**Integration, Test, and Validation Procedure**

WAVE will design the WPT 250 kW charging system (primary and secondary). In this task, the WAVE shall:
- Design all necessary WPT charging infrastructure for the WPT Primary Charging Station.
- Provide design support related to road and site modification, necessary for placement of charging station.
- Design the modifications to the buses necessitated by the installation and integration of the secondary charging systems, including the following interfaces:
  - Mechanical
  - Cooling
  - Electrical
  - Software

Deliverables include:
- Document defining the mechanical, cooling, electrical, and software interfaces.
- Confirmation of Preliminary Design Review.
- Confirmation of Critical Design Review.

After design is completed, and WPT system built, WAVE will integrate the buses with the WPT charging system. In this task, the WAVE shall:
- Install all Primary WPT charging station equipment, including:
  - WAVE Primary Electronics, Enclosure & Pad
  - Installation and validation of primary system interfaces
- Install all Secondary WPT equipment, including:
  - WAVE Secondary Electronics, Enclosure & Pad
  - Installation and validation of system interfaces of WPT system on bus

Deliverables include:
- Primary WPT charging station(s) including pad installed in roadway.
- BYD buses with WAVE secondary electronics, enclosure & pad installed.
- Bench top demonstration of 250 kW power transfer with assembled enclosures.

After integration, WAVE will test and validate the integrated system. In this task, WAVE shall:
- Test and validate the mechanical, cooling, electrical, and software interfaces between the WAVE WPT system and the BYD bus.
- Validate the air gap between the primary and secondary pads.
- Demonstrate 250 kW power transfer under engineering control.
- Demonstrate 250 kW power transfer with automated software.

Deliverables include:
- Test plan for system-level testing.
- Test plan for validation of interfaces.
- Brief document confirming 250 kW power transfer.

**WAVE Quality Assurance Process**

The WAVE Quality Assurance process will involve the following key elements:

- **Quality Planning**: WAVE employs a Design for Six Sigma (DFSS), sometimes referred to as APQP, which includes the following seven major elements:
  - Understanding the needs of the customer
  - Proactive feedback and corrective action (Bi-Weekly Meetings)
  - Designing within the process capabilities (Utilizing DFSS)
  - Analyzing and mitigating failure modes (Design FMEA)
  - Verification and validation (DMAIC)
  - Design reviews
The American Society of Quality Control defines quality assurance as the planned and systematic actions necessary to provide adequate confidence that a material, component, structure, system or facility will perform satisfactorily in actual service. Quality assurance and quality control are not synonymous. Quality Assurance is an auditing function. Quality control is a checking function. The following definitions of quality assurance (QA) and quality control (QC) will apply:

- **Quality Assurance**: is a project-wide approach incorporating all those planned and systematic activities that establish, oversee and monitor project-related policies, procedures, standards, guidelines, conceptual and functional development, and any other activities directed toward producing an acceptable level of quality in the finished products, including documents, drawings and specifications. QA actions include design checks and reviews, design approvals, document control, and audits of QC procedures.

- **Quality Control**: means the total of all those project-specific activities undertaken to apply the quality control policies, procedures, standards and guidelines, and intended to maintain an acceptable level of quality in the preparation of written documents, design calculations, design drawings, specifications and contract bid documents; and to achieve conformity with the project goals and requirements. The quality control program includes independent reviews, calculation checks, constructability reviews, plan reviews, documentation of all design work, manufacturing, assembly, and construction.

WAVE will produce, demonstrate and validate the en route charging equipment that is proposed for use at the en route charging station. At the time for demonstration, WAVE will have deployed four systems with four different transit agencies. If requested, WAVE can demonstrate the proposed equipment at any of its deployed 250 kW systems. Additionally, WAVE plans to demonstrate and validate the actual system that will be used for the client’s Electric Bus Project during a Pre-Delivery Inspection/Demonstration. Finally, once deployed to the client, WAVE will again demonstrate and validate the 50 kW charging system.

**WAVE Charging System**

The WAVE charging system consists of 5 major subsystems:

1. Primary power conversion from grid power (60 Hz) to inductive transfer power (X Hz)
2. Coupler pad, primary (primary charging plate embedded in the ground)
3. Coupler pad secondary (secondary charging plate mounted on the underside of the target vehicle)
4. Secondary power conversion from X Hz back to direct current (DC) for battery charging operations
5. Primary and secondary cooling systems (to cool the power electronics in the control system)
6. Control system (consists of power electronics on both the primary and secondary sides)

1. Primary and Power Conversion – This system converts the 480 volt/60Hz service to the high frequency power utilized in the coupling system. The electrical components consist of standard off-the-shelf (OTS) high power electronics (transformers, breaker panels, etc.) and DC power converters and WAVE custom designed components. The OTS components are purchased from large power electronics companies, normally through local distributors. The WAVE custom components are purchased from contract manufacturers skilled in the specific area of manufacture, such as PCBA manufacturing, cable/harness, and machined components. All the components have quality control points identified and planned by engineering, supply chain management and in many cases with the suppliers. The assembly of the components – ‘Box Build’ - is completed by WAVE technicians at our Salt Lake City Technical Center. After completion of the WAVE assembly, final assembly into Primary Enclosure is completed at the WAVE technical center using a pre-assembled traditional high power enclosure by a local electrical contractor (See Installation Plans).
2. Coupler Pad, Primary – The primary coupler pad is constructed by PacWest, a regional construction company with engineering expertise in roadway devices. PacWest constructs the pad with concrete, rebar, resin and WAVE proprietary components supplied by commodity suppliers. This pad is then delivered to WAVE for final testing at the Technical Center and supplied to the installation site (see Installation Plans).

3. Coupler Pad, Secondary – The secondary pad is designed by WAVE, with components supplied by contract manufacturing for molding and machining. Commodity suppliers provide the balance of OTS components. This coupler pad is assembled and tested at the WAVE Technical Center before shipping to our OEM bus partner.

4. Secondary Power Conversion – Similar to primary power conversion above, with the completed ‘box’ provided to our OEM bus partner for installation.

5. Cooling System – The cooling system provides the cooling to the power conversion systems. The cooling system consists of OTS components such as a chiller, tubing, fittings, and cold plates. WAVE assembles and tests these components in our Technical Center and are physically included in the WAVE primary and secondary conversion systems.

6. Control System – The control system includes custom designed PCBA's, a tablet computer and software. The PCBA's are provided by contract manufacturers. The software is written and tested by WAVE at the Technical Center. The control system is included into the WAVE boxes that also include the power conversion systems.

Maintenance Requirements

Attached is WAVE’s System & Maintenance Manual for WAVE’s UTA project at the University of Utah. The system that will be built now will have a superior design to the UTA project and will have a slightly different maintenance manual but this is an illustrative example for what WAVE will provide. In addition, WAVE provides manuals for all major sub componentry.

Contractor’s Experience and Capability

WAVE Inc. is a Delaware Corporation and a technology spin-off from the Utah State University Research Foundation. WAVE (Wireless Advanced Vehicle Electrification) is commercializing a suite of WPT technologies that create practical and economical solutions for the transit and off-road industrial electric vehicle markets worldwide. WAVE overcomes battery limitations in electric buses by delivering energy wirelessly to stationary vehicles using electrical infrastructure embedded in the roadway and vehicle-mounted receiver plates. Charging vehicles wirelessly enables them to reduce on-board battery size by up to 85% and increases battery life. WAVE is partnering with several bus manufacturers to deliver “WAVE Powered” buses to the market. WAVE charging systems extend the short ranges of traditional plug-in electric buses to meet the requirements of urban transit routes. WAVE has developed charging solutions for electric bus transit and shuttle systems and is currently engaged in commercial demonstrations in partnership with the Utah Transit Authority (UTA), Monterey Salinas Transit (MST), McAllen Metro (MCA), and Antelope Valley Transit Authority (AVTA).

Currently, WAVE has approximately 26 employees.

WAVE, Inc.
4752 West California Ave
Suite B400
Salt Lake City, UT 84104
WAVE EXPERIENCE

Projects

In the past 3 years, WAVE has performed services of similar size and scope to the services proposed, on five projects:

- **Utah Transit Authority (UTA) Feeder Shuttle**  
  WAVE’s first commercial, wirelessly charged bus was delivered to UTA in 2013, and began partial service in February 2014. The system had its official in service launch on October 29th, 2014. The wireless charging system is installed at the University of Utah and the receiver pad and electronics have been installed and integrated on an electric bus from Complete Coach Works (CCW). WAVE has provided a fully warranted, wirelessly powered charging system under a contract with UTA. The system power a 40’ all electric bus, built by CCW, serving as a feeder route to UTA’s South Campus TRAX light rail station. With WAVE’s 50 kW charging system in place, the bus will be able to run a full duty cycle. The project is being funded by a TIGGER grant from the Federal Transit Administration (FTA).
State Rep. Johnny Anderson (R-Taylorsville), Salt Lake County Mayor Ben McAdams, Utah Transit Authority CEO Michael Allegra cut the cord at WAVE’s official 50 kW system launch.

- Monterey Trolley
  Monterey-Salinas Transit, in partnership with WAVE, is replacing a diesel vehicle with a zero-emissions electric trolley powered by WAVE’s 50 kW wireless charging system, reducing emissions and noise pollution. The trolley will operate along Monterey’s scenic waterfront and connect the Monterey Bay Aquarium with Fisherman’s Wharf, downtown Monterey and historic Cannery Row, allowing travel between these landmarks to be more enjoyable for both locals and tourists. Funding for this project comes from a Clean Fuels Grant from the FTA. WAVE developed and issued a Request for Proposal for OEMs to remanufacture the trolley in February and selected CCW as the repower contractor for the vehicle. The WAVE charging system was be installed in Monterey by spring 2015 with service beginning in summer 2015 with the summer trolley season.
• **McAllen Metro**  
In November 2013, WAVE was selected as the prime contractor on a TIGGER funded project to deliver two electric buses “Powered by WAVE”. The buses will be provided by CCW and when completed will provide all-electric bus service to the airport, hospital and main shopping center. WAVE completed delivery on the project in summer 2015.

• **Antelope Valley Transit Authority**  
In March 2014, WAVE was awarded a contract by the AVTA Board of Directors for two wireless charging stations to support two BYD all electric buses. The contract was executed in the beginning of December 2014, and WAVE completed delivery on the project in summer 2015.
• **Utah State University "Aggie" Bus**
  WAVE, in partnership with Utah State University (USU), developed the first solid-state 25 kW wireless power transfer charging system in North America for bus transit. The wireless charging unit charges a 22’ Ebus on USU's Innovation Campus. USU’s Aggie Bus has achieved several significant milestones: a power level up to 25 kW on a single pad (under bus in image below), greater than 90 percent efficiency from the power grid to the battery, and a maximum misalignment tolerance of up to four inches.

![Aggie Bus image](image_url)

**References:**

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<td>Agency Name</td>
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Financial Standing

WAVE is financially solvent and has the capacity to carry out all proposed activities assigned to it in the Scope of Work. WAVE can provide financial statements under a Non-Disclosure Agreement if requested.

WAVE generates revenue through the sales of WPT products and engineering services to transit agencies to enable them to incorporate battery operated buses that can achieve route expectations. Since October 2011, WAVE has generated over $7.1 million of sales for three contracted projects. Finally, WAVE has a robust sales pipeline of projects in development that are expected to lead to several additional contracts in the next 6-12 months.

WAVE has also been granted over $2 million USD in R&D grants from the Department of Energy, the State of Utah’s Technology Commercialization & Innovation Program (TCIP), the Utah State University Research Foundation (USURF), and the Utah Science Technology & Research Initiative (USTAR) for development of high power WPT systems.

WAVE has also raised significant investments from private investors.

Based on current revenue projections, cash flow, and positive support from the financial community, WAVE expects no issues in maintaining positive funding during the delivery of this project.

The expenses and balance sheet requirements of WAVE are largely dependent on the number and size of projects. We currently contract with construction companies, contract manufacturers, and component suppliers to fulfill contracts, minimizing our need for a large balance sheet. With this in mind, we have been approved by a regional bank for loans and have excellent support from equity investors to provide investment as needed to manage debt equity ratio targets.

Manufacturing Process

WAVE has a 2,100 square foot manufacturing and test facility at our Technical Center in Salt Lake City. The WAVE facility has a ‘Low Power’ workshop for the assembly of WAVE systems and subsystems. There is also a ‘High Power’ bay that has high power electronics and safety equipment for testing prototype and production WAVE equipment.

The WAVE manufacturing process is focused on the following:

1. Validate the design
2. Validate the component
3. Validate the assembly
4. Validate the sub-system
5. Validate the system

WAVE utilizes component/assembly specific work instructions embedded in automotive style (APQP) quality control plans. Components or assemblies (including sub-systems and systems) that do not meet quality standards are segregated from the workshop into a Material Review Board (MRB) area for review and disposition. The process aspect to our business is the development of strong quality control plans (work instructions) for each of our assemblies – including receipt of OTS components.
Professional Experience

Resumes attached for the following WAVE employees: Michael Masquelier, Chief Executive Officer & Chief Technology Officer; Guy Letendre, Chief Operating Officer; Hunter Wu, Chief Scientist; Tracie Peterson, Project Manager. No known complaints have been levied by any regulatory authority against any WAVE employees.

WAVE Technology

WAVE-powered buses are charged wirelessly from a charging pad embedded in the roadbed and another identical pad mounted underneath the bus. The WAVE Wireless Power Transfer (WPT) system is open and capable of supporting buses of varying types or models making it scalable for future growth at a transit property without proprietary constraint. Any future electric vehicle purchases by our clients can be equipped with the WAVE charging system.

WAVE's WPT system can provide 250 kW of power across a seven to eight inch air gap with greater than 90% transfer efficiency (DC to DC). In this system, the secondary pad is completely sealed from the elements, insulated and isolated from human exposure, and is attached to the underside of a transit bus. It has no moving parts and only requires basic bus driver maneuvering to couple. The WAVE WPT charging system interfaces with the vehicle battery and battery management system (BMS) via a Controller Area Network (CAN) bus interface. The system meets international guidelines concerning electromagnetic field (EMF) exposure for humans and other electronic devices (including medical devices).

WPT is created through magnetic fields that move power from underneath the roadway to the vehicle, without wires or cables, while the vehicle is stationary and loading/off-loading passengers. Charging vehicles wirelessly reduces the required on-board battery size, increases battery life by avoiding deep cycling—the discharge of a significant percentage of the battery charge—and extends vehicle range. Already used in many applications (e.g., industrial cranes, consumer electronics, roadway lighting, and medical devices), WPT has recently undergone technological improvements in transfer distances, power levels, and efficiency that now allow for cost effective solutions for electric vehicles in key applications such as electric buses and streetcars.

In the WAVE WPT charging system, power obtained from the electric utility grid is converted to a higher frequency, then driven through wire made from specialized materials arrayed in a unique, proprietary geometry. The magnetic field is focused between the primary, or in-ground pad and the secondary pad mounted on the underside of the vehicle, to maximize power transfer efficiency. The WAVE system creates a current in a wire that produces a magnetic field in the space around the primary pad. Conversely, placing the coil inside the secondary pad in the presence of this magnetic field produces an output voltage that is rectified in a small WAVE secondary power electronics box that fits readily into the rear or roof of the vehicle. This output voltage is readily converted to a level suitable for directly charging the battery of a transit bus. See the below visual diagram.
Termination of the charging process for the WAVE system is automatic – the charging begins when the bus is in position and ends when the bus pulls away – but it can also be terminated manually by the bus driver and automatically upon reaching Maximum Standard Operating SOC or a user specified SOC.

The WAVE system is fully automated and can include a driver display to assist the driver in pickup positioning. The states that are displayed to the driver in WAVE’s current iteration include: driving, aligning, and charging. From approaching alignment to charge takes less than three seconds.

The WAVE WPT system can be equipped with an E-Mon Class 3200 submeter.

The WAVE Charging Interface meets industry standards, as they currently exist. The nascent wireless charging industry has yet to agree to “Industry Standards”; at this point, there are guidelines and draft standards. Industry Standards do not exist, but WAVE sits on all relevant committees and follows the developments around these standards very closely. Once standards for the industry are defined and approved, WAVE will adhere to them. WAVE’s system will meet IEEE, & NEC standards and ICNIRP guidelines. While there is currently no UL Classification for wireless chargers, the WAVE WPT system will use UL rated components and follow UL standards wherever possible.

The WAVE system includes the following protections and driver alerts: (i) dynamic state of charge of the Energy Storage System, (ii) charge rate, and (iii) fault codes for Charging System failure alerting the operator to the severity of the fault.

The WAVE charging system does not interfere with the normal operation of the bus, passengers, pedestrians, or other vehicular traffic. Any above ground equipment associated with the WAVE charging station is vandal-resistant and weatherproof.

The WAVE WPT system is comprised of four main components:

- WAVE Primary Electronics & Enclosure
- WAVE Primary Pad
- WAVE Secondary Electronics & Enclosure
- WAVE Secondary Pad
Below are renderings of WAVE’s new Primary Electronics Enclosure that will be located at the charging site.

Service pedestal (Grid panel, disconnect, power meter)  WPT cabinets (WAVE power supplies, electronics boxes, chiller)

Below is an image of WAVE’s Primary Charging Pad that is in use at the University of Utah in Salt Lake City with the Secondary Pad above it:
The WAVE alignment method consists of passive inputs to the bus drivers. The basic procedure for alignment is as follows:

- The charge site is currently equipped with 2 alignment mechanisms:
  1. Center paint line (for lateral alignment)
  2. Right side vehicle mounted mirror and horizontal paint line (for vertical alignment)
- Before vehicle use, check that mounted mirror is present and secure
- Upon approach, align center line with tape marking on lower windshield
- Using mirror, approach forward until bus bumper aligns up to (not overlapping) horizontal white line on roadway (up to 5 secs)
- Engage parking brake and place bus in neutral – system aligns (1-3 secs)
- If misalignment occurs (as indicated by alignment GUI), proceed with unload/load of passengers and attempt charging alignment next time; do not attempt to correct a failed alignment
- Once aligned, charging begins (1 sec)
- Charging will reach full power within 20 seconds
- **During charging, do not attempt to move or kneel the bus**

![Windshield tape aligned with line on road](image1)

![Bumper lines up to line (using mirror) but doesn’t overlap](image2)
Driver can see painted line in front of bus bumper
Driver aligns side-to-side using mark on windshield and painted line on road (parallel to curb).

Driver uses convex side mirror to move forward until the front bumper of the bus aligns with the horizontal painted line on road (perpendicular to road).

OPTIONAL: mount a second mirror on the driver's side to improve visibility of line under various lighting conditions.

- Alignment lines painted on the roadway require simple maintenance:
  - Before vehicle use, make sure snow is removed from lines if necessary
  - If other objects are covering lines, make sure to remove before operating bus
  - Make sure line paint quality is good and lines are visible
- Visual cues around the charge site increase driver alignment success!
- Other permanent items around the charge site could include:
  - Trees
  - Benches
  - Light posts
  - Information kiosks

The WAVE system is designed to operate in the full operation mode. If the pad is within the alignment tolerance, 50 kW is transferred. If the bus is out of alignment (beyond the +/- 4 inches), the driver will see a symbol on the dash indicator that the bus is not aligned correctly.

**Infrastructure Requirements**

WAVE has prepared the attached Primary Electronics Enclosure and Primary Charging Pad Installation Plans as an illustrative example of a typical installation. While each WAVE installation has different requirements based on site-specific concerns, this document serves as a good example of the construction requirements necessary for installation of the WAVE WPT Charging System.

The attached breaks down in detail what WAVE will provide for the installation.

**Items Provided By Wave In A Static WPT Charging System:**
1. WAVE WPT Primary Charging Pad and installation.
2. Primary Electronics Enclosure and installation.
3. All underground conduits, wire and connection between Electronics Enclosure and WAVE WPT Primary Charging Pad, (which must be located within 35’ of each other).
4. Installation of all supplied equipment once site work preparation is completed by others (WAVE will have single mobilization to site to install equipment).
5. WAVE equipment FOB Salt Lake City, Utah.
6. System start up by WAVE after project has reached substantial completion.

**Site Work Required By Others:**
1. Site engineering and design, permits & approvals for location & construction.
2. Set up & maintain all state and federal required traffic control.
3. Demo road, removal of curb and gutter and excavate.
4. Install 12" of 3/4" aggregate base to designed elevations for WAVE WPT Primary Charging Pad and Primary Electronics Enclosure Pad.
5. Excavate and backfill trenches for WAVE conduits.
6. Provide and install 6’ chain link fence for the Primary Electronics Enclosure.
7. Provide 480V-280Amp service to enclosure.
8. Make all surface repairs needed for: roadway, curb and gutter, park strip, sidewalk, and any ground covered between the WAVE WPT Primary Charging Pad and the Primary Electronics Enclosure.
9. Backfill all excavated areas with aggregate base.
10. Replace curb and gutter to meet the local specifications or 2007 APWA, reconstruct roadway around WAVE WPT box to match existing road way.
11. Install any striping that might be required.
12. Install or replace any required landscaping in park strip and around WAVE enclosure.

Below are two diagrams of an example of a charging station site layout: