Robotic Technology Demonstration System (RTDS)
The Jumpstart and Silent-Watch Robot
Technical Summary

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Figure 2: Single Li-ion 6T Jumpstart Robot

Figure 1: Dual Li-ion 6T Jumpstart Robot

BACKGROUND

Currently, small and medium sized robotic platforms operate at a characteristic bus voltage, typically over 30 VDC, which is not compatible with the large base of existing commercial and military ground vehicle platforms which are based on the 12/28-V nominal bus characteristic. This choice is principally due to the lack of common requirements between the two platforms given their perceived differences in applications, allowing the robotic platforms to choose dissimilar requirements towards their own individualized technical best practices. This makes it so that the two systems lack the ability to share energy in a meaningful way even in instances where the robot is physically docked onboard the vehicle platform. While DC-DC power conversion is an option to allow the two disparate platforms to connect with one another, the size and weight and power limitations of DC-DC conversion prevent high-rate sustained currents required for silent-watch and starting functions on the much larger military ground vehicle platforms. Also, the batteries currently available in the logistics system for small and medium sized robotic platforms is the BB-2590 battery, which is a Li-ion battery designed for communications applications. This battery is extremely limited on available power and requires packs composed of from between 4 to 12 BB-2590s to meet platform power and energy needs. The use of BB-2590's in packs also results in great disparity between the Li-ion batteries installed in a vehicle based on age, cycle life, remaining capacity, and resistance that decreases cycle life and degrades performance. These packs cannot be controlled and restricted to a single robotic vehicle over their whole life as they are batch charged external to the vehicle and not tracked by serial number to the specific platform they came from. Also, given the BB-2590 was not designed specifically for robotic applications, it is not necessarily optimum for a given platform. The Li-ion 6T battery provides a number of advantages to a pack composed of BB-

2590s (explained in subsequent sections), so its addition to small to medium sized robots provides a number of significant advantages. Given these advantages, GVSC invested in the development of conversion kit for small to medium sized robots whereby a Li-ion 6T could be used, and the addition opened up a number of new applications, novel use cases, and advances not initially the genesis for the design change, such as Silent-watch support and autonomous charger-less jumpstart and maintenance applications. Consideration around these benefits allowed for the identification of a number of disadvantages that exist with existing robotic platforms and methods/procedures required to carry out the functions achieved by the Jumpstart robot, including:

- Jumpstarting a vehicle currently involves a Soldier performing the function outside of a vehicle. This presents potential safety hazards in military environments, and there is not currently an autonomous way for this function to be provided.
- Periodic starting/jumpstarting of military vehicles is often required on Navy vessels for vehicle offloading and periodic maintenance. This is labor intensive and could be accomplished by an autonomous or semi-autonomous robot.
- Currently, robotic platforms cannot be charged off of the NATO receptacle connection of most military vehicles because of a difference in the characteristic voltage of the two platforms.
- Currently, the energy storage device cannot be interchanged between a robot and ground vehicle due to a difference in form factor.
- Although robotic platforms carried with a ground vehicle have available on-board energy, that energy cannot currently be used to extend vehicle silent watch.
- Docked robotic platforms on military vehicles often need to be completely shut down to conserve power during transport, requiring boot up on location.

SUMMARY

The Robotic Technology Demonstration System (RTDS), hereafter referred to as just the Jumpstart Robot, is a robot capable of autonomously, or semi-autonomously, jumpstarting a vehicle through a NATO receptacle connection. The jumpstarting device includes a mobile robotic platform. The mobile robotic platform includes an energy storage device matched to the voltage of the vehicle to be jumpstarted and with sufficient power to perform this function. This energy storage device is also used to provide power to the robotic platform (directly or through DC/DC conversion) and optionally to a power generation device (example: fuel cell startup energy, generator ignition, etc.). The energy storage device is also capable of being charged off of the vehicle bus or the optional power generation device and is capable of supplying energy and power for silent-watch operations (either carried internally with the vehicle in a docking bay or through temporary external connection). The Jumpstart robot includes methods for using the robot for the transfer of auxiliary silent-watch energy as well as for the autonomous starting of military vehicles, such as on Navy vessels, as part of routine maintenance. Currently, jumpstarting of vehicles is accomplished using a portable jumpstart device which is rolled up to the vehicle and manually connected by a person. While autonomous, semi-autonomous, or tele-

op robotic platforms are currently being used to provide a number of military functions, jumpstarting is not currently accomplished in this way.

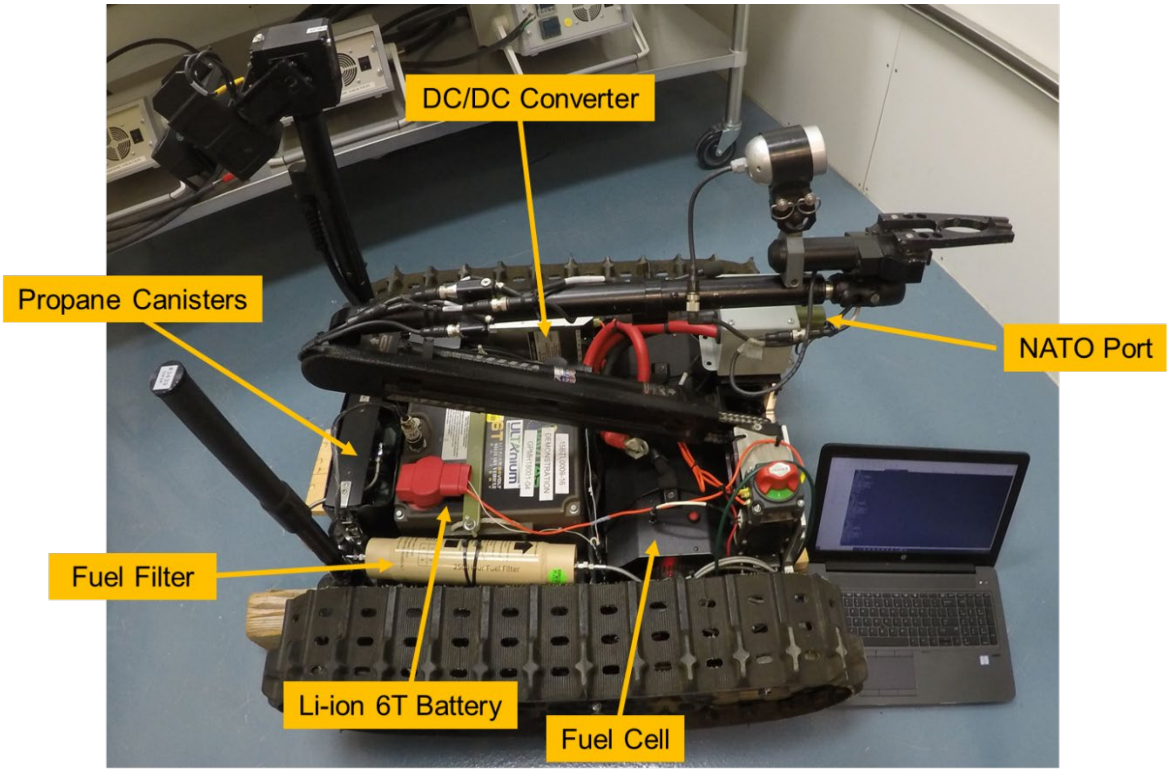


Figure 3: Fuel Cell Li-ion 6T Jumpstart Robot

DETAILED DESCRIPTION

The basic Jumpstart robot is built from an autonomous, semi-autonomous, or tele-op mobile robotic platform and includes the following required elements:

- An energy-storage device (ex: Li-ion 6T Battery) matched to the characteristic bus voltage of the target vehicle (ex: 28-V) with sufficient power capability for engine starting.
- A DC/DC Converter to convert the energy-storage device voltage to the characteristic bus voltage of the mobile robotic platform, if necessary (robot bus voltage matched to bus voltage of target vehicle is preferred, but is not the case for currently fielded systems)
- A bi-directional power connection (NATO Receptacle)

Current methods of jumpstarting vehicles require a human operator and involve using a Jumpstart kit, Jumpstart equipment, another of the same vehicle platform with NATO receptacle or jumpstart cables, or a battery bank with jumpstart cables. The Jumpstart robot has a much larger capacity and sized Li-ion battery and bi-directional power connection which provides a number of advantages, including the ability to not only provide power for jumpstarting the vehicle, but also the ability to charge from the vehicle and for the robot to remain with the vehicle as it travels (docked or alongside) providing silent-watch energy. Additionally, in the preferred embodiment, the battery within the robot is the same battery as in the vehicle platform (ex: Li-ion 6T battery), meaning that in an emergency, the robot can give up its battery/batteries in a sacrificial way to provide a direct replacement to the vehicle such that the vehicle can proceed on without the robot if necessary. The use of a NATO receptacle or similar connection also provides advantages as no interfacing directly with battery terminals is required and can be done from a port external to the vehicle. The ability to Jumpstart with a robot also provides the advantage of removing humans from the activity in situations where it might be unsafe to do so.

In addition to the three main elements above, a number of optional elements can be added to the Jumpstart Robot to add additional features and capabilities. Optional elements are as follows:

- OPTIONAL: Integral heaters/CAN in the Li-ion battery. This feature is useful to provide enhanced cold cranking capabilities at sub-zero conditions. The use of a heater might also allow for reduced energy storage capacity as power could be delivered at a more optimal temperature point, then if full cranking power were needed without a heating period.
- OPTIONAL: A power-generation device (ex: fuel cell)
- OPTIONAL: An energy management controller
- OPTIONAL: A fuel storage device (ex: propane gas canister)
- OPTIONAL: A camera system for detection and tracking of AR (Augmented Reality) tags for autonomous jumpstarting
- OPTIONAL: Data connection (CAN-bus) to vehicle to allow auto start & stop commands

The Jumpstart Robot can also be thought of as a system construct involving the target vehicle which would be a (military) vehicle platform including:

- A bi-directional power connection (NATO Receptacle)
- An energy-storage device (ex: Li-ion battery/Lead-Acid 6TAGM)
- OPTIONAL: An internal (or external-mounted) docking bay for the mobile robotic platform
- OPTIONAL: An AR tag on the bi-directional power connection

A detailed description of the individual components of the Jumpstart Robot follows:

Energy Storage Device:
The jumpstart robot includes an energy storage device. This device supplies energy & power for jumpstarting a vehicle, powering the robotic platform & power generation device, and for storing energy from the power generation device. The energy storage device is matched to the characteristic bus voltage of the vehicle being jumpstarted through the NATO receptacle port, in this case 28V. The energy storage device used in this case is a Li-ion 6T battery, which includes a CAN communication port to supply SOC (State of Charge) and voltage information used by the energy management controller. The energy storage device also includes a power switch, internal contactors, internal heaters, and has a tie down apparatus to prevent movement. Also, if

a common battery solution is used, such as Li-ion 6T, the battery on the robot could be interchanged with the vehicle battery in emergency circumstances.

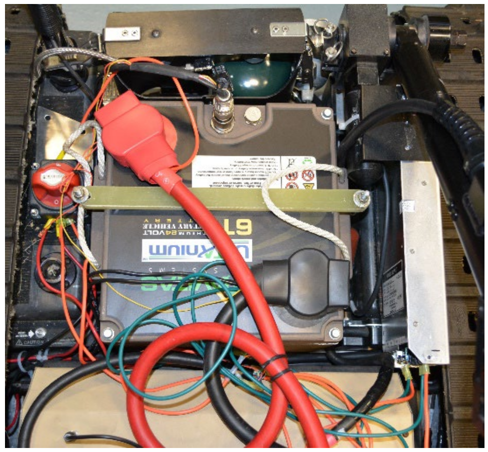


Figure 4: Li-ion 6T Battery

Bi-Directional Electrical Connection:
The jumpstart robot includes a bi-directional electrical connector device, in this case a NATO receptacle connection, for connection of the energy storage device and power generation device to the electrical bus of a ground vehicle platform. This could be connected to the vehicle either autonomously, semi-autonomously, tele-op, or manually. The voltage at the NATO receptacle connection is matched to the characteristic bus voltage of the ground vehicle (in this case 28V). This port provides necessary power from the energy storage device for jumpstarting, for charging the vehicle battery, provides auxiliary energy and power for silent-watch, and allows the energy storage device on the robotic platform to be charged by the vehicle alternator as the connection is bi-directional.

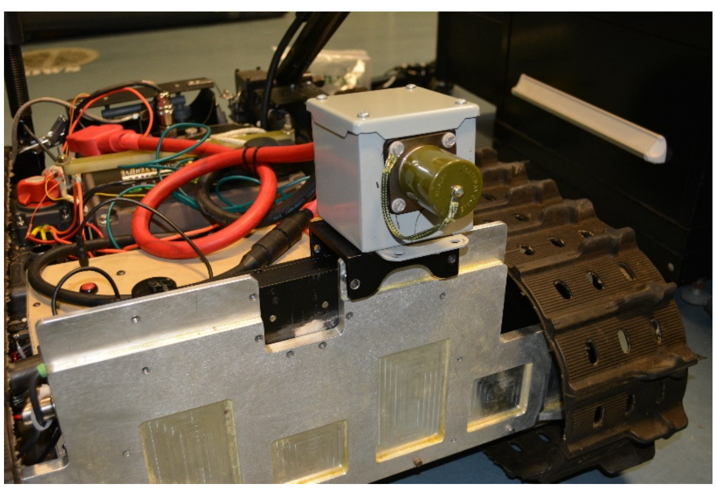


Figure 5: NATO Receptacle

Docking mechanism:
The dock mechanism may be either external to the vehicle or internal to the vehicle. In the case of an internal dock, the robot could travel with the vehicle and remain connected to the DC bus

of the vehicle. This would allow the jumpstart robot to be charged off of the vehicle or it could provide power & energy back to the vehicle to provide additional energy for silent-watch from the energy storage device and power generation device. By the nature of the robotic platform's independent mobility, it could also refuel or recharge offsite from the vehicle's silent-watch position and bring that energy back to the vehicle.

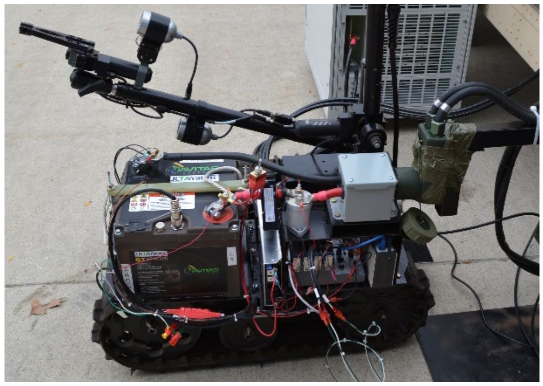


Figure 6: Robot Docking Station

Power Conversion Device:
The jumpstart robot includes a power conversion device, in this case a military-grade DC/DC converter. This power conversion device is necessary to convert the characteristic voltage of the energy storage device & power generation device, which are matched to the ground vehicle being jumpstarted (28V), to the voltage of the robotic platform (48V). Under the optimal solution, the robotic platform, energy storage device, power generation device, and vehicle to be jumpstarted would all have the same characteristic bus voltage.

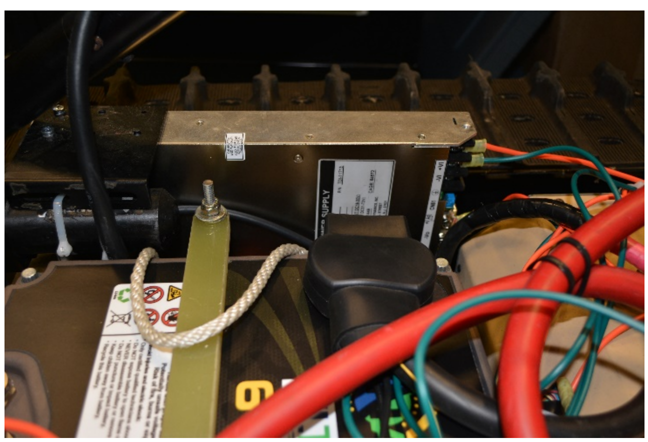


Figure 7: DC-DC Converter

Power Generation Device:
The jumpstart robot includes a power generation device, in this case a solid-oxide fuel cell. This system when combined with the energy storage device (Li-ion 6T) makes the jumpstart robot a hybrid-electric platform. The power generation device provides additional energy to the battery & platform to provide extended range and silent-watch times. The fuel cell could be replaced by any other electrical power generation device, such as a small engine-generator unit.

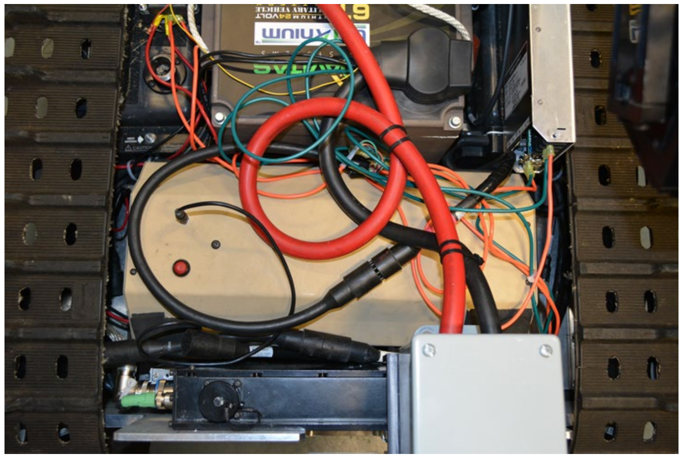


Figure 8: Fuel Cell

Energy Management Controller:

The jumpstart robot includes an energy management controller to coordinate and optimize the energy transfer between the power generation device and the energy storage device. This controller coordinates when the energy storage device is being charged or discharged and where robotic platform power is coming from to optimize the output from the two electrical energy sources. Additionally, the controller, in this case, is designed to ensure that the fuel cell is properly started and shutdown under various state of charge conditions to ensure abrupt shutdown of the fuel cell is avoided as this could result in damage. Energy could also be supplied based on the controller to add-on devices on the robot, such as a BB-2590 battery charger, which would allow for charging of soldier portable batteries directly on the robot. In the case of a Fuel Cell (or engine generator though shorter duration start/stop times) the start-up and shutdown durations were included in the control strategy used to coordinate the two hybrid sources of energy. The fuel cell has a fixed start-up time to achieve required temperature and to start producing useable electrical power. The fuel cell also has a fixed shutdown time required to prevent damage to the fuel cell due to abrupt change of conditions, such as fuel starvation causing localized degradation effects. Consequently, since a smart battery, such as a Li-ion 6T will open safety contactors at the end of charge or top of charge, it is necessary to avoid these conditions as power must be available from the battery to safety shutdown or start the Fuel Cell and also the battery provides a fixed DC load that the fuel cell would need to respond to ensure there are no abrupt changes in output power which could also result in conditions which can cause degradation to the fuel cell. To counter these effects, a pattern was employed by the energy management controller whereby, battery only power would be used to power the robotic platform from higher SOC down to the minimal SOC where there is sufficient energy & power left in the battery to run the full Fuel Cell startup procedure, such that the fuel cell can start producing sufficient electrical power to power both the robot and provide reasonable charge current to the battery. Determining this minimal state can be as simple as using the SOC provided by the Li-ion 6T for example and choosing a known SOC whereby the battery is expected to have sufficient energy for maintaining robot power and powering fuel cell start-up while waiting for the power generation to start. An SOC could be chosen during charge to ensure fuel cell shutdown could occur before the battery would open contactors and remove load from the fuel cell. This could likely be a similar 20-80% window which would also help to generally improve battery cycle life. In a more complicated controller, additional databases and information should be used to increase the robustness of this process and include the following: (1) Li-ion battery SOC and Open Circuit Voltage (OCV) as a function of Temperature, (2) Li-ion battery Capacity as a function of Temperature and Charge & Discharge Rate, (3) Li-ion battery power as a function of SOC and Temperature, (4) Cycle life as a function of Temperature and Charge and Discharge Rates. Using these parameters, more precise SOC fuel cell shutdown and startup points can be determined to better utilize battery available capacity and ensure no damage to the fuel cell occurs, thereby expanding the range to more likely a 10-90% window. These parameters could of course be weighted to achieve benefit in battery cycle life by using battery less often as platform duty cycle permits.

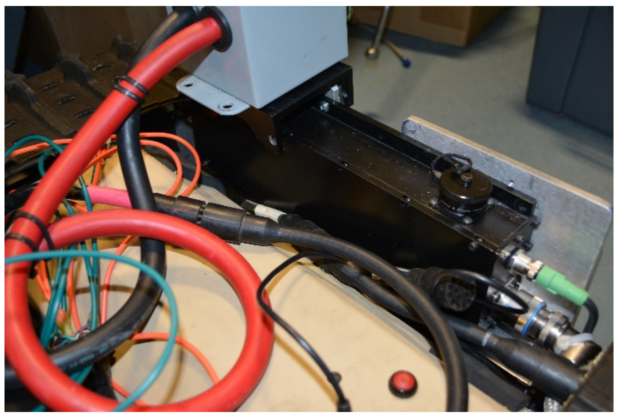


Figure 9: Energy Management Controller

Fuel Storage Device:

The jumpstart robot includes a fuel storage device, in this case for propane fuel, which provides fuel to the power generation device, in this case a solid-oxide fuel cell. The fuel storage device could be designed for any number of fuels and the fuel cell could be replaced by any other electrical power generation device, such as a small engine-generator unit.

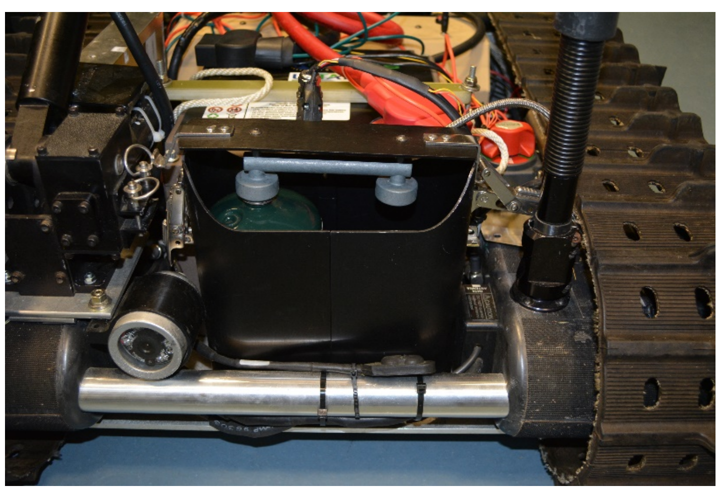


Figure 10: Fuel Canisters

BENEFITS

The Jumpstart robot allows the jumpstarting of a vehicle using an autonomous, semi-autonomous or tele-op robotic platform to lower the need for personnel to be outside of the vehicle or present during a jumpstart event. Additionally, if docked on a platform and connected by a NATO receptacle connection, the robot can provide auxiliary power generation and additional battery energy for silent-watch events. Other benefits include the following:

(1) the ability to charge the robot directly off a ground vehicle's NATO receptacle connection, removing the need for an external charger;
(2) the ability to supply additional energy to a vehicle for silent-watch;
(3) the ability to jump-start a vehicle autonomously;
(4) direct interchangeability of the battery in a manned ground vehicle with the battery in the robot;
(5) increased on-board energy storage over soldier-portable battery solutions, such as the BB-2590;
(6) the ability to integrate future 6T batteries from Army R&D programs;
(7) enhanced battery features, including CAN bus communication for state of charge and integral battery heaters;
(8) significantly extended range and battery charging through on-board power generation;
(9) use of logistically friendly fuels like propane;
(10) near silent power generation; and
(11) reduction in the number of BB-2590 chargers and spares in the field needed to support charge of current robot batteries as the batteries can be charged directly off the vehicle.

The Jumpstart Robot can also be used in a number of systems/methods, including one for Silent-Watch and one for Maintenance of Vehicles, such as on Navy vessels. The jumpstart robot could be used simply as a companion to a service technician, where it could follow the technician to work sites and provide jumpstart & auxiliary power capabilities.

The jumpstart robot could also be configured to detect and automatically connect a charging plug to a vehicle (ex: using the robot's articulating arm). The jumpstart robot could also simultaneously fully recharge from the bi-directional power connection. AR Tags would be one way to achieve this automated detection and connection. AR Tags and April Tags are closely related technologies that are "QR Code like" fiducial markers added to the environment. They provide unique information and allow a single camera to determine range and orientation information. An AR Tag would be affixed near the vehicle plug so a robot could locate a specific vehicle's plug and use the AR Tag to automatically connect. The AR Tag could encode a specific vehicle ID that would allow the user to select a specific vehicle for recharge. The robot would search for the tag, then use the tag itself to supply range and orientation information to auto-connect to a plug.

SUPPLEMENTAL SILENT WATCH ENERGY

The Jumpstart Robot is also an ideal companion to a vehicle platform to provide supplemental energy and remote power generation for Silent Watch. In particular, the robot can provide additional silent supplemental energy/power from its onboard energy storage, can provide quiet power generation with a fuel cell, and can provide for noisy generation but done at a distance from the platform and then transported silently back to the platform. Elements of a Silent-Watch System using the Jumpstart Robot are as follows:

An (autonomous/semi-autonomous/tele-op) mobile robotic platform including:

- An energy-storage device (ex: Li-ion 6T Battery) matched to the characteristic bus voltage of the target vehicle (ex: 28-V) with sufficient power capability for engine starting. OPTIONAL: Integral heaters/CAN.
- A DC/DC Converter to convert the energy-storage device voltage to the characteristic bus voltage of the mobile robotic platform, if necessary
- A bi-directional power connection (NATO Receptacle)
- A power-generation device (ex: fuel cell)
- An energy management controller
- A fuel storage device (ex: propane gas canister)
- Data connection (CAN-bus) to vehicle for authentication

  This data connection would be to insure that the Jumpstart Robot is providing services to the correctly assigned vehicle platform in need of assistance/silent-watch supplement.

- Mapping device (Lidar, etc.)

  This mapping device would assist the Jumpstart Robot in assessing the terrain to determine an appropriate location for it to locate itself relative to the vehicle platform to provide silent, quiet, or noisy energy or power generation. The Jumpstart robot could move away from the silent-watch vehicle in a preset pattern such as an outward spiral, moving farther and farther away until the desired range as computed by on-board and vehicle coordinated sensors is achieved.

- Two-way radio for linkage to military vehicle & to battle network

  This would be used to allow the Jumpstart Robot and Vehicle to coordinate its position and traversal distance based on their relative positions and shared sensor data. Waypoints could also be established via GPS coordinates, which could also be pre-selected by human interaction, whereby the Jumpstart Robot would traverse to that set location for power generation and use the sensors and data only for confirmation of effect and autonomous movement.

- Acoustic sensors for measuring environment noise

This would be used to monitor noise generated by the Jumpstart during various modes such as traversal and power generation.

- Central processing unit to compute power generation location based on acoustic, terrain, and map info

  The Jumpstart Robot would compute using the available data appropriate locations to perform its functions. This could also be achieved by user command or by tele-op to determine an appropriate position.

A (military) vehicle platform including:

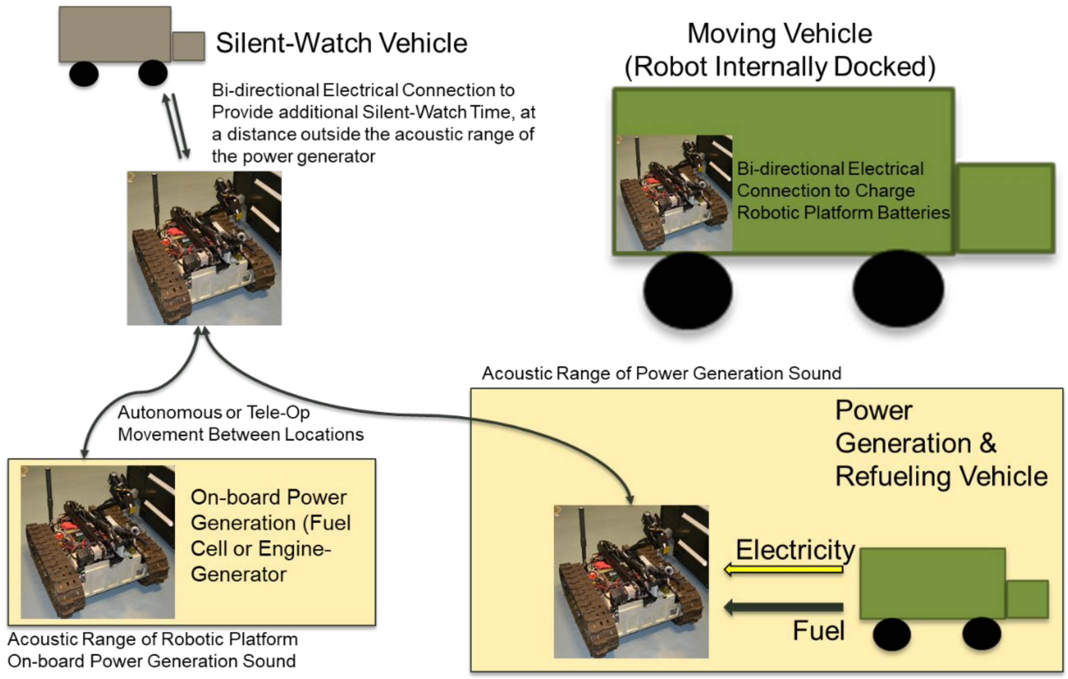
- A bi-directional power connection (NATO Receptacle)
- Data connection (CAN-bus) to robot for authentication & transfer of mobile robotic platform recon & mapping data
- An energy-storage device (ex: Li-ion battery/Lead-Acid 6TAGM)
- An internal (or external-mounted) docking bay for the mobile robotic platform
- Two-way radio for linkage to military vehicle & to battle network
- Acoustic sensors for measuring environment noise

  This would monitor Jumpstart Robot noise relative to the vehicle's fixed position.

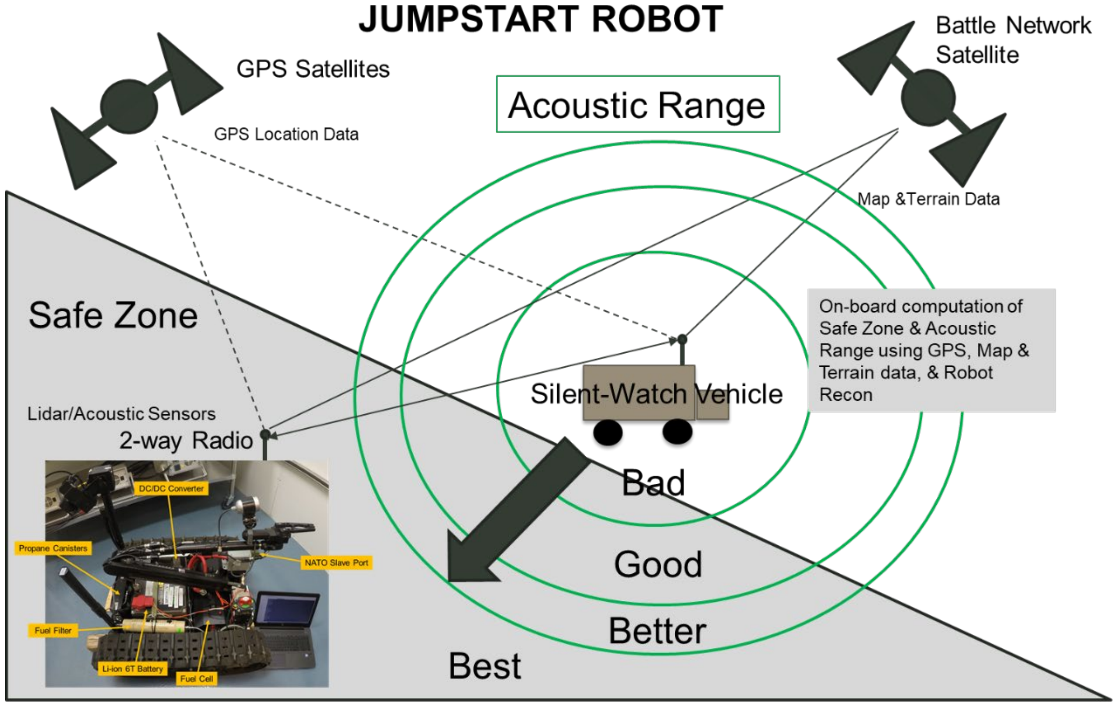
- Database including terrain & mapping information used to determine safe zone and acoustic range limitations for transfer to the mobile robotic platform
- Computer used to computer safe zone and acoustic range limitations for transfer to the mobile robotic platform
- Positioning System, such as Global Position System (GPS)
- Battle Network System

  Used to coordinate the Jumpstart Robot's location relative to the larger battlespace.

A METHOD FOR THE ROBOTIC TRANSFER OF SILENT-WATCH ENERGY THROUGH REMOTE POWER GENERATION OUTSIDE OF THE ACOUSTIC RANGE OF THE VEHICLE



SILENT-WATCH SYSTEM USING JUMPSTART ROBOT



AUTOMATED CHARGERLESS MAINTENACE

The Jumpstart Robot can also be used in a number of configurations to support vehicle maintenance, such as routine vehicle starts on a naval preposition ship for example. In this configuration, the added benefit is that the Jumpstart Robot could provide this function without the need for a central charging dock or power connection that is typically seen for maintenance/cleaning robots. Elements of an autonomous charger-less jumpstart system for naval applications is as follows:

An (autonomous/semi-autonomous/tele-op) mobile robotic platform including:

- An energy-storage device (ex: Li-ion 6T Battery) matched to the characteristic bus voltage of the target vehicle (ex: 28-V) with sufficient power capability for engine starting.
- A DC/DC Converter to convert the energy-storage device voltage to the characteristic bus voltage of the mobile robotic platform, if necessary
- A bi-directional power connection (NATO Receptacle) for robot charging
- An energy management controller

  While the Jumpstart robot could be configured in this system with a power generation device as well, most likely, only the energy storage device would be needed/used. So, this energy management controller would focus on calculations and operations required to ensure sufficient energy is reserved to maintain the robot's primary functions and services.

- Data connection (CAN-bus) to vehicle for authentication
- Central processing unit to compute optimized maintenance routes that allow vehicle start/stop maintenance and recharge of jumpstart robot while minimizing unnecessary vehicle runtime and vehicle battery drain

  This could be computed similar to the classic traveling salesman computer algorithm program whereby the most optimal route would be computed to perform the intended maintenance routines while maintaining sufficient energy capacity for the robot to continue functioning indefinitely using recovered energy from the vehicle alternators. The algorithm would be simplified to only achieve the required maintenance periods and to sustain sufficient robot power, versus necessarily finding the optimum or shortest time/distance solutions required a required complexity of algorithm computations. The Jumpstart Robot would access a Ship Board database which included the following minimum parameters: (1) Number of vehicles requiring maintenance, (2) Types of vehicles, (3) Maintenance routine, (4) Period between maintenance routines, and (5) location of vehicle on the vessel. The Jumpstart robot would combine this database with a built in database containing energy/power required for each maintenance routine versus vehicle type along with information of the excess power/energy available from each vehicles' alternator when in idle condition (this could be specified based on ambient temperature as a 2nd dimensional factor, though it is likely less needed in this application as temperatures would be generally above temperatures where power and energy capability of the vehicle or robot are greatly diminished. The robot would use this information to compute an energy map to determine the sequence of maintenance that allows it to recoup energy lost in the jumpstart, traversal, and maintenance functions, typically focusing on fully recharging the battery prior to moving onto the next vehicle, though it need not necessarily do so if it can perform its function more optimally by servicing multiple vehicles and then reaching a higher SOC. The computation could also take into account cycle life of the battery if set as a weighted factor in determining the optimum schedule.

- Database including energy storage device characteristics (charge time, capacity, etc.)

  This database would need to include information of the battery's characteristics as a function of ambient temperatures and would include (1) maximum charge rates, (2) maximum charge currents, and (3) SOC vs. Power and Capacity. This information would be used to ensure that the energy storage device is not depleted more than is put back in during one overall maintenance schedule. After performing maintenance the Jumpstart Robot could sit in a Dormant or Operation State waiting for the next period of performance. This would be based on Retention of Charge parameters for the battery as based on ambient temperature and time between use as well as required remaining energy to get to the next maintenance task whereby excess alternator energy would be available.

  The robot could also maintain a database including information gathered from the batteries, such as Li-ion 6Ts, on the vehicle it is servicing to aid in maintenance and prognostics on those batteries. This information could be shared with the main maintenance servers on a ship and could include items such as (1) manufacture dates, (2) serial numbers, (3) current State of Health, and (4) predicted cycle life remaining.

- Database including robot power characteristics (power per meter of movement, etc.)

  A database reflecting the Jumpstart Robots self-power consumption would be needed based on operations, such as track movement and arm movement, based on number of actions required per task along with traversal distances between maintenance locations. This power consumption data could be at multiple ambient operation temperature points.

A (military) vehicle platform including:

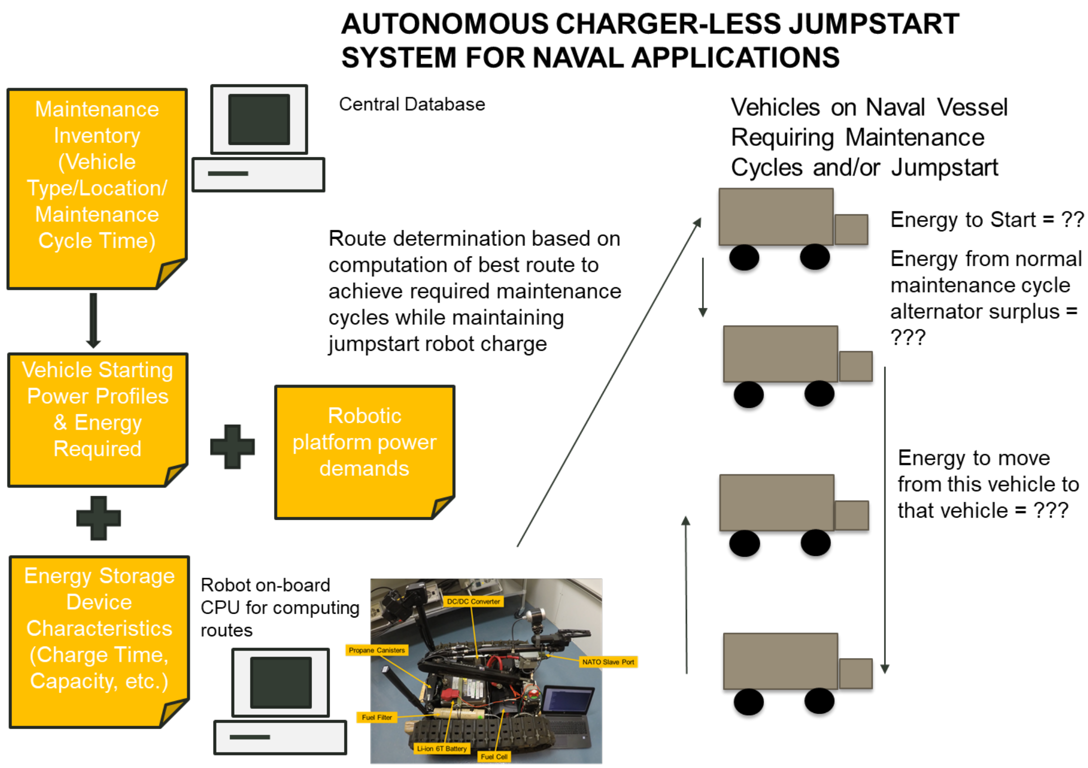
- A bi-directional power connection (NATO Receptacle)
- Data connection (CAN-bus) to robot for authentication & start/stop commands & vehicle identification

  Auto-start via CAN-Bus would be preferred for automated vehicle starting, however, the robot could accomplish this function in the same way as a human operator, by physically manipulating the starter with its articulated arm for example.

- An energy-storage device (ex: Li-ion battery/Lead-Acid 6TAGM)
- A power generation device (alternator)

Central computer database of maintenance cycles, vehicle inventory, etc.

This data base would be accessed from time to time by the Jumpstart Robot either through wired or wireless communication method to update for changes to the vehicle inventories and positions over time.



HISTORY OF PROTOTYPES

The Jumpstart robot development was initially funded as a FY16 GVSC Innovation Project Grant and was subsequently self-funded by the GVSC Energy Storage Branch. Additional FAST funding was received in FY19 to adapt the Jumpstart Robot for use in Extreme Cold Weather environments for use in Alaska to provide enhanced cold weather performance and capability. A total of four different versions of the Jumpstart robot have been built to demonstrate various options, principally for conversion of existing robots in the fleet into Jumpstart robots. The first version of the Jumpstart robot was built from a TALON 4 and the jumpstart kit was installed onto an over-the-track, side mounted plate on the robot. This kit include a Li-ion 6T, NATO connector, and vehicle docking stand. Subsequently, three fully integrated versions of the Jumpstart Robot where built, including a fuel-cell Li-ion 6T battery hybrid platform that provided substantial increase to Silent Watch power as well as a single Li-ion 6T and two-Li-ion 6T robot. Each of these three robots was designed with a kitted solution in minds, which would allow for conversion of any TALON 3, 4, or 5 to a Jumpstart TALON Robot. The single Li-ion 6T Jumpstart Robot was tested and demonstrated to an EOD unit at Fort Wainwright, Alaska. With very little additional development funds, the current prototype Jumpstart kit could be produced for fielded TALON robots in need of this functionality. In particular, the single Li-ion 6T Jumpstart Robot was designed for ease of transition by allowing minimal configuration changes and consists principally of only one added metal part to the TALON's chassis structure, whereas the Jumpstart robots with additional 6Ts and the fuel cell require a chassis widening kit that replaces 4 structural components.

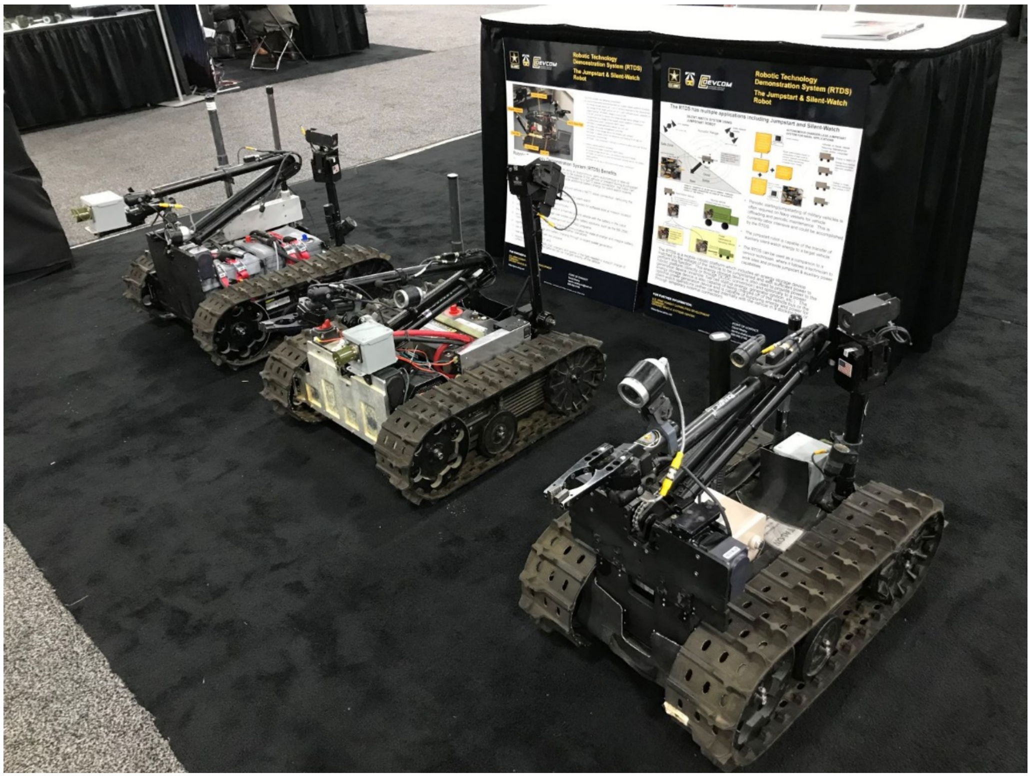


Figure 11: Single 6T, Dual 6T, and Hybrid Fuel Cell 6T TALONS (multiple NATO receptacle configurations shown)

PLANNED IMPROVEMENTS

Subsequent improvements to the Jumpstart Robot will first focus on improvements to the mobility of the system subsequent to conversion, with focus on center of gravity, drivetrain power, and weight reduction. It is believed the kitted solution can be reduced in weight by up to 20 lbs. Additional improvements to the Jumpstart robot could also revolve around addition of the required autonomy kit.