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Tagging, Tracking and Locating without GPS

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Joseph V. Cordaro, Todd Coleman and Davis Shull
Savannah River National Laboratory, Aiken, SC and
Dr. James Shuler, Manager, DOE Packaging and Certification Program

ABSTRACT

The Savannah River National Laboratory (SRNL) was requested to lead a Law Enforcement Working Group that was formed to collaborate on common operational needs. All agencies represented on the working group ranked their need to tag, track, and locate a witting or unwitting target as their highest priority. Specifically, they were looking for technologies more robust than Global Positioning Satellite (GPS), could communicate back to the owner, and worked where normal cell phone communications did not work or were unreliable. SRNL brought together multiple technologies in a demonstration that was held in in various Alaska venues, including metropolitan, wilderness, and at-sea that met the working group's requirements. Using prototypical technologies from Boeing, On Ramp, and Fortress, SRNL was able to demonstrate the ability to track personnel and material in all scenarios including indoors, in heavily wooden areas, canyons, and in parking garages. In all cases GPS signals were too weak to measure. Bi-directional communication was achieved in areas that Wi-Fi, cell towers, or traditional radios would not perform. The results of the exercise will be presented. These technologies are considered ideal for tracking high value material such has nuclear material with a platform that allows seamless tracking anywhere in the world, indoors or outdoors.

INTRODUCTION

GPS uses an array of satellites orbiting 1000's of kilometers above the earths. Knowing the orbits and timing signals from these satellites allows the position on the earth to be determined when four or more satellites can be viewed by the GPS receiver. GPS satellites are located in medium earth orbit of 19,715 kilometers above the earth. GPS allows position locations to be determined within 5 meters. However, GPS signals are not strong enough to penetrate structures and foliage.

Real-time tracking systems typically use the public cell phone network to transmit tracking device locations back to a monitoring post. Cell phones often do not make connections deep within buildings or in underground parking garage. Other information transmission is done with radio signals that requires nearby receiving stations. The Law Enforcement Working Group (LEWG) tasked SRNL to address the problems with GPS and short range communications associated with tagging and tracking.

The LEWG specifically had the following requirements:

- Operate with GPS or independently of GPS, as needed.
- Function without access to cell towers.
- Work without access to Wi-Fi.
- Operate indoors, in basements, in parking garages, in heavily wooded areas, in urban canyons and other similar areas in which GPS signals often become lost.
- Communicate bi-directionally with the tag under the above conditions
- Operate anywhere in the world including at sea

These attributes would allow law enforcement, search-and-rescue teams, and a host of other users to locate and track the movements of people and items in areas and under circumstances that have been impossible with existing technologies.

SRNL evaluated all known technologies (established as well as emerging) that could be combined to address the needs of the LEWG. Companies were contacted, statements of work issued, and dry-runs were completed in July 2010. In October 2010, SRNL led a technology integration exercise in Alaska that was attended by several state and federal law enforcement agencies and the US Department of Energy. Assistance was provided by the Alaskan State Troopers, the US Coast Guard, Alaska Chiefs of Police and the Seward Police Department, Harbor Master, and City Government.

The exercise included tracking inside a 6 story build, 3-level parking garage, moving vehicle, boat, and airplane. Several different tracking methods were shown to work well in these situations. The exercises were conducted with prototypes and laboratory equipment. Tracking situations require that the location information be transmitted back to a monitoring location or access point. This transmission must also be able to penetrate buildings and reach distances of several miles, if possible.

HARDWARE AND DEMONSTRATION RESULTS

The Iridium satellite communications system uses a constellation of low earth orbit satellites to communicate directly with an array of Iridium-equipped data and voice receivers. The 66 Iridium satellites are only 781 kilometers above the earth, which results in a signal that is more than 300 times stronger at the earth's surface than GPS satellites. These stronger Iridium signal can penetrate into structures, urban areas, and valleys.

Boeing has developed a prototype tracking device that takes advantage of the Iridium satellite constellation which it manages for Iridium Communications Inc. Each Iridium satellite produces a multiple beam pattern that covers approximately the area of the United States and consists of smaller spot beams that are approximately the size of a state. Like the GPS system, by monitoring timing signals from multiple Iridium satellites, the receiver's location on the earth can be determined. With bias correction, accuracy from 50 meters can be achieved. A combination GPS/Iridium receiver allows GPS accuracy when in range of the GPS constellation with automatic switching to Iridium as necessary.

Figure 1 shows the coverage of the Iridium signal across the United States. The Iridium satellite constellation has global coverage, unlike local infrastructure-based solutions or Wi-Fi Positioning Systems. Coverage of only two satellite vehicles' is depicted (reference 1). The Iridium satellites travel approximately 27,000 kilometers per hour and the time to orbit the earth is roughly 100 minutes. Each satellite has 48 spot beams with each beam having a diameter of about 400 km. Boeing has taken advantage of an unused paging channel to transit ephemeris, clock signals, and clock bias correction. A random number unique to each spot beam is also transmitted providing authenticity that the Iridium receiver is actually where its geo-location data indicates. By storing the geo-location and the random generator information during transport or storage, the location data can be independently validated.

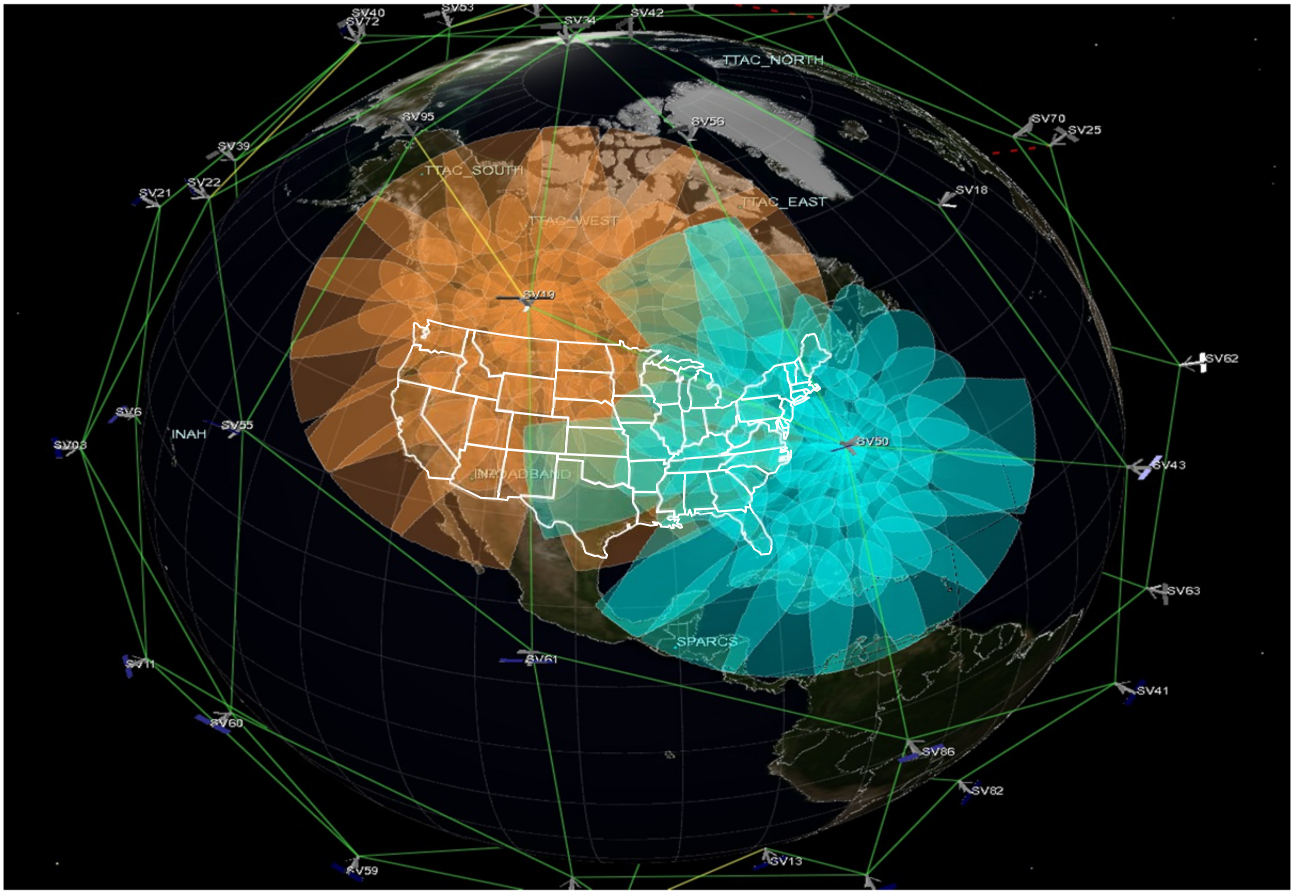
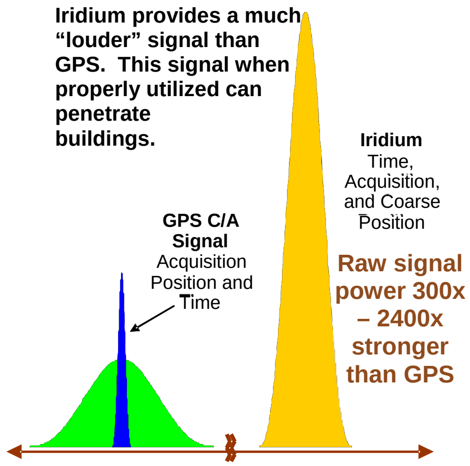


Figure 1 – Iridium satellite coverage over the United States

Figure 2 shows a graphical representation of the signal strength of the Iridium signal vs. GPS. Since the Iridium transmit frequency is close to GPS, similar front end electronics can be used allowing for a dual GPS/Iridium receiver.

A GPS receiver and Iridium receiver were moved throughout the 6-story Crown Plaza Hotel in Anchorage Alaska (Figure 3) to determine effectiveness indoors. GPS signals were detected on the first and six floors and near windows. The Iridium signal was received throughout the 6 floors including inside the elevator. Figure 4 shows a Google map overlay with the Iridium data during the walkthrough (Note: The satellite image was taken before the hotel was built so it appears as a parking lot). Accuracy of 50 meters or less vs. actual position was achieved.



Iridium Satellite

Other technical advantages:

- **<u>Reduced handset power consumption</u> due to fast acquisition**
- **<u>Ubiquitous Coverage</u>, i.e. available regionally or globally with no roaming issues**
- **<u>No Additional Carrier Infrastructure Required</u>**

Figure 2: Signal Strength Comparison

Figure 3: Six Story Crown Plaza Hotel

The next phase of testing was to evaluate the effectiveness inside a concrete parking garage. A 3-story parking garage adjacent to the Anchorage hospital was chosen since one floor was below grade. A drive thru test was completed with GPS signals lost at the entrance to the parking garage. The Iridium connection was maintained throughout the garage except at a location underground that was attached to the radiology section of the hospital. The tracking data is shown in Figure 5. The On Ramp Ultra Link Processing was used for short range communication in both the hotel and parking garage tests.

Note that the Satellite Image was taken before the hotel was built

Figure 4: Tracking Inside the Anchorage Hotel

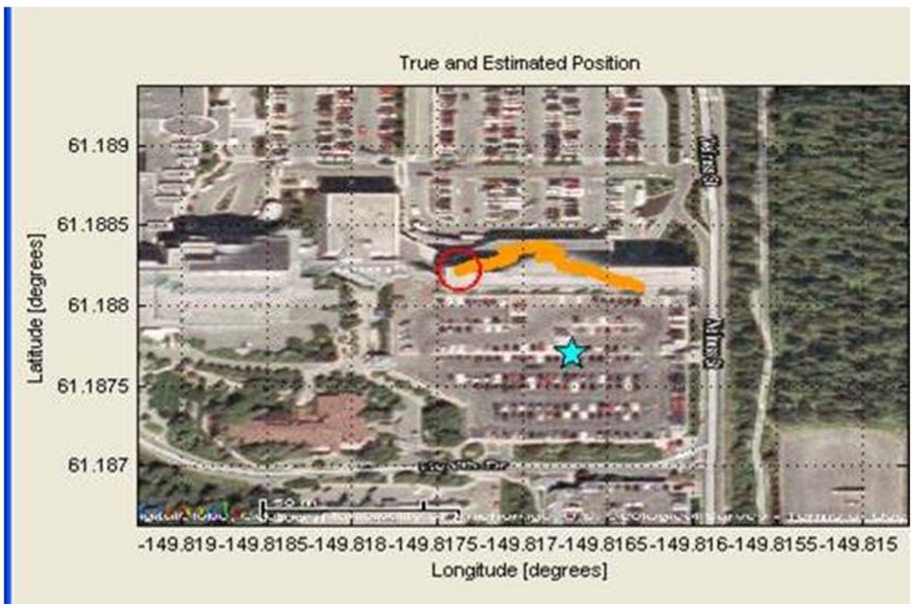


Figure 5: Tracking Inside a 3 Story Parking Garage Anchorage Alaska

The prototype system was next driven from Anchorage to Seward, Alaska. The approximate 209 kilometer drive runs parallel to a bay fed from the Gulf of Alaska. During portions of the route, the road is bordered on one side by a steep mountain range. This incline caused a reduction in accuracy at times for the GPS receiver which showed the vehicle position in the bay instead of the road. The Iridium tracking data is shown in red in Figure 6.

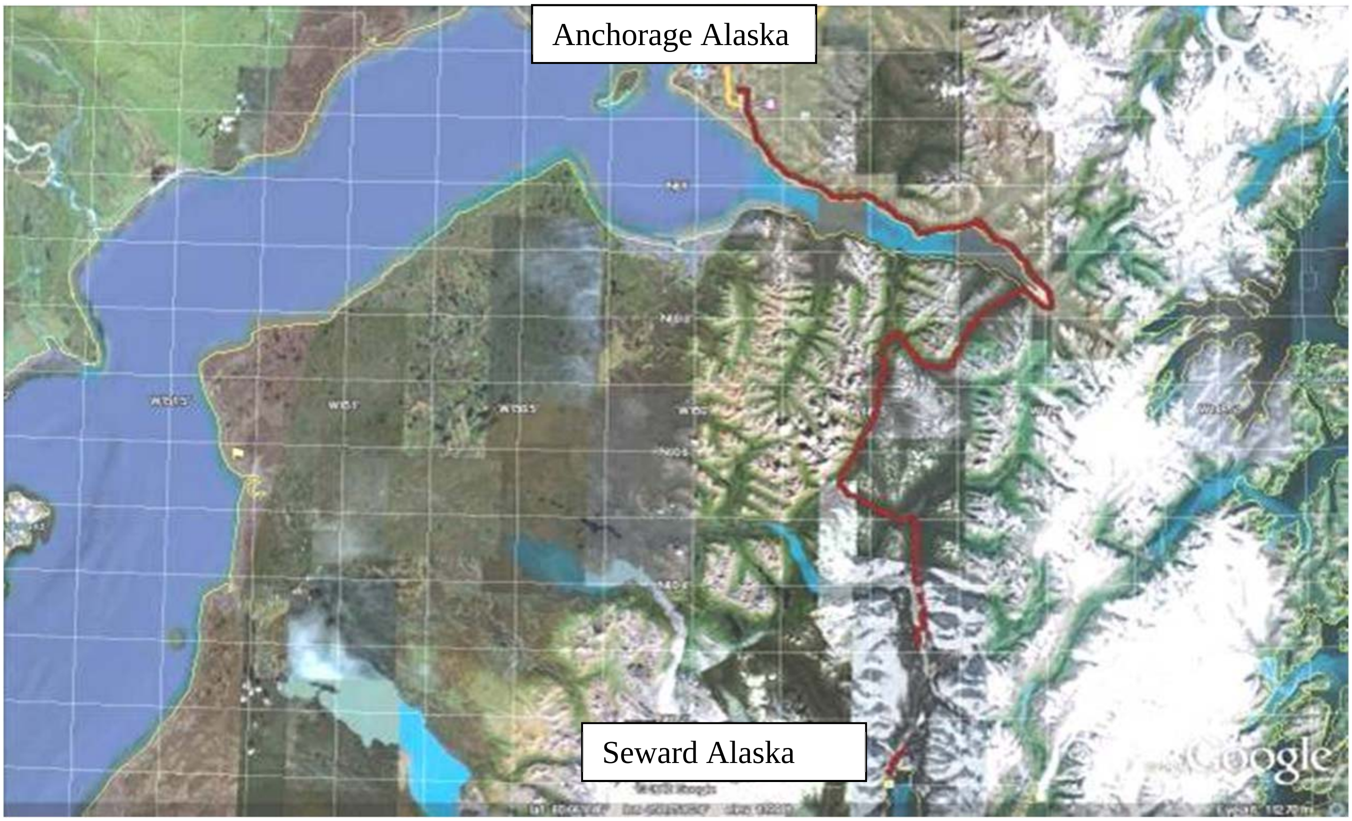


Figure 6: Tracking during drive from Anchorage to Seward Alaska

Figure 7: Alaskan State Trooper Sea Plane

Figure 8: Coast Guard Vessel for Sea Test

The Iridium receive was connected to an Iridium satellite modem for a flight test on an Alaskan State Trooper sea plane. The plane departed from the Seward airport and flew south over the Gulf of Alaska. The geo-location data is shown in Figure 9. The gaps in the data represent lapses in the satellite up-link transmissions. The Iridium receiver maintained position lock throughout the flight. GPS receivers also maintained reception during this flight. A coast guard vessel was taken out and maintained Iridium and GPS lock at all times. The On Ramp ULP maintained contact with the On Ramp Access Point for 15 miles.

Table 1 shows a comparison of the three communication links used to transfer data from the Iridium receiver the monitoring system.

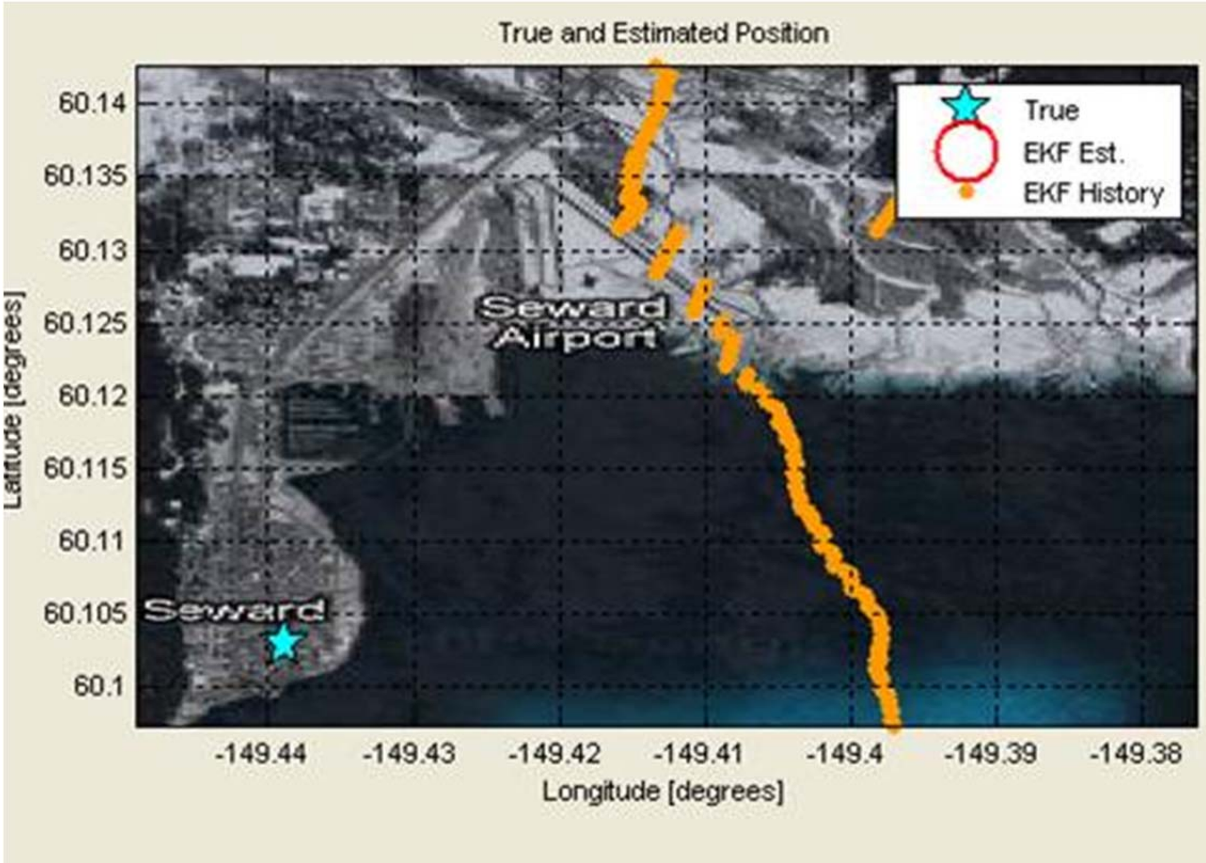


Figure 9: Tracking during plane flight using Iridium Satellite Up-Link

Fortress 802.11 WiFi	**On Ramp ULP**	**Iridium Satellite Modem**
Up to 54 Mbps	Up to 60 kbps	2 kbps uplink
Range less than a mile	Range - 15 miles	Worldwide
Near Line-of-sight (LOS)	Non LOS	Satellite LOS
Mesh Capable	Very Resilient Link	Relies on Internet Access
Portable	Increased Latency	Secure Website
Suite B Security	Portable	
	Supports AES Encryption	

Table 1: Communication Link Comparisons

Each link has pros and cons. The first link shown in Table 1 is the ultra-secure Fortress 802.11 Wi-Fi. It was used for transmitting real-time video and sound during the exercise. It uses a set of Suite B Encryption algorithms based on a National Security Agency (NSA) design that is the highest security without using NSA Type 1 Crypto (Reference 3)

ES210 ES210 ES210 ES820

Figure 10: "Bread Crumbing" and Mesh Networks using Secure Fortress hardware

The limitations in the range of 802.11 can be improved using "bread crumbing" (figure 10) in which the Fortress 210 Clients can automatically form a mesh network between ES210's with the strongest links forming a path back to the ES820 Access Point. A smaller version of the ES210 is being developed for DOE/NNSA applications. This was demonstrated in Seward, Alaska by setting up a mesh from the street into the city council chambers building which housed the city jail in the basement.

The On Ramp ULP used for the majority of testing in Alaska is ideal for transmitting position information since its max speed of 60 kbps is sufficient and the update time of one transmission every 10 seconds is typically fast enough for tracking high value material. With a receiver sensitivity of -143 dBm, the client can receive and transmit position information long range (i.e. 15 miles for air and sea test) or penetrate deep indoors, or inside a nuclear storage container. One On Ramp Access Point can support up to 1000 client devices. Table 2 shows the signal strength as seen by the Access Point (AP) and the Client. With a receiver sensitivity of -143 dBm vs. 802.11 of -82 dBm the ULP signals are able to penetrate inside a storage container (see Reference 2.) Table 2 shows the communication link signal margin with the On Ramp ULP client inside a closed and sealed container.

The third communication link was a commercial Iridium satellite modem. Unlike the down link signal, an Iridium modem just as with an Iridium phone, is essentially line-of-sight with a clear view of the sky needed. An Iridium modem would be typically connected to an AP which monitors a short range network such as 802.11 or ULP and then transmits updates to the Iridium satellites which can be monitored real time from a secure website. The satellite up-link data rate at 2 kbps is sufficient for position and basic sensor data updates. The 66 Iridium satellites provide the back channel network down to a ground station which can then transmit to a secure web site to provide real-time monitoring.

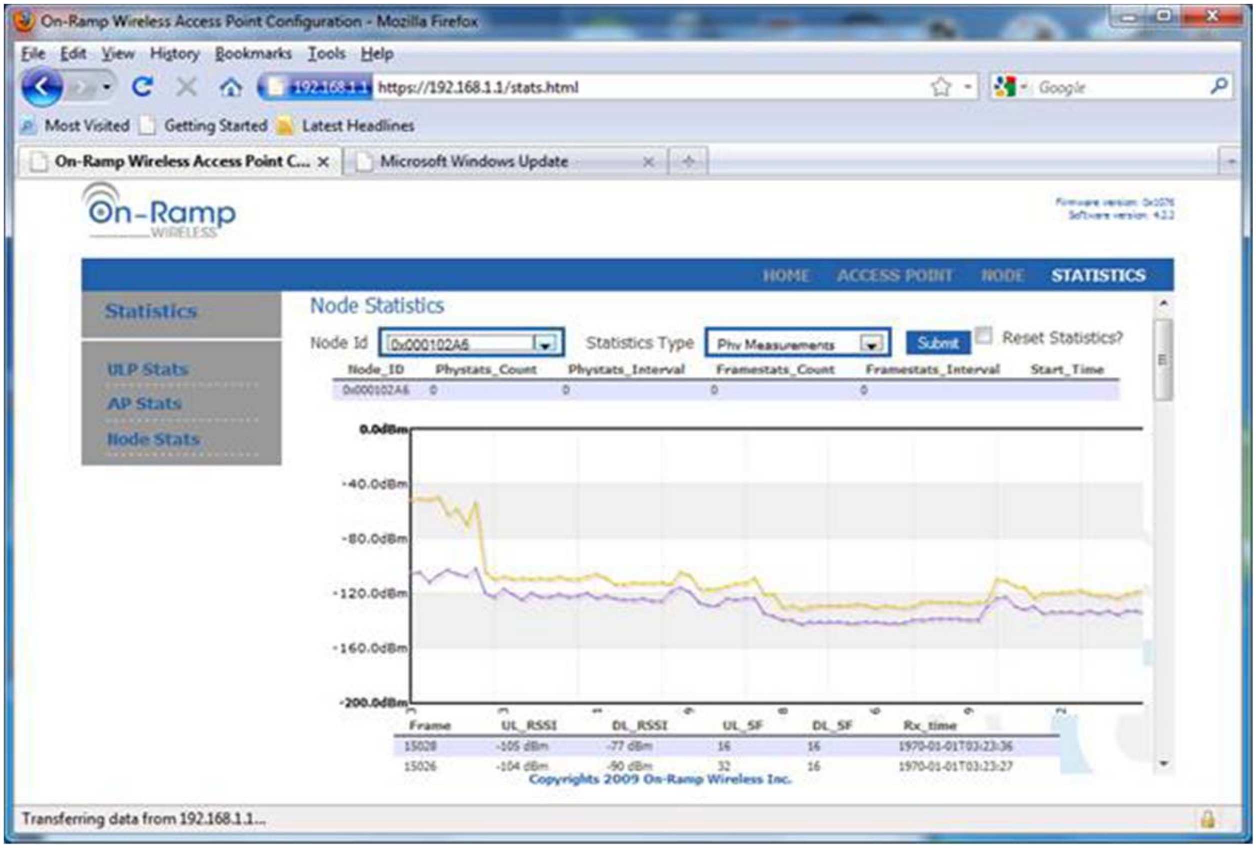


Table 2: On Ramp ULP Signal Strength

CONCLUSIONS

The demonstrations showed that the Boeing Iridium receiver can be as effective as GPS with the advantage that it can track targets within buildings and structures where GPS signal cannot. The combination of an Iridium receiver with a robust short range link such as the On Ramp Ultra Link Short range networks can be connected to an Iridium satellite modem for uplink transmissions when at sea or in other cases that a short range link alone is sufficient. The Iridium receiver can also provide a z axis or height reference that has similar accuracy (50 meters) to the x and y axes. This would allow for tracking shipments in flight. A dual GPS/Iridium receiver with integrated short range link and sensors inputs would provide an ideal platform for tracking high value material worldwide.

<u>Savannah River National Laboratory</u>

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