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IMPLEMENTING A TRACKING AND INTRUSION DETECTION SYSTEM FOR TRANSPORTATION OF TYPE B PACKAGES: IMPLEMENTATION, BENEFITS, AND LESSONS LEARNED

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ABSTRACT

The National Nuclear Security Administration (NNSA) Office of Radiological Security (ORS) has developed a tracking and detection system to address the difficulty of providing in-transit visibility and security of conveyances used to transport radioactive material. The Transport - Security Tracking and Reporting System (T-STAR) was developed to enhance security of high-consequence cargo by providing near-real-time tracking of cargo shipments and detection of cargo tampering using an inexpensive, modular system that provides alerts to authorized users via a streamlined web-based application accessible on a desktop or mobile device. While there are systems available to track the cab units and trailers, installing a tracking system on a Type B package inside a freight container presents a challenging environment. A T-STAR unit was installed on a 435-B package skid in order to provide real-time tracking of the package during operations (loading, transport, and unloading) as well as provide intrusion detection for the freight container using multiple motion, door, and cargo removal sensors. This presented unique challenges requiring both battery and vehicle power supplies as well as internal and external antenna configurations in order to provide reliable short-term tracking of the package itself. In addition to the technical challenges, it was important to ensure that the system was easy to use, effective, and did not negatively impact operations during normal loading and unloading of the package and freight container. The benefits of installing such a system, such as increased visibility and understanding of operations, monitoring, and security will also be discussed.

INTRODUCTION

The National Nuclear Security Administration (NNSA) and the Off-Site Source Recovery Program (OSRP), along with our commercial partners, have developed a Type B package called the 435-B to address the need for transport of disused radioactive sources recovered in the interest of national security. The 435-B is an unshielded leak-tight container with a total maximum weight of 4,581 kg (10,100 lbs). The 435-B relies on the shielding of the radiological devices or the long-term storage shield (LTSS) that are currently authorized content for the container. Two production units have been fabricated and a third is nearly ready to send to the IAEA to support international recoveries. The first two units are being used to transport disused radiological sources and devices, primarily from medical and research applications, in the continental US. The relatively light weight and small size of the 435-B make it easier to recover sources in congested areas, provide flexibility in the types of vehicles that can be used to transport it, and allow it to be transported in an intermodal container. The 435-B is designed to be transported by ground, air, or water. The features that contribute to the versatility of the 435-B may also make it more vulnerable to theft and present unique security challenges. While being designed, potential security issues were taken into consideration. During fabrication, additional security features were identified, which in some cases resulted in the need for a revision to the Safety Analysis Report (SAR) and a modified Certificate of Compliance (CoC). For a container of this size and ease of transport, tracking, detection, and delay measures are a necessity. A tracking and detection system has been developed and installed on the container pallet and conveyance. The Transportation – Security, Tracking, and Reporting (T-STAR) system was designed to avoid impact to the performance and operation of the package while providing in transit visibility and detection.

Why was T-STAR developed? To answer that question, it is necessary to understand that ORS has an international mission to assist partner countries to implement security of radioactive material during use, transport, and storage. While other tracking systems exist, they are often permanently installed on the cab of the vehicle; those that are installed in the cargo compartment are limited to only a few sensors, and can be expensive in terms of upfront costs and monthly communications fees. The types of conveyances in use range from open straight trucks with cranes, vans, and freight containers. Further, there is often a lack of clear regulations in many countries with regard to the use of tracking systems and how to integrate them into security response or how best to use them on a day to day basis. Many competent authorities expressed an interest of gaining visibility of shipments within their borders, and a system that could be installed and then removed easily from multiple types of conveyances was desired. Also required was the ability to host the tracking system server on a local host rather than in the cloud or on a 3rd party server to ensure data security and confidentiality, an easy to use interface which could be accessed from a mobile device. Finally, the user interface and alert notifications and messages should be available in a number of different languages. For this reason, Oak Ridge

National Laboratory developed the hardware and software to accomplish this goal of providing an easy to use, modular, and effective tracking, security, and reporting system.

Because ORS had started development of T-STAR, using satellite and cellular RF communications with GPS and wireless security sensors, it made sense to utilize this same basic equipment on domestic shipments with a few additional enhancements. These enhancements include the ability to switch antennas from an internal to an external antenna to ensure RF signal integrity can be maintained within the conveyance while the package is removed during unloading, utilize vehicle power to augment battery power for extended trips, and a keypad to enter a code to confirm security sensor presence and arm the system. The 435-B was designed to utilize a pallet with a mounting plate for a tracking system, and members of Oak Ridge National Laboratory, Los Alamos National Laboratory, Idaho National Laboratory, and ORS program managers began the process of adapting the T-STAR system for use during OSRP recoveries. This paper briefly describes the team’s experience implementing the T-STAR tracking system and lessons learned during the last three months of operations.

BACKGROUND

There were three main components to implementation; hardware, software, and development of a conduct of operations (CONOPS). Without all three, the system would not be effective in providing relevant information to support detection and assessment of alerts.

Figure 1 Using a forklift to unload a 435-B from an intermodal container

System Hardware

The T-STAR is installed on the vertical plate on the 435-B's pallet and includes a battery charger connected to vehicle power as shown in Figure 2.

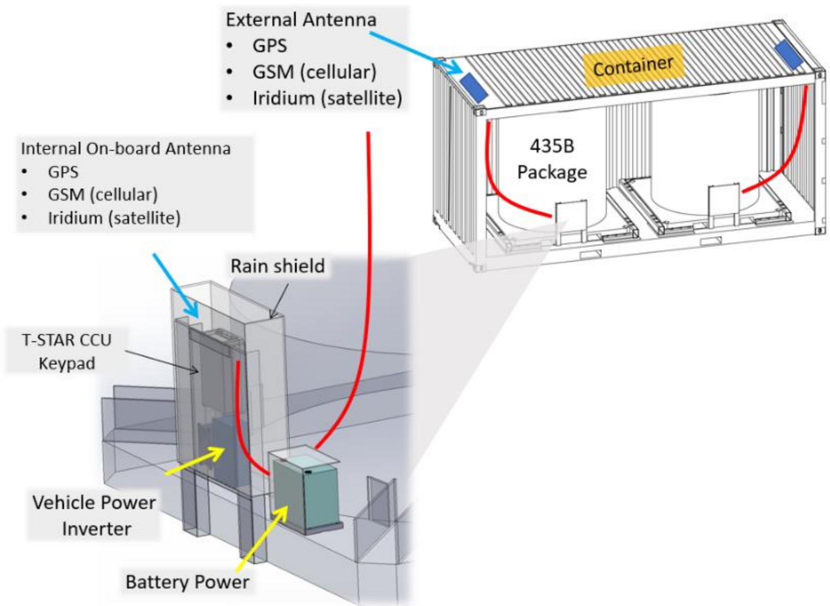

Figure 2 T-STAR System Installation on 435-B

The T-STAR main control board features an Iridium SBD 9603 modem, UBLOX LISA U200 cellular modem and a LowPower Labs Moteino radio using 433Mhz to connect to the wireless sensors with the control unit. The two sets of GPS/GSM/Iridium antennas round out the components as shown in Figure 3. Sensors are developed by ORNL and are relatively inexpensive, ranging between \$20 and \$50 in parts and are powered by a 9V battery which lasts between 30-120 days depending on the sensor and how often it reports to the main control unit. For example, a Passive Infra-Red (PIR) motion sensor reporting movement during load and unload will last less time than a door sensor reporting open/close only a few times per week. A sensor's battery life is most affected by the number of reports to the control unit informing the control unit that the sensor is still present and functioning. While the system will support up to 256 sensors, it was found that in a contained environment such as a freight container that 4 to 5 sensors worked well. At first, adding more sensors tended to cause problems with rates of detection. When the sensors were generating messages to the control unit constantly, the control unit's Moteino radio would be overwhelmed by the number of inbound transmissions and some signals and alerts would be dropped. This was unacceptable, but rather than limiting the numbers of sensors, the solution was to increase the heartbeat or regular reporting interval to 2 to 3 minutes per sensor. In the event of an alert, the sensor will still report its status immediately to the control unit, and alert message is sent out using Iridium or GSM communications. Increasing the pause between reports to the control unit improved dropping of signals as well as improving battery life of the sensors themselves.

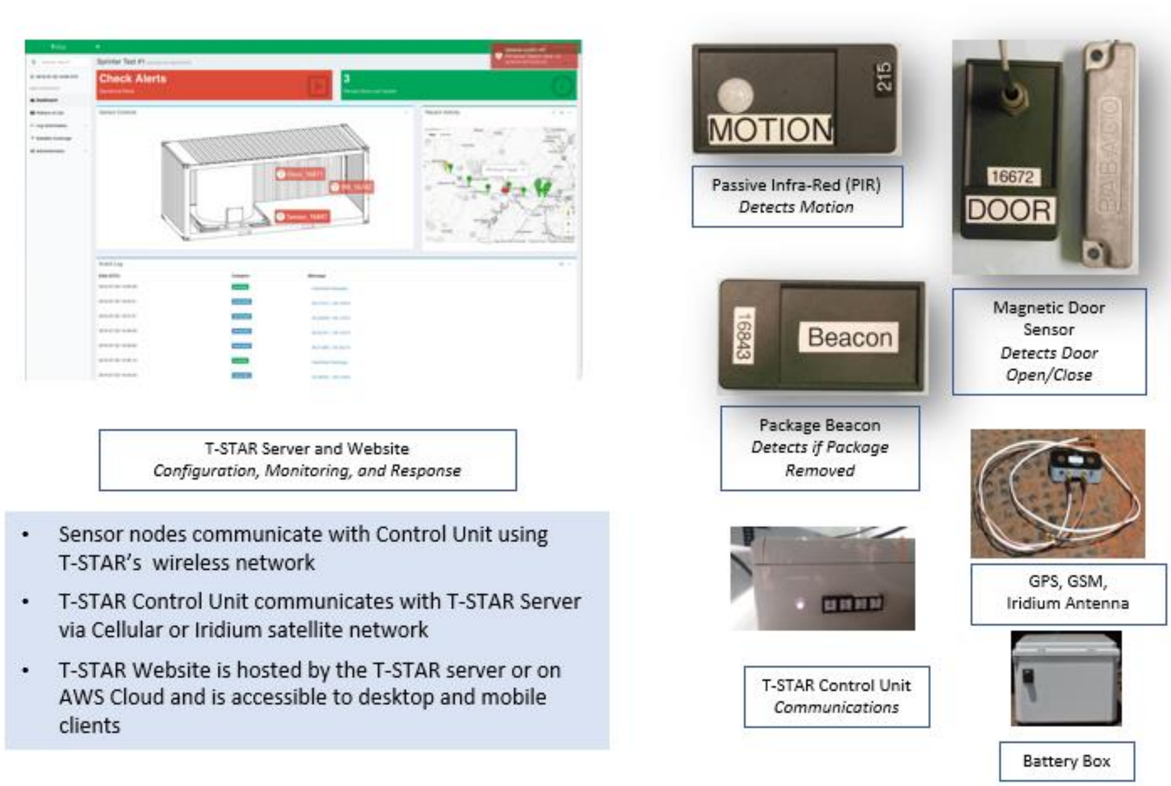

Figure 3 T-STAR System Components

The T-STAR can be used with either internal antennas or external antennas connected through the roof of the freight container. This requires drilling a small hole at the center top of the container to install the antenna. A typical transport arrangement used for the 435-B is a 9.5-foot-high container. However, when adding air ride suspension and trailer, the entire height of the container is approximately 13 feet. In order to be compliant with a typical height for underpass clearance, this leaves only 6 inches for an antenna, and while some low-profile antennas exist, only a few were found that could support a 20 ft antenna connection and offer three communications channels to simplify installation by requiring only one hole to drill in the conveyance rather than holes for each communication channel. The first antenna used was a marine antenna that, while robust, did present a challenge when used on tree lined streets where branches often scraped the top of the container.

Because the system is installed on the pallet of the 435-B, this allows for a larger 55 Watt/Hour sealed lead acid battery to be used to power the system unattended for 2 weeks.

While other batteries are available, this battery size and chemistry was chosen to ensure that the system could report once per minute for that length of time to facilitate recovery if necessary. Typical operations tempo was expected to be 4 to 5 days per trip; however, it was found that there were often back-to-back trips and, in some cases, unexpected delays, thereby requiring charging between trips. The solution was to install a pass through between the 9-pin trailer connection and the T-STAR charger installed on the skid plate. This enables the field operator to disconnect the power connection from outside of the freight container if the container needs to be removed from the trailer for maintenance or for shipping on another conveyance. The system can detect if it is being powered from its battery or from the 9-pin trailer connection. This enables different types of alerts, 1) the trailer has been disconnected from the cab, 2) the vehicle power has been cut, or 3) the package is being loaded/unloaded. A message notification is generated when power changes from vehicle to battery in order to give monitoring personnel some insight into what is happening with regards to power.

System Software

The T-STAR user interface was developed using open source software and Google Maps API. The operating system is Linux Ubuntu 18.04, and the database is POSTGRE SQL. The backend server which processes the messages from the Iridium and GSM vendors is written in Python and can be deployed on Amazon Cloud (AWS) or on an inexpensive server. Software updates can be distributed using GitHub and deployed using simple scripts that can be executed by the system administrator of the host server. The user interface was designed to manage shipment information, tracking units, reporting intervals, sensor deployment, and users as well as the ability to assess and acknowledge alerts. Alerts are presented as a red bubble on the interface and an exclamation triangle on the map, and remain there until a user monitoring the system clicks on it to dismiss it after adjudicating the alarm. SMS and Email notifications are passed to a 3rd party service called Twilio which handles requests to various international telecommunications vendors if necessary. Other features of the interface are the ability to create geofences which are virtual areas that can be drawn on the map and used to generate a notification if the conveyance enters or leaves the area. The user-interface (dashboard) uses icons to help the user assess the status of the system and sensors, last mode of communication (GSM or Satellite), battery health, time since the last communication of the T-STAR unit, and change the conveyance depiction to represent the conveyance and cargo by picking from a list of pictures. Shipments can be organized into Campaigns based on origin and destination, common geofences and users. Users are managed by using roles (Administrator, Normal User, and Watcher) to limit the amount of information as well as the ability to modify the system. Users need to be added to a Campaign in order to have visibility of the transport and status of the system. Administrators have the ability to modify any configuration setting in the system. Normal Users have read access, but can only access campaigns to which they are assigned, and Watchers only receive notifications and alerts. The system continues to improve based on user feedback. The ability to archive shipment information as well as an audit log of all system configuration changes have been added recently. User roles will be changed to Administrator, Manager, Field Manager, and Watcher in the future to better reflect how shipments are managed and organized. Figure 4 illustrates the dashboard elements of the user interface on an active campaign.

Operations

INL field operations staff noticed a number of operational issues during the first few test runs. The first major issue was that the PIR motion sensor was generating a number of false alarms. This was resolved by replacing the sensor with a new PIR sensor that had an additional resistor added to the Moteino board. Other false alarms were due to the configuration of the package sensor dropping signals between the control unit and the sensor. This control unit is programmed to alert if the package sensor is undetected. However, it was continuously monitoring for the package sensor, and any dropped messages resulted in an alert. This was resolved by increasing the time interval for the sensor to 2 to 3 minutes which dramatically reduced the number of false alarms, but battery life is still less than ideal. Another type of sensor may be better suited for detection of package removal such as a load cell to sense pressure.

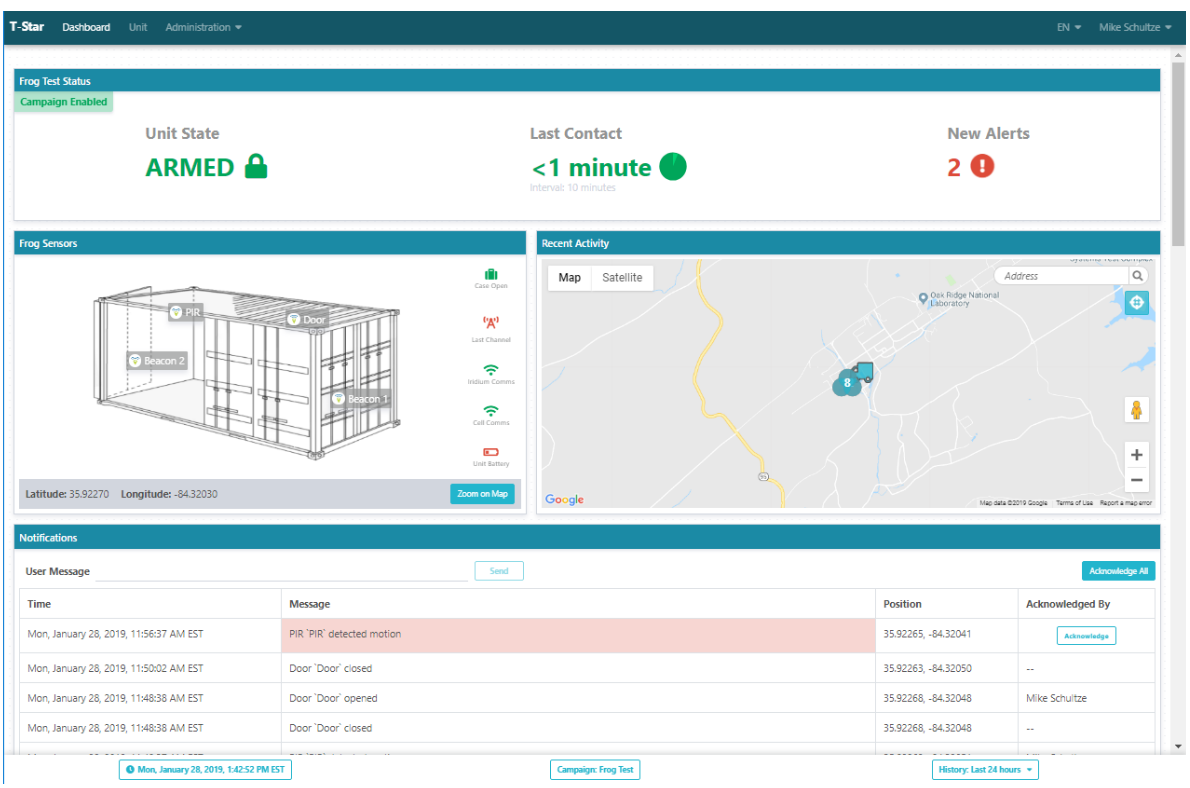

Figure 4 T-STAR User Interface Dashboard is used to communicate status and alerts

The INL team also reported issues when attempting to recharge a dead battery using vehicle power. There were rare instances during testing when the system was not reconnected to vehicle power after reloading and the battery was fully discharged during tracking. When reconnected to vehicle power there was insufficient power to recharge the battery making it necessary to charge during the next time the container was unloaded. Swapping the battery or charging from a wall charger is required to bring a dead battery back to operational readiness until an alternative battery can be found which can be fully charged using vehicle power.

Finally, while the keypad offers additional functionality to arm or disarm the system using a keypad and keycode, it was determined to allow only arming the system in order to prohibit the field operator from disabling the system in the field. In future versions, it may be desirable to replace the keypad with an application or simply have a single button to arm the system.

Of critical importance to a tracking system is how accurate its location is being reported. GPS accuracy appears to be sufficient in most cases. There have been cases when the package has entered a metal highbay building where the GPS seems to be incorrect by 50 to100 feet. However, tests were conducted in a parking garage where GPS is still accurate despite being one level under concrete and steel. Further testing is required to determine the type of structures that cause T-STAR's GPS signal issues. However, while on the road, the GPS/GSM/Iridium work extremely well. Over the last three months of operations, we found very few "dead" areas except where the cellular coverage was non-existent for the data plan we were using. Additional testing is necessary to ensure that data roaming continues to work as intended. Latency between the field unit and server did not appear to be an issue; in fact, it was possible to track the unit and verify its position using roadside traffic cameras (Figure 5).

SUMMARY

It is possible to overcome the challenges of tracking a 435-B package inside and outside a container by using the pallet design of the 435-B to mount the equipment and providing the ability to connect an external antenna installed on the roof of the container. Once the field operator disconnects the external antenna, the T-STAR system automatically switches to its internal on-board antenna to track the package itself. Wireless sensors are used to communicate with the control unit and it was found that 5 to 7 sensors offered detection without RF interference between sensors and the control unit. While battery power is sufficient given the expected time frame of transports, vehicle power was passed through the container in order to charge the battery during operations to support longer campaigns of months or more. A user interface was developed to enable monitoring, manage units and users, and communicate notifications of alert events via SMS and email to stakeholders monitoring the transport.

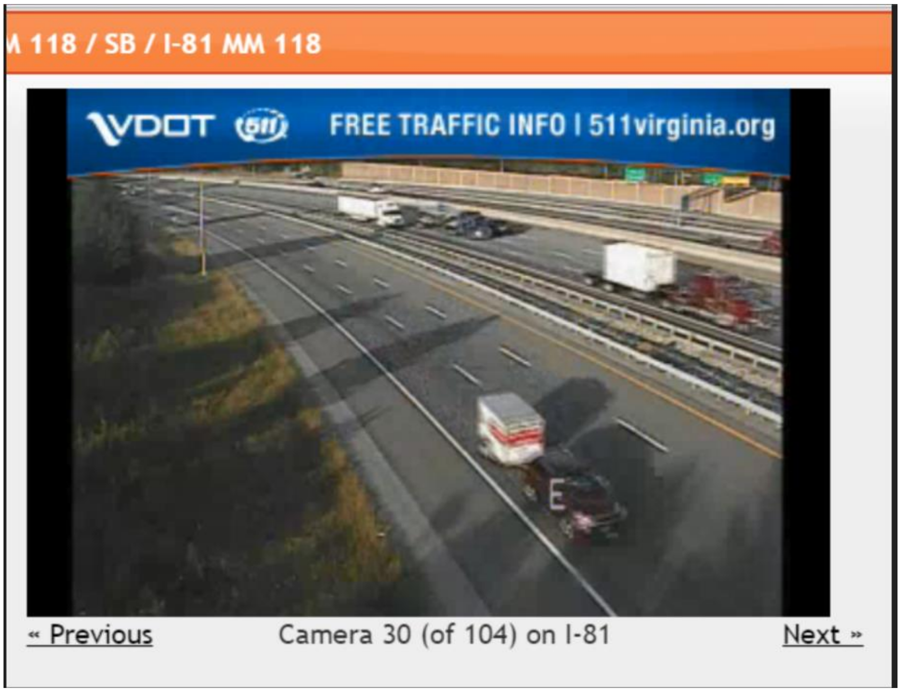

Figure 5 Screen capture of conveyance in far travel lane

Future versions of the system will include a smaller communications control unit, improved power management that will allow for much lower power consumption to eliminate the need for the large battery, and commercial off the shelf wireless sensors.

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