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Geofence for ARG-US TRAVELER during RAM Shipment

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ABSTRACT

A server-based geofence program has been developed for the ARG-US TRAVELER to enable establishment of a virtual geographic boundary for a vehicle shipment of radioactive material (RAM). The ARG-US system administrator defines and adjusts constraints to create a geofence for a shipment using Global Positioning System location and travel time. Advanced notifications of arrival and alarms due to geofence violations are automatically sent to personnel responsible for the shipment that is being tracked and monitored by the TRAVELER unit. Implementation of the geofence program and testing of the program are described, along with highlights of a recent geofence demonstration at a facility simulating in-transit storage, and during vehicle movement. Addition of the geofence capability to the TRAVELER greatly enhances the implementation and effectiveness of the Transport Security Plans for nuclear and other radioactive materials during normal operation and security incidents requiring immediate emergency response.

INTRODUCTION

The ARG-US TRAVELER [1] has been developed by Argonne National Laboratory (Argonne) under the auspices of the U.S. Department of Energy Packaging Certification Program (PCP), Office of Packaging and Transportation, Office of Environmental Management. It is the latest innovative product in the family of ARG-US (meaning "Watchful Guardian") remote monitoring system technologies for the shipment of risk-significant materials by truck, rail, or ship. Risk-significant materials may include nuclear and other radioactive materials, radiological sources, and/or hazardous chemicals, for which safety, security, and safeguards are major concerns, as the threats of sabotage and theft are real and have very serious potential consequences. The ARG-US TRAVELER is designed with a modular suite of sensors, which may include, depending on monitoring needs, temperature, humidity, and radiation (gamma and neutron) sensors, as well as a 3-axis digital accelerometer, an electronic loop seal, and a digital camera. The sensors have thresholds that can be adjusted for the application environment and will trigger alarms if the thresholds are exceeded. The TRAVELER is equipped with both cellular and satellite communication modems, which allow for message transmission, Global Positioning System (GPS) location acquisition, and synchronization of date and time. The latest development for the TRAVELER is a server-based geofence program. A geofence is a virtual geographic boundary, defined by GPS, that enables software-triggered responses, e.g., alarms, when a vehicle enters or leaves a defined geographic area. The ARG-US TRAVELER's geofence program is designed to provide the ability to define constraints based on location and time, and to trigger alarms if the specified geofence constraints are violated. In this paper, we describe the features, administration, and test results of the TRAVELER's geofence program, followed by highlights of a recent demonstration and discussion of its significant enhancement of Transport Security Plans (TSPs) for nuclear and other radioactive materials.

GEOFENCE FEATURES AND PARAMETER CONSTRAINTS

The geofence program for ARG-US TRAVELER runs on a dedicated server and uses latitude-longitude data to check a TRAVELER unit's location against constraints defined by the ARG-US system administrator. When the constraints are violated, the program issues automatic alarm notifications similar to notifications caused by violations of pre-set thresholds in any of the sensors in the TRAVELER unit.

The ARG-US system administrator has the ability to define a geofence for a TRAVELER unit on the basis of time and the unit's location along a specified route, defined as a Trip. A geofence Trip can be configured to issue alarm notifications if the unit violates the time and location constraints. This is useful for actively monitoring a radioactive material (RAM) shipment, as an alarm message will be triggered if the unit deviates from an expected route or does not reach a destination by a specified time. A geofence Trip can also issue custom notifications based on time and position constraints, such as an advance notification when the shipment is approaching a state or country border, or notification of arrival at the final destination, as illustrated by the e-mail message in Figure 1.

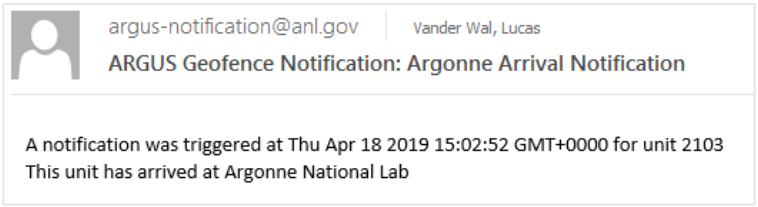
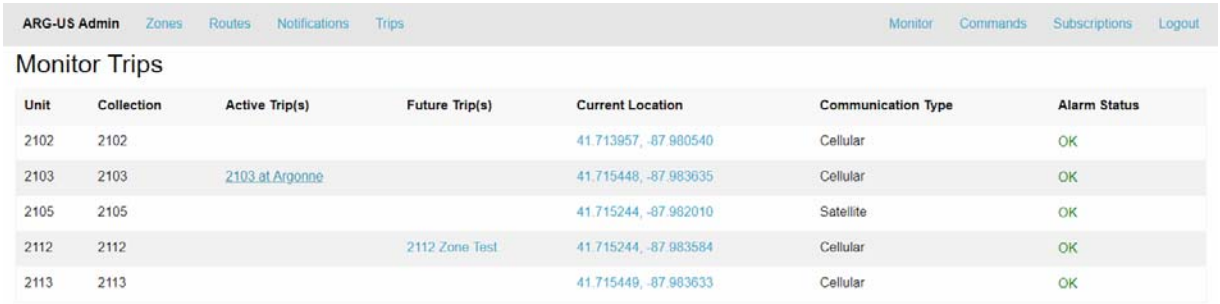


Figure 1. ARG-US TRAVELER geofence arrival notification.

The ARG-US system administrator can also view all currently defined geofence Trips and information about each TRAVELER unit currently monitored by the program. The geofence monitor page, shown in Figure 2, provides a list of Active and Future Trips for each TRAVELER unit, as well as each unit's Current Location (latitude and longitude), Communication Type (cellular or satellite), and geofence Alarm Status. The ARG-US Admin menu bar on the TRAVELER's geofence monitor page shows the features buttons (shaded in blue) for Zones, Routes, Notifications, and Trips to the left of the menu bar, and Monitor, Commands, Subscriptions, and Logout to the right. Each of these buttons, when clicked, reveals details related to the Trip implementation discussed in the next section



Unit	Collection	Active Trip(s)	Future Trip(s)	Current Location	Communication Type	Alarm Status
2102	2102			41.713957, -87.980540	Cellular	OK
2103	2103	2103 at Argonne		41.715448, -87.983635	Cellular	OK
2105	2105			41.715244, -87.982010	Satellite	OK
2112	2112		2112 Zone Test	41.715244, -87.983584	Cellular	OK
2113	2113			41.715449, -87.983633	Cellular	OK

Figure 2. The TRAVELER's geofence monitor page

TRIP IMPLEMENTATION

The basic building block of a Trip is a Zone. A Zone is a single, contiguous area that is marked with a boundary. Examples of a Zone may be the city of Chicago, IL; the stretch of Interstate 55 between Chicago and Bolingbrook, IL; or the Argonne property line. Zones may be used in multiple Trips or at multiple times in the same Trip. Zones designate distinct areas of interest. Figure 3 shows a Zone defined around Argonne.

The ARG-US system administrator can draw custom zones, or upload an existing zone using common mapping file formats.

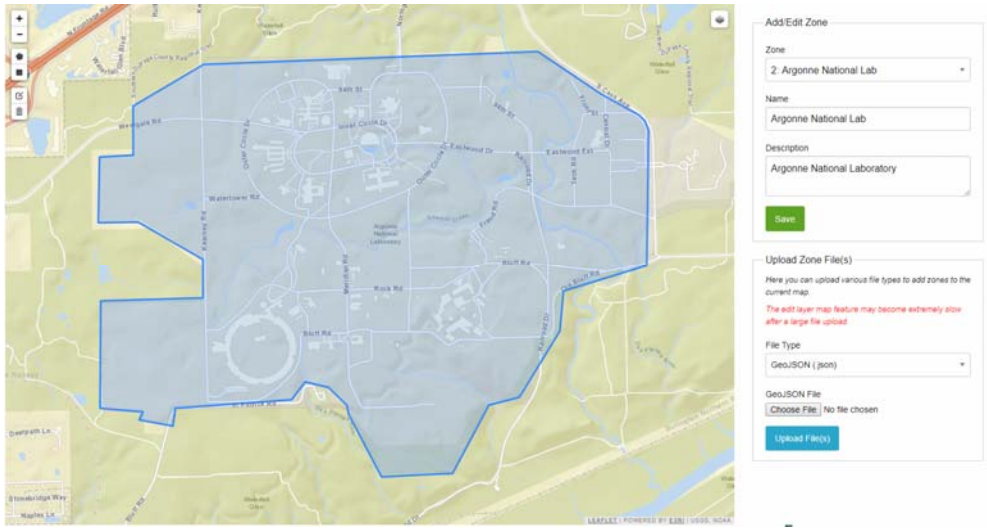


Figure 3. The Zone definition page

The next step in building a geofence for a Trip is stitching Zones together to form a Route. A Route is an itinerary that specifies where a TRAVELER unit should or should not be, relative to the amount of time that has passed since the start of the defined Route. Each Route must have one or more Legs. A Leg is the combination of a single Zone, which is the geographic area of interest, and an activity window, which is the time period of interest. Each Leg is also marked as Inclusive or Exclusive. An Inclusive Leg indicates that the TRAVELER unit is expected to traverse the given Zone during the activity window, while an Exclusive Leg indicates that the TRAVELER unit should not traverse the given Zone during the activity window. Figure 4 is an example Route definition page showing a Route from downtown Chicago to Argonne via Interstate 55. The Zone surrounding Chicago will be active from the start of the Trip until 30 minutes into the Trip. The Zone surrounding Interstate 55 to Argonne is active from

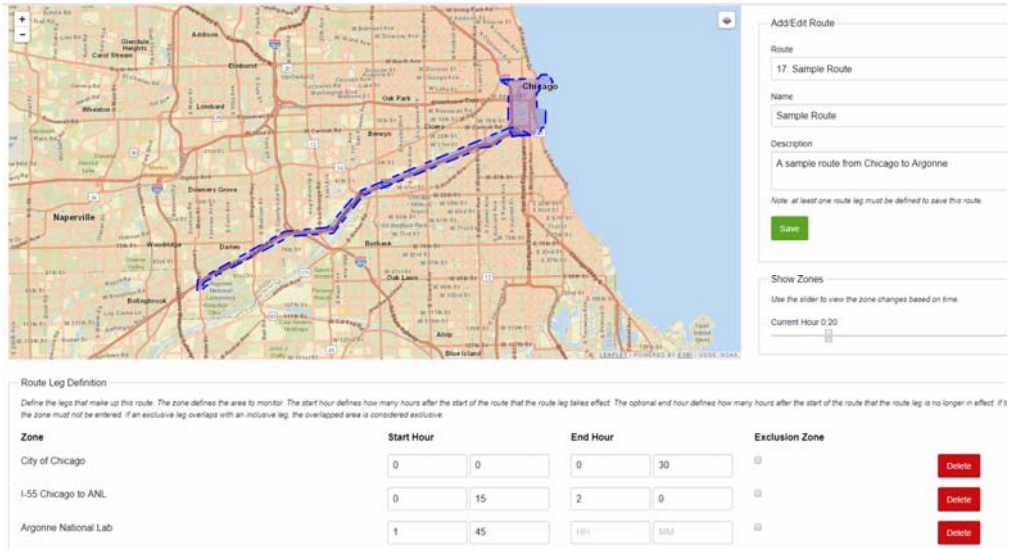


Figure 4. The Route definition page

15 minutes after the start of the Trip until 2 hours after the start of the Trip. The Zone surrounding Argonne is active from 1 hour and 45 minutes after the start of the Trip until the end of the Trip. Note that only the Zones surrounding Chicago and Interstate 55 to Argonne are displayed when the Current Hour slider bar in Fig. 4 is set to 20 minutes. Sliding the bar to other minute values will update the Zones that are displayed on the map.

Finally, a geofence Trip is defined by choosing a TRAVELER unit to monitor, the Route to follow, and the start time and end time. The geofence program uses the start and end times of a Trip, in combination with the selected Route's activity windows, to determine when the Route Legs are active. Notifications can also be added to a Trip, including a message, a list of subscribers, and a Zone. When the geofence program detects that the TRAVELER unit enters a given Zone during the Trip, a message to this effect is sent automatically to the subscribers.

While a Trip is active for a TRAVELER unit, there are two ways that an alarm can be triggered. An alarm will be triggered if the program detects that the unit is inside the Zone of an Exclusive Leg while the Leg is active. An alarm will also be triggered if the program detects that the unit is not inside the Zone of an Inclusive Leg when one or more Inclusive Legs are active. If multiple Inclusive Legs are active at the same time, the unit must be in at least one but does not need to be in all of them. When an alarm is triggered, an alarm message is sent automatically to each subscriber. Once the TRAVELER unit has returned to a valid location, the ARG-US system administrator can clear the alarm from the web monitor page. Automatic notification of arrival is an important feature when crossing state borders with changed jurisdictions.

TESTING

The geofence program has been tested extensively during 2018, both on-site at Argonne using two ARG-US TRAVELER units and off-site with a single TRAVELER unit in a vehicle Trip to Cleveland, Ohio. The on-site tests included altering the geofence constraints involving Inclusive, Exclusive, or both types of Route Legs. Figure 5 is a screenshot of the TRAVELER map page showing that an alarm was triggered during a test in July 2018. The blue truck icon indicates the location of the TRAVELER unit, which was

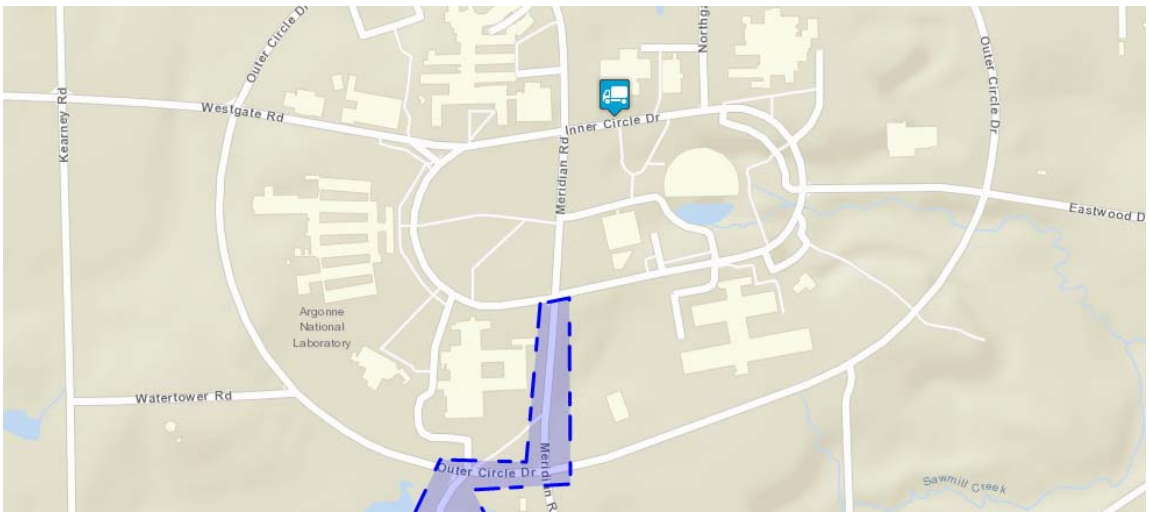


Figure 5. The TRAVELER monitor map page during a test in July 2018

outside the highlighted purple area of an active Inclusive Leg. The alarm was triggered immediately when a location update that violated the active geofence constraints was received from the unit.

Figure 6 shows the tracked history of a TRAVELER unit during a vehicle Trip in September 2018 between Argonne and Cleveland, OH. (The numbers in the circles are aggregated breadcrumbs, each representing a successful data transmission during the Trip.) A geofence was set up along the defined Route. The geofence program tracked the unit's location and an alarm message notification was issued because the departure was earlier than planned.

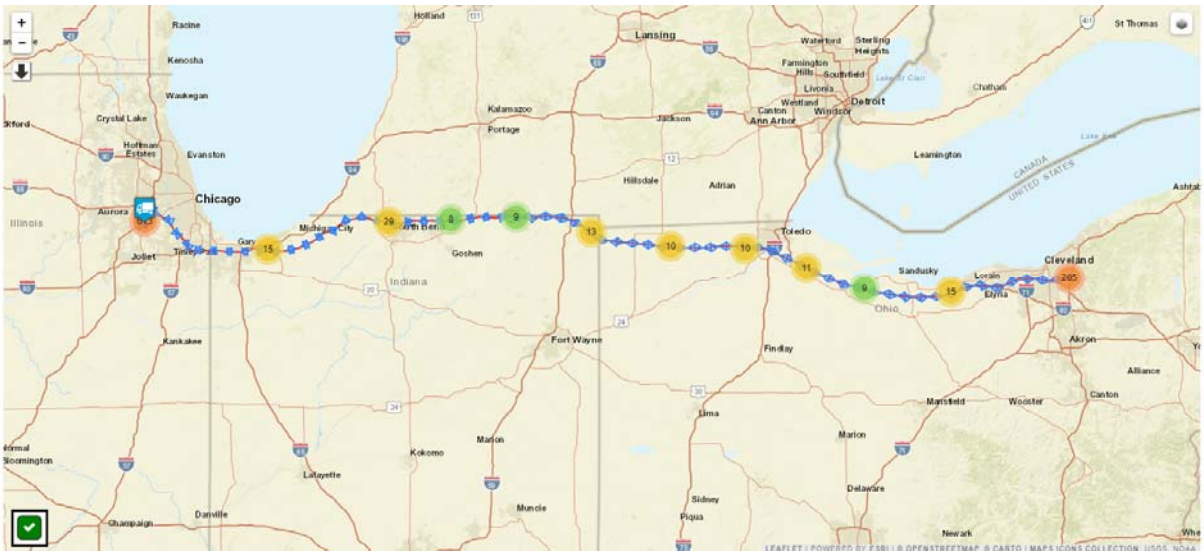
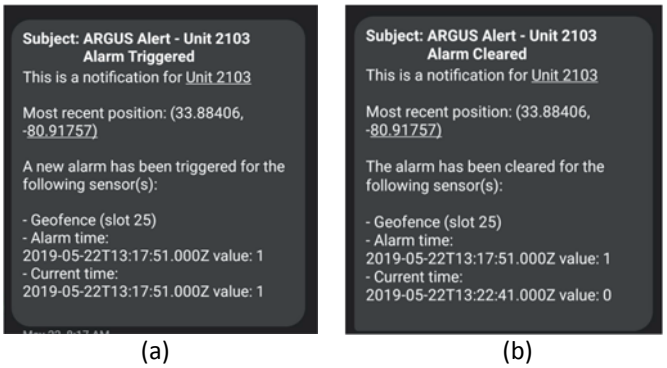


Figure 6. The TRAVELER monitor map page during a Trip between Argonne and Cleveland, OH.

DEMONSTRATION

In May 2019, a TRAVELER unit was affixed to a flatbed truck for a shipment of fresh-fuel assembly containers from a South Carolina plant to Kansas and back. The Trip lasted more than three days, and the truck traveled over 2000 miles. The geofence program sent text notification messages automatically to fourteen subscribers when the truck shipment arrived at its destination. No alarms were triggered, as the TRAVELER unit did not violate the parameter constraints defined for the Trip.

Upon the unit's return to South Carolina, another demonstration of the geofence program was conducted at the plant facility. A new geofence Trip was created that did not include the location of the TRAVELER unit, and an alarm was triggered immediately and text notifications were sent and received by the subscribers at or away from the facility within 60 seconds. Figure 7(a) shows the SMS text message sent to



(a) (b)

Figure 7. SMS text messages ARG-US Alert – Unit 2103 (a) new alarm Geofence, and (b) alarm clearance.

subscribers' mobiles with date, time, GPS location of a new geofence alarm. Notice that the Alarm Time 2019-05-22T13:17:51.000Z Value: 1 and Current Time 2019-05-22T13:17:51.000Z Value: 1 are identical in the text message. Figure 7(b) shows the SMS text message sent to subscriber's mobiles following clearance of the geofence alert with a Current Time of 2019-05-22T13:22:41.000Z Value: 0. The subscribers will receive repeated SMS alarm notifications messages, every five minutes, until the geofence violation is resolved and the alarm is cleared.

A geofence Trip was also set up for the return of the TRAVELER unit to Chicago, IL, in a vehicle. An alarm was triggered when the vehicle entered a gap in the Route that was intentionally created near Knoxville, TN. Alarm text notifications were sent and received by subscribers within 2 minutes after the vehicle left the last active Leg. Figure 8 shows the active Legs in purple and the location of the TRAVELER unit that violated the geofence parameter constraints, triggering the alarm. The history of the vehicle and the TRAVELER's locations within the active Legs and the gap are shown by the numbers in the encircled green breadcrumbs. After the vehicle re-entered the active Leg on the other side of the gap, the alarm was cleared via the Commands button on the geofence monitor page.

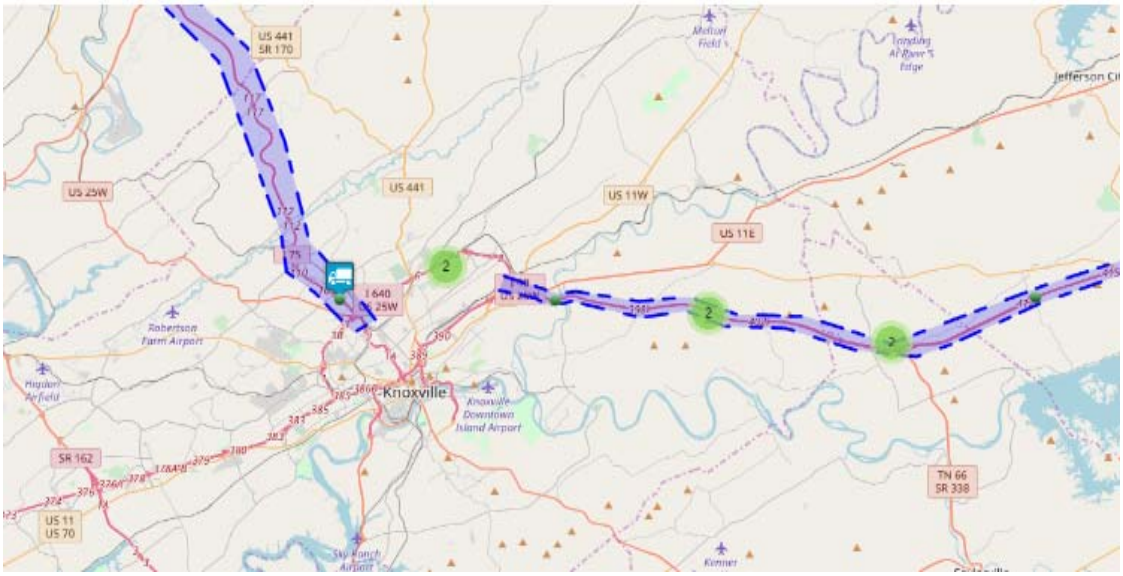


Figure 8. The TRAVELER monitor map page during the return Trip from South Carolina to Argonne.

SUMMARY AND DISCUSSION

A geofence program has been developed for the ARG-US TRAVELER to enable establishment of a virtual geographic boundary during a vehicle shipment of RAM. The geofence program is run on a dedicated server that allows parameter constraints to be defined to effect a geofence for a vehicle shipment using GPS locations and travel time. Advanced notifications of arrival, as well as alarms due to geofence violations, are automatically sent to subscribers of the shipment that is being monitored and tracked by the ARG-US TRAVELER unit. Implementation and testing of the geofence are described, along with highlights of a recent geofence demonstration at a facility simulating in-transit storage, and during vehicle movement.

The IAEA Nuclear Security Series No. 26-G [2] and No. 9 [3] are Implementing Guides for transport security of nuclear and other radioactive material, respectively. Both documents contain guidance on preparing a TSP, which typically contains eight topical sections: (1) Scope, (2) Objectives, (3) Applicability, (4) Administrative Requirements, (5) Responsibilities, (6) Information Management, (7)

Operational Transport Security Measures, and (8) Emergency Response. The Operational Transport Security Measures section includes these topics: (a) primary and alternate routes, intermodal transfers, storage in transit, and stopping places; and (b) description of the security system, which includes equipment and modes of transport; operations communications, command and control, and shipment tracking; escort, guards and response personnel; additional security measures; and maintenance and testing of systems and equipment. The Emergency Response section includes these topics: (a) non-tactical emergency response; (b) tactical emergency response; (c) incident communication; and (d) notification of relevant agencies.

The addition of the geofence capability to TRAVELER greatly enhances the implementation and effectiveness of the TSPs for nuclear and other radioactive materials during normal operation (by addressing topics under operational transport security measures), security incidents (by addressing topics under emergency response), and/or other safety-related incidents and accidents. The USDOE/PCP/Argonne training course on Transport Security for Nuclear and Other Radioactive Material [4] contains modules on TSP and hands-on exercises involving readiness reviews of TSPs for a mock RAM shipment using a checklist and corrective actions, followed by a field exercise in which the mock shipment is tracked and monitored by a TRAVELER unit with simulated geofence incidents. Training on the TRAVELER's geofence program as part of the TSP for nuclear and other radioactive material can be provided by Argonne, upon request.

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3. IAEA Nuclear Security Series No. 9, *Security in the Transport of Radioactive Material – Implementing Guide*, 2008.
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