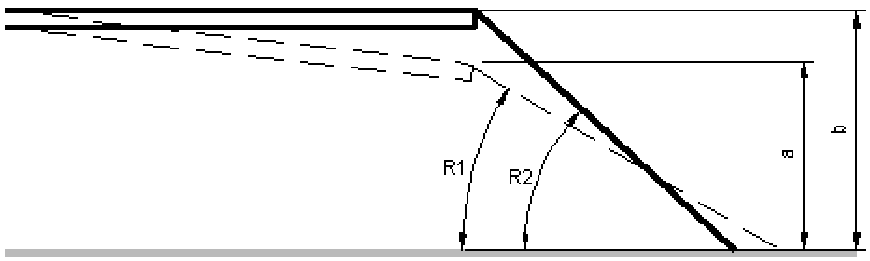
CER 10. Vehicle Technical Information

This form must be completed and included in the Technical Proposal. NOTE—one form must be completed for each type of bus submitted in response to this RFP

GENERAL COACH DATA SHEET						
Bus manufacturer:	Proterra Inc					
Bus model:	ZX5					
Understructure manufacturer:	Proterra Inc					
Model number:	ZX5+					
Size/Type of Bus	40' Transit Bus					
Basic Body Construction						
Type:	Composite Monocoque					
Tubing or frame member thickness and dimensions						
Overstructure	N/A					
Understructure	N/A					
Skin thickness and material						
Roof	1.38 inch, Composite Laminate					
Sidewall	0.94 inch, Composite Laminate					
Skirt panel	1.00 inch, Composite Laminate					
Front end	1.30 inch, Composite Laminate					
Rear end	0.90 inch, Composite Laminate					
Dimensions						
Overall length	Over bumpers	42	ft	6	in.	
	Over body	41	ft	5	in.	
Overall width	Over body excluding mirrors	8	ft	6	in.	
	Over body including mirrors–driving position	9	ft	8	in.	
	Over tires front axles	6	ft	3	in.	
	Over tires center axle	N/A	ft	N/A	in.	
	Over tires rear axles	6	ft	3	in.	
Overall height (maximum)		10	ft	9	in.	
Overall height (main roof line)		10	ft	9	in.	
Angle of approach	9.3	deg				
Breakover angle	7.8	deg				
Breakover angle (rear)	N/A	deg				
Angle of departure	9.3	deg				

Doorway Dimensions	Front		Rear	
Width between door posts	43.2	in.	49.1	in.
Door width between panels	33.2	in.	49.1	in.
Clear door width	33.2	in.	39	in.
Doorway height	75	in.	75	in.
Knuckle clearance	1.625	in.	1.625	in.

Step height from ground measured at center of doorway



	Front doorway, empty			Ramp angle			Rear Doorway, empty		
Kneeled	a.	13	in.	R1	10	deg	a.	14.4	in.
Unkneeled	b.	15.7	in.	R2	15	deg	b.	17.1	in.

Interior head room (center of aisle)

Front axle location	90	in.
Center axle location	N/A	in.
Rear axle location	75	in.

Aisle width between transverse seats	25.8	in.

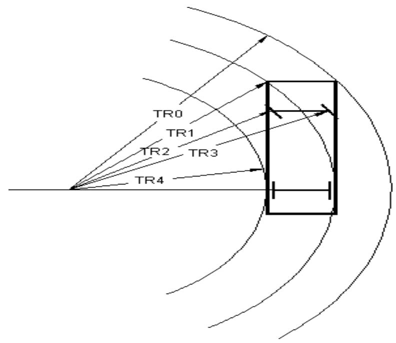
Floor height above ground (centerline of bus)

At front door	17.1	in.
At front axle	18.1	in.
At drive axle	34.1	in.
At rear door	18.1	in.

Minimum ground clearance (between bus and ground, with bus unkneeled)

Excluding axles	9	in.
Including axles	6	in.

Horizontal turning envelope (see diagram below)				
Outside body turning radius, TR0 (including bumper)	42	ft	0	in.
Front inner corner radius, TR1	37	ft	2.4	in.
Front wheel inner turning radius, TR2	36	ft	2.4	in.
Front wheel outer turning radius, TR3	30	ft	2.4	in.
Inside Body Turning Radius innermost point, TR4 (including bumper)	17	ft	9.6	in.



Wheel base

Front	24.7	ft.
Rear	N/A	ft.

Overhang, centerline of axle over bumper

Front	8.58	in.
Rear	9.25	in.

Floor

Interior length	32	ft	6	in.
Interior width (excluding coving)	7	ft	8	in.
Total standee area (approximately)	47.3	sq ft		
Minimum distance between wheelhouses:	Front		35.3	in.
	Rear		23.6	in.
	Center		N/A	in.
Maximum interior floor slope (from horizontal)	1.5	deg		

Passenger capacity provided

Total maximum seating	40	
Standee capacity	30	
Minimum hip to knee room	26	in.
Minimum foot room	14	in.

Weight

	No. of people	Front axle			Center axle			Rear axle			Total bus
		Left	Right	Total	Left	Right	Total	Left	Right	Total	

Empty bus, full fuel and farebox	0	6,981	6,981	13,962	N/A	N/A	N/A	8,195	8,195	16,390	30,352
Fully seated, full fuel and farebox	41	7,903	7,904	15,807	N/A	N/A	N/A	10,347	10,348	20,695	36,502
Fully loaded standee and fully seated, full fuel and farebox	71	9,028	9,029	18,057	N/A	N/A	N/A	11,472	11,473	22,945	41,002
Crush load (1.5x fully loaded)	106	10,341	10,341	20,682	N/A	N/A	N/A	12,785	12,785	25,570	46,252
GVWR	-	-	-	-	N/A	N/A	N/A	-	-	-	43,650
GAWR	-	-	-	18,078	N/A	N/A	N/A	-	-	28,660	

Energy Storage

Batteries – low voltage

Manufacturer	X2Power	
Type	Group 31 AGM	
Model number	SLI31AGMDPM	
Cold Cranking Amps	1150	Amps

Cranking Amps	-	Amps
Reserve Capacity	-	Amps

Batteries – high voltage

Manufacturer	Proterra
Type	Lithium Ion
Model Number	Proterra HV Pack
Total Battery Capacity (kWh)	452
Standard Charge Time	2 hrs (overhead), 2.9 hrs (plug-in)
Charging Capacity	TBD
Operating Temperature Range	-4 to 131 deg F
Cooling/Heating System	Valeo

Performance

Fuel Economy (w/full passenger load, HVAC, and all electric accessories in use)	**	kWh	****Please refer to simulation report (SIM-R2021-037A-PSTA)***
Fuel Economy (w/full passenger load, HVAC, and all electric accessories in use)	**	MPGE	****Please refer to simulation report (SIM-R2021-037A-PSTA)***
Max Gradeability	35	%	
Top Speed	65	MPH	
Battery Range	**	Miles	****Please refer to simulation report (SIM-R2021-037A-PSTA)***
Acceleration (20 MPH)	7.4	Seconds	
Acceleration (40 MPH)	23.4	Seconds	
Top Speed (stated above)	65.6	Seconds	

Performance information/graphs to be attached with this form:

Energy consumption vs. Vehicle speed

Vehicle speed vs. time (both loaded and unloaded)

Vehicle speed vs. grade (both loaded and unloaded)

Acceleration vs. time

Change of acceleration vs. time

****Please refer to simulation report (SIM-R2021-037A-PSTA) for performance graphs***

Traction Motor/Drive Motor

Manufacturer	Parker			
Type	GVM310			
Speeds	6,000 RPM max			
Traction motor horsepower rating	N/A			
Type ventilation/cooling	Glycol/water 50/50%			
Gear ratios	Forward:	Competition Sensitive	Reverse:	Competition Sensitive

Voltage Equalizer

Manufacturer	Vanner
Model	70-60 CAN

Auxiliary Inverter (120/240)

Manufacturer	Lenze
Model	EMDDAG23003303U00000
Inverter Technology	TBD
Output Voltage	220 V

Traction/Drive Motor			
Manufacturer	Parker		
Type	Brushless, permanent magnet synchronous motor		
Model	GVM310		
Quantity	1		
Torque Rating	850 N-m @ 3000 rpm		
kWh Rating	240 kW @ 3000 rpm		
Air compressor			
Manufacturer	Hydrovane		
Type	Rotary Vane		
Rated capacity		8.96	CFM
Capacity at idle (approximately)		N/A	CFM
Capacity at maximum speed (engine)		N/A	CFM
Maximum warranted speed		2800	rpm
Speed idle		Electric	rpm
Drive type	N/A		
Governor:			
Cut-in pressure		110	psi
Cut-out pressure		130	psi
Axles			
First			
Manufacturer	ZF		
Type	Independent, double A-arm		
Model number	RL-82EC		
Gross axle weight rating		18,078	lb
Axle load		17,067	lb
Second			
Manufacturer	ZF		
Type	Drop Portal		
Model number	AV-133/90		
Gross axle weight rating		28,660	lb
Axle load		22,135	lb
Third			
Manufacturer	N/A		
Type	N/A		
Model number	N/A		
Gross axle weight rating		N/A	lb

Axle load	N/A	lb
Axle ratio	TBD	
Suspension system		
Manufacturer	ZF	
Type:	First:	Heavy-duty Independent Front Suspension (IFS), Model RL-82EC
	Second:	H-Frame Beam Rear, Model AV-133/90
	Third:	N/A
Springs:	First:	Firestone, Model 1T1SL-4
	Second:	Firestone, Model 1T1SL-4
	Third:	N/A
Joint		
Manufacturer	N/A	
Type	N/A	
Model number	N/A	
Wheels and tires		
Wheels		
Make	Alcoa	
Size	22.5 x 9"	
Capacity	9,090 lbs	
Material	Aluminum	
Tires		
Manufacturer	TBD	
Type	Leased	
Size	Leased	
Load range/air pressure	TBD	psi
Steering, power		
Pump		
Manufacturer and model number	Eaton, Vickers V10	
Type	Hydraulic Vane Pump	
Relief pressure	2100	psi
Booster/gear box		
Manufacturer and model number	TRW, TAS85153A	
Type	Fully integral, recirculating ball	
Ratio	21:1	
Power steering fluid capacity	2	gal
Maximum effort at steering wheel	20	lb (unloaded stationary coach on dry asphalt pavement)
Steering wheel diameter	18	in.

Brakes		
Make of fundamental brake system	Knorr-Bremse	
Brake chambers vendor size and part number:	First:	Type 24
	Second:	Type 24/24
	Third:	N/A
Brake operation effort	75 lbs	
Slack adjuster's vendor's type and part numbers		
First:	Right:	N/A
	Left:	N/A
Second:	Right:	N/A
	Left:	N/A
Third:	Right:	N/A
	Left:	N/A
Length:	First take-up:	N/A
	Second take-up:	N/A
	Third take-up:	N/A
Brake _____Drums __X__Discs (Place X denoting type)		
First:	Manufacturer	Knorr-Bremse
	Part number	0501.316.953
	Diameter	17 in.
Second:	Manufacturer	Knorr-Bremse
	Part number	0501.316.953
	Diameter	17 in.
Third:	Manufacturer	N/A
	Part number	N/A
	Diameter	N/A in.
Brake lining/pad manufacturer	MAT Holdings	
Type	Premium Long Life	
Brake lining/pad identification		
First:	Forward	MAT 6900
	Reverse	MAT 6900
Second:	Forward	MAT 6900
	Reverse	MAT 6900
Third:	Forward	N/A
	Reverse	N/A
Brake linings per shoe		

First	N/A	
Second	N/A	
Third	N/A	
Brake lining widths		
First	3.23	in.
Second	3.23	in.
Third	N/A	in.
Brake lining/pad lengths		
First	4.72	in.
Second	4.72	in.
Third	N/A	in.
Brake lining thickness/pad	0.83	in.
Brake lining/pad per axle		
First	61	sq. in.
Second	61	sq. in.
Third	N/A	sq. in.

Cooling system

Radiator					
Manufacturer	Modine				
Type	Liquid to air heat exchanger				
Model number	1A021657000				
Number of tubes	88				
Tubes outer diameter	0.75	in./	N/A	in.	
Fins per inch	88	fins			
Fin thickness	0.004	in.			
Total cooling and heating system capacity	*	gal	**12 gal in power electronics loop; 13 gal in battery loop*		
Radiator fan speed control	Electric				
Surge tank capacity	14.8	qt			
Thermostat temperature setting:	Initial opening (fully closed)	N/A	°F		
	Fully open	N/A	°F		
Overheat alarm temperature sending unit setting	320	°F			
Shutdown temperature setting	221	°F			

Air reservoir capacity

Supply reservoir	18.30	cu in.
Primary reservoir	1,848	cu in.
Secondary reservoir	1,848	cu in.

Packing reservoir	577.5	cu in.
Accessory reservoir	2x 1,848	cu in.
Other reservoir type	N/A	cu in.

Heating, ventilation and air conditioning equipment

Heating system capacity	68,000	BTU/hr
Air conditioning capacity	102,000	BTU
Ventilating capacity	4,000*	CFM *(recirc, 10% of which is fresh air option)

Compressor

Manufacturer	Sanyo				
Model	C-SWS225H00A				
Number of cylinders	N/A				
Drive ratio	Direct				
Maximum warranted speed	5,400	rpm			
Operating speed	5,400	rpm (recommended)			
Weight	99	lb			
Oil capacity	Dry	0.42	gal		
	Wet	TBD	gal		
Refrigerant:	Type	R407C		-	lb

Condenser

Manufacturer	Kayer	
Model	TBD	
Number of fins/in.	14	
Outer diameter of tube	3/8	in.
Fin thickness	0.008	in.

Condenser fan

Manufacturer	Spal	
Model	TBD	
Fan diameter	12	in.
Speed maximum	4100	rpm
Flow rate (maximum)	2200	CFM

Receiver

Manufacturer	Valeo Supply	
Model	TBD	
Capacity	0.5 approx.	lb

Condenser fan drive motors

Manufacturer	Spal

Model	TBD	
Type	Centrifugal	
Horsepower	2	hp
Operating speed	TBD	rpm
Evaporator fan drive motors		
Manufacturer	Spal	
Model	TBD	
Type	Centrifugal	
Horsepower	2	hp
Operating speed	TBD	rpm
Evaporator(s)		
Manufacturer	Kayer	
Model	TBD	
Number of rows	4	
Number of fins/in.	14	
Outer diameter of tube	3/8	in.
Fin thickness	0.008	in.
Number of evaporators	2	
Expansion valve		
Manufacturer	Danfoss	
Model	TBD	
Filter-drier		
Manufacturer	Valeo, integrated with receiver	
Model	TBD	
Heater cores		
Manufacturer	PTC Heater	
Model	TBD	
Capacity	68,000	Btu/hr
Number of rows	N/A	
Number of fins/in.	N/A	
Outer diameter of tube	N/A	in.
Fin thickness	N/A	in.
Number of heater cores	N/A	
Floor heater blowers		
Front	N/A	
Rear	N/A	

Controls		
Manufacturer	Valeo	
Model	SC600, CAN Controlled	
Driver's heater		
Manufacturer	TBD	
Model	TBD	
Capacity	TBD	Btu/hr
Ventilation system		
Type	In HVAC	
Coolant heater		
Make	TBD	
Model	TBD	
Capacity	TBD	Btu

Interior lighting		
Manufacturer	Pretoria	
Type	LED	
Number of fixtures	N/A	Lights are built into the overhead system with covers)
Size of fixtures	N/A	
Power pack	TBD	

Doors	
Front	
Manufacturer of operating equipment	Ventura
Type of door	In-swinging
Type of operating equipment	Pneumatic
Rear	
Manufacturer of operating equipment	Ventura
Type of door	In-swinging
Type of operating equipment	Pneumatic

Passenger windows			
Front			
Manufacturer	Arow		
Model	Storm-Tite		
Type	Flush-mount, Fixed		
Number:	Side	13	

	Rear	1	
Sizes:	(13) 46" x 39"	(1) 50.45" x 20.32"	
Glazing:	Type	Tempered	
	Thickness	5 mm	
	Color of tint	Gray	
	Light transmission	13%	

Mirrors

	Size	Type	Manufacturer	Part no.	Model no.
Right side exterior	9 x 13"	Cast Steel	SafeFleet	M15CS001-TS	M15CS001-TS
Left side exterior	9 x 13"	Cast Steel	SafeFleet	PR01024-TS	PR01024-TS
Center rearview	16" x 8-14"	Flat	Hadley	A1706-1	A1706-1
Front entrance area	N/A	N/A	N/A	N/A	N/A
Upper-right corner	Ø 8.5"	Flat	Hadley	A1708NF	A1708NF
Rear exit area	Ø 12"	Convex	Hadley	A1712NF-1	A1712NF-1

Seats

Passenger

Manufacturer	USSC
Model	Gemini
Type	Cantilever

Operator

Manufacturer	Recaro
Model and part number	Ergo Metro M384
Type	Pneumatic Suspension

Paint

Manufacturer	TBD
Type	TBD

Wheelchair ramp equipment

Manufacturer	Lift-U
Model number	LU18

Capacity	1,000	lb
Width of platform	30	in.
Length of platform	48	in.
System fluid capacity	N/A	qt
Type of fluid used	N/A	
Operating hydraulic pressure	N/A	psi

Hydraulic cylinders:	Size	N/A	

	Number	N/A	

Wheelchair securement equipment

Manufacturer	Q'Straint
Model number	4pt - Floor Mounted

Destination signs

Manufacturer	Luminator
Type	Smart Series III

Character length		
Front destination	160	in.
Front route	N/A	in.
Curbside destination	112	in.
Rear route	48	in.
Character height		
Front destination	16	in.
Front route	N/A	in.
Curbside destination	14	in.
Rear route	16	in.
Number of characters		
Front destination	TBD	
Front route	TBD	
Curbside destination	TBD	
Rear route	TBD	
Message width		
Front destination	16 x 160"	in.
Front route	N/A	in.
Curbside destination	14 x 112"	in.
Rear route	16 x 48"	in.

Electrical

Multiplex system	
Manufacturer	Continental
Model number	ZR32-B
Batteries	
Manufacturer	X2Power
Model number	SLI31AGMDPM

Type	Group 31 AGM		
Communication system			
GPS			
Manufacturer	TBD		
Model number	TBD		
PA system			
	Manufacturer	**Model number**	**Number**
Amplifier	TBD	TBD	TBD
Microphone	TBD	TBD	TBD
Internal speakers	TBD	TBD	TBD
External speaker	TBD	TBD	TBD
Energy storage			
Type	Lithium Ion		
Number of cells	3.6	V	
Battery pack voltage	648	V	
Weight	1587*	lb	*weight per pack
Security camera system			
Manufacturer	TBD		
Model number	TBD		
Number of cameras	TBD		
Storage capacity	TBD		
Bike racks			
Manufacturer	TBD		
Model number	TBD		
Fire detection system			
Manufacturer	Amerex		
Model number	V25		
Fire detectors	350F Detection Sensors		
Type (thermal or optical)	Thermal		
Number of detectors	4		
Automatic voice annunciator system			
Manufacturer	TBD		
Model and part number	TBD		

Annunciator LED sign		
Number of signs	TBD	
Housing dimensions	TBD	
Character length	TBD	in.
Character height	TBD	in.
Character width	TBD	in.
GPS antenna		
Manufacturer	TBD	
Model and part number	TBD	
Automatic passenger counter		
Manufacturer		TBD
Model and part number	a.	TBD
	b.	TBD
	c.	TBD
Sensor type		TBD

Real-time bus arrival prediction system

	Manufacturer	Model number
Router	TBD	TBD
Cellular modem	TBD	TBD
Charge protection	TBD	TBD

NOTE: All information above is accurate to the timeframe upon submission. The Agency reserves the right to update above data if changes occur, upon consultation with the customer.

PROTERRA

Pinellas Suncoast Transit Authority

7. References and Non-Priced Information

RFP 21-980369

PROTERRA

Proterra References

1. **Broward County Transit**
   1 N. University Dr. Suite 3100A
   Plantation, FL 33324
   James Fourcade – Director of Maintenance
   garry.hurkens@edmonton.ca
   (780) 496-4478

   Fleet Information:
   Broward County Transit Twelve (12) 40' ZX5 MAX buses that were delivered between August and September 2021.

2. **City of Tallahassee – StarMetro**
   555 Appleyard Dr.
   Tallahassee, FL 32304
   Walter Kirkland – Supervisor of Equipment Services
   Walter.kirklandjr@talgov.com
   (850) 891-5183

   Fleet Information:
   StarMetro is a repeat customer whose first order of three (3) Proterra BE35 buses were accepted in late 2012. StarMetro's second order of thirteen (13) 35' Catalyst E2 buses were accepted in August 2019. Two additional orders for Proterra ZX5 buses are on order with an anticipated delivery in 2022.

3. **GO Raleigh**
   4104 Poole Rd.
   Raleigh, NC 27610
   Byron Bryant – General Manager
   byron.bryant@raleighnc.gov
   (919) 996-3942

   Fleet Informaiton:
   Go Raleigh has a diverse fleet of electric buses, that include
   Two (2) Proterra 40' ZX5 buses and three (3) Proterra Catalyst E2 buses.

PROTERRA

Pinellas Suncoast Transit Authority

8. Engineering Organization Chart, Engineering Change Control Procedure, and Field Modification Process

PROTERRA

Engineering and Service Personnel

Engineering

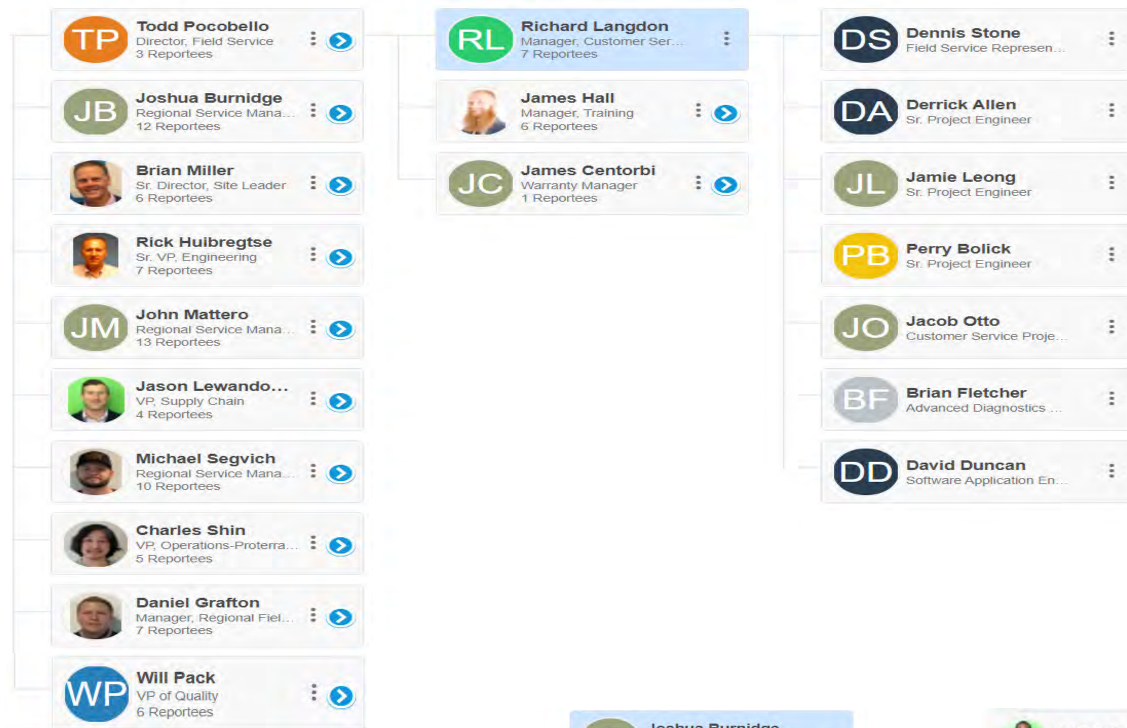
- **Rick Huibregtse** — Sr. VP, Engineering — 7 Reportees
- **Joshua Burnidge** — Regional Service Mana… — 12 Reportees
- **Brian Miller** — Sr. Director, Site Leader — 6 Reportees
- **John Mattero** — Regional Service Mana… — 13 Reportees
- **Jason Lewando…** — VP, Supply Chain — 4 Reportees
- **Michael Segvich** — Regional Service Mana… — 10 Reportees
- **Charles Shin** — VP, Operations-Proterra… — 5 Reportees
- **Todd Pocobello** — Director, Field Service — 3 Reportees
- **Daniel Grafton** — Manager, Regional Fiel… — 7 Reportees
- **Erin Carroll** — Parts Manager — 11 Reportees
- **Will Pack** — VP of Quality — 6 Reportees

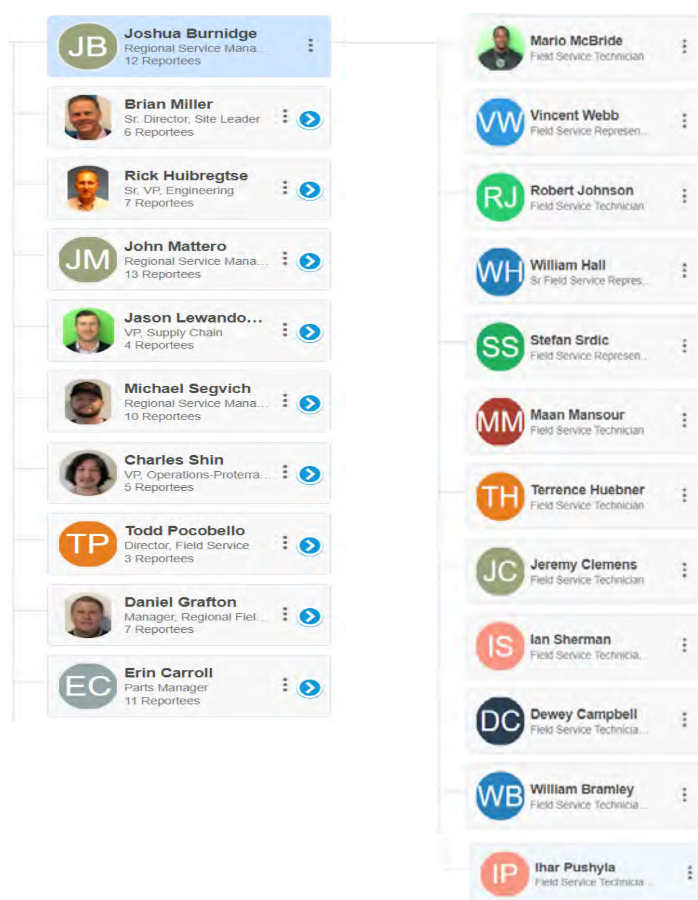
- **Matthew Wagner** — Sr. Manager, Mechanic… — 16 Reportees
- **Matt Simonini** — Sr. Manager, Drivetrain … — 6 Reportees
- **Scott Baker** — Director, Engineering O… — 4 Reportees
- **Timothy Stafford** — Director, Test and Valid… — 8 Reportees
- **Yogesh Pawar** — Director, Program Mana… — 3 Reportees
- **David Boucard** — Director, Body — 4 Reportees
- **Michael Boggess** — VP, Vehicle Controls an… — 5 Reportees

- **John Zielinski** — Senior Staff Engineer
- **Wes Waitman** — Team Leader- Mechani…
- **Vishaal Kannan** — Sr. Project Engineer
- **Arturo Bautista** — Project Engineer
- **Thomas Reno** — Staff Engineer
- **Joseph Holden** — Project Engineer – Mec…
- **Paul Toledo** — Project Engineer (Mech…
- **James Knockeart** — Sr. Project Engineer-Ch…
- **Drew Blanchard** — Associate Engineer - M…
- **Matt Sisson** — Project Engineer
- **Tucker Steiner** — Project Engineer
- **Santiago Marula…** — Associate Engineer-Me…
- **Aaron Augustine** — Associate Engineer - M…
- **Laura Sacristan-…** — Mechanical Engineerin…
- **Nathaniel Merriw…** — Associate Engineer - M…
- **Shane Dunlavey** — Associate Engineer

PROTERRA

Service

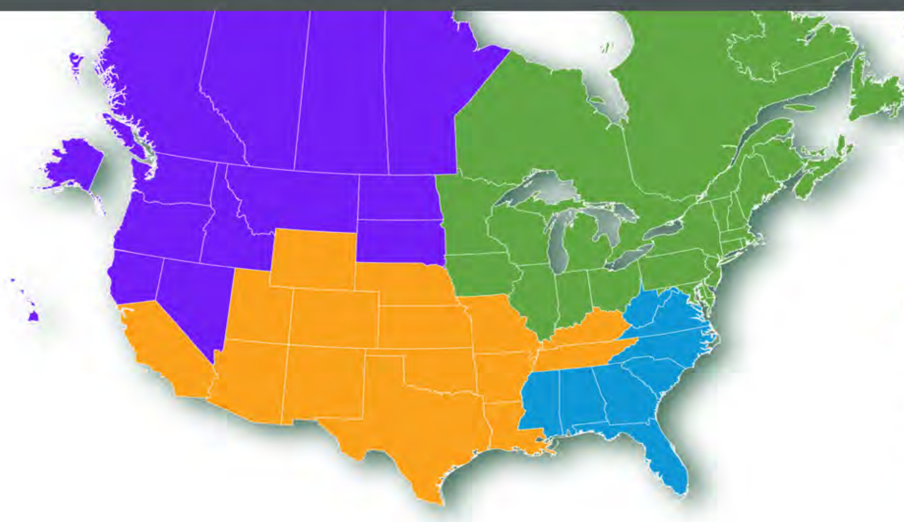




Regional Support

The Regional Field Service Representatives (FSRs) are assigned to a property to support the delivery of customer buses, assist with the training, and act as liaison between Proterra, our local dealer and the customer to ensure a perfect launch in to revenue service. The FSR will provide direct, on-site support for our dealer as well as remote telephonic support for the vehicles.

PROTERRA FIELD SERVICE REPS



NORTHWEST

Regional Service Manager:
Dan Grafton
Field Service Representatives:
Stephen Lollis - TBD
Joe Goins - Patterson, CA
Ramon Barroso - Sparks, NV
William Rogers - TBD
Jonnathan Thompson – Oak Harbor, WA
Josiah Goins – Atwater, CA
Leo LeBarre – Santa Cruz, CA

NORTHEAST

Regional Service Manager:
John Mattero
Field Service Representatives:
Thomas McDuffie – Munster, IL
Lorand Moldovan – NY, NY
David Kirlin – Nottingham, PA
Jason Patrick – Newtown, CT
Justin ONeill – Dover, DE
Robert Galea - TBD
Everth Zavala – Totowa, NJ
Antonio Dos Santos
Ronald Pare – Chicopee, MA
Joshua Miller – Felton, DE
Kevin Rumbaugh - TBD
Kevin Lewallen – Dixon, IL
James Williams - TBD

SOUTHWEST CENTRAL

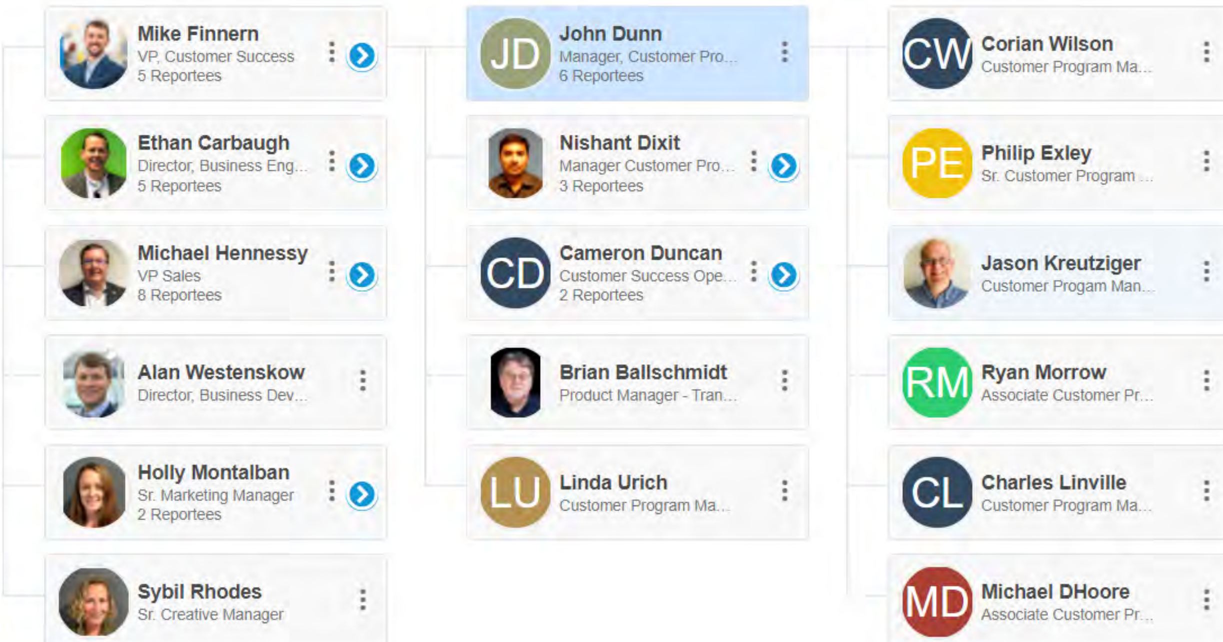
Regional Service Manager:
Michael Segvich
Field Service Representatives:
Dan Brogan – Bedford, TX
Juan Ocoa – Bakersfield, CA
Armando Jimenez – TBD
Mark Parriott – San Clemnte, CA
Phillip Chapa – Round Rock, TX
Christian Villarreal – Park Ridge, IL
John Woody – Ft. Worth, TX
Clint Luft – West Jordan, UT
Tadden Towery – Arvada, CO

SOUTHEAST

Regional Service Manager:
Joshua Burnidge
Field Service Representatives:
Mario McBride - TBD
Vincent Webb – Williamston, SC
Robert Johnson – Duncan, SC
William Hall – Mcleansvill, NC
Stefan Srdic - TBD
Maan Mansour – Washington, DC
Terrence Huebner - TBD
Jeremy Clemens – Orlando, FL
Ian Sherman – Miami, FL
Dewey Campbell - TBD
William Bramley – Fort Lauderdale, FL
Ihar Pushyla - TBD

In addition, Proterra's staff of Customer Service Engineers provide technical support to our FSRs, our local dealer, or our customers directly. These skilled individuals constantly monitor field anomalies and, when appropriate, create and distribute service bulletins to enhance overall operation of the fleet. They work closely with vendor networks and FSRs to optimize preventative maintenance schedules to increase reliability and performance by utilizing data collected from the vehicle directly and feedback from the FSRs.

Customer Success Team



The above organization chart reflects the Customer Success team which consists of twelve (12) Customer Program Managers who report to the Vice President of Customer Success (Mike Finnern), who in turn reports to the Chief Commercial Officer (John Walsh). Mike Finnern is one of Proterra's longest tenured employees and has been helping customers successfully deploy their BEBs for over eleven (11) years. In fact, he has lead Proterra's Customer Service department for seven (7) years and has a unique perspective on the steps required during pre-production to ensure the downstream steps of production, inspection and acceptance, training, and entry into service are successful. He also chairs APTA's Clean Propulsion Committee, helping North American transit agencies implement best practices associated with the transition to BEBs and other clean propulsion technologies.

The Customer Success Department is also growing to ensure that our customers receive the necessary care and attention while they embark on their BEB journey.

Customer Definition, Engineering Design, Procurement, Build, & Test

Proterra is deeply committed to the success of our partner agencies and takes a very hands-on partnership approach with all of our customers. With every successful procurement, Proterra assigns a dedicated Customer Program Manager (CPM) to the project once we receive notice of award. During the configuration definition process, the CPM will take the lead and coordinate the kick-off meeting and design overview meetings with PSTA. Once the design portion of the activity is complete, the CPM will work with PSTA to ensure the build process is smooth and meets the requirements of the contract and configuration.

As the internal customer champions, the CPM will conduct weekly internal meetings to ensure issues are resolved, questions answered, and open items closed in a timely manner.

Primary Tasks of the CPM

Once the contract is awarded the project can be defined by a series of tasks that break down as follows:

- Schedule and hold Kick-Off Meeting at PSTA
- Finalizing the bus configuration definition (configuration templates & option tracker)
- Schedule and hold design overview meetings
- Finalize the design with PSTA
- Coordinate development of Training Program

Once the design is finalized, the CPM will be responsible for completing the following tasks:

- Coordinating office requirements & familiarization training with CARTA's resident inspector
- Beginning Bus production
- Delivering Buses
- On-site acceptance testing at PSTA
- Assisting Proterra's customer service team with coordination / scheduling of training

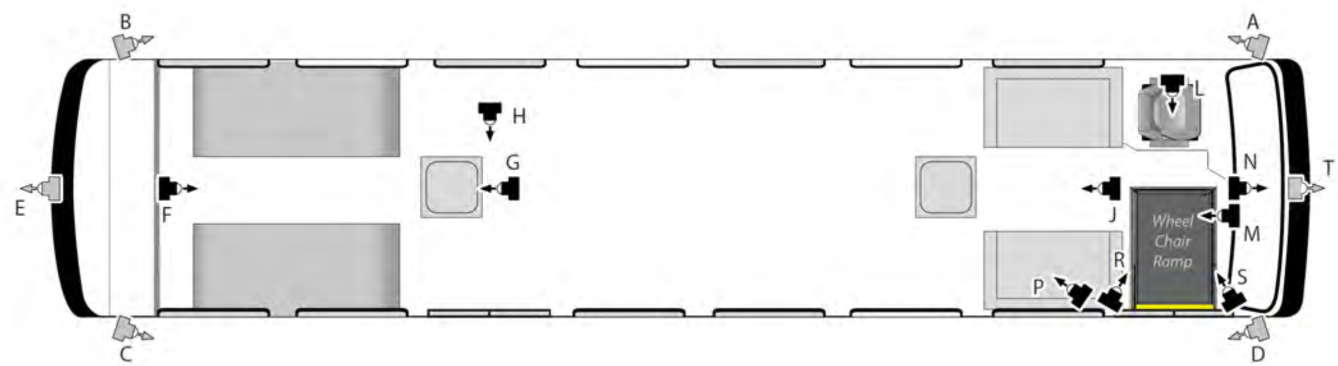
Configuration Templates

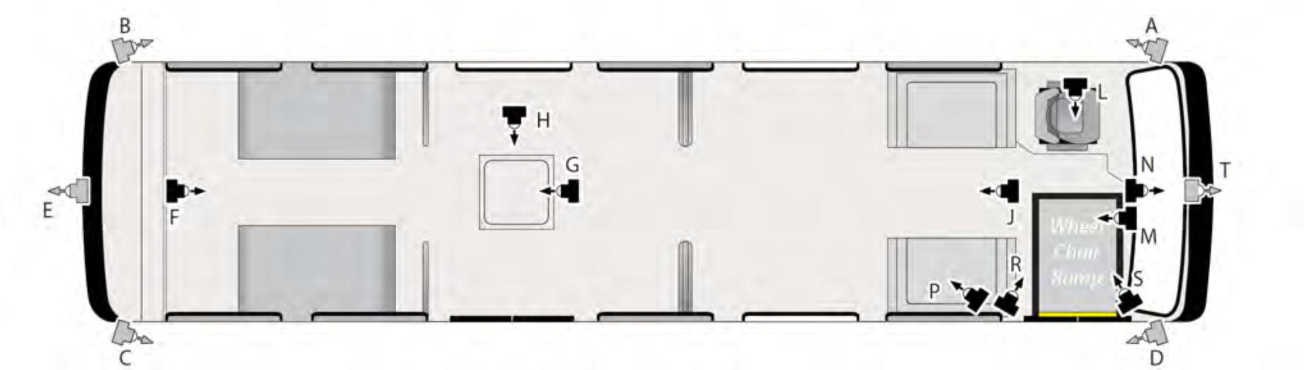
In 2017, Proterra's customer-facing Business Engagement team and Customer Engineering team began utilizing standardized templates as tools to confirm exact vehicle configurations well in advance of any design reviews. The CPM's will fill out the templates based on the information contained in the RFP technical specification and send them to their counterparts at PSTA for review and input. In total, there are seven (7) distinct configuration templates; two of which are shown on the next two pages (first page only):

PROTERRA	Video Surveillance System - Heron		
Agency:			
Contract Program Manager:	CPM Name CPM@Proterra.com 001.864.214.7076	Dated:	
Agency Contact:	Contact Name Contact@Agency.gov 001.864.123.4567	Deadline:	

Agency Technical Contact	
Name:	
Phone:	
Email:	

Please indicate desired camera placements (40ft and 35ft layouts):





Note: If a desired location is not represented on the pictures above, please indicate a location on the picture and provide a brief description of the view in the table on the next page.

PROTERRA	Side Windows & Doors (35’)		
Agency:			
Contract Program Manager:	CPM Name CPM@Proterra.com 001.864.214.7076	Dated:	
Agency Contact:	Contact Name Contact@Agency.gov 001.864.123.4567	Deadline:	

Agency Technical Contact	
Name:	
Phone:	
Email:	

Proterra 35ft Catalyst Side Windows

	Standard	Request
Driver’s Window Light Transmittance	75% Green	
Side Window Light Transmittance	50% Gray	
Serviceability	Non-Serviceable	
Material	5mm Tempered Glass (Laminated Not Available for Tip-In)	
Misc. Non-Standard Requests	n/a	
Window Decal Location	If vandal shields are used, decals are attached to the vandal shield	

Note: Windows are manufactured by Arow Global Inc.

Proterra Representative:	(Print)(Sign)	Date:
Agency Representative:	(Print)(Sign)	Date:
Note: This document is intended to provide information to minimize design changes at the formal Design Review and/or Pre-Production Review. Signature doesn’t equate to design acceptance.		

PROTERRA

Pinellas Suncoast Transit Authority

9. Manufacturing Facilities plant layout, Other Contracts, and Staffing

RFP 21-980369

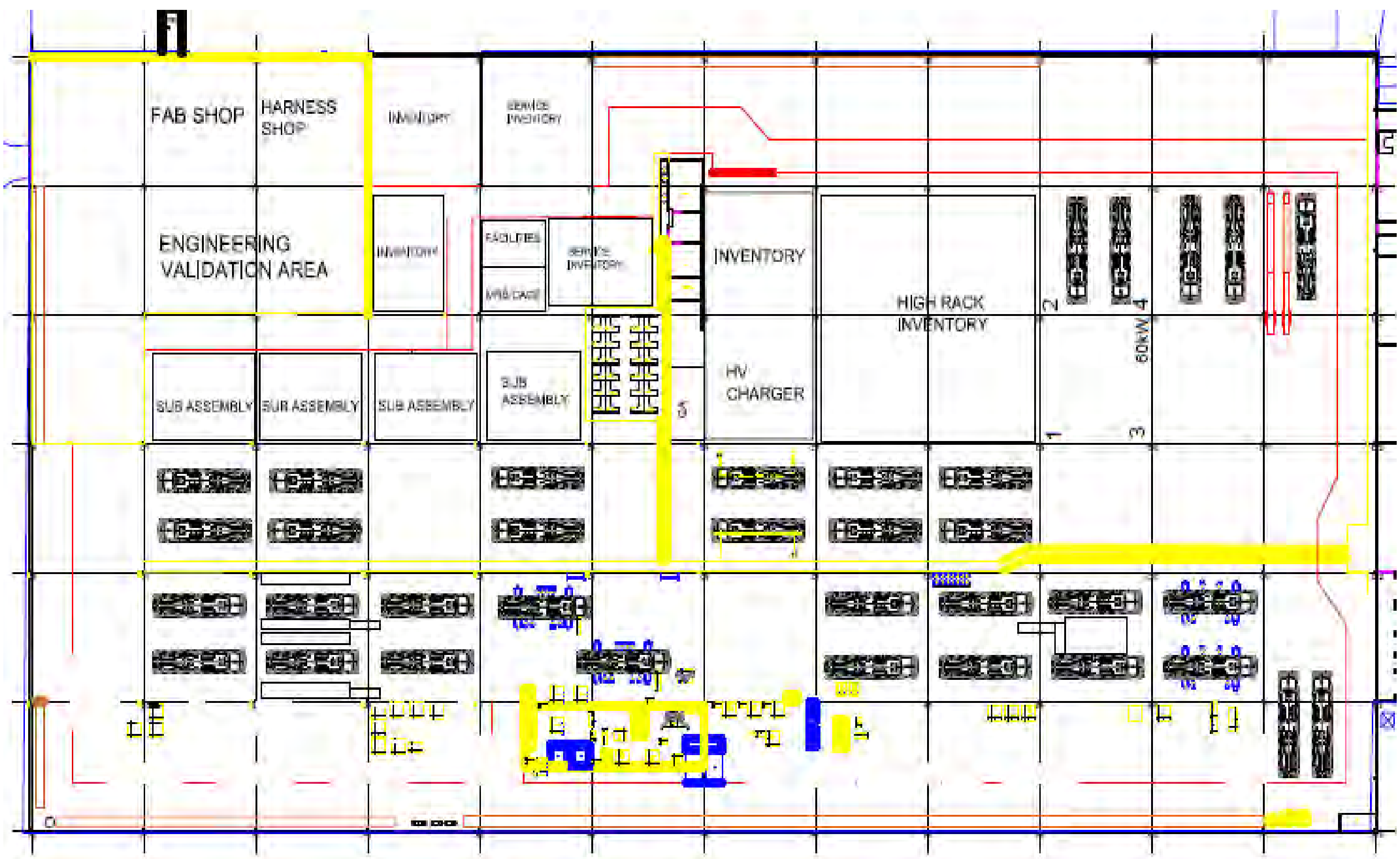
Manufacturing Facilities Plant Layouts & Staffing

<u>East Coast Manufacturing / Primary Engineering Facility</u>
1 Whitlee Court
Greenville, SC 29607

Number of Employees: 338

Activities Performed: Supply Chain, Legal, Sales, Accounting, Audit, Engineering, Battery Electric Bus Manufacturing,Testing, Inspection, and Validation.

The image to the right is the outside of our facility and the below image contains an image representing the two (2) separate lines of production manufacturing lines in Greenville:

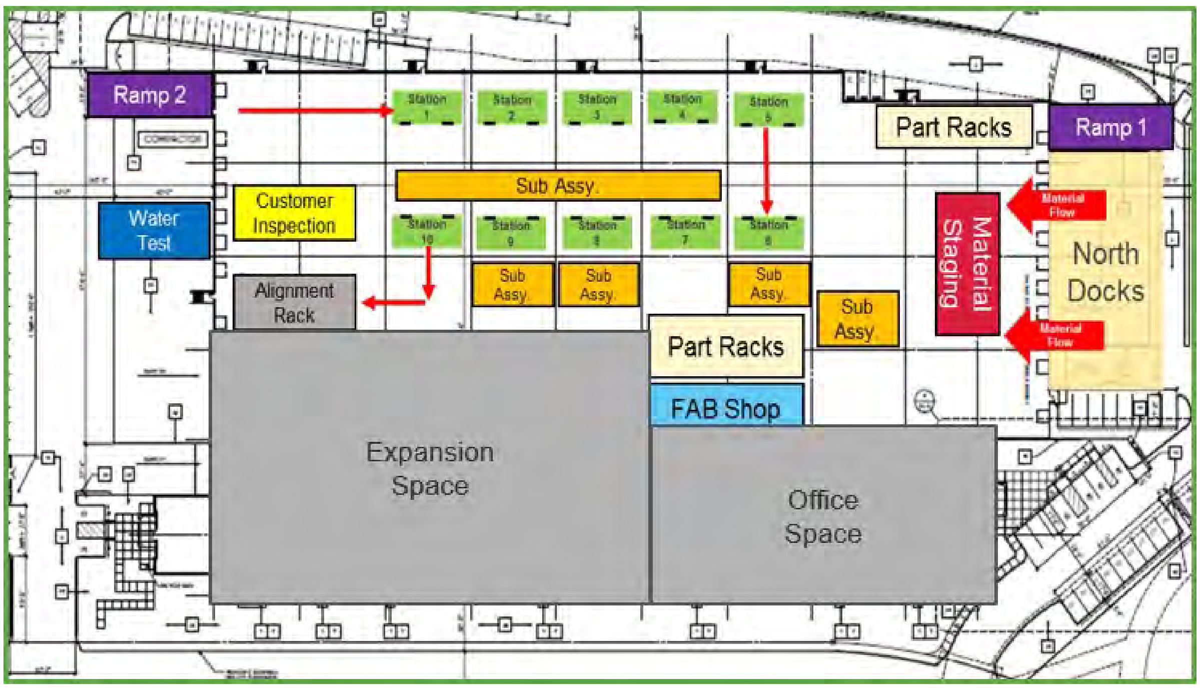


Proterra Confidential Information

West Coast Manufacturing Facility & Service Hub
383 Cheryl Lane
Walnut, CA 91789 (Los Angeles County)

Number of Employees: 118

Activities Performed: Legal, Sales, Accounting, Audit, Engineering, Vehicle Testing, Battery Electric Bus Manufacturing and Validation. The image to the right is outside of our facility and the below is an image of the Los Angeles facility layout:



Proterra Confidential Information

Proterra Headquarters / Advanced Battery R&D and Manufacturing

1815 Rollins Road
Burlingame, CA 94010

Number of Employees:130

Activities Performed: Executive Leadership, Legal, Sales, Accounting, Audit, Engineering, Advanced Battery R&D, Charger Manufacturing and Validation.

The heavy-vehicle industry's most advanced lithium-ion batteries are being designed, tested, validated, and manufacture in Burlingame, CA. Proterra's battery engineering team has extensively tested and validated the E2 battery packs and as a result Proterra offers a 12-year warranty on all high voltage battery packs.

The image to the right is the outside of our facility. The high voltage battery pack manufacturing layout is confidential, although we would encourage a team from Lextran to travel to Burlingame to visit the facility during the evaluation process. It is unrivaled in the North American transit market as no one else designs, validates, and manufactures their own high voltage battery packs in the United States.

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Pinellas Suncoast Transit Authority

10. Production and Delivery Schedule and Other Contract Commitments

PROTERRA

Proterra Delivery Schedule (Typical)

Task Name	Milestone (Start Dates)	Duration of Task	Responsibility
Notice of Award / Purchase Order	**Date of Issuance**	1 day	FL Agency / Customer
Phase 1.A – Pre-Production	**# from Notice of Award**		
Kick-Off Meeting • Infrastructure Site Walk (If required) / Planning • Configuration Process • Preliminary Build Schedule • Service Overview	+ 1 month	2 days	Proterra/Customer
Configuration Discussions	+ 1 month	60 days	Proterra/Customer
Pre-Production Meeting	+ 1 month	2 days	Proterra/Customer
Configuration/Design Freeze	+ 3 months	1 day	Proterra
Phase 1.B – Charger Equipment / Infrastructure (if applicable)	**# from Notice of Award**		
Design and Permitting	+0 months	3 months	Proterra or Customer / 3rd Party
Construction	+4 months	3 months	Proterra or Customer / 3rd Party
Delivery of Charging Equipment	+ 6 months	1 day	Proterra
Installation and Commission	+7 months	1 months	Proterra or Customer / 3rd Party
Phase 2 – Bus Build	**# from Configuration/Design Freeze**		
Engineering Design	+ 0 months	~3 months	Proterra
Design Overview Meeting	+ 1 months	1 hour	Proterra/Customer
Bus Production (For up to 5 buses)	+ 6 months	2 months	Proterra
Inspection, Delivery and Final Acceptance	+ 7 months	1 month	Proterra/Customer

PROTERRA

Task Name	Milestone (Start Dates)	Duration of Task	Responsibility
Phase 3 - Deployment	**# Of Days from Final Acceptance**		Proterra or Customer / 3rd Party
Operator/Maintenance Training	+0 months	5 days	Proterra/Customer
Shadow Service	+1 month	14 days	Customer
Launch Revenue Service	+2 months	1 day	Customer

Note: This timeline is illustrative of the typical lifecycle of a BEB Project, from Notice of Award / Purchase Order to Initiation of Revenue Service. Actual milestones may vary based on project specifics and agency approach.

Note: Actual build slots will be finalized when the Purchase Order is issued to Proterra.

Understanding Proterra's Delivery Commitment

PURCHASE ORDER ISSUANCE	EXPECTED DELIVERY DATES
12/31/2021	Q4 2022
3/31/2022	Q1 2023
6/30/2022	Q2 2023
9/30/2022	Q3 2023

PROTERRA

Other Contract Commitments

Account Name	Bus Qty	Plant Location	Projected Completion Date (First Bus)
City of San Luis Obispo	1	LAX	10/6/2021
Detroit	4	GVL	10/11/2021
Hillsboro Transit	10	GVL	10/13/2021
Mountain Metro	4	LAX	10/15/2021
Rock Island County Metropolitan Mass Transit	14	LAX	10/18/2021
SUBURBAN MOBILITY AUTHORITY FOR REGIONAL TRANSPORTATION	4	GVL	10/23/2021
City of Rock Hill	4	GVL	11/3/2021
Iowa City Transit	4	LAX	11/10/2021
Duke University	2	GVL	11/14/2021
Biddeford Saco Old Orchard Beach (BSOOB) Transit	2	GVL	11/15/2021
San Jose Airport	6	LAX	12/1/2021
Valley Regional Transit	8	LAX	12/1/2021
Belle Urban System – Racine (The Bus)	9	GVL	12/6/2021
Charleston Area Regional Transportation Authority (CARTA)	20	GVL	12/12/2021
Miami-Dade Transit(MDT)	32	GVL	1/3/2022
Miami Dade County	62	GVL	1/5/2022
John Wayne Airport	3	LAX	1/6/2022
City of Albuquerque	5	LAX	1/29/2022

PROTERRA

Guam Regional Transit Authority	8	GVL	1/31/2022
City and Borough of Juneau	8	LAX	2/8/2022
City of Moline	9	GVL	2/11/2022
Greater Portland Transit District	2	GVL	2/11/2022
Edmonton Transit System	20	GVL	2/27/2022
AppalCart	1	GVL	3/9/2022
Avon	2	LAX	3/9/2022
Santa Maria Area Transit	2	LAX	3/16/2022
Prince George County Transit System	8	GVL	3/21/2022
Ontario International (Lot 2)	8	LAX	3/23/2022
Bridgeport	3	GVL	3/31/2022
City of Fresno	7	LAX	4/24/2022
Napa County Transportation Planning Agency (NVTA)	2	LAX	5/13/2022
Santa Rosa City Bus	4	LAX	5/21/2022
Sacramento International Airport	7	LAX	6/6/2022
Sam Trans	4	LAX	8/27/2022
Roseville Transit	10	LAX	11/12/2022
DC Circulator	13	GVL	5/19/2023
D-DOT	13	GVL	5/19/2023

PROTERRA

Pinellas Suncoast Transit Authority

11. Management Plan

RFP 21-980369

PROTERRA LEADERSHIP

JACK ALLEN
Chairman and CEO

GARETH JOYCE
President of Proterra

JOSH ENSIGN
President of Proterra Transit

JOANN COVINGTON
Chief Legal Officer & Head of Government Relations

DUSTIN GRACE
Chief Technology Officer

JOHN WALSH
Chief Commercial Officer

KELLY SCHEIB
Vice President of Human Resources

RICK HUIBREGTSE
Senior Vice President of Engineering

Jack Allen - CHAIRMAN AND CEO

Jack Allen is the Chairman and Chief Executive Officer of Proterra. He is a results-focused leader who has spent his career defining the commercial truck industry. He has more than three decades of experience in the driving core businesses at Navistar International Corporation where he successfully strengthened its core businesses, improved quality and customer satisfaction, drove profitability and delivered value to shareholders. He most recently served as Navistar's executive vice president and chief operating officer, and previously was president of that company's North America truck and parts division. Allen also served as president of Navistar's engine group, where he led major business initiatives including the acquisition of Brazilian engine producer MWM and a partnership with MAN of Germany. He also has served as vice president and general manager of the company's parts organization. He holds a bachelor of science degree from the Milwaukee School of Engineering and an MBA from the Illinois Institute of Technology. He serves on the boards of the Milwaukee School of Engineering's Board of Regents and Lurie Children's Hospital of Chicago.

PROTERRA

Gareth Joyce - President of Proterra. Gareth Joyce is President of Proterra. He previously served as Chief Sustainability Officer for Delta Air Lines, overseeing Delta's $1 billion commitment toward becoming carbon neutral and leading the airline's Global Sustainability team. His responsibilities included building on Delta's industry-leading voluntary sustainability efforts to expand the airline's carbon reduction and removal work, while engaging with partners and other stakeholders to advance global sustainability. Prior to joining Delta, Joyce held a variety of senior leadership positions with Mercedes-Benz throughout South Africa, Europe, and North America – his last role being CEO of Mercedes-Benz Canada. Prior to his time at Mercedes-Benz, Joyce held positions with IQ Business Group, Standard Bank South Africa, Blick PLC, Austen Security, and Deloitte & Touche.

A resident of Atlanta, Joyce has also served on the board of the American Cancer Society since 2016. The society's investment into cancer research and treatment is second only to the United States government and has contributed to a 29% decrease in the overall US cancer death rate since 1991. Joyce holds a Bachelor of Science in Engineering from the University of Witwatersrand and a Master of Commerce in Business Management from the University of Johannesburg.

Josh Ensign – President of Proterra Transit. Josh serves as President of Proterra Tranisit. A U.S. Army veteran and former executive of Honeywell International and Tesla Motors, Ensign's track record includes leading global operations for 42 factories in 15 countries and managing the supporting supply chains. As vice president of manufacturing at Tesla Motors, Ensign was responsible for all manufacturing activities at the Fremont, California production site. This included the installation of the current Model S high volume production line, the launch of both the dual-motor platform and the Model X, and the establishment of Tesla's new seat manufacturing facility. Before Tesla, Ensign led global operations in Honeywell International's automotive and aerospace businesses. Ensign has extensive functional experience in supply chain, logistics, purchasing, and manufacturing and has lived and operated abroad in Germany, Mexico, China and Switzerland. Josh has a bachelor's in engineering from Gonzaga University and an MBA from the University of Southern California.

JoAnn Covington - Chief Legal Officer & Head of Government Relations

JoAnn Covington, Proterra's chief legal officer, leads the company's legal and government relations, and serves as corporate secretary. JoAnn joined Proterra from advertising technology firm, Rocket Fuel Inc., where she served as senior vice president and general counsel and led the legal, policy, business affairs and business development functions. While there she was instrumental in leading Rocket Fuel through its 2013 IPO when that company was the fastest growing technology company on Deloitte's Fast 500. Prior to Rocket Fuel, JoAnn held senior legal roles for Electronic Arts Inc., an entertainment software company. She began her career with Fenwick & West LLP representing technology companies in intellectual property litigation. JoAnn received her law degree from Harvard Law School, magna cum laude.

PROTERRA

Other Key Personnel of Proterra

Proterra has assembled a world-class leadership team that is focused on replacing every heavy-duty emission-producing transit coach with clean, quiet battery electric coaches. The leadership team's experience varies between heavy-duty transit, automotive, aerospace, and high voltage battery technology. Listed below are key members of the team that will support CARTA's electric transit bus project if awarded:

Dustin Grace, Chief Technology Officer

- Dustin Grace is the Chief Technology Officer at Proterra, responsible for Energy Storage and Power Systems development programs. He joined Proterra five years ago to establish and build the engineering team located at Proterra's Silicon Valley headquarters. Since completion of Proterra's first generation high voltage battery program in 2017, he is now leading future developments projects which adapt Proterra battery technology into heavy duty OEM vehicle applications, second life stationary storage, and fleet scale high power charging systems. He brings nine years of powertrain development expertise from Tesla Motors prior to joining the Proterra team.

John Walsh - Chief Commercial Officer

- John Walsh serves as the Chief Commercial Officer at Proterra. Prior to joining Proterra, Walsh was President and Chief Operating Officer of Davey Coach Sales, Inc., one of the leading dealers of new and used mid-sized buses and shuttles in North America. Prior to that, he served as President of the REV Group, one of the largest bus manufacturing groups in the United States. Walsh was also Vice President of Sales and Marketing at ARBOC Specialty Vehicles and CEO of VPG Autos, maker of the MV-1, the first purpose-built wheelchair-accessible car. Before that, Walsh spent more than two decades at National Bus Sales & Leasing, Inc. and served as President, where he grew National from a small school bus dealership to the largest bus dealership at the time.

Rick Huibregtse, Senior Vice President Engineering

- Rick leads Proterra's engineering organization, including battery & charger engineering, vehicle engineering, and electrical / controls engineering. Under Rick's leadership, Proterra has implemented a more controlled, phase-gate approach to new product development and strengthened our relationship with the FTA Office of Technology, or commitment to meeting SAE standard for electric vehicles and chargers, and our position as the leading innovator in heavy-duty bus transportation.

Kelly Scheib - Vice President of Human Resouces

- Kelly Scheib leads the Human Resources department at Proterra. Scheib has over 15 years of progressive Human Resources experience, most recently serving as the Vice President of Human Resources for Tindall Corporation. Prior, she worked for Hubbell Lighting in positions including HR Management, Organizational Development and Organizational Effectiveness. She holds certifications including the Senior Professional in Human Resources certification (SPHR) awarded by the HR Certification Institute and the Senior Certified Professional certification awarded by the Society for Human Resource Management (SHRM-SCP) and was recently named as the South Carolina Human Resources Professional of the Year by the South Carolina Chamber of Commerce. Kelly graduated from Penn State University with a Master of Science, Industrial Relations and Human Resources, as well as a Bachelor of Science, Labor and Industrial Relations

PROTERRA

Customer Definition, Engineering Design, Procurement, Build, & Test

Proterra is deeply committed to the success of our partner agencies and takes a very hands-on partnership approach with all of our customers. With every successful procurement, Proterra assigns a dedicated Customer Program Manager (CPM) to the project once we receive notice of award. During the configuration definition process, the CPM will take the lead. The CPM will coordinate the kick-off meeting and design overview meetings with PSTA. Once the design portion of the activity is complete, the CPM will continue to be the primary point of contact to ensure the build process is smooth and meets the requirements of the contract and configuration.

As the internal customer champions, the CPM Team will conduct weekly internal meetings to ensure issues are resolved, questions answered, and open items closed in a timely manner.

Once the contract is awarded the project can be defined by a series of tasks that break down as follows:

Primary Tasks of the Customer Program Manager

- Schedule and hold Kick-Off Meeting at PSTA
- Provide pre-award Buy America documentation
- Finalizing the bus configuration definition (configuration templates & option tracker)
- Schedule and hold design overview meetings
- Finalize the design with PSTA
- Coordinate development of Training Program
- Coordinating office requirements & familiarization training with PSTA's resident inspector
- Producing/delivering the Prototype Bus, if required
- Coordinating the Testing Program for the Prototype Bus, if required
- Beginning Production Bus production
- Delivering Production Buses
- On-site acceptance testing at PSTA
- Assisting Proterra’s customer service team with coordination / scheduling of training

Configuration Templates

In 2017, Proterra’s customer-facing Business Engagement team and Customer Engineering team began utilizing standardized templates as tools to confirm exact vehicle configurations well in advance of any design reviews. The Customer Success Team will fill out the templates based on the information contained in the RFP technical specification and send them to their counterparts at PSTA for review and input. In total, there are seven (7) distinct configuration templates.

PROTERRA BOARD OF DIRECTORS

Board of Directors

JACK ALLEN

Chairman and CEO

RYAN POPPLE

Co-Founder and Executive Director

JAKE ERHARD

Board Member

JOCHEN GOETZ

Board Member

BROOK PORTER

Board Member

JOAN ROBINSON-BERRY

Board Member

JEANNINE SARGENT

Board Member

CONSTANCE SKIDMORE

Board Member

MIKE SMITH

Board Member

PROTERRA

Pinellas Suncoast Transit Authority

12. Quality Assurance Plan

Certificate of Registration

This certifies that the Quality Management System of

Proterra Inc.

1815 Rollins Road
Burlingame, California, 94010, United States

has been assessed by NSF-ISR and found to be in conformance to the following standard(s):

ISO 9001:2015

Scope of Registration:
Design, and assembly of batteries and supporting power and charging systems.

Certificate Number:	C0525087-IS1
Certificate Issue Date:	01-SEP-2020
Registration Date:	01-SEP-2020
Expiration Date *:	31-AUG-2023

Tom Chestnut,
Sr Vice President - ISR,
NSF-ISR, Ltd.

NSF International Strategic Registrations
789 North Dixboro Road, Ann Arbor, Michigan 48105 | (888) NSF-9000 | www.nsf-isr.org

ANNEX PAGE FOR CERTIFICATE REGISTRATION NUMBER
C0525087-IS1
CERTIFICATE ISSUE DATE: 01-SEP-2020
CERTIFICATE EXPIRATION DATE: 31-AUG-2023

Proterra Inc.
1815 Rollins Road
Burlingame, California, 94010, United States

Remote Location:	Scope:
Proterra Inc.- C0525088 383 Cheryl Lane City of Industry, California, 91789, United States	Design and Assembly of electrical buses.
Remote Location:	**Scope:**
Proterra Inc.- C0525089 1 Whitlee Court Greenville, South Carolina, 29607, United States	Design and Assembly of electrical buses.

This Annex is only Valid in connection with the above-mentioned certificate issued by NSF-ISR

Certificate of Registration

This certifies that the Quality Management System of

Proterra Inc.

383 Cheryl Lane
City of Industry, California, 91789, United States

has been assessed by NSF-ISR and found to be in conformance to the following standard(s):

ISO 9001:2015

Scope of Registration:

Design and Assembly of electrical buses.
The validity of this certificate depends on the validity of the main certificate C0525087 Proterra Inc.

Certificate Number:	C0525087-IS1-C0525088
Certificate Issue Date:	01-SEP-2020
Registration Date:	01-SEP-2020
Expiration Date *:	31-AUG-2023

Tom Chestnut,
Sr Vice President - ISR, NSF-ISR, Ltd.

NSF International Strategic Registrations

789 North Dixboro Road, Ann Arbor, Michigan 48105 | (888) NSF-9000 | www.nsf-isr.org

Certificate of Registration

This certifies that the Quality Management System of

Proterra Inc.

1 Whitlee Court
Greenville, South Carolina, 29607, United States

has been assessed by NSF-ISR and found to be in conformance to the following standard(s):

ISO 9001:2015

Scope of Registration:
Design and Assembly of electrical buses.
The validity of this certificate depends on the validity of the main certificate C0525087 Proterra Inc.

Certificate Number:	C0525087-IS1-C0525089
Certificate Issue Date:	01-SEP-2020
Registration Date:	01-SEP-2020
Expiration Date *:	31-AUG-2023

Tom Chestnut,
Sr Vice President - ISR, NSF-ISR, Ltd.

NSF International Strategic Registrations
789 North Dixboro Road, Ann Arbor, Michigan 48105 | (888) NSF-9000 | www.nsf-isr.org

Certificate of Registration

This certifies that the Environmental Management System of

Proterra Inc.

1815 Rollins Road
Burlingame, California, 94010, United States

has been assessed by NSF-ISR and found to be in conformance to the following standard(s):

ISO 14001:2015

Scope of Registration:
The Design, Development, Assembly, test and delivery of Electric Buses and supporting power and charging systems.

Certificate Number:	C0525087-EM1
Certificate Issue Date:	31-AUG-2020
Registration Date:	31-AUG-2020
Expiration Date *:	30-AUG-2023

Tom Chestnut,
Sr Vice President - ISR,
NSF-ISR, Ltd.

NSF International Strategic Registrations
789 North Dixboro Road, Ann Arbor, Michigan 48105 | (888) NSF-9000 | www.nsf-isr.org

ANNEX PAGE FOR CERTIFICATE REGISTRATION NUMBER
C0525087-EM1
CERTIFICATE ISSUE DATE: 31-AUG-2020
CERTIFICATE EXPIRATION DATE: 30-AUG-2023

Proterra Inc.
1815 Rollins Road
Burlingame, California, 94010, United States

Remote Location:	Scope:
Proterra Inc.- C0525088 383 Cheryl Lane City of Industry, California, 91789, United States	The Design, Development, Assembly, test and delivery of Electric Buses and supporting power and charging systems.
Remote Location:	**Scope:**
Proterra Inc.- C0525089 1 Whitlee Court Greenville, South Carolina, 29607, United States	The Design, Development, Assembly, test and delivery of Electric Buses and supporting power and charging systems.

NSF International Strategic Registrations
789 North Dixboro Road, Ann Arbor, Michigan 48105 | (888) NSF-9000 | www.nsf-isr.org

This Annex is only Valid in connection with the above-mentioned certificate issued by NSF-ISR

Certificate of Registration

This certifies that the Environmental Management System of

Proterra Inc.

383 Cheryl Lane
City of Industry, California, 91789, United States

has been assessed by NSF-ISR and found to be in conformance to the following standard(s):

ISO 14001:2015

Scope of Registration:

The Design, Development, Assembly, test and delivery of Electric Buses and supporting power and charging systems.
The validity of this certificate depends on the validity of the main certificate C0525087 Proterra Inc.

Certificate Number:	C0525087-EM1-C0525088
Certificate Issue Date:	31-AUG-2020
Registration Date:	31-AUG-2020
Expiration Date *:	30-AUG-2023

Tom Chestnut,
Sr Vice President - ISR, NSF-ISR, Ltd.

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Quality Assurance Overview

Proterra has an established quality assurance program that is fully supported by the Executive Leadership Team. At Proterra, we strive to continually improve our product quality by:

- communicating the importance of meeting customer and regulatory requirements
- having a dedicated quality department
- ensuring quality objectives are established, monitored and achieved
- ensuring adequate resources are available for continuous improvement of quality
- striving for building quality products right the first time

Proterra's quality assurance program controls all phases of the product life cycle including proposals, contracts, design, sourcing, manufacturing, delivery and service. By gathering reliable information on customer expectations through the proposal and contracts processes, Proterra can design, manufacture, deliver and service a product the meets those expectations.

Headquarters
1815 Rollins Road, Burlingame, CA 94010
East Coast Manufacturing
1 Whitlee Court, Greenville, SC 29607
West Coast Manufacturing
383 Cheryl Lane, City of Industry, CA 91789
www.proterra.com

Proterra's product quality starts with control of engineering design and development. The inputs to this process are customer requirements, functional and performance requirements, regulatory requirements, and lessons learned from previous experience. By following our Engineering Change Order (ECO) process, we have systematic review and approval of the design and validation results by a cross functional team. This process ensures that the engineering design meets all of the input requirements and has sufficient definition to be manufactured and assembled into the vehicle.

To maintain the integrity of our drawings, specifications and procedures, Proterra uses a Change Control Board (CCB) to review and approve all changes impacting the definition of the vehicle. The CCB requires review and approval from Engineering, Manufacturing, Quality and Service before changes can be implemented. The ECO and CCB processes ensure that the engineering definition of the bus is maintained in a controlled manner and that sufficient definition is available to source, manufacture, assemble and deliver a completed vehicle.

Proterra ensures that the correct parts are purchased by including detailed information of all drawings, specifications and standards on the purchase order. Information is transferred to suppliers using secure file sharing software which allows Proterra and its suppliers to maintain current revisions of all controlled documents. Where warranted, suppliers must submit supporting data to prove manufactured parts meet the purchase order requirements. Certain critical components also have required reception inspection, and every part is inspected at point of use before assembly onto the vehicle.

Once conforming parts are received, they are assembled onto the vehicle using well defined and controlled processes. The primary controls for assembly are the engineering Bill of Materials (BOM), drawings, specifications and work instructions. These materials ensure that assembly professionals, meeting the minimum training requirements, have all of the information and tools necessary to assemble the vehicle properly. Tools used for product acceptance to meet an engineering standard must be compliant with Proterra's gage calibration program. Proterra uses a reputable 3rd party vendor to ensure that all gages, tools, and instruments are certified to national standards.

Proterra monitors adherence and compliance to the engineering specifications using a rigorous inspection program. Proterra quality inspectors are involved in approving products from incoming inspections, sub-assemblies, individual work stations, and the final completed vehicle. Quality inspector approval is required for material to move between sections of the assembly process. Proterra's quality inspectors are senior, experienced quality professionals who have received 3rd party training in quality assurance principles. In addition to our quality inspectors, all Proterra employees are well informed of customer expectations and can stop the line if they have a quality concern.

If a non-conformance is detected, it is logged in our Non-Conformance Record (NCR) database. This database is available for all Proterra employees to raise a quality concern. It also serves as a template to walk employees through the process of containing, identifying, segregating, correcting and preventing non-conformances. The keys to this process are having engineering provide a disposition and the quality department verify that the disposition is appropriately applied. There are multiple check points in the vehicle assembly process to ensure that all non-conformances are resolved in a timely manner and that every non-conformance is addressed before delivery of a vehicle to the customer. The NCR database also allows the quality

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department to use statistical techniques to track quality performance and isolate areas for continuous improvement.

Detailed records of all quality processes are retained by Proterra to serve as evidence that the processes are being followed and that a completed vehicle meeting the engineering requirements is delivered to the customer. This data also allows Proterra to review long term trends and continually improve the effectiveness of our quality management system. The goal at Proterra is to do everything right the first time through careful planning, detailed execution and continuous improvement.

Business System Manual

ISO 9001: 2015; Quality Management Systems - Requirements

ISO 14001: 2015; Environmental Management Systems – Requirements with guidance for use

Copy Number: ________

Section 0.0 – Table of Contents

Section 0.1 – Policy Statements

Proterra Quality and Environmental Policy

Safety, Quality and the Environment are integral elements of Proterra's Business Principles. They are the core of our beliefs and values. They are at the heart of how we add value to the world. At Proterra, our commitment is to never compromise on the safety, compliance and quality of our products and services and to protect the environment in our daily activities. It requires everyone to be engaged, to understand our responsibilities and to be empowered to act to live up to these principles.

Proterra's Quality and Environmental Policy is:

- **Foster a Customer oriented quality mindset with the intent to develop, manufacturing and deliver products and services with Zero Defects**
- **Encourage participation of all our associates, suppliers, business partners and customers in the improvement of quality and the environment**
- **Drive an Environmental Management System that is consistent with our Zero Emissions objectives and prevent pollution, minimize waste, recycle materials and utilize materials efficiently wherever practical throughout the company, to protect the environment**
- **Commit to continually improve the Quality and Environmental Management Systems by focusing on our fundamental principles of Safety, Quality and the Environment, and our commitment to improve our carbon footprint and reduce carbon emissions.**
- **Comply with all relevant laws, regulations and compliance obligations**

To achieve this policy, Proterra is committed to establish and maintain an effective Quality Management System (QMS) as well as an Environmental Management System (EMS) conforming to the requirements of ISO 9001 and ISO 14001, respectively. Both management systems are described within this common manual.

To ensure that Proterra fully meets these policies and objectives, the effectiveness of the Quality and Environmental Management Systems are subject to regular review by Proterra executive management.

The Proterra policies are accessible to interested parties on Proterra's website.

Section 0.2 – Revision History

The Business System Manual was issued originally on September 30, 2019. The following revisions for the last three years have been approved and issued:

Revision Date	Revision Details
10/31/19	Cover Page – added logo. Sec. 0.3 – added that Public Drive is list of documents applicable to system. Sec. 0.4 – added availability of EMS scope. Sec. 1.2 – updated the form numbers listed in the bus short ship process flow. Sec. 1.6 – changed title of Aftermarket Warranty Parts Manager to Parts Manager. Sec. 2.4 – added list of engineering groups in Purpose section. Also changed Manager of Publications responsibilities from Customer Service process. Added new form number for Change Management. Sec. 2.9 – added Warranty Manager responsibilities. Sec. 2.11 – removed reference to Red Carts. Sec. 3.3 – added reference to resume as part of competency records and changed Grandfather clause to 11/1/19. Sec. 3.5 – added Master Compliance Obligation Matrix. Appendix – updated list of records
12/31/19	All – updated titles to match titles in Proterra's Org. Chart in intranet. Sec. 1.1 – removed reference to C of A's since these are not required from suppliers. Sec. 1.5 – added responsibility of notifying contractors of the environmental requirements for construction of infrastructure. Sec. 2.3 – added CPM-WI-009 to process flow and revised process flow to include last step of resolving post-delivery concerns and issues. Sec. 2.4 – added if required for product validations in Responsibilities and Authorities section and in process flow, added requirement to address the environmental requirements for each life cycle stage of company products. Sec. 2.5 – updated titles and added environmental criteria for approving and evaluating new direct suppliers. Also added "if required" to SQE auditingall new suppliers. Sec. 2.7 – added subcontracted services to meeting compliance obligations and removed reference to Demand Planning Manager. Sec. 2.9 – added process flow for customer concerns and issues and process flow for customer surveys. Sec. 2.10 – added responsibility for control of non-precise measuring tools. Sec 2.11 – added responsibilities for removing obsolete parts or product from inventory. Sec. 2.12 – added responsibilities for VP of IT, changed title of ISO Coordinator to QS Coordinator and changed responsibilities from NQD to site Quality Leader. Sec. 3.1 – improved verbiage to demonstrate plan to achieve objectives and replaced "statutory and regulatory" with compliance obligations. Sec. 3.2 – revised requirements for management review to cover all management review requirements instead of all requirements. Sec. 3.4 – removed "weekly" before CQE meeting reference, revised corrective action process flow to include review of Risks and Opportunities Matrix, and changed to appropriate Facility Manager coordinating compliance audits. Sec. 3.5 – add responsibility for maintenance of facility and production equipment plus any changes that effect the environment and modified significant aspects process flow to add if additional controls are required. Records Table – removed to a standalone document.
1/31/20	Sec. 0.0 – Renumbered all processes to align with Sec. 0.6 Interaction Flowchart. Sec. 0.3 – replaced National Quality Director (NQD) with Director, Battery Operations and Manufacturing Strategy (DBO). Sec. 0.4 – added breakdown of QMS Scope of Registration by plant and eliminated development, test and delivery from scope. Sec. 0.5 – replaced NQD with DBO. Sec. 0.6 – added new process flowchart showing interactions of all processes. Sec. 1.1 – removed reference to Business Engagement and updated responsibilities for Business Development. Sec. 1.2 – combined Business Engagement (old Sec. 2.1) and Customer Program Management (old Sec. 2.3) into a new process called Customer Success and moved the SIOP process (old Sec. 2.2) into new Sec. 2.3. Sec. 1.3 – changed inputs from Program Management requests to Customer Success requests. Sec. 1.4 – moved requirement to notify supplier of lost or damaged supplier owned material to Sourcing process (Sec. 2.4) and moved requirement to notify customer of lost or damaged customer owned material to new Customer Success process (Sec. 1.2). Sec. 1.6 and 1.7 – removed reference to factory OEE. Sec. 2.1 – added VP, HR responsibilities and substituted DBO for NQD. Sec. 2.3 - substituted DBO for NQD. Sec.

	2.4 – added a fourth supplier ranking called problem supplier. Also added responsibilities as described in Sec. 1.4 above. Sec. 2.7 – renamed to add Process Engineering and added responsibilities of Burlingame Process Engineer. Sec. 2.10 – added responsibilities for controlling 3D models and changes to BOMs. Sec. 3.1 – substituted DBO for NQD. Sec. 3.2 – substituted DBO for NQD. Sec. 3.3 – moved Customer Program Management to Sec. 1.2 and Technical Publications to Sec. 1.3. Revised flowcharts to new responsibilities and titles. Sec. 3.4 – added requirement for layered process audits and substituted DBO for NQD.
2/29/20	Sec. 0.5 – changed Quality Management Systems Coordinator to ISO Document Control Specialist in all sections. Sec. 1.2 – updated responsibilities and flowchart to current process. Sec. 1.3 – changed titles to reflect current customer success process. Sec. 1.4 – revised the process flowchart. Sec. 1.8 – added to purpose that the infrastructure designs do not follow the requirements of Sec. 1.3 for products. Sec. 1.9 – Revised process flowchart. Sec. 2.1 – added reference to Skills Matrix for verifying competency and added HR Leadership to 2nd box of process flowchart. Sec. 2.3 – removed requirement for Contingency Plan and modified flowchart to add QMS Coordinator to update Risks and Opportunities Matrix and training records. Sec. 2.8 – added that tools calibrated internally have a work instruction. Sec. 2.9 – updated responsibilities and flowchart to current process. Sec. 2.10 – updated titles in responsibilities and flowchart. Sec. 3.1 – updated responsibility for Risks and Opportunities Matrix. Sec. 3.4 – updated flowcharts to current requirements.
5/20/2020	Section 3.2 Separated performance trends on Quality and Environmental Objectives to two meetings Quality and Safety and Environmental Sec. 1.8 Replace SR. Director with VP, Energy
7/14/2020	Section 0.3 Master Copy 2 changed DBO to Quality Management Systems Coordinator. Sec 2.0 replaced DBO with Quality Management Systems Coordinator. 2.3 replaced DBO with Quality Management Systems Coordinator. Section 3.1 Replaced DBO with Quality Management Systems Coordinator. Replaced ISO Document Control specialist with Quality Management Systems Coordinator. Section 3.1 Replaced ISO Document Control Specialist with Quality Management Systems Coordinator and replaced DBO with VP of Quality. Removed percentages from Proterra's Metrics. Remove CQE. Sec 3.2 Rewrote paragraph 1 to reflect new Quality and Environmental Meetings being held separately. Replace DBO with Quality Management Systems Coordinator. 3.4 Replaced DBO with Quality Management Systems Coordinator. Removed internal audits will be performed by a third parts to QMS Coordinator will conduct them. Changed paragraph six to read Quality Management Systems Coordinator responsible for quality and DBO responsible for Environmental. Changed the seventh paragraph from DBO to VP of Quality. Updated Environmental and Quality Policy to include Proterra's commitment to protect the environment, .06 gave Proterra Powered its own box in process flow
8/4/20	Updated Sec. 3.4 Updated Corrective action process flow

Only revisions issued in accordance with the Control of Documents and Records Process in Section 2.10 of this manual and authorized by the CEO or COO below are inserted in the manual.

Approved By: Josh Ensign COO
(CEO or COO)

Section 0.3 – Circulation List

The Quality Management Systems Coordinator or designee controls an electronic copy and a hardcopy, Master Copy, of the Business System Manual. The following are controlled hardcopy holders:

Copy Number	Manual Holder
Electronic	PDF on Public Drive
Master Copy 1	Quality Management Systems Coordinator,

Additional copies of this manual are available upon request and authorization by the Quality Management Systems Coordinator. If controlled, the list is amended and the Quality Management Systems Coordinator, or designee, as necessary, provides the additional copy. Unauthorized photocopying of any part of the manual is not permitted, under any circumstances.

Printed copies of any of the controlled documents, other than the Master Copy, are uncontrolled copies. They are not updated. The Public Drive is the list of the internal and external documents, standards and reference manuals applicable to Proterra.

Section 0.4 – Company Background and Scope of Registration

Proterra was established in 2004 in Golden, Colorado to produce electric buses with Zero Emissions for a cleaner environment. In 2011, Proterra opened the Greenville, South Carolina facility for bus assembly and engineering. The Burlingame, California corporate headquarters and battery manufacturing center was opened in 2015, making Proterra a high-tech company located in the heart of Silicon Valley. In 2017, Proterra opened the West Coast bus assembly plant in City of Industry, California. In 2019 the Proterra Powered business group was organized to provide parts and products to OEM companies worldwide.

All Proterra facilities have modern offices, conference rooms, and communication and development equipment.

Its customers and its peers in the industry recognize Proterra for its innovative parts and products. The Company has also been recognized for its excellent quality and service plus its commitment to providing “Zero Emission” products to protect the environment. The Company is focused on the future, recognizes that their associates are their most valuable resource, and strives continually to exceed their customer’s expectations.

Scope of Registration: The design and assembly of electric buses and supporting power and charging systems.

Burlingame – The design and assembly of batteries and charging systems.

Greenville – The design and assembly of electric buses.

City of Industry – The design and assembly of electric buses.

The scope of the Environmental Management System includes all current facilities. This scope is available to interested parties when requested.

Section 0.5 – Organization Chart

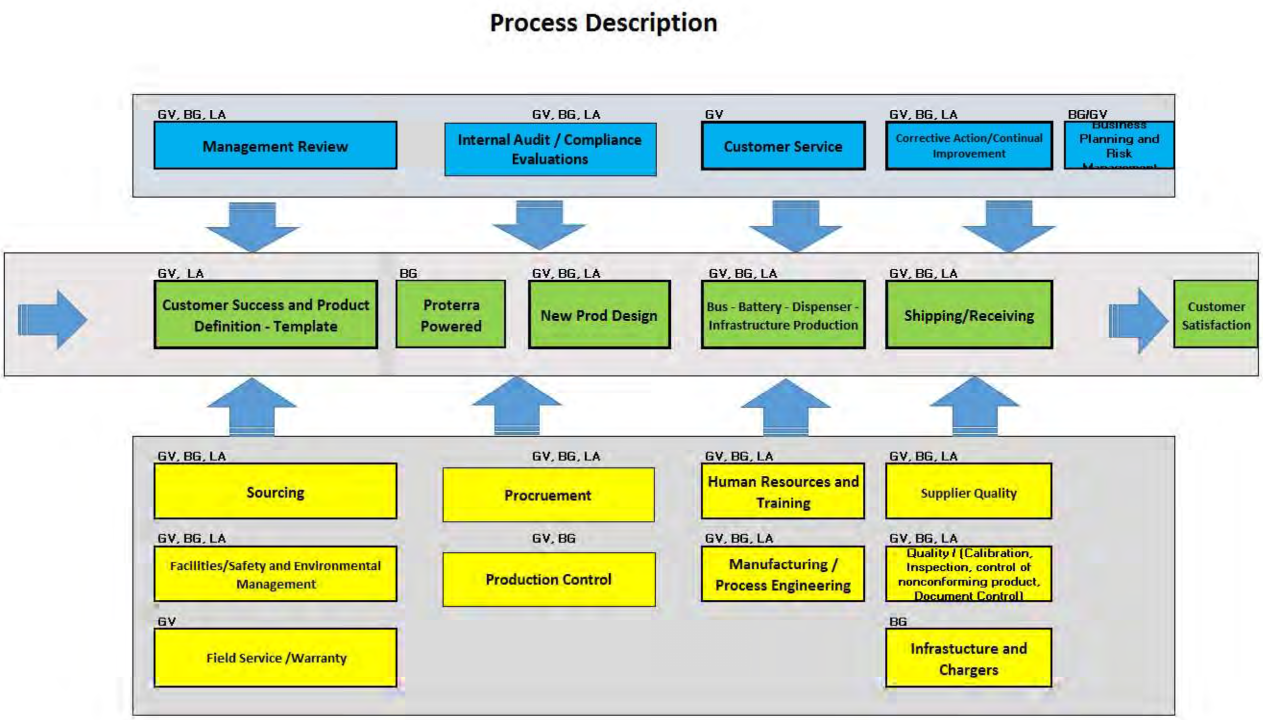
The complete Organization Chart with names is in Proterra's Intranet. The Organization Chart along with the Responsibilities and Authorities defined in each section of the manual effectively communicates the responsibility and authority of the Quality and Environmental Management Systems to the organization.

https://proterra.mangoapps.com/sites/peoples?org_chart=true

The CEO and COO have appointed the VP of Quality, The Quality Management Systems Coordinator) to manage the Quality System and the DBO the Environmental Management Systems and report on their performance, effectiveness and opportunities for improvement. The Director of Bus Quality has been appointed to be the backup for the Quality Management Systems Coordinator, if the Quality Management Systems Coordinator is unavailable. The Quality Management Systems Coordinator or designee also promotes customer focus throughout the organization and coordinates changes to the Quality and Environmental Management Systems so that the changes are planned and implemented.

Section 0.6 – Process Interaction Flowchart

The sequence and interaction of the processes of the overall organization are described by the flowchart below. Each section of the manual also has a more detailed flowchart for that section, if applicable.



Section 1.0 – Core Processes

Section 1.1 – Sales and Business Development (Proterra Powered)

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the sales and business development process.

Responsibilities and Authorities

The VP, Proterra Powered, Director, Business Development, Director, Product Management or designee are responsible for contacting customers, obtaining customer-specific requirements, including special characteristics, and getting feedback from customers.

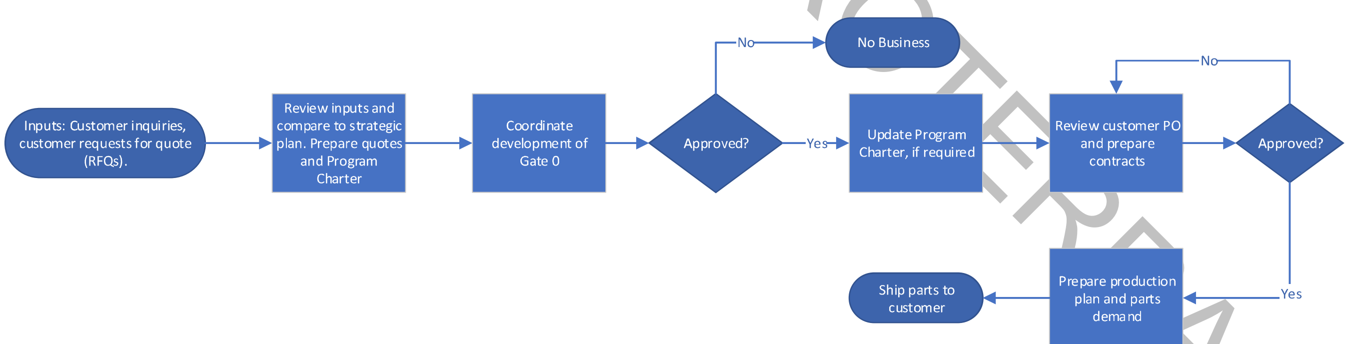
The Director, Business Development or designee is responsible for preparing quotations, establishing a Program Charter, executing contracts, and updating the Program Charter, if required.

The Program Manager, Proterra Powered, or designee is responsible for review of customer Purchase Order, the demand planning process, and creating the demand for parts.

The Director, Product Management, or designee is responsible Gate 0 sign-off.

The Director, Field Service or designee is responsible for working with the customer on any customer issues or concerns (See BSM Section 3.3).

Process



Section 1.2 – Sales and Customer Success (Bus Business)

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the sales and customer success process.

Responsibilities and Authorities

The CEO or COO, the Sr. VP, Sales, VP, Customer Success or designee are responsible for contacting customers, obtaining customer-specific requirements, including special characteristics, and getting feedback from customers.

The bid and proposal team are responsible for responding to formal customer solicitations including obtaining appropriate approvals from the Executive Team.

The VP, Customer Success, the Customer Program Manager (CPM) or designee is responsible from the point of award to establish a program charter, obtain customer configuration requirements, facilitate and execute the contract, and enter the Customer Purchase Order.

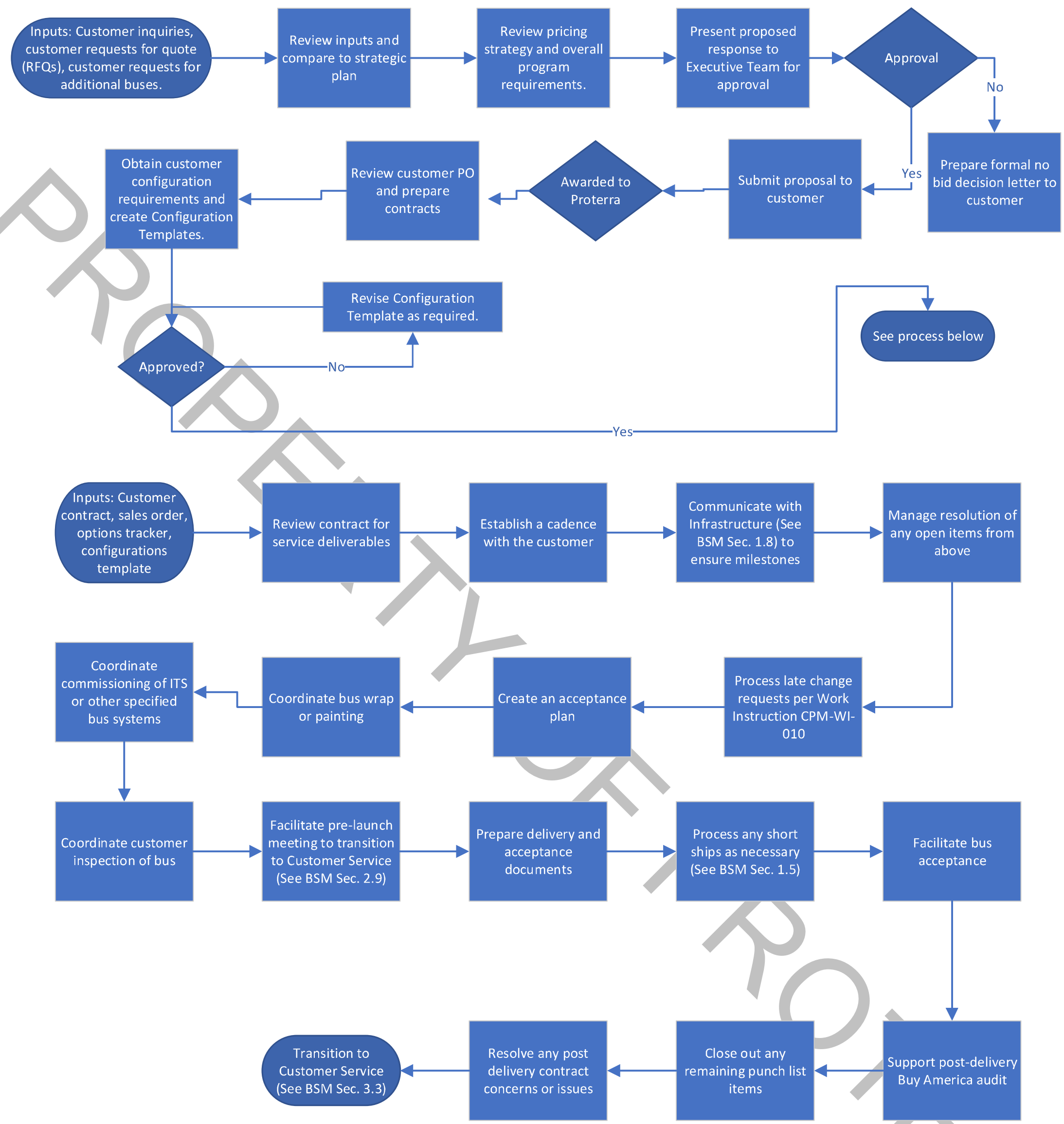
The CPM introduces the customer program into the Sales, Inventory, Operations, Planning (SIOP) Process (See BSM process 2.2), obtains approval for configurable options via the customer design review meetings and creates the demand for parts based on the completed bus templates. The CPM also manages late changes and assesses and mitigates risks associated with the production of the bus and facilitates response to Customer Change Request.

The CPM enables the receipt of any customer supplied equipment, provides regular customer communication throughout the build, coordinates for external graphics, customer visits, customer inspections and 3rd party installations like wrapping the bus or Infrastructure (see BSM Section 1.8) and commission as appropriate.

The CPM also coordinates with logistics for shipment and notifies the Field Service Representative (FSR) to plan for Post Delivery Inspection (PDI), confirms resolution of inspection findings, ensures completion of project deliverables, coordinates for project closure and acceptance documents and transfers customer to the Field Service Team.

The CPM is also responsible for notifying the customer if any customer property on site is lost, damaged or becomes unsuitable for use by completing an External Property Notification form.

Process



Note: The above activities may be performed in any order based on customer requirements or priority

Section 1.3 – New Product Design and Development

Purpose

This Process describes the policies, individual responsibilities, procedures, documents and records used to define the new product design and development process.

Responsibilities and Authorities

The Director, Product Management is responsible for setting the product roadmap and strategy for the company and determining the requirements and communicating them to the Company.

The Director, Product Management and Sr. Manager, Program Management are responsible for developing new internal modified product and service requirements. The Director, Product Management and Sr. Manager, Program Management is also responsible for establishing controls, as appropriate, to ensure that the environmental requirements are addressed for Proterra's products at each life cycle stage.

The Director, Product Management and Sr. Manager, Program Management are responsible for maintaining the new product development documentation and communicating the results to the enterprise. See New Product Development document ENG-WI-006.

Engineering Operations is responsible for controlling, documenting and facilitating changes, including those from the supplier that affect production or the customer. Changes are validated, if required, before being implemented and approved by the customer, if required. Additional verification or validation is performed, if required by the customer. The change records are maintained in the Product Lifecycle Management (PLM) system in Arena. See Change Management document PRC-CM-001 in PLM system.

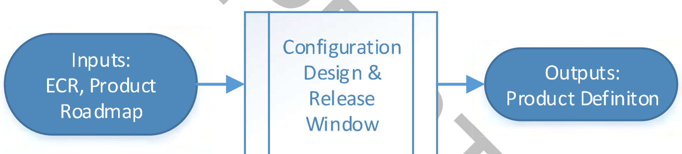
The Manager, Publications or designee is responsible for creating the technical operation and repair manuals for each product, as required.

All persons responsible for the design and development process ensure confidentiality of customer-contracted products and projects under development and related product information.

Process

New Product Development

Engineer to Order



Section 1.4 - Receiving

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the receiving process.

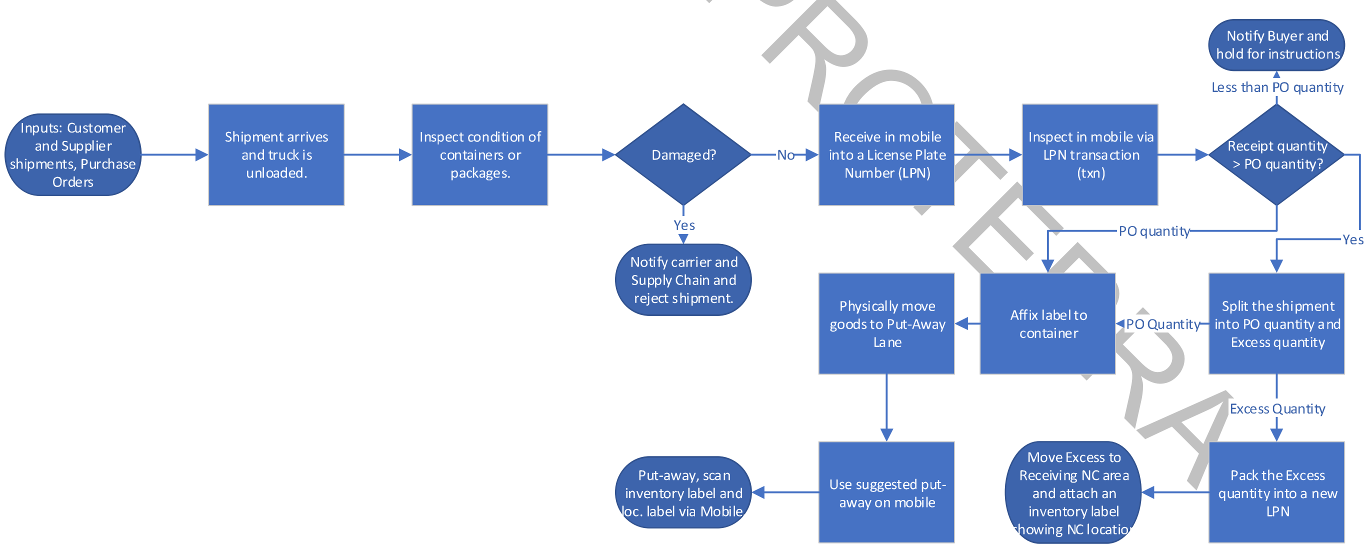
Responsibilities and Authorities

The Director, Materials and appropriate site Sr. Manager, Materials and Supervisor, Materials are responsible for establishing and maintaining the requirements for the receiving process. The appropriate site Sr. Manager, Materials or Supervisor, Materials is also responsible for the care, identification, verification and protection of customer and supplier property while it's in the facility.

The appropriate site Quality Leader (QL) or designee is responsible for approving the use of items in damaged packages, if any.

The site Shipping and Receiving (S/R) personnel are responsible for inspecting incoming material for correct identification and paperwork, quantity of material and condition of containers or packages. Additionally, the site Shipping and Receiving (S/R) personnel are responsible for logging in receipts, scanning barcode labels, applying part identification labels, and placing materials in appropriate stocking locations after it is approved.

Process



Section 1.5 – Bus Assembly

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the bus assembly process from approval of bus bodies to the commissioning and customer inspection and approval of the finished bus.

Responsibilities and Authorities

The appropriate Site Director is responsible for implementing and maintaining the operations activities necessary to meet the internal and customer requirements for quality and the environment.

The Advanced Manufacturing Engineering Manager, Manager, Manufacturing Engineering or designee is responsible for creating appropriate Work Instructions in Visual Factory for controlling quality and environmental operational controls. See BSM Section 2.7.

The appropriate site Sr. Manager, Materials, or designee is responsible for providing the required items for sub-assembly and bus assembly.

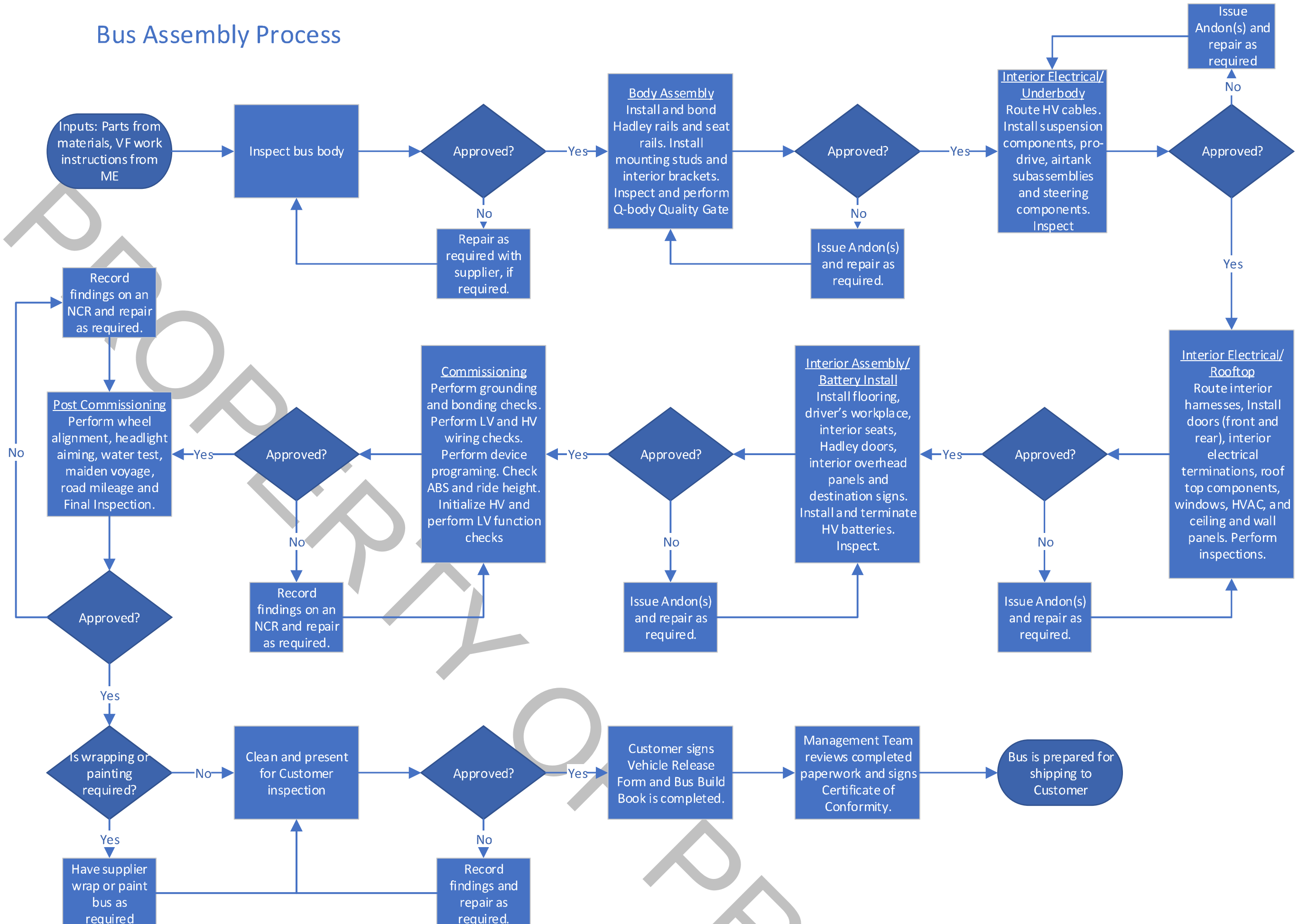
The Quality Technician is responsible for doing the required inspections at each station of the assembly process verifying the operation's quality. Required inspection Work Instructions are found in Visual Factory.

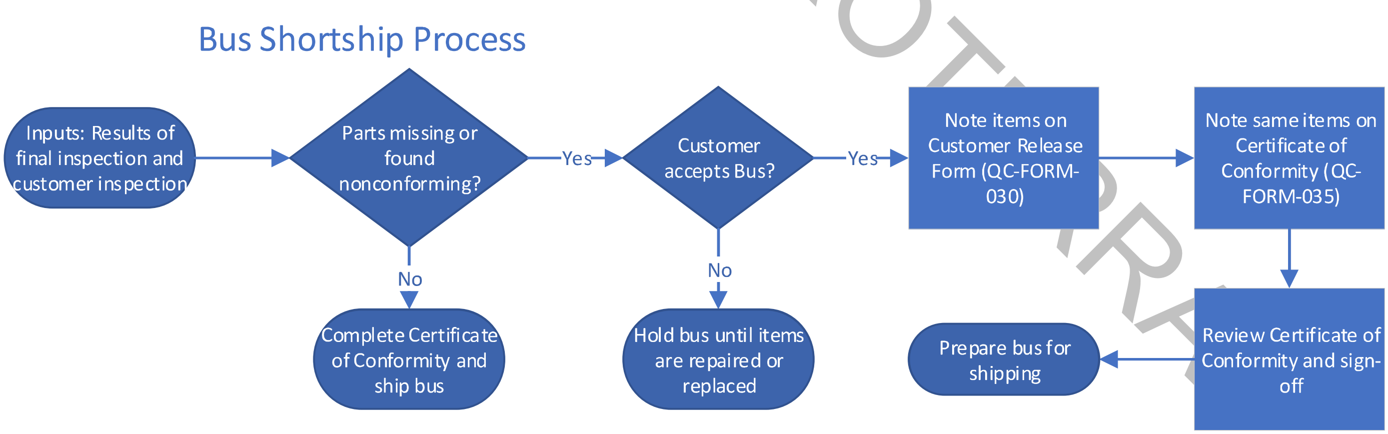
The Operations Associates are responsible for following the work instructions in Visual Factory and maintaining the fixtures and gages used in assembly. Some parts and the completed product are identified according to company and customer requirements throughout the assembly process. The completion of the work instructions in Visual Factory indicates the bus's monitoring and measurement status. Records of any serialized parts are listed in Box and some are in the Bus Build Books for traceability purposes, as required.

The site Quality Leader or designee is responsible for documenting and communicating any short ship items to Proterra leadership and the customer. The signed Certificate of Conformity with a minimum of the Site Director and site Quality Leader or their designees indicates the bus is approved for shipping to the customer. See Short ship process flow below.

All Associates are responsible for quality, following their applicable Work Instructions, the cleanliness of their work area, working safely and protecting the environment. All Associates are also responsible for stopping production, completing an Andon and/or notifying their Supervisor when a quality or environmental problem is found.

Process


Bus Assembly Process
Inputs: Parts from materials, VF work instructions from ME
Inspect bus body
Approved?
Yes
No
Repair as required with supplier, if required.
Body Assembly
Install and bond Hadley rails and seat rails. Install mounting studs and interior brackets. Inspect and perform Q-body Quality Gate
Approved?
Issue Andon(s) and repair as required.
Interior Electrical/ Underbody
Route HV cables. Install suspension components, pro-drive, airtank subassemblies and steering components. Inspect
Approved?
Issue Andon(s) and repair as required
Interior Electrical/ Rooftop
Route interior harnesses, Install doors (front and rear), interior electrical terminations, roof top components, windows, HVAC, and ceiling and wall panels. Perform inspections.
Approved?
Issue Andon(s) and repair as required.
Interior Assembly/ Battery Install
Install flooring, driver's workplace, interior seats, Hadley doors, interior overhead panels and destination signs. Install and terminate HV batteries. Inspect.
Approved?
Issue Andon(s) and repair as required.
Commissioning
Perform grounding and bonding checks. Perform LV and HV wiring checks. Perform device programing. Check ABS and ride height. Initialize HV and perform LV function checks
Approved?
Record findings on an NCR and repair as required.
Post Commissioning
Perform wheel alignment, headlight aiming, water test, maiden voyage, road mileage and Final Inspection.
Record findings on an NCR and repair as required.
Approved?
Is wrapping or painting required?
Have supplier wrap or paint bus as required
Clean and present for Customer inspection
Approved?
Record findings and repair as required.
Customer signs Vehicle Release Form and Bus Build Book is completed.
Management Team reviews completed paperwork and signs Certificate of Conformity.
Bus is prepared for shipping to Customer


Bus Shortship Process
Inputs: Results of final inspection and customer inspection
Parts missing or found nonconforming?
Yes
No
Complete Certificate of Conformity and ship bus
Customer accepts Bus?
Yes
No
Hold bus until items are repaired or replaced
Note items on Customer Release Form (QC-FORM-030)
Note same items on Certificate of Conformity (QC-FORM-035)
Review Certificate of Conformity and sign-off
Prepare bus for shipping

Section 1.6 – Battery Pack Assembly

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the battery pack assembly process from selection of raw material to the inventory of finished product.

Responsibilities and Authorities

The Director, Battery Operations and Manufacturing Strategy (DBO) is responsible for implementing and maintaining the operation's activities necessary to meet the internal and customer requirements for quality and the environment.

The site Process Engineer, or designee is responsible for creating appropriate Work Instructions in Visual Factory for controlling quality and environmental operational controls.

The site Sr. Manufacturing Engineer or designee is responsible for equipment sustainment.

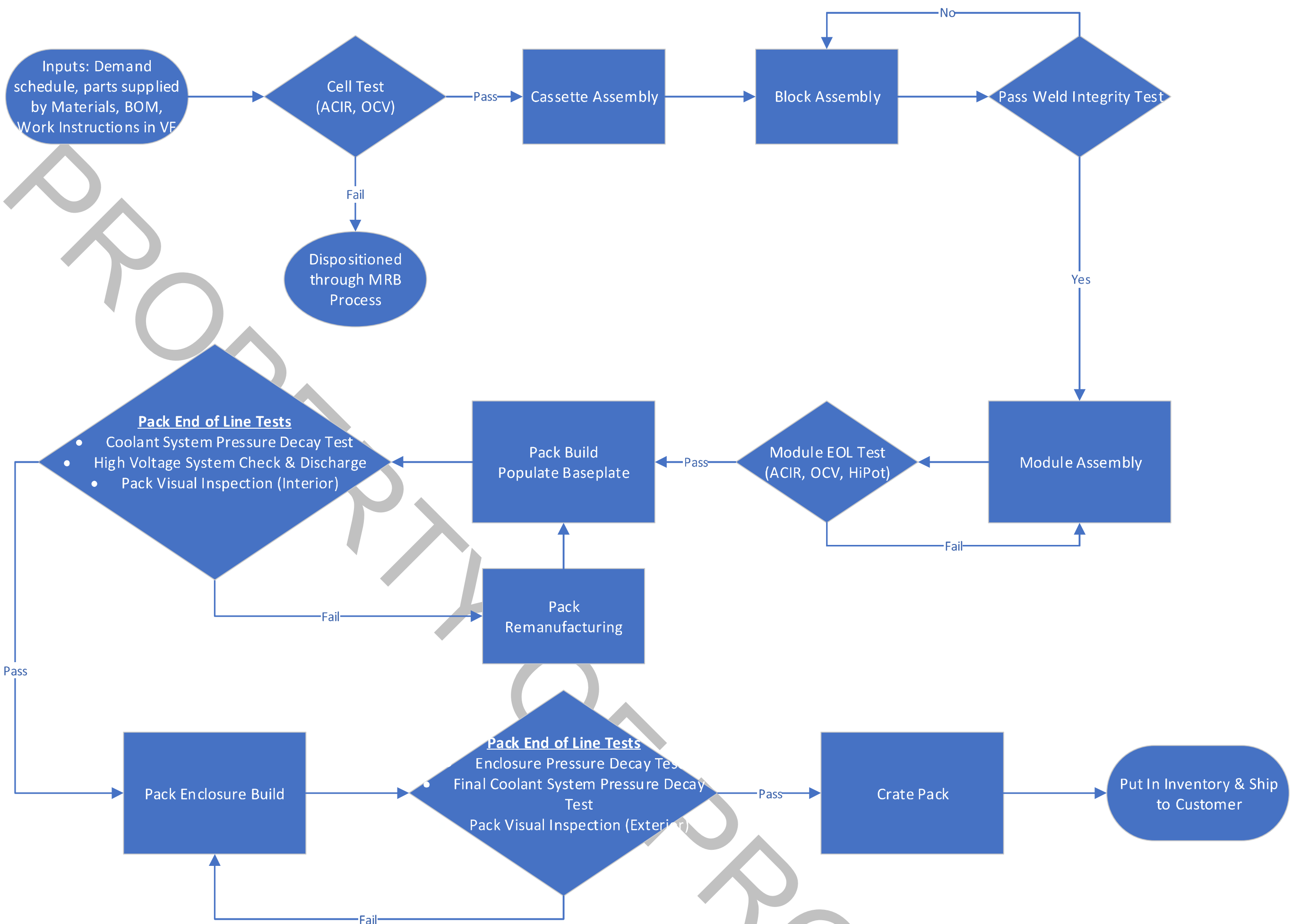
The site Supervisor, Materials or designee is responsible for providing the required items for sub-assembly and final battery pack assembly.

The site Quality Leader or designee is responsible for doing the required inspections at each step of the assembly process verifying operation's quality.

The Operations Associates are responsible for following the Work Instructions in Visual Factory and maintaining the fixtures and gages used in assembly. Some parts and the completed product are identified according to company and customer requirements throughout the assembly process. The completion of the Work Instructions in Visual Factory indicates the battery pack's monitoring and measurement status. Records of the serialized parts, if any, are listed in Box.

All Associates are responsible for quality, following their applicable Work Instructions, the cleanliness of their work area, working safely and protecting the environment. All Associates are also responsible for stopping assembly, completing an Andon and/or notifying their Supervisor when a quality or environmental problem is found.

Process


Inputs: Demand schedule, parts supplied by Materials, BOM, Work Instructions in VF
Cell Test (ACIR, OCV)
Pass
Fail
Dispositioned through MRB Process
Cassette Assembly
Block Assembly
Pass Weld Integrity Test
No
Yes
Module Assembly
Module EOL Test (ACIR, OCV, HiPot)
Fail
Pass
Pack Build Populate Baseplate
Pack End of Line Tests
Coolant System Pressure Decay Test
High Voltage System Check & Discharge
Pack Visual Inspection (Interior)
Fail
Pack Remanufacturing
Pass
Pack Enclosure Build
Pack End of Line Tests
Enclosure Pressure Decay Test
Final Coolant System Pressure Decay Test
Pack Visual Inspection (Exterior)
Pass
Fail
Crate Pack
Put In Inventory & Ship to Customer

Section 1.7 – Dispenser Assembly

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the dispenser assembly process.

Responsibilities and Authorities

The Director, Battery Operations and Manufacturing Strategy (DBO) is responsible for implementing and maintaining the operation's activities necessary to meet the internal and customer requirements for quality and the environment.

The site Process Engineer, or designee is responsible for creating appropriate Work Instructions in Visual Factory for controlling quality and environmental operational controls.

The site Manufacturing Engineer or designee is responsible equipment sustainment.

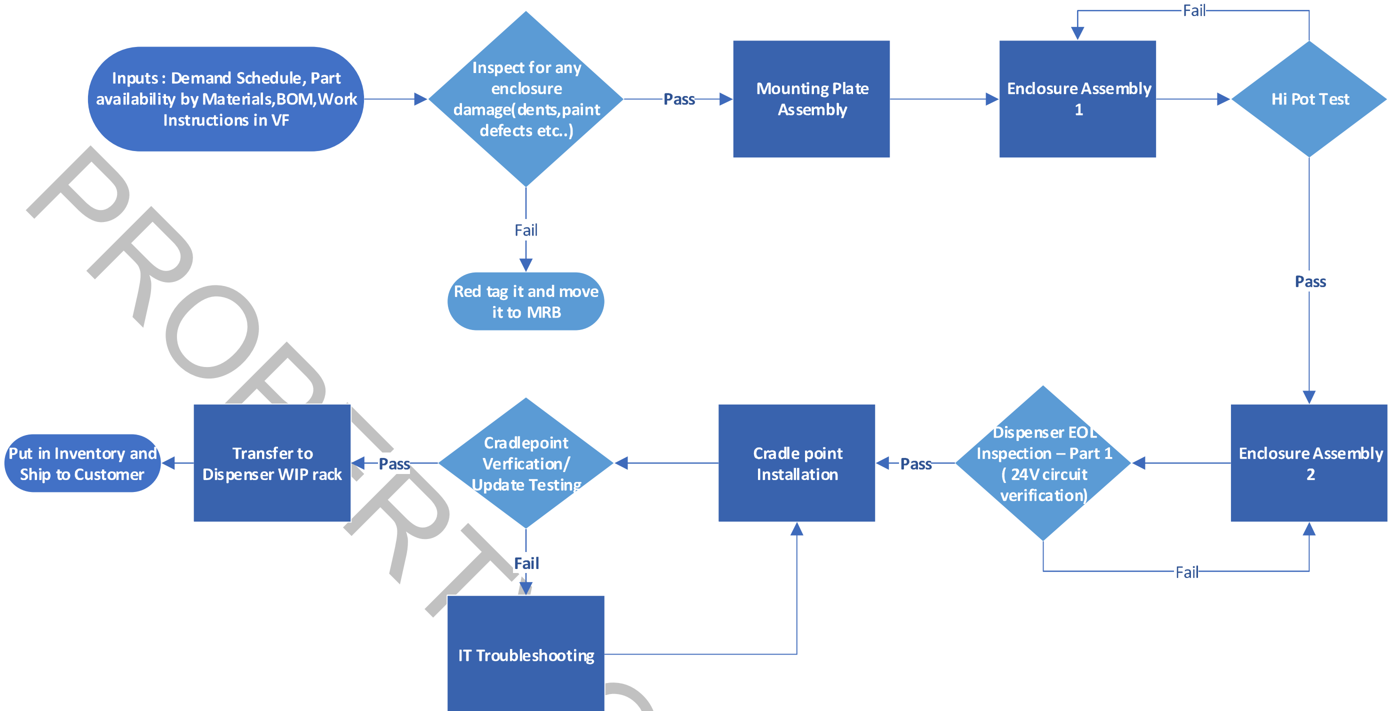
The site Supervisor, Materials or designee is responsible for providing the required items for dispenser assembly.

The site Quality Leader or designee is responsible for doing the required inspections at each step of the assembly process verifying operation's quality.

The Operations Associates are responsible for following the Work Instructions in Visual Factory and maintaining the fixtures and gages used in assembly. Some parts and the completed product are identified according to company and customer requirements throughout the assembly process. The completion of the Work Instructions in Visual Factory indicates the dispenser's monitoring and measurement status. Records of the serialized parts, if any, are listed in Box.

All Associates are responsible for quality, following their applicable Work Instructions, the cleanliness of their work area, working safely and protecting the environment. All Associates are also responsible for stopping assembly, completing an Andon and/or notifying their Supervisor when a quality or environmental problem is found.

Process


Inputs : Demand Schedule, Part availability by Materials,BOM,Work Instructions in VF
Inspect for any enclosure damage(dents,paint defects etc..)
Pass
Mounting Plate Assembly
Enclosure Assembly 1
Fail
Hi Pot Test
Fail
Red tag it and move it to MRB
Pass
Put in Inventory and Ship to Customer
Transfer to Dispenser WIP rack
Pass
Cradlepoint Verfication/ Update Testing
Cradle point Installation
Pass
Dispenser EOL Inspection – Part 1 (24V circuit verification)
Enclosure Assembly 2
Fail
Fail
IT Troubleshooting

Section 1.8 – Charger System and Infrastructure

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the charger system and Infrastructure process. Infrastructure designs are strictly to customer design requirements and do not follow the part and product design requirements of BSM Sec. 1.3.

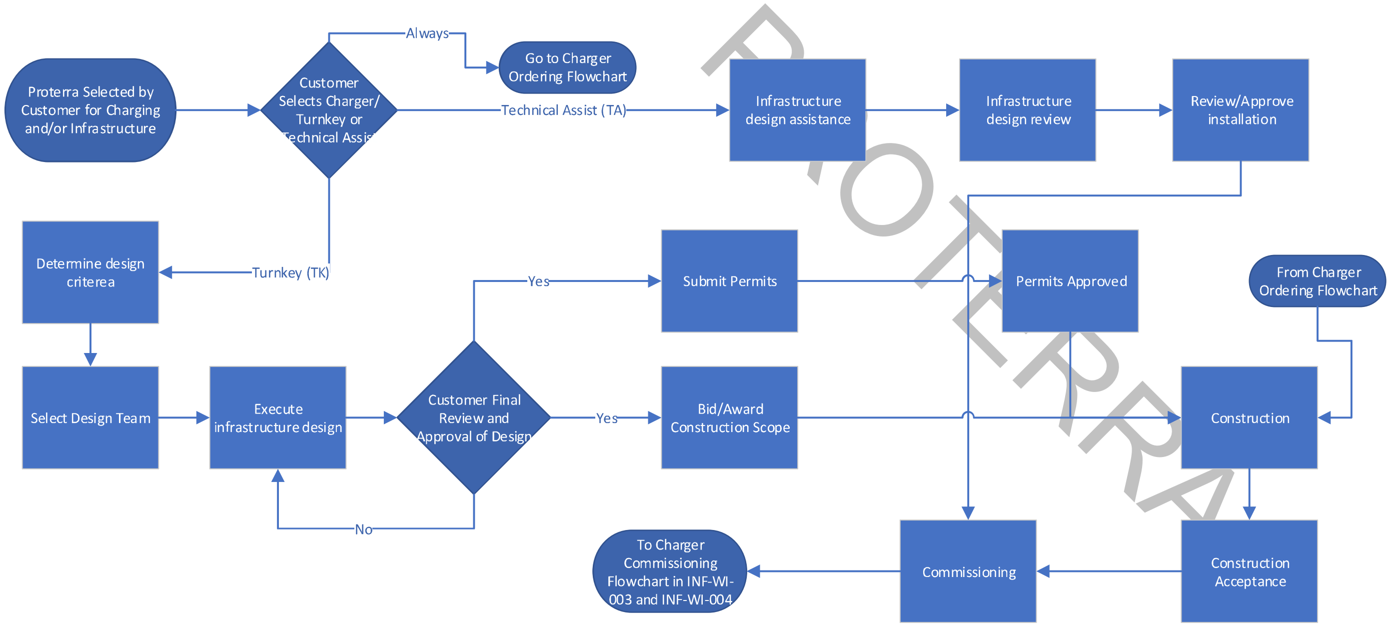
Responsibilities and Authorities

The VP, Energy or designee is responsible for working with the customer to determine if Proterra is to assist with infrastructure design and installation.

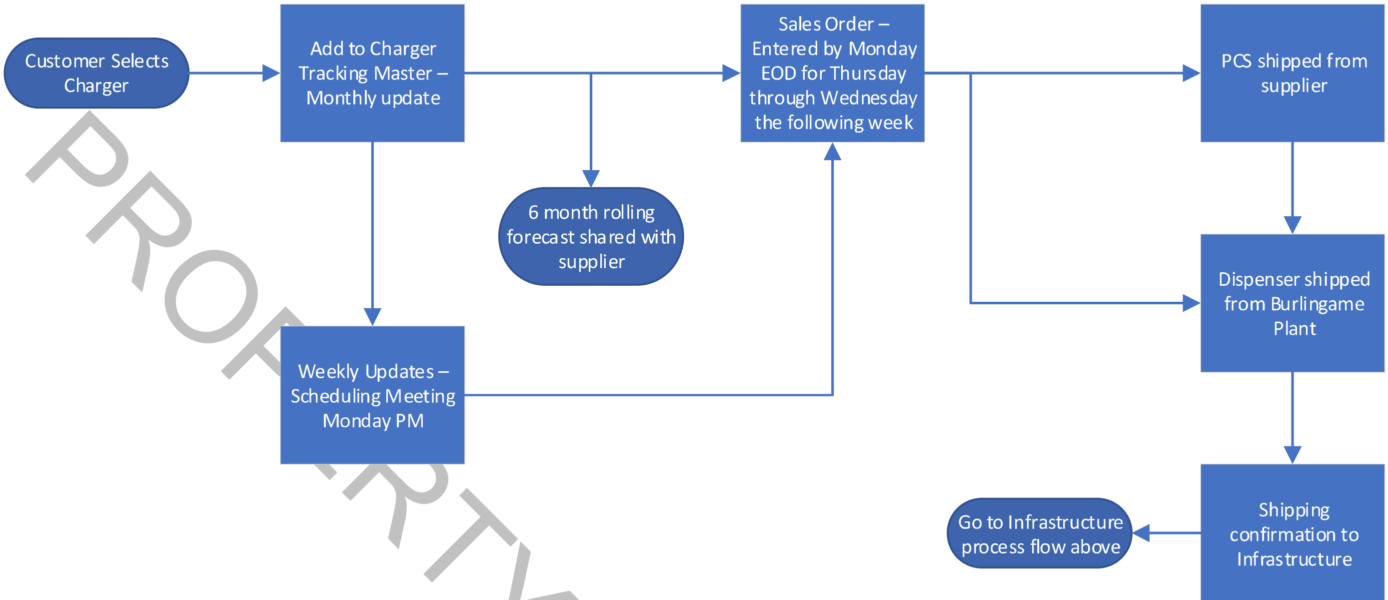
The VP, Energy or designee is also responsible completing the customer design requirements, obtaining any required permits, communicating any environmental requirements and coordinating the construction and final customer approval, as required.

The VP, Energy or designee is also responsible for coordinating the ordering and delivery of the chargers and dispensers when the infrastructure is completed. See Charger Ordering Process below.

Process



Charger Ordering Process



Section 1.9 –Shipping

Purpose

This Process describes the policies, individual responsibilities, procedures, documents and records used to define the shipping process.

Responsibilities and Authorities

The Manager, Logistics (ML) or designee is responsible for the overall transportation and coordination of raw material, prototypes, finished product and aftermarket warranty parts. The ML or designee is also responsible for transportation, coordination and documentation of all international logistics and shipping including compliance to international tariff and treaty requirements. Transportation suppliers are reviewed and approved by the ML and a list of approved suppliers is on the network

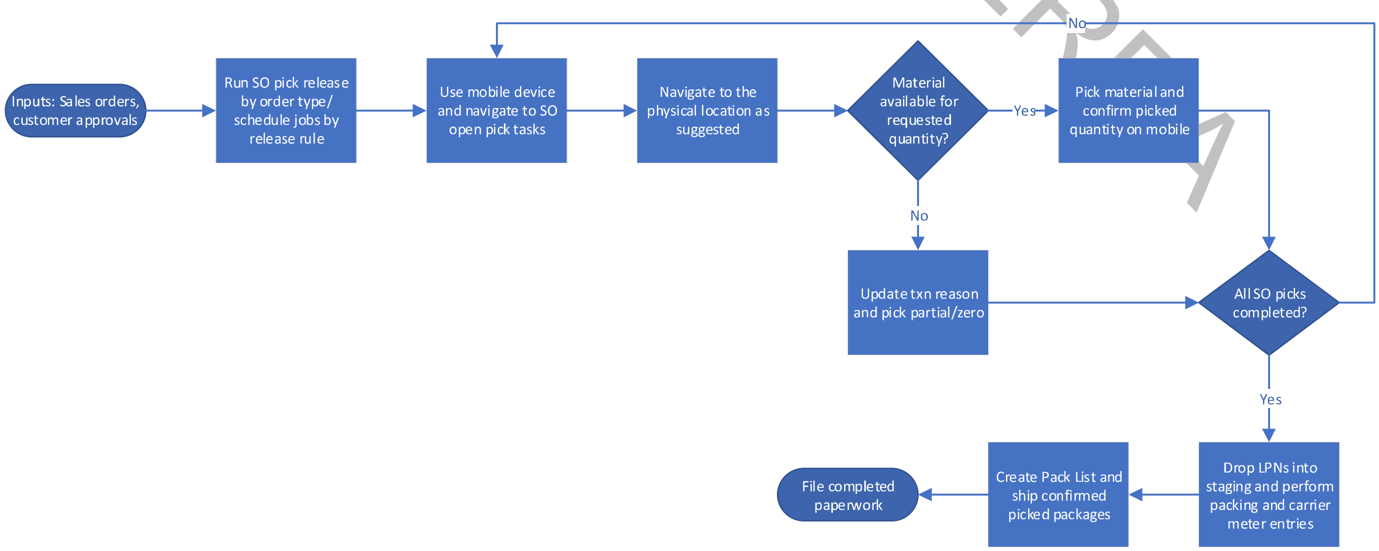
The appropriate site Manager, Materials, Supervisor, Materials or designee is responsible for establishing and maintaining the requirements for the handling, storage and warranty part shipping process. Obsolete parts or product is handled per the Control of Nonconforming Parts and Product Process, See BSM Section 2.9.

The Warranty Manager or designee is responsible for the final release of warranty parts and product to be shipped to the field. See BSM Section 3.3.

The ML, site Manager, Materials or designee is also responsible for preparing the Bill of Lading, Packing Slip, and Invoice, if required.

The site Shipping and Receiving (S/R) personnel are responsible for obtaining the appropriate paperwork, staging and loading the outbound parts or product according to the First-in First-out (FIFO) inventory management system, scanning the barcodes, if applicable, and completing the appropriate shipping paperwork with the driver.

Process



Section 2.0 – Support Processes

Section 2.1 – Human Resources and Training

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the process for human resources and training.

Responsibilities and Authorities

The CEO or COO (Top Management) are responsible for providing the required resources, quality, environmental, health and safety training for the organization and motivation to achieve objectives and targets, make continual improvements and create an environment to promote innovation.

The VP, Human Resources (HR) or designee is responsible for hiring and facilitating the creation of Job Descriptions for all positions covering required education, training, skills and experience. The appropriate HR person reviews the new associate's resume and provides the on-boarding training but the quality, environmental, health, safety and technical training is provided within the appropriate department as required. The resume and appropriate training records are the records of competency. Note: Those persons who were hired prior to November 1, 2019 are fully competent with or without a formal record.

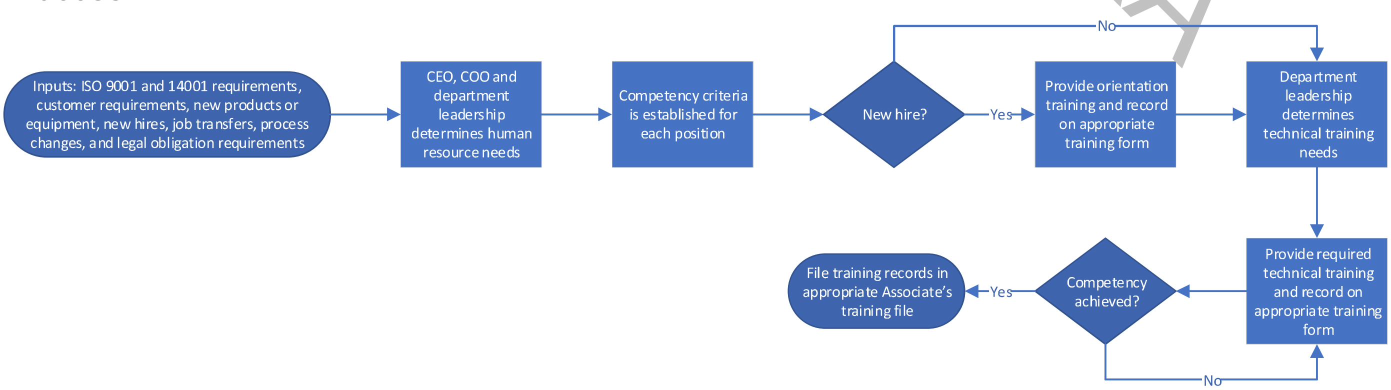
The Quality Management Systems Coordinator or designee is responsible for coordinating the required quality and environmental training and maintaining the quality and environmental training files. The internal audits evaluate the effectiveness of the training provided and measure the extent to which people are aware how they contribute to meeting Proterra Objectives. See BSM Section 3.4.

The Leadership Team, consisting of Top Management and their direct reports, is responsible for determining the training needs of their people and then coordinating the required internal, external or on-the-job training so that customer requirements are consistently and effectively met. A training Skills Matrix is created to verify competency requirements.

The Quality Management Systems Coordinator or designee is responsible for internal quality and environmental communication through bulletin board postings, email bulletins and staff meetings.

All Associates are responsible for attending the provided training classes and applying the lessons learned to meet customer requirements and continually improve Proterra's processes and its objectives. Each person is aware of the relevance and importance of their activities and how they contribute to meeting the Proterra Objectives.

Process



Section 2.2 – Sales, Inventory and Operations Planning (SIOP)

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the sales, inventory and operations planning (SIOP) process.

Responsibilities and Authorities

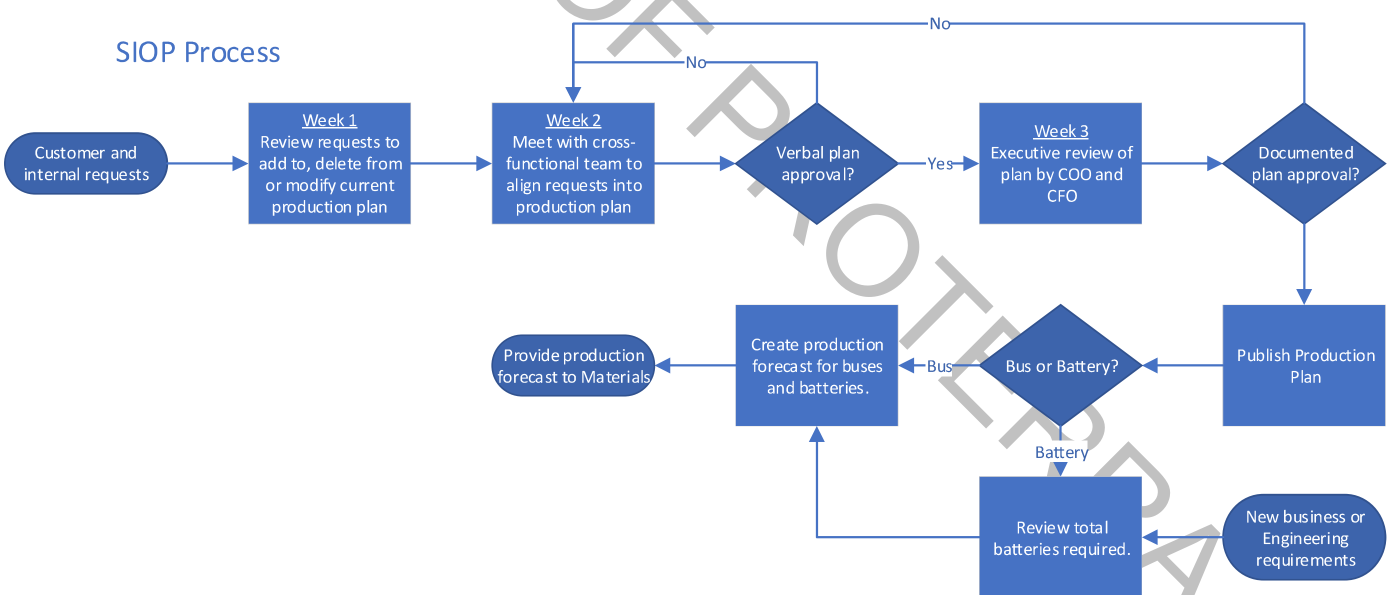
The Manager, SIOP and Operations Planning or designee is responsible for reviewing customer and internal requests and developing the proposed Production Plan.

The cross-functional planning team meets each month to review and approve the proposed Production Plan.

The COO and the CFO reviews and approves the Production Plan.

The Manager, SIOP and Operations Planning provides the approved Production Plan to Materials for procurement to support Operations.

Process



Section 2.3 – Facilities and Environmental Management System

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the facilities process and the requirements of ISO 14001 not covered by any other process.

Responsibilities and Authorities

The CEO or COO (Top Management) is responsible for providing the required infrastructure including the facility, production tooling, qualified and maintained processes and product monitoring and measuring equipment.

Quality Management Systems Coordinator is responsible for the Quality Management System (QMS) and the DBO for the Environmental Management System (EMS).

The appropriate site Facilities Manager or designee is responsible for maintaining the facility and appropriate production equipment, if any, and if controlled planned changes occur, the changes are reviewed, and actions are taken to mitigate any adverse environmental effects.

The appropriate site Facilities Manager or designee is also responsible for establishing and maintaining the Emergency Action Plan (EAP) including the review of this process and the EAP after drills or real emergency situations. Drills are performed at least annually.

The appropriate site Facilities Manager, DBO and site Leadership Team are responsible for identifying the environmental aspects and impacts of the Company's activities, products and services and determining their significance. The significant aspects are listed in the Master Environmental Aspect List maintained by the appropriate site Facilities Manager.

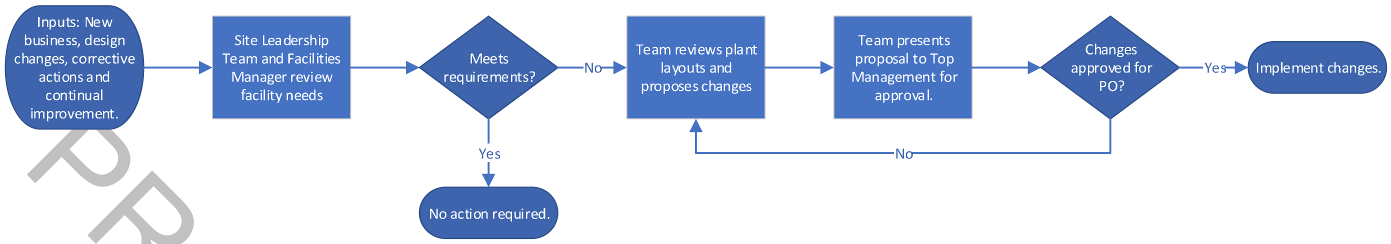
The appropriate site Facilities Manager, DBO or designee is responsible for identifying and having access to the compliance obligations. These are listed on the Master Compliance Obligation Matrix maintained by the appropriate site Facilities Manager.

The appropriate site Facilities Manager or designee is also responsible for receiving, logging and responding to relevant internal and external environmental communications. These are recorded on the Environmental Correspondence Log.

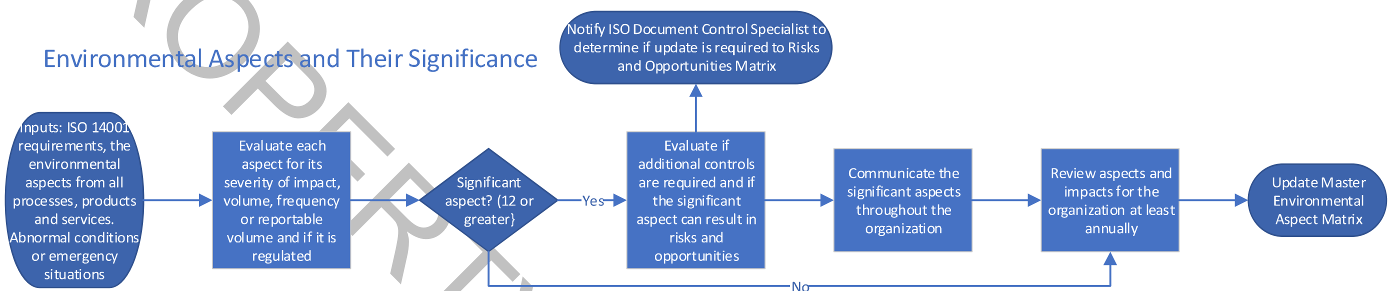
All Associates are responsible for protecting the environment throughout their job activities and for reporting to their Supervisor when they have an environmental concern.

Process

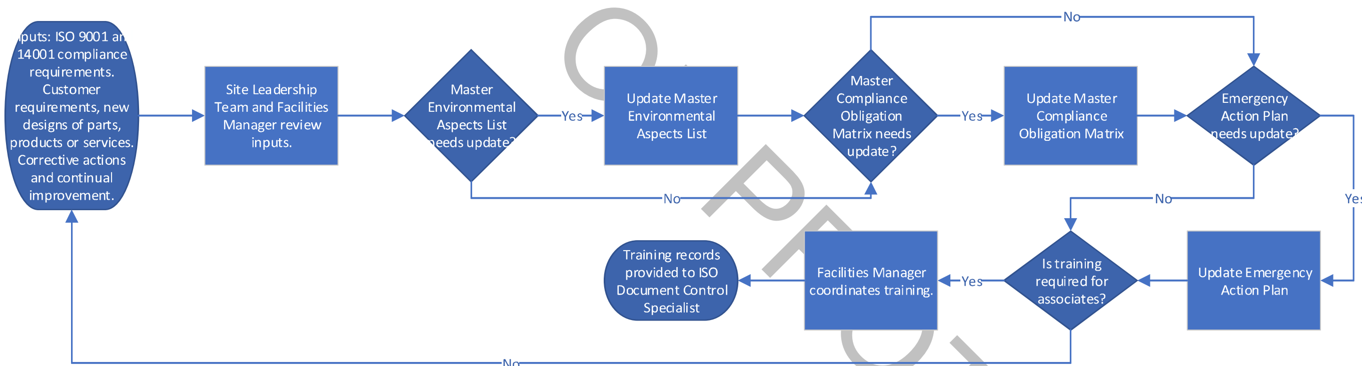
Facilities Management



Environmental Aspects and Their Significance



Maintaining Environmental Compliance Obligations



Section 2.4 – Sourcing

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the sourcing process.

Responsibilities and Authorities

The VP, Supply Chain Management (VP SCM) is responsible for assuring the top 75 suppliers by spend are evaluated and reviewed for performance and improvement cross-functionally at a minimum of a quarterly basis. The VP SCM or designee conducts monthly meetings for the review of scores and supplier improvement plans provided by the individuals listed below. The final supplier rankings (premier, preferred, probation or problem supplier) are used to support commodity sourcing strategies.

The Director, Sourcing (DS) is responsible for developing and guiding the overall strategy and supply base for each commodity. The DS is also responsible for assuring the sourcing team conducts monthly reviews of supplier performance in the areas of cost, cash, technical feedback and ease of business for the top 75 suppliers by spend. Note – the top 75 suppliers by spend account for approximately 80% of the money spent by Proterra monthly.

The Commodity Buyers (CB) and Commodity Managers (CM) are responsible for the preparation of the monthly scorecard followed by the monthly evaluation of the top 75 suppliers based on supplier performance areas of cost, cash, technical feedback and ease of business. The CBs and CMs maintain supplier action items and work with suppliers to improve performance.

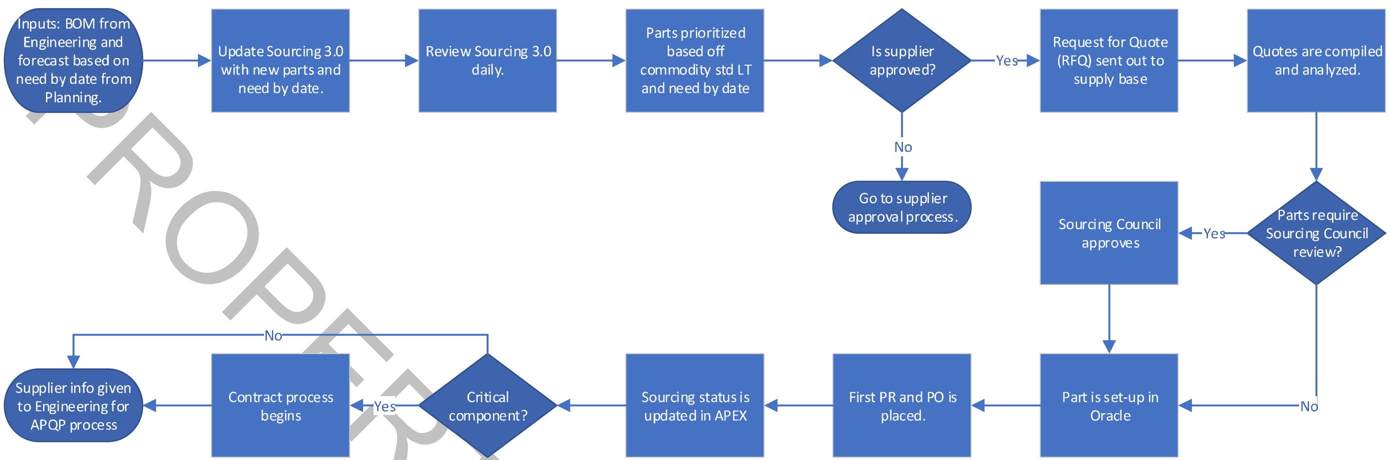
The appropriate Sourcing Manager (SM) is responsible for developing and defining individual commodity strategy, supplier negotiations and management, and approving the sourcing decisions of the CBs. If any supplier property is lost, damaged or becomes unsuitable for use, the SM or designee notifies the supplier and documents the problem on an External Property Notification form.

The appropriate Sourcing Buyer (SB) is responsible for issuing the Request for Quotes (RFQs), supplier negotiation, supplier selection based off analysis from the SM developed bid list, system setup, the initial Purchase Request (PR) and Purchase Order (PO), if there is compression in the delivery requirement, and system integrity.

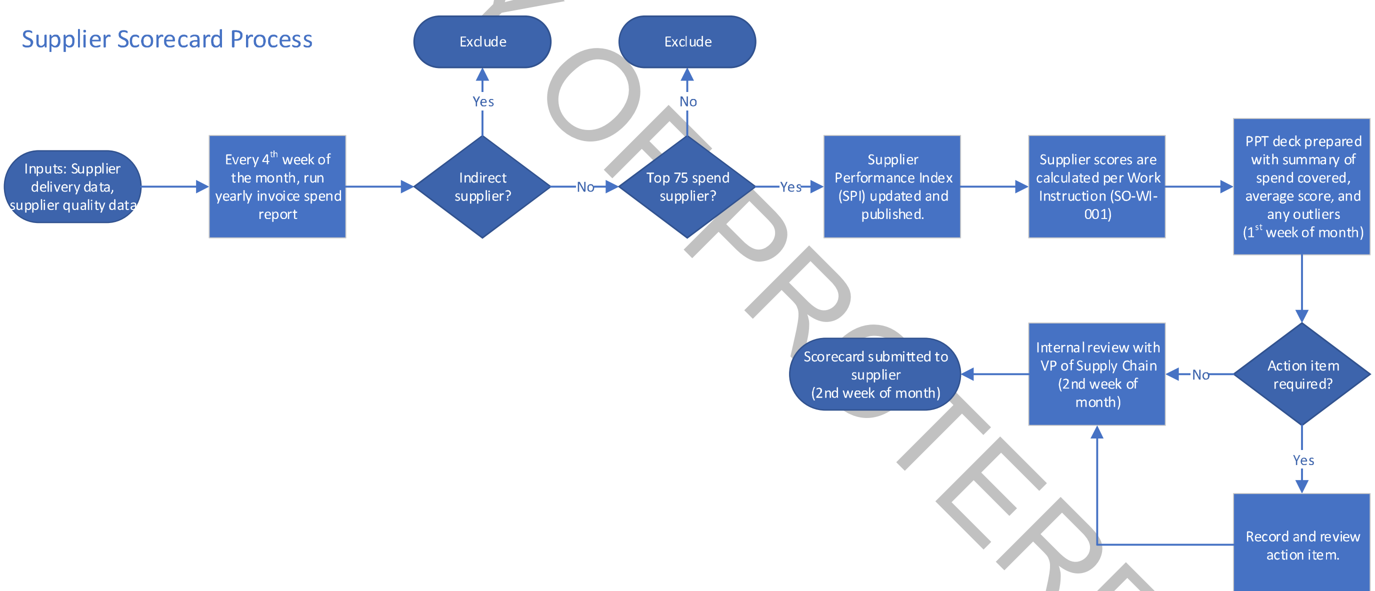
The New Product Sourcing Program Manager is responsible for communicating new program requirements and maintaining & improving the sourcing process.

The Manager, Supplier Quality (SQM) or designee is responsible for assessing the quality of new direct suppliers (for quality and for environmental implementation status), qualifying parts produced by suppliers per the Proterra Qualification Process, managing supplier deviations and/or nonconformances and reporting supplier performance of the top 75 suppliers by spend on the Supplier Scorecard and at Management Review. See BSM Section 3.2.

Process



Supplier Scorecard Process



Section 2.5 – Production Control

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the production control process.

Responsibilities and Authorities

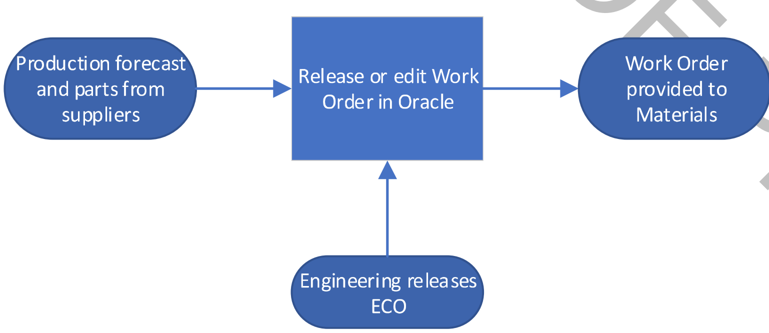
The Manager, SIOP and Operations Planning or designee is responsible for reviewing customer and internal requests for bus, battery, charger, dispenser and OEM production to create a monthly Production Plan and forecast.

The CEO, COO and CFO review and approve the Production Plan at least monthly. See BSM Section 2.2.

The Manager, SIOP and Operations Planning or designee is also responsible for releasing and editing the Work Orders in Oracle.

Process

Production Control Process



Section 2.6 – Procurement

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the procurement process.

Responsibilities and Authorities

The Director, Materials or designee is responsible for obtaining the required components for the assembly operations from suppliers approved by Sourcing. See BSM Section 2.4.

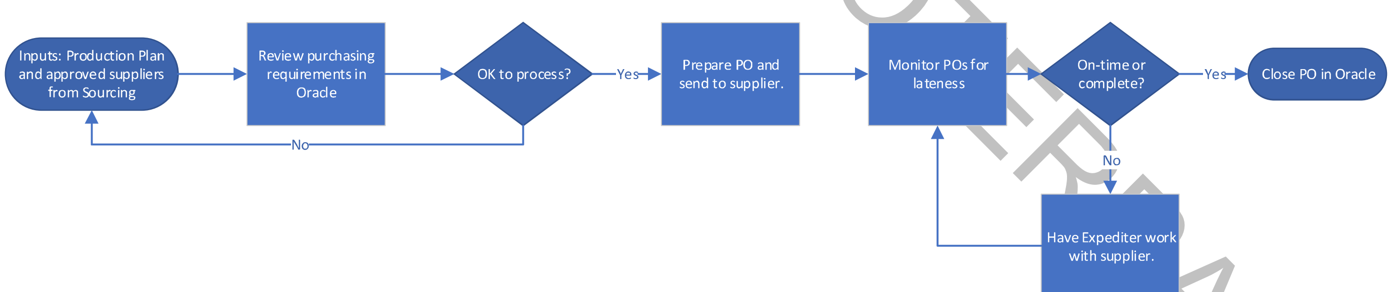
The Buyer/Planners, site Facilities Manager or designee is responsible for communicating any environmental procedures and requirements to suppliers who perform work on Proterra's premises. All parts or products purchased or used in production and subcontracted services conform to appropriate compliance obligations.

The Materials Expeditors are responsible for timely follow-up with the supplier on PO receipt and material delivery dates.

The Shipping and Receiving personnel are responsible for verification of incoming parts or product to ensure it meets Proterra and applicable customer requirements. See Receiving Process BSM Section 1.4.

All Associates are responsible for completing an IPROC Requisition Form for requesting materials or services to be purchased, having the requested purchase approved, if required, and forwarding it to the Buyer/Planner for processing.

Process



Section 2.7 – Manufacturing/Process Engineering

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define manufacturing/process engineering process.

Responsibilities and Authorities

The appropriate site Manager, Manufacturing Engineering (MME) or designee is responsible for production tool and gage design. Customer-owned tooling, if applicable, is permanently marked or tagged with the customer’s name.

The MME, Process Engineer or designee is responsible for verifying the BOM, item quantity, template and attribute are correct and matches with customer configuration. If changes are required, an ECR (Engineering Change Request) is submitted to Engineering.

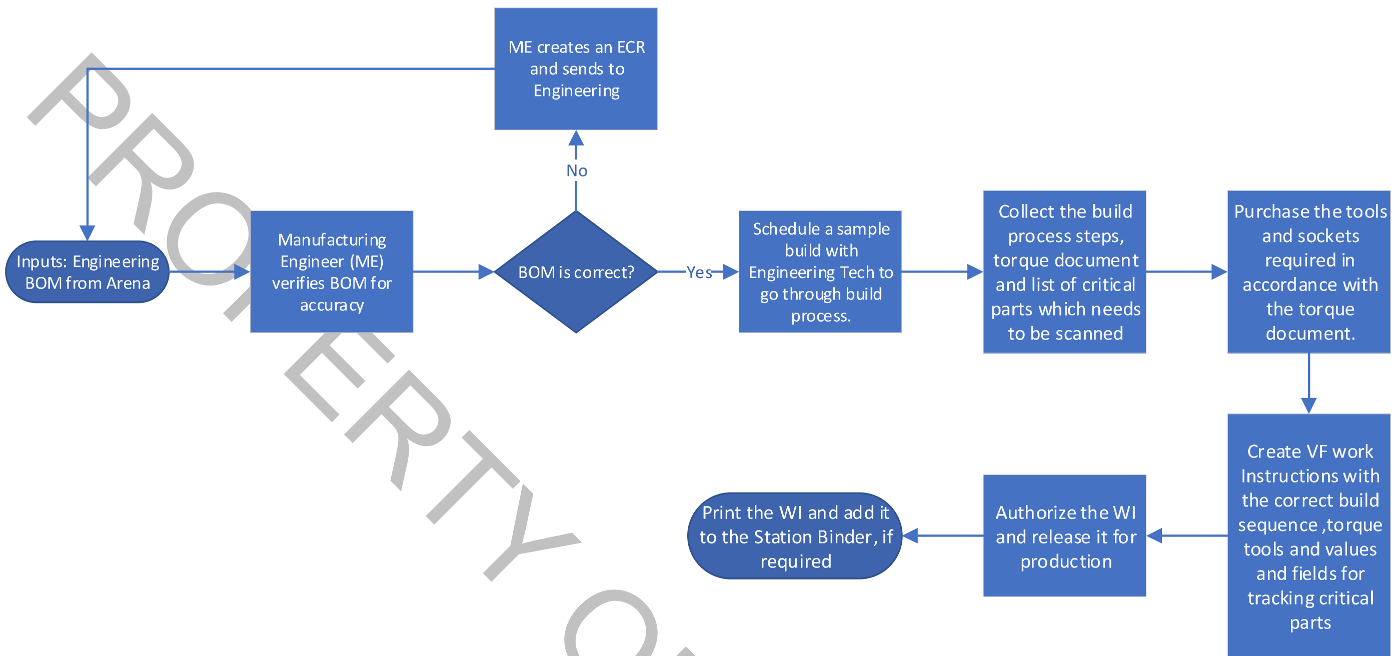
The MME, Process Engineer or designee is responsible for purchasing tools, sockets and setting the tools up in accordance with the torque document. The MME, Process Engineer or designee is also responsible for creating Work Instructions (WI) in Visual Factory with all the required data (build sequence, tool used, part tracking and required inspections).

The MME, Process Engineer or designee is responsible for reviewing the Andon’s issued by Operations or Quality and make changes if necessary and authorize the WI. The MME, Process Engineer or designee also needs to make sure the station binder has the recent authorized revision of the WI in the station binder, if required.

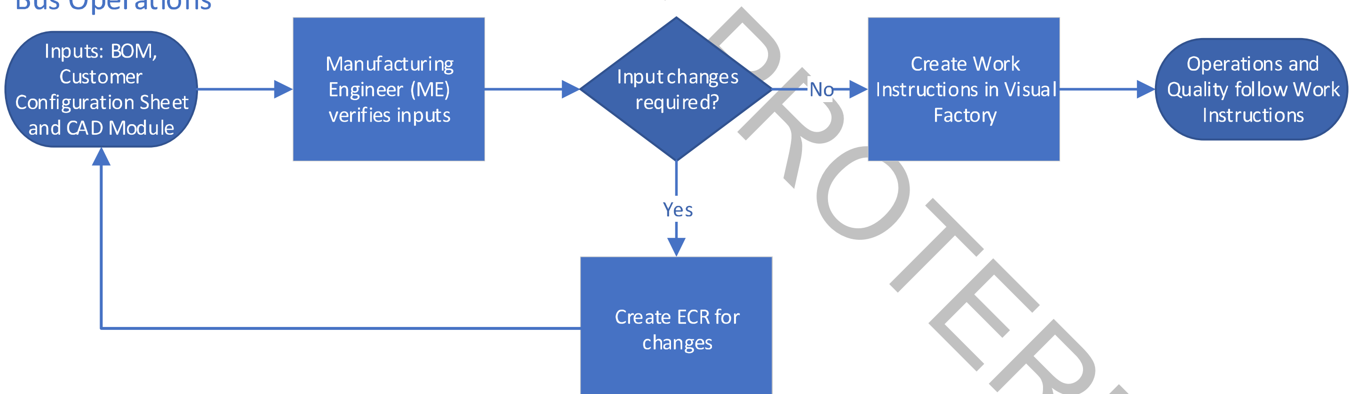
All Associates are responsible for working safely, maintaining the cleanliness of their work areas and tooling, protect production tooling while handling and reporting any equipment maintenance problems to their Supervisor.

Process

Battery Pack and Dispenser Operations



Bus Operations



Section 2.8 – Calibration and Verification

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the process for calibration and verification of monitoring and measurement devices (MMD).

Responsibilities and Authorities

The appropriate site Quality Leader or designee is responsible for determining the MMD needed to provide evidence of product conformity to Proterra and customer requirements.

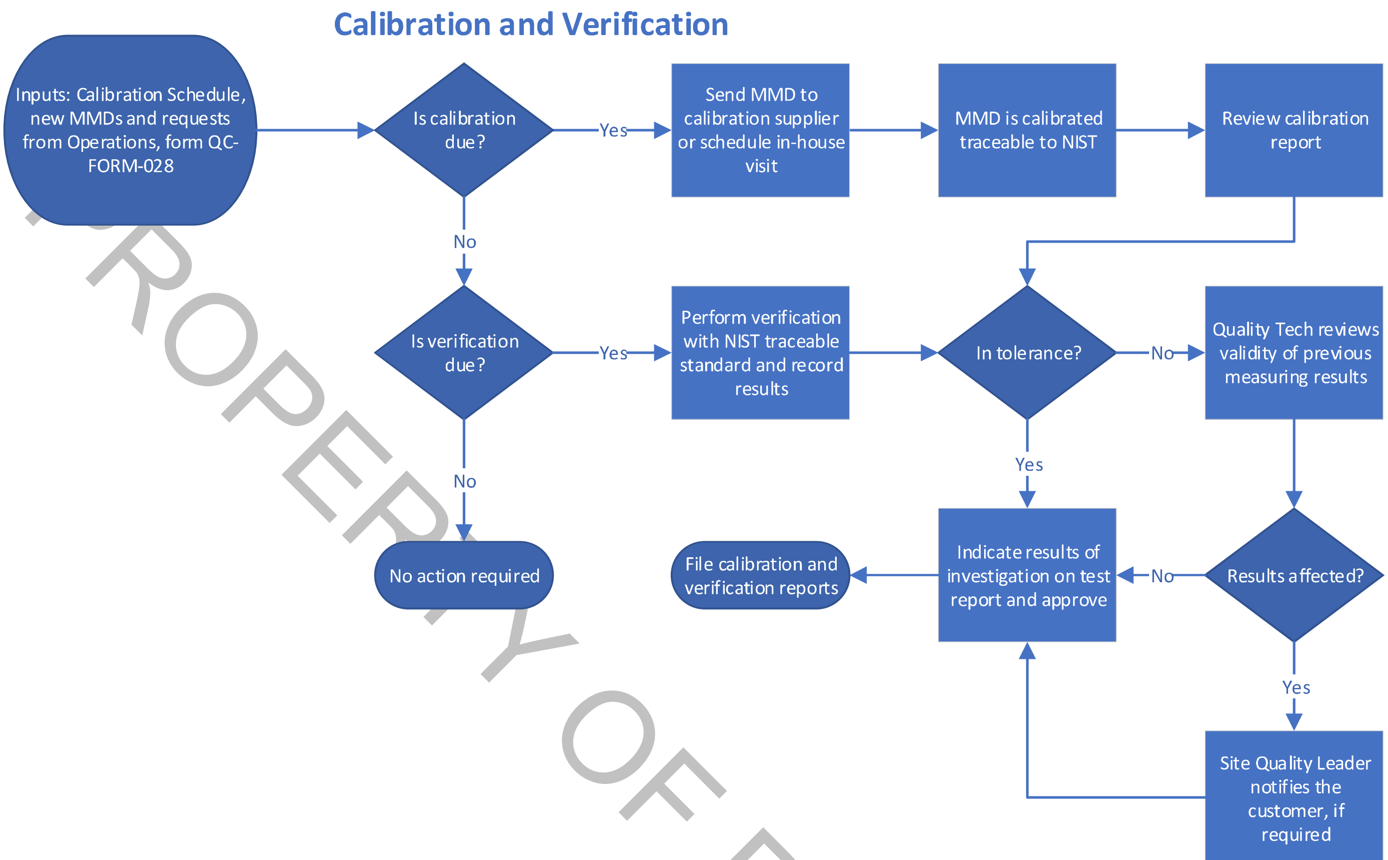
The appropriate Quality Engineer (QE) or Quality Technician (QT) is responsible for the calibration and verification of MMD. This includes MMD for monitoring quality and environmental characteristics, if any. Non-precise measuring tools like scales, tape measures, templates and fixtures are checked at least annually and marked or stickered “Fit for Use”. The QE or QT is also responsible for maintaining calibration, verification and fit for use records.

Qualified, accredited and approved external suppliers perform all the MMD calibrations with traceability to national or international standards. Calibration reports are provided to the QE or QT who reviews and files them. Those tools calibrated internally have an appropriate Work Instruction.

Qualified, accredited and approved external laboratories perform part and product testing, as required. The test reports are reviewed and filed by the site Quality Leader or designee.

All personnel that use MMDs are responsible for only using currently calibrated MMD and handling the MMD in a manner so that the calibration, verification or the measurement is not affected.

Process



Calibration and Verification
Inputs: Calibration Schedule, new MMDs and requests from Operations, form QC-FORM-028
Is calibration due?
Yes
Send MMD to calibration supplier or schedule in-house visit
MMD is calibrated traceable to NIST
Review calibration report
No
Is verification due?
Yes
Perform verification with NIST traceable standard and record results
In tolerance?
No
Quality Tech reviews validity of previous measuring results
No
No action required
Yes
File calibration and verification reports
Indicate results of investigation on test report and approve
No
Results affected?
Yes
Site Quality Leader notifies the customer, if required

Section 2.9 – Control of Nonconforming Parts and Product

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the control of unidentified, suspect or nonconforming parts and product.

Responsibilities and Authorities

The Site Director or designee is responsible for identifying and controlling nonconforming parts and product so that they are not inadvertently shipped to a customer. Nonconforming includes unidentified and suspect parts and product.

The site Operations Manager or designee is responsible to identify suspect parts and initiate the Red Tag form with basic information describing the part as well as the problem description and affixing the form to the suspect part. The part with the Red Tag is placed onto the appropriate nonconforming cart or moved to the appropriate quarantine area.

The site Quality Leader or designee is responsible to conduct the daily nonconforming material meeting and is authorized to make decisions to disposition the parts as usable, repairable, return to supplier or scrap. A Nonconformance Report (NCR) is initiated for each return to supplier nonconforming part.

The site Manager, Operations or designee is also responsible for reworking the part or product, if required, and physically separating the nonconforming from the conforming parts.

The site Supplier Quality Engineer or MRB Coordinator is responsible to handle the return to supplier, scrapping of parts and to control the suspect parts until they are removed from the site.

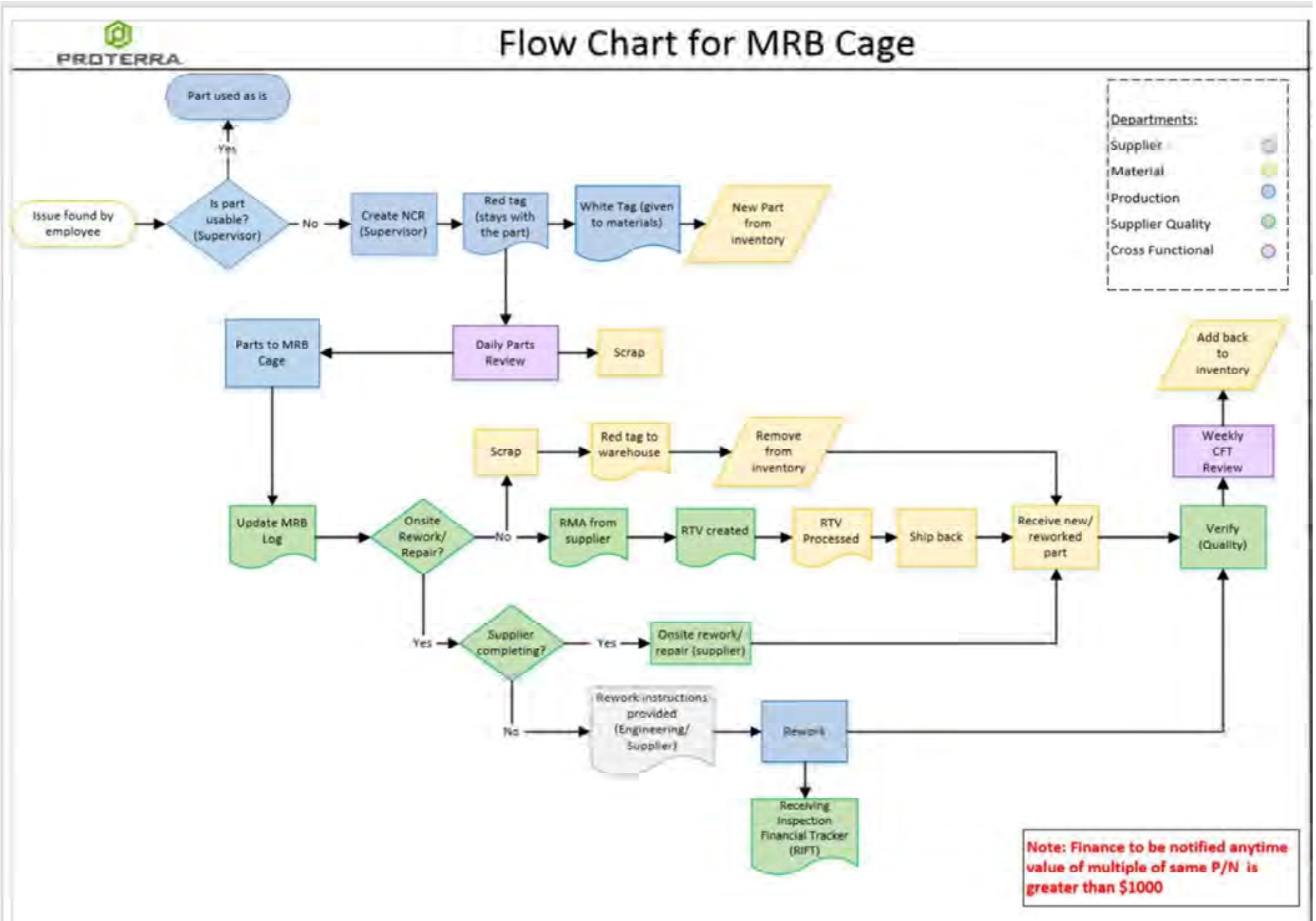
The site Quality Leader or designee is also responsible for obtaining any customer waiver of any known short ship items or nonconformances and obtaining customer signoff prior to shipment. See BSM Section 1.5.

The Director, Field Service or designee is responsible for notifying the customer of any nonconforming product that has shipped to the customer. The Director, Field Service or designee also coordinates the appropriate repair. See BSM Section 3.3.

The appropriate site Manager, Materials, Supervisor, Materials or designee is responsible for removing obsolete parts or product from inventory and either returning to supplier or discarding in appropriate containers.

All Associates are responsible for notifying the site Manager, Operations or designee when parts or products are nonconforming.

Process



Flow Chart for MRB Cage
PROTERRA
Part used as is
Yes
Issue found by employee
Is part usable? (Supervisor)
No
Create NCR (Supervisor)
Red tag (stays with the part)
White Tag (given to materials)
New Part from inventory
Departments:
Supplier
Material
Production
Supplier Quality
Cross Functional
Parts to MRB Cage
Daily Parts Review
Scrap
Add back to inventory
Scrap
Red tag to warehouse
Remove from inventory
Weekly CFT Review
Update MRB Log
Onsite Rework/ Repair?
No
RMA from supplier
RTV created
RTV Processed
Ship back
Receive new/ reworked part
Verify (Quality)
Yes
Supplier completing?
Yes
Onsite rework/ repair (supplier)
No
Rework instructions provided (Engineering/ Supplier)
Rework
Receiving Inspection Financial Tracker (RIFT)
Note: Finance to be notified anytime value of multiple of same P/N is greater than $1000

Section 2.10 – Control of Documents and Records

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the control of system documentation and records.

Responsibilities and Authorities

The CEO or COO is responsible for approving the Business System Manual and appropriate department heads or Subject Matter Experts (SME) approve the other controlled documents.

The appropriate site Quality Leader, Quality Management Systems Coordinator or designee is responsible for the control of quality and environmental documents and records. The controlled documents, internal and external, are saved as PDF files in the Proterra Public Drive and obsolete documents are archived. The controlled records are listed in the Records Table for the control of identification, storage, protection, retrieval, retention time and disposition. The recorded retention times satisfy customer, Proterra and compliance obligations.

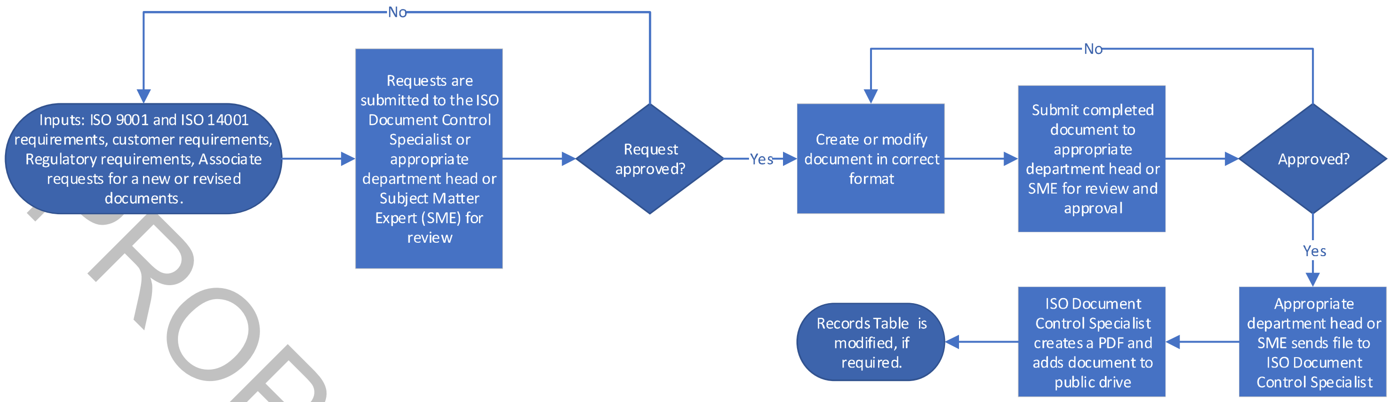
The Sr. VP, Engineering or designee is responsible for controlling customer specifications, Bill of Materials (BOMs), 3D Models and drawings, if applicable. The customer specifications and drawings are reviewed within two working weeks of receipt and are implemented to meet customer requirements. BOMs and changes are managed within the Product Lifecycle Management (PLM) system. Specifications, 3D models and drawings are managed in PLM and Electronic Product Definition Management (EPDM) system.

The appropriate department head or SME in each process is authorized to approve or reject requests for changes to controlled documents submitted to them. If approved, the appropriate department head or SME facilitates the document modification(s), updates the document and submits the approved document to the Quality Management Systems Coordinator, who enters it into the system.

The VP, Information Technology (IT) or designee is responsible for new software development and reviewing and approving purchased software before implementation. The VP, IT is also responsible for the back-up system to protect electronic documents and records within Proterra's quality and environmental management systems.

All Associates are responsible for identifying the need for initiating or revising documented Procedures and Work Instructions required for their job and communicating this request by submitting a marked-up copy or a highlighted file for proposed changes to the (QMS) Coordinator or the appropriate department head or SME. All Associates are also responsible for following their applicable controlled documents and storing the assigned records.

Process


Inputs: ISO 9001 and ISO 14001 requirements, customer requirements, Regulatory requirements, Associate requests for a new or revised documents.
Requests are submitted to the ISO Document Control Specialist or appropriate department head or Subject Matter Expert (SME) for review
Request approved?
No
Yes
Create or modify document in correct format
Submit completed document to appropriate department head or SME for review and approval
Approved?
No
Yes
Appropriate department head or SME sends file to ISO Document Control Specialist
ISO Document Control Specialist creates a PDF and adds document to public drive
Records Table is modified, if required.

Section 3.0 – Management Processes

Section 3.1 – Business Planning and Risk Management

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the business planning and risk management process.

Responsibilities and Authorities

The CEO or COO (Top Management) or designee is responsible for setting Quality and Environmental Objectives, developing the company Business Plan and maintaining the Risk and Opportunities Matrix. The plan and matrix are reviewed at least annually bythe Leadership Team and contain as a minimum the objectives and targets addressing the effectiveness and efficiency of the organization, enhancing customer satisfaction and protecting the environment.

Top Management along with the Quality Management Coordinator is responsible for communicating to the organization the importance of meeting customer and compliance obligations at least annually. Top Management has designated all personnel to be responsible for ensuring products and services meet customer requirements.

The Sr. VP, Engineering is responsible for product design and development. See BSM Section 1.3.

The Quality Management Systems Coordinator is responsible for maintaining the Risks and Opportunities Matrix and for communicating these risks and opportunities to Top Management during Management Review (See BSM Sec. 3.2).

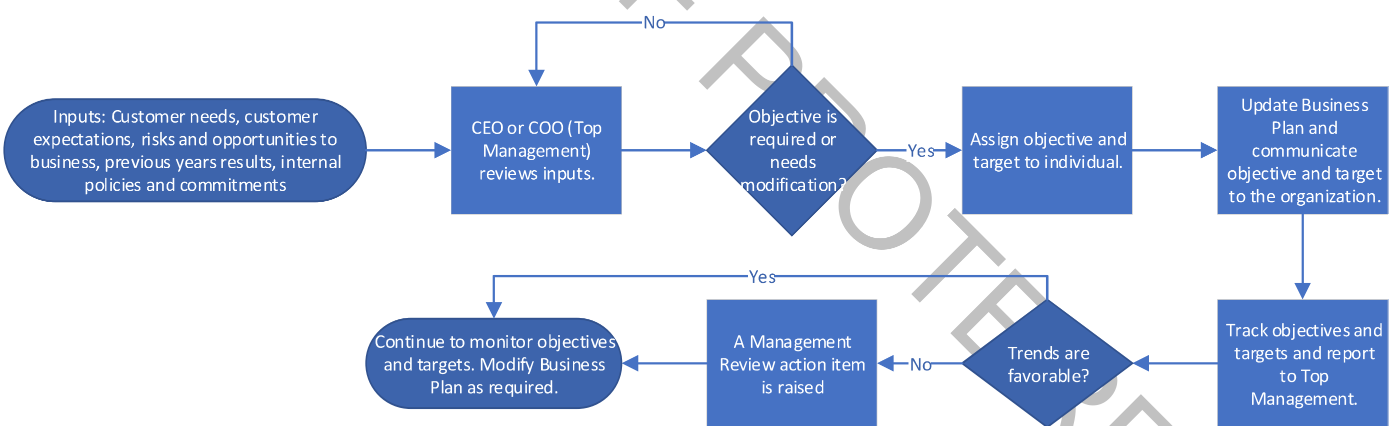
The VP of Quality or designee is responsible for corrective actions (See BSM Section 3.4) and relevant technical training (See BSM Section 2.1 Human Resources and Training).

The quality and environmental objectives of the Company and the person assigned to track them is as follows;

- **Quality and Customer Experience:**
  - Average Daily Availability for Buses and Chargers at (VP, Customer Service)
- **People:**
  - Total Case Incident Rate (TCIR), (COO)
- **Operations:**
  - Delivery of quality products on time to our promise dates – (VP, Customer Service)
- **Engineering:**
  - Product designs, BOMs, and validation tests released in time for supply chain lead time (Sr. VP, Engineering)
- **Supply Chain:**
  - Parts sourced to qualified suppliers on time to support Clear to Build (VP, Supply Chain)
- **Environmental:**
  - No Environmental Violations (Sr. Facilities Manager – Greenville)
  - Achieve companywide diversion and pursue Zero Waste Certification (Sr. Facilities Manager – Greenville)

The assigned individual or designee is responsible for determining the resources required, collecting data, analyzing the data trends and reporting the results at the Corporate Quality and Environmental Meetings and at Management Review Meetings, as appropriate.

Process



Section 3.2 – Management Review

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define Management Review of both the Quality Management System and the Environmental Management System.

Responsibilities and Authorities

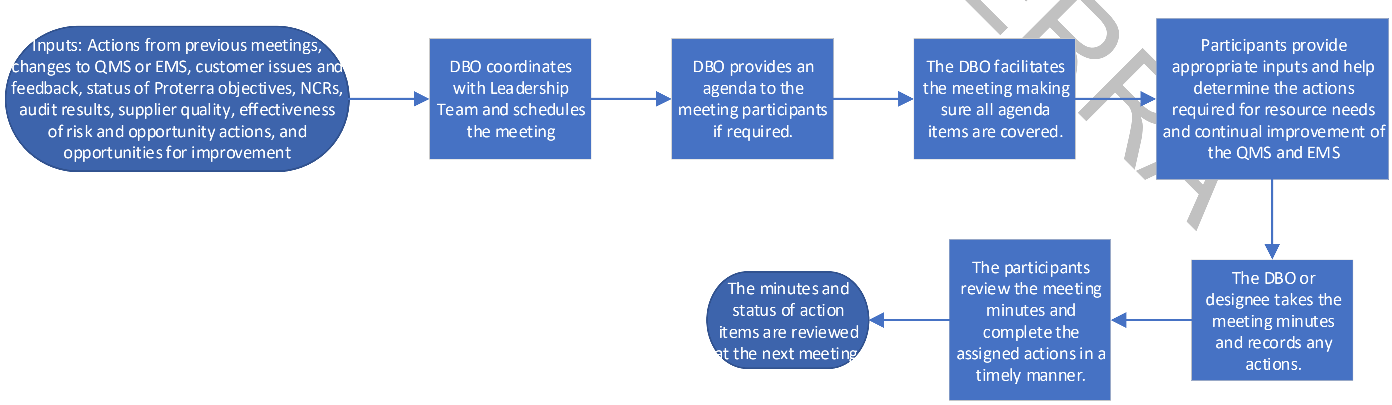
The CEO or COO (Top Management) is responsible for holding a Management Review Meeting at least annually. Meetings can be held more frequently so long as all requirements of the Management Review sections of the ISO 9001 Quality Management System (QMS) and ISO 14001 Environmental Management System (EMS) are reviewed at least annually. Performance trends on Quality are reviewed at least monthly in the Corporate Quality Meetings and at Management Review. Performance trends for Environmental Objectives are reviewed at least monthly during the Safety and Environmental meetings.

The VP of Quality or designee is responsible for reporting to Top Management on the effectiveness of the implementation of the appropriate management system and maintaining the meeting minutes. The Quality Management Systems Coordinator also represents Proterra with the external registration company.

The Quality Management Systems Coordinator or designee is also responsible for taking the meeting minutes and tracking the action items from each meeting. The action items are tracked per the Continual Improvement Process. See BSM Section 3.4.

Participants in the meetings are responsible for providing input to the meeting, helping identify actions required to improve parts, products, services and the appropriate management system and implementing the identified actions on a timely basis.

Process



Section 3.3 – Customer Service

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the customer service process.

Responsibilities and Authorities

The VP, Customer Service or designee is responsible for field service, customer service engineering and warranty and post-delivery part replacement.

The Director, Field Service (DFS) or designee is responsible for receiving and satisfying customer issues and concerns. The concerns and issues are entered into ServiceMax and Nonconformance Reports (NCRs) are generated, if required, per the Continual Improvement Process, see BSM Section 3.4.

The Manager, Customer Service Engineering (CSE) or designee is responsible for supporting field service in solving customer issues and concerns. CSE also works with Development Engineering to resolve customer issues and concerns, if required.

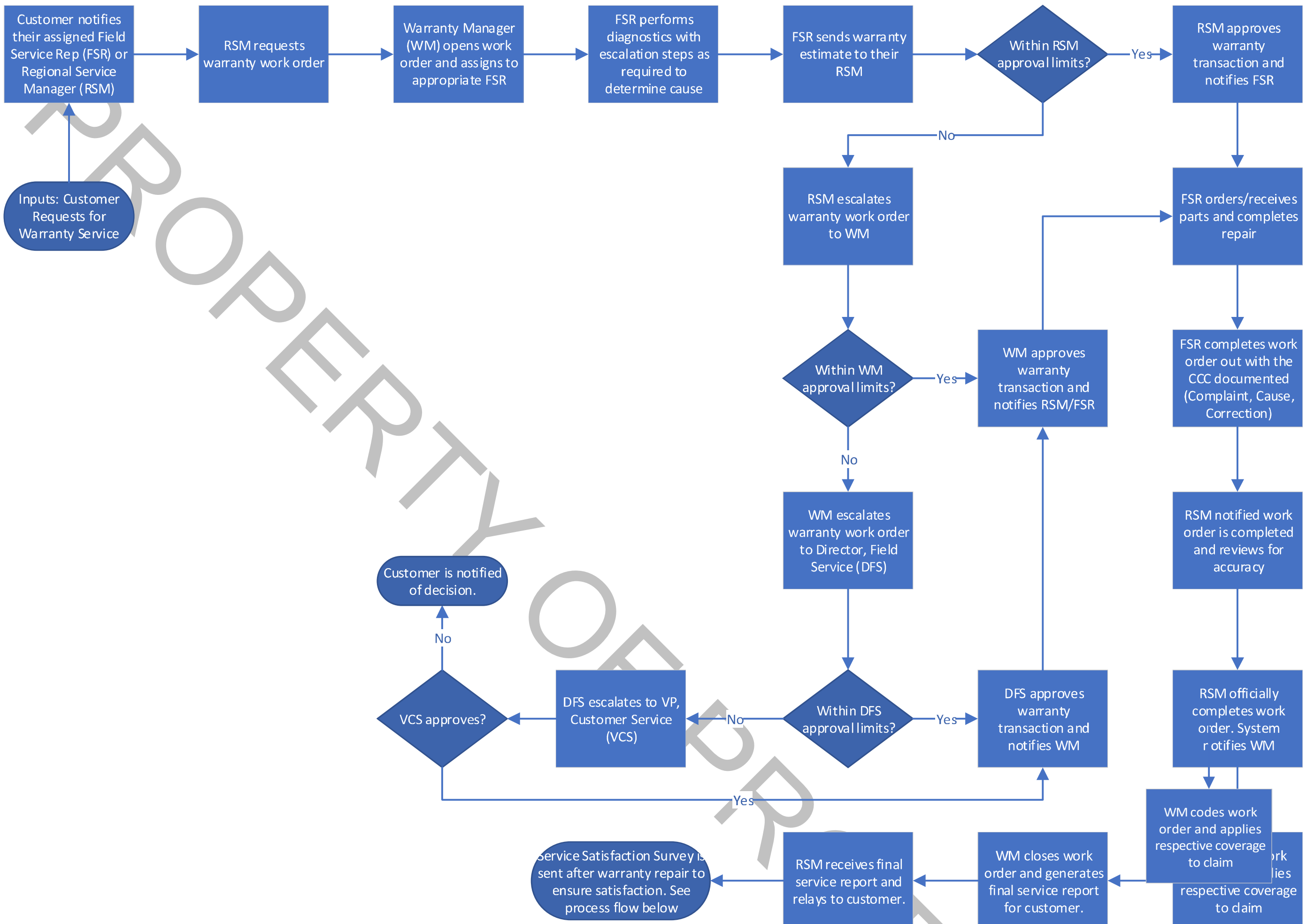
The Regional Service Managers and Field Service Representatives are responsible for working with the customers on solving their issues and concerns.

The Manager, Parts or designee is responsible for coordinating the purchase and delivery of parts needed by field service or the customer to repair and maintain vehicles in the field.

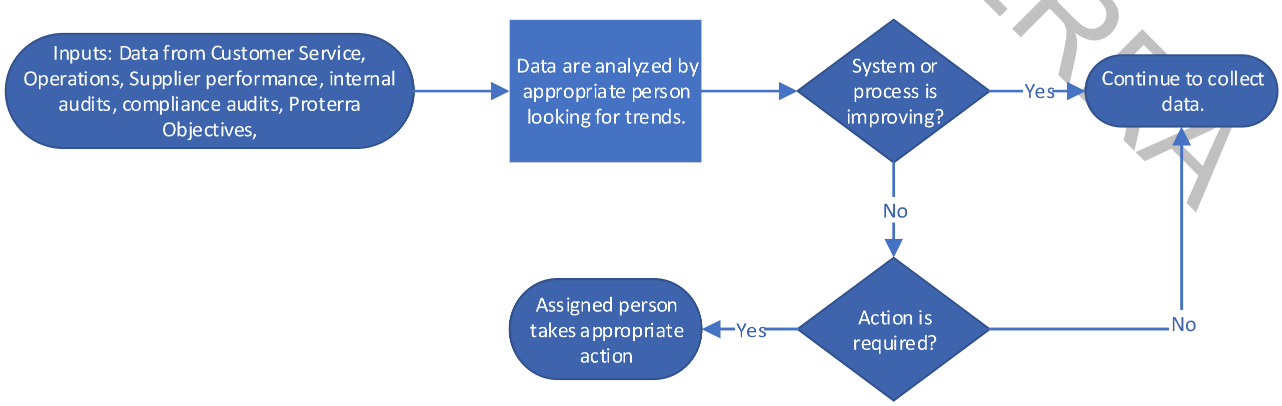
The Warranty Manager or designee is responsible for handling and processing all warranty claims and payment. Warranty claims are tracked on the Warranty Claim Log.

Process

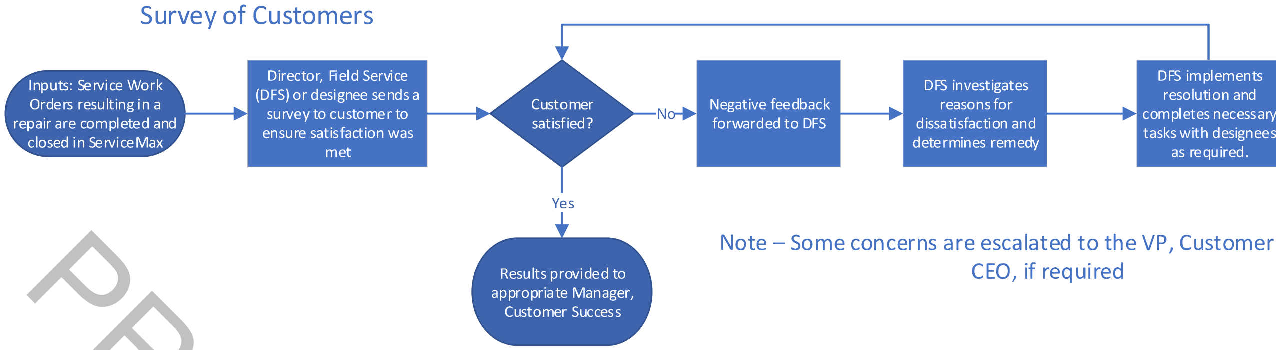
Warranty Approval Process



Continual Improvement



Survey of Customers



Note – Some concerns are escalated to the VP, Customer Service or CEO, if required

Section 3.4 – Continual Improvement

Purpose

This process describes the individual responsibilities and authorities, procedures, documents and records used to define the continual improvement process including internal audits of quality and environmental management systems, environmental compliance evaluations, layered process audits, customer satisfaction and corrective actions.

Responsibilities and Authorities

The CEO or COO (Top Management) is responsible for continual improvement of the Quality and Environmental Management Systems using the appropriate Proterra Policy statements, Proterra Quality and Environmental Objectives, audit results, analysis of data including risks and opportunities to the organization, corrective actions and management reviews.

The Quality Management Systems Coordinator or designee is responsible for scheduling, at least annually, and coordinating quality and environmental internal audits, monitoring customer satisfaction, managing the corrective action system and reporting the results at Management Review. The internal audits are performed by The Quality Management Systems Coordinator, and shall cover all processes, activities and shifts, if appropriate. The frequency is increased based on status or importance of process or area, nonconformances from previous audits, customer complaints or internal process failures.

The Quality Management Systems Coordinator or designee and appropriate site Facilities Manager are responsible for coordinating the required environmental compliance evaluations with an approved, qualified third party at least every three years and managing any environmental compliance corrective actions.

The Quality Management Systems Coordinator is also responsible for coordinating the Corporate Quality Meetings and the Facilities Manager the Environmental Meetings to review the Proterra Objectives and the other Management Review requirements of both ISO 9001 and ISO 14001 management systems. See BSM Section 3.2.

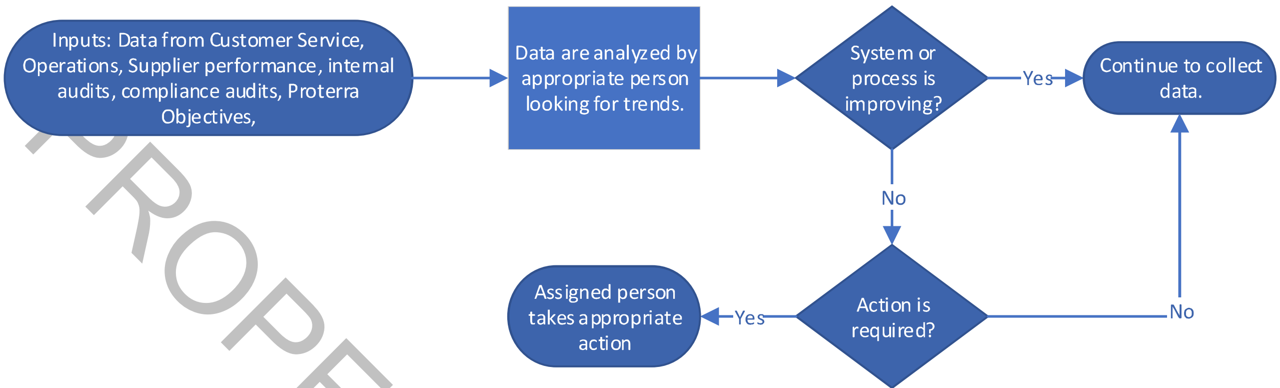
The VP of Quality or designee also coordinates disciplined problem solving to identify root causes so problems can be eliminated and uses error-proofing methods in the corrective action process, as practicable. The customer-prescribed format for corrective actions is used when required.

The DBO, site Quality Leader or designee is responsible for analyzing, in a timely manner, parts or product rejected by the customer and for maintaining records of the analysis.

The VP, Supply Chain or designee is responsible for monitoring supplier performance and for reporting the results at CQE Meetings and Management Review. See BSM Section 2.4.

Process

Continual Improvement



Corrective Action Process