A Challenge Problem for SAR-based GMTI in Urban Environments

Steven M. Scarborough*, Curtis H. Casteel Jr, LeRoy Gorham, Michael J. Minardi, Uttam K. Majumder, Matthew G. Judge, Edmund Zelnio, Michael Bryant
Air Force Research Laboratory, Sensors Directorate
2241 Avionics Circle, Bldg 620
Wright-Patterson AFB, OH 45433-7321

Howard Nichols, Douglas Page
BAE Systems
#6 New England Executive Park
Burlington, MA 01803

ABSTRACT

This document describes a challenge problem whose scope is the detection, geolocation, tracking and ID of moving vehicles from a set of X-band SAR data collected in an urban environment. The purpose of releasing this Gotcha GMTI Data Set is to provide the community with X-band SAR data that supports the development of new algorithms for SAR-based GMTI. To focus research onto specific areas of interest to AFRL, a number of challenge problems are defined.
The data set provided is phase history from an AFRL airborne X-band SAR sensor. Some key features of this data set are two-pass, three phase center, one-foot range resolution, and one polarization (HH). In the scene observed, multiple vehicles are driving on roads near buildings. Ground truth is provided for one of the vehicles.

Keywords: SAR, SAR change detection, GMTI, Radar, tracking

1. INTRODUCTION

This document describes a challenge problem whose scope is the detection, geolocation, tracking and ID of moving vehicles from a set of X-band SAR data collected in an urban environment. The data for this problem was collected at a scene consisting of numerous buildings and civilian vehicles. The radar operated in circular SAR mode and completed two circular flight paths around the scene at a fixed altitude. The provided data consists of a 71-second portion of phase history data for each of these two circular flight paths. In Section 3, this data is described in more detail.
The purpose of releasing this Gotcha GMTI Data Set is to provide the community with X-band SAR data that supports the development of new algorithms for SAR-based GMTI. To focus research onto specific areas of interest to AFRL, a number of challenge problems are defined.

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2. PROBLEM DESCRIPTION

Research interest is primarily focused on using SAR change detection for detecting moving targets in regimes where traditional GMTI often fails: namely, for slow-moving targets in nonhomogeneous clutter. Specific interests include continuous detection, geolocation, tracking, and ID of vehicles as they pass through move-stop-move states while in the presence of urban clutter.

To guide potential research, five problems will be defined here:

2.1 Problem 1: Use two-pass SAR change detection to detect vehicles as they pass through move-stop-move states in the presence of urban clutter.

2.2 Problem 2: Develop useful geolocation and tracking methods using two-pass SAR Change detection (from Problem 1).

2.3 Problem 3: Take advantage of properties of staring SAR to develop features that improve track association or target ID.

2.4 Problem 4: Incorporate multiple phase centers to improve results in Problems 1-3

2.5 Final challenge: Go out and do great things with the data. We hope that people will use the data in ways that will both surprise and delight us.

Published Results: We would ask that the results of any research using this data be shared with ATR Division of AFRL Sensors Directorate and that the authors acknowledge AFRL/RYA as the source of the data in any resulting publications or presentations.

3. DATA DESCRIPTION

The data set consists of motion-compensated phase-history airborne radar data and associated truth data of a moving ground vehicle in a cultural clutter environment. The vehicle of interest is a Dodge Durango instrumented with a hand-held GPS device which recorded motion estimates at a 1 Hz rate. The phase-history data is from two spotlight passes that cover coincident viewing geometry. Both passes contain three phase centers of HH polarization data. Each pass of phase-history data is augmented with pulse-wise auxiliary data, or PAUX data, to provide the necessary information for processing the phase-histories (i.e. pulse time, antenna position, PRF, etc.).

The scenario covered by the data-set is about 71 seconds in duration. The GPS recorded motion of the Durango is pictured below in Figure 1. For about the first 25 seconds the Durango is waiting in line to cross a busy intersection at a stop sign. At the start of the scenario, the Durango is stopped at the third position in line. The Durango then nudges to the second position and stops again. As the Durango nudges toward the first position in line, it starts to slow down, but then accelerates through the intersection without stopping. The Durango continues to accelerate until reaching the bend in the road, at which point the road starts downhill. In order to take the right turn at the bottom of the hill, the Durango begins to slow down. After the right turn, the Durango accelerates again.

The Durango GPS truth data for the 71 second scenario is included in the data-set. This truth data is in the form of a Matlab structure contained in a save file (.mat extension). The fields in the structure include vehicle heading in degrees, vehicle speed in meters per second, truth time in GPS time-of-day, and vehicle position in the same coordinate system used for the PAUX data, namely the Processor Coordinate System (PCS). The PCS coordinate system is a locally-level (tangent plane), right-handed, Cartesian coordinate system with the origin at the collection reference point. The vehicle heading is in degrees where 0 degrees indicates travel along the positive PCS Y-axis and 90 degrees indicates travel along the positive PCS X-axis. Also, included in the Durango truth structure are a GPS height error and GPS time offset. The GPS height error and GPS time offset were subtracted from the vehicle height and GPS time-of-day, respectively, to better align the truth data to the image data produced by the phase-histories. An extra 15 seconds of truth data is included before and after the scenario to allow refinement to these offset values.

The PAUX data contains 34 data fields for each pulse of phase-history data. Reader code will be provided with the data-set that includes brief descriptions for each of the data fields.

Ordinarily, 2 passes, each with 3 phase-centers of phase-history data, covering a 71 second scenario would require many DVDs of storage. In order to provide a useful, manageable data-set, the phase-histories were range-gated to center the Durango within 384 range-bins, rather than the original 5400 bins. This processing allows a data-set covering a longer contiguous time period to fit onto one DVD while providing enough clutter context to be representative. The range-gating steps are described below in Figure 2.

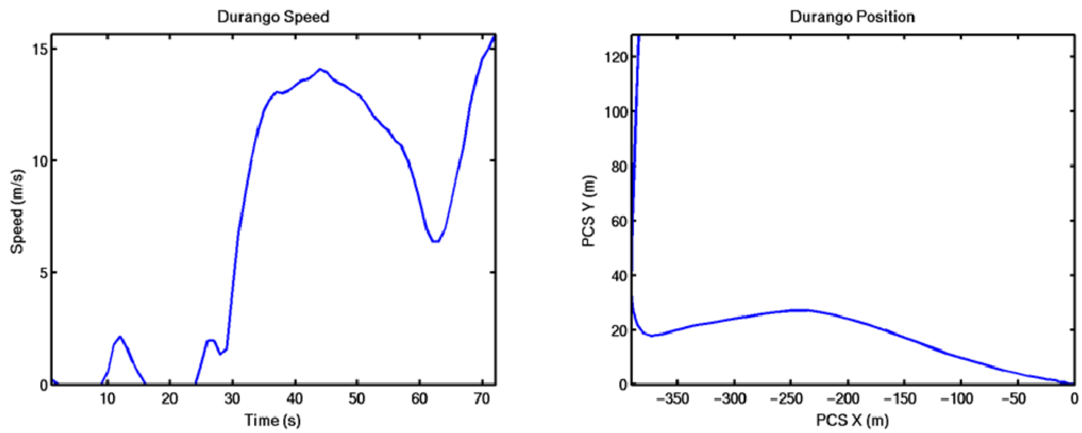

Figure 1 The plot on the left is the GPS recorded Durango speed and the plot on the right is the GPS recorded Durango position relative to its starting point.

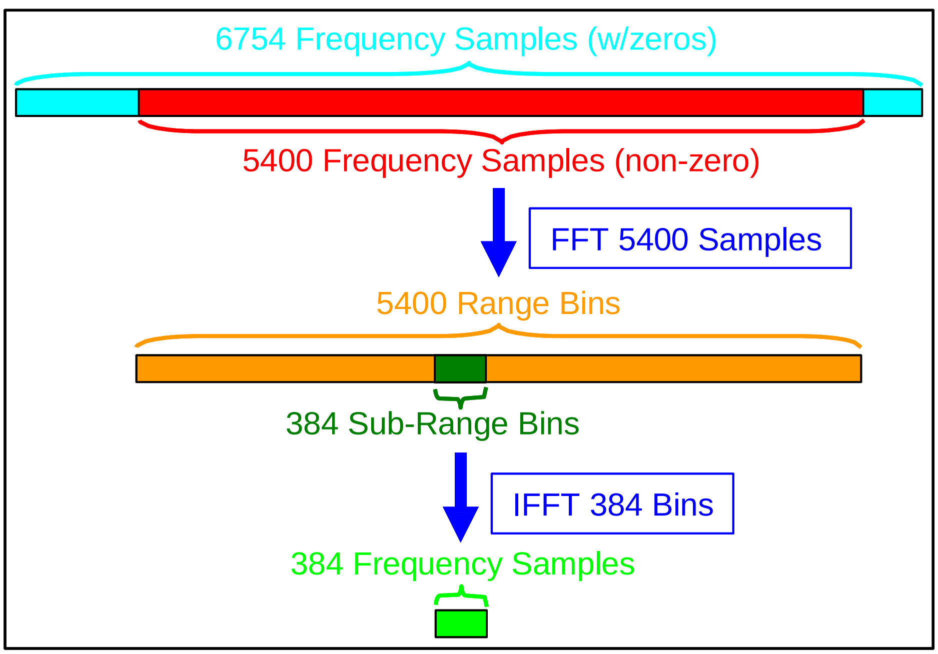

Figure 2 Processing steps for range-gating each slow time pulse of phase-history data.

Below in Figure 3, is a notional diagram of the processing scheme to produce the range-gated phase-history data. The PAUX data provides information for each pulse to determine a frequency sample offset value used to extract the 5400 frequency samples from the original 6754 samples. A delta range value is calculated for each pulse in the mission pass using the GPS truth and PAUX data to estimate the range bin corresponding to the Durango. This delta range value corresponds to a range bin offset which is used to extract the 384 sub-range bins from the 5400 range bins. Mission pass pulses are chosen to correspond to the desired 71 second scenario. Reference pass pulses are chosen to correspond to the same viewing angles as the mission pass pulses. For the 71 second scenario, the number of mission pass pulses will differ from the number of reference pass pulses based on the variations in platform speed. Similarly, the range bin offsets used to extract the 384 sub-range bins for the reference pass pulses were resampled from those used for the mission pass pulses. An additional 6 data files in the form of Matlab save files will be included to correspond to the 6 (2 passes of 3 phase-centers each) phase-history files. These auxiliary save files will include the data necessary to calculate the start frequency sample for the 5400 frequency samples and the start range bin for 384 sub-range bins for each range-gated phase-history pulse. Also, reader code will be provided for the phase-history data files.

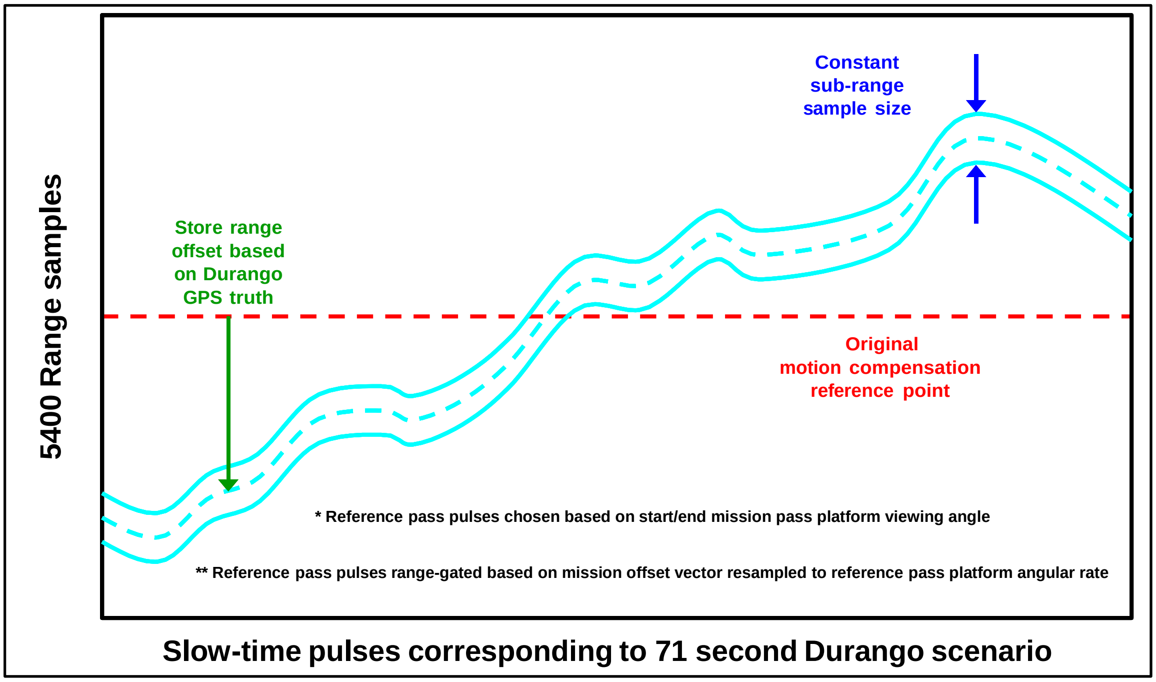

Figure 3 Processing scheme to ensure Durango is centered within the range samples extracted.

4. IMAGE EXPLOITATION EXAMPLES

In this section we will show several image examples in the subsequent figures. All images shown have about a 1 second CPI-length. Images are oriented such that the platform is imaging from the bottom looking up. The mission CPIs were formed centered at 4 particular points in the scenario and the reference CPI was chosen to most closely match the mission imaging geometry according to the PAUX data. Both mission and reference images are formed on coincident polar grids that extend beyond the range extent supported by the data to highlight the range-gating process. This is evident by the black bands at the top and bottom of the full-Doppler images.

The mission CPI in Figure 4 and Figure 5 is centered 3 seconds after the start of the scenario when the Durango was stopped in line at the intersection. The red box is to indicate the Durango’s location in the image as calculated using the GPS truth and PAUX data.

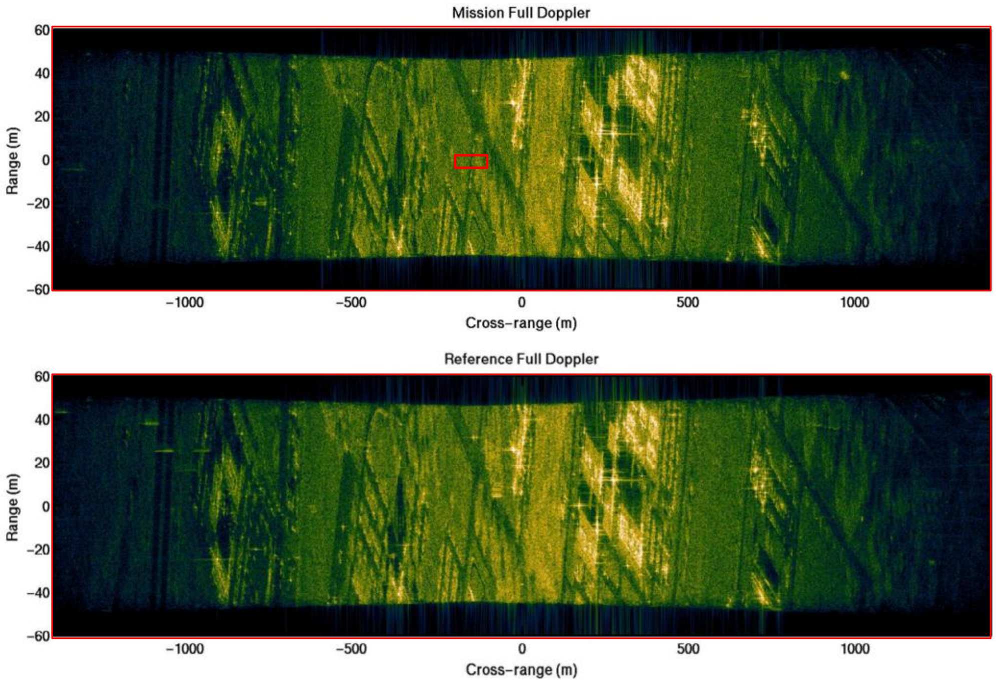

Figure 4 Full-Doppler images of the mission and reference pass formed at 3 seconds after the start of the scenario while the Durango was stopped in the third position in line at an intersection. Red box indicates target location.

In the mission and reference images shown below in Figure 5, the area of interest (AOI) is chosen surrounding the calculated image location of the Durango using GPS truth and PAUX data. In the coherent change image, areas of high correlation appear white and the darker areas correspond to areas of low correlation. In the non-coherent change image targets, such as the vehicles lined up at the intersection, that are present in the mission AOI and not in the reference AOI will appear.

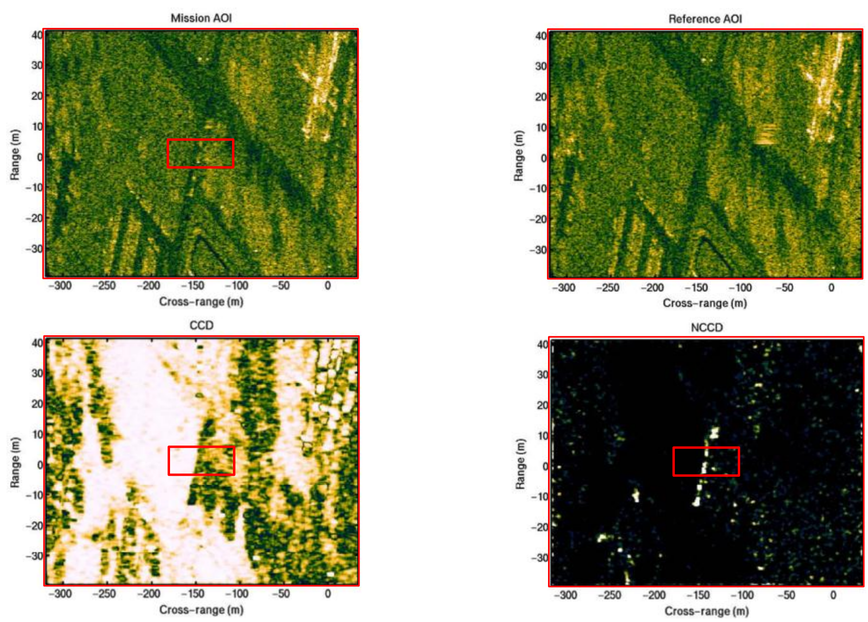

Figure 5 Combining the mission pass AOI (top left) and corresponding reference pass AOI (top right) to yield a coherent change image (bottom left) and non-coherent change image (bottom right). The Durango is stopped in the third position in line at the intersection. Red box indicates target location.

The mission CPI in Figure 6 and Figure 7 is centered 46 seconds after the start of the scenario when the Durango had a particularly large Doppler-shift. The red box is to indicate the Durango's Doppler-shifted location in the image as calculated using the GPS truth and PAUX data. The blue box is to indicate the Durango's actual location in the image again as calculated using the GPS truth and PAUX data.

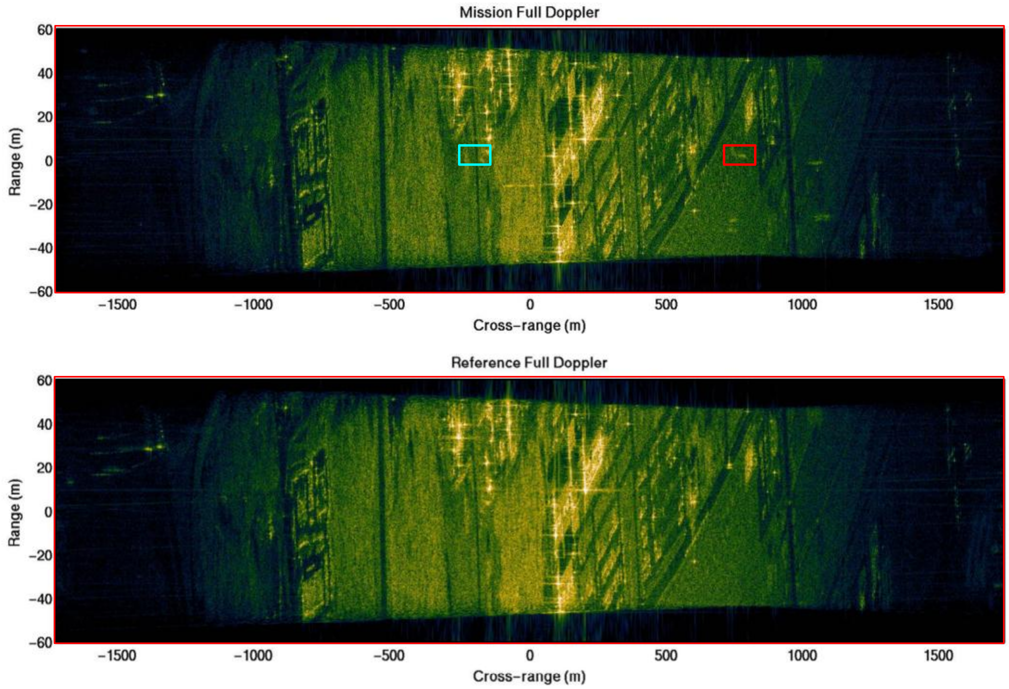

Figure 6 Full-Doppler images of the mission and reference pass formed at 46 seconds after the start of the scenario when the Durango experienced a large Doppler-shift. Blue box indicates actual target location. Red box indicates location of target's Doppler-shifted energy.

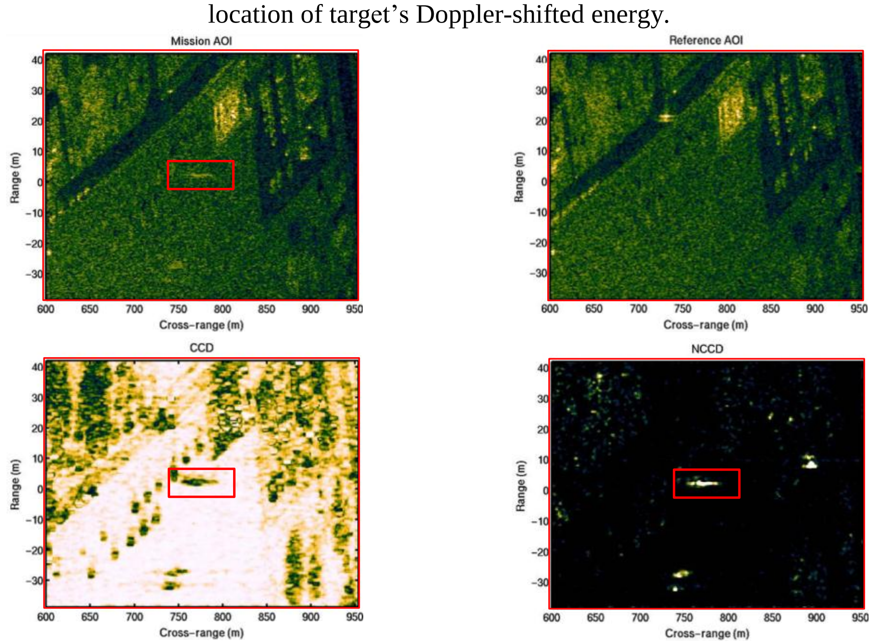

Figure 7 Combining the mission pass AOI (top left) and corresponding reference pass AOI (top right) to yield a coherent change image (bottom left) and non-coherent change image (bottom right). The moving Durango is Doppler-shifted over relatively benign clutter. Red box indicates location of target's Doppler-shifted energy.

The mission CPI in Figure 8, Figure 9, and Figure 10 is centered 51 seconds after the start of the scenario when the Durango was Doppler-shifted over cultural clutter. The red box is to indicate the Durango's Doppler-shifted location in the image and the blue box is to indicate the Durango's actual location in the image. In this example CPI pair, the Doppler-shifted target was not apparent in either change detection image shown in Figure 9. Only after applying a STAP AMF metric [1] and object level change detection using the other phase centers was the target detected despite the competing clutter, as shown in Figure 10.

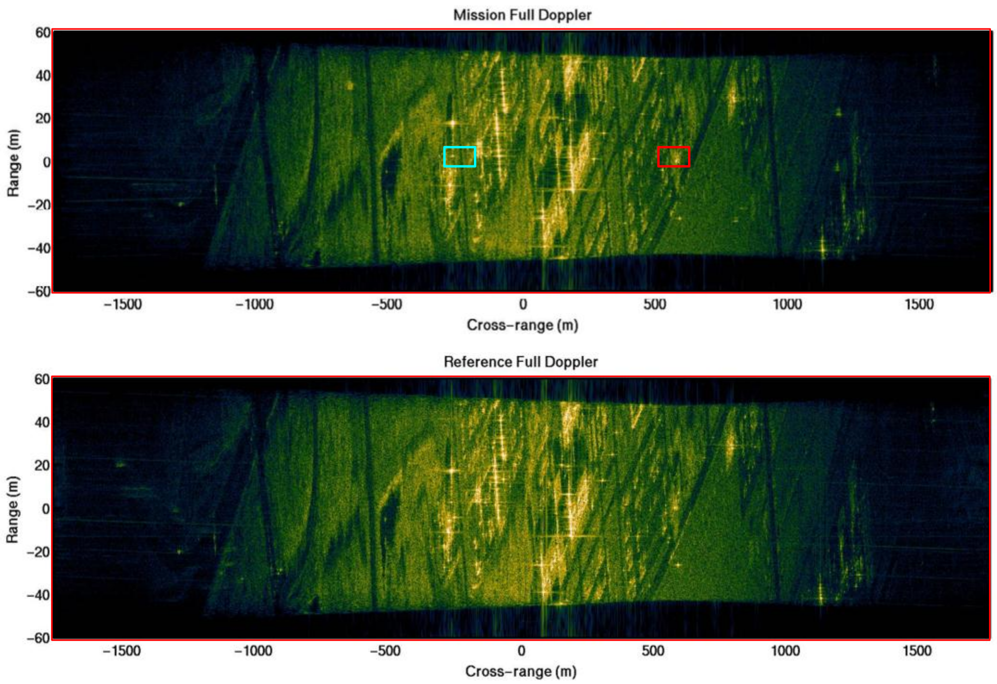

Figure 8 Full-Doppler images of the mission and reference pass formed at 51 seconds after the start of the scenario while the Durango was Doppler-shifted over cultural clutter. Blue box indicates actual target location. Red box indicates location of target's Doppler-shifted energy.

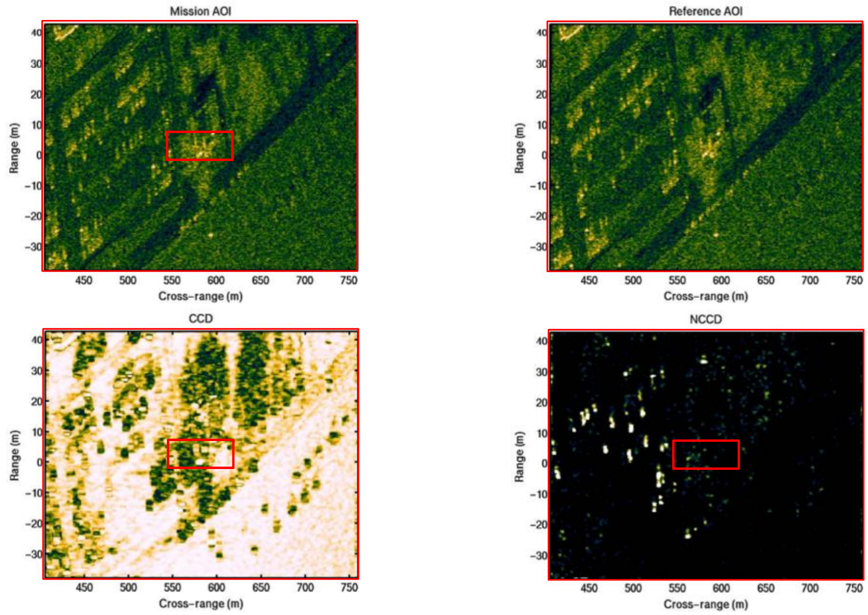

Figure 9 Combining the mission pass AOI (top left) and corresponding reference pass AOI (top right) to yield a coherent change image (bottom left) and non-coherent change image (bottom right). The moving Durango is not evident in either of the change detection images due to the competing cultural clutter.

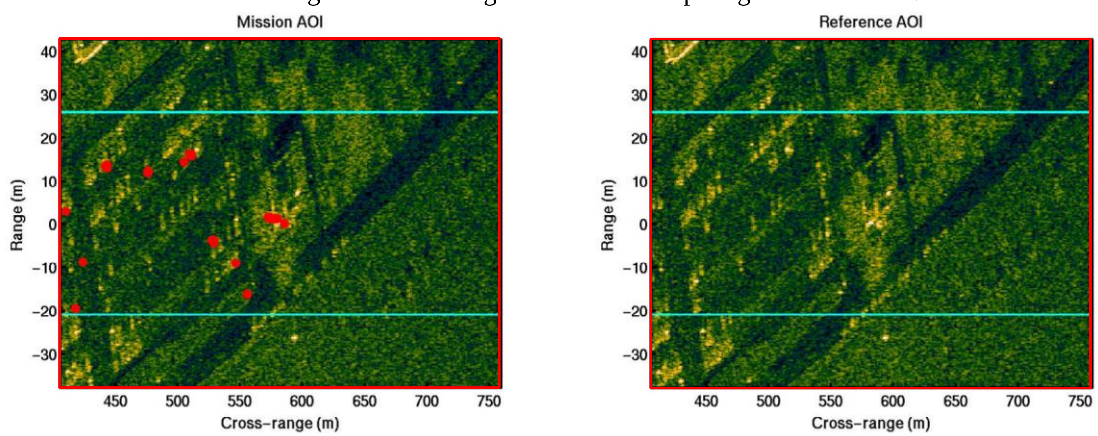

Figure 10 Using the other two phase centers from the mission pass (AOI shown on the left) and the reference pass (AOI shown on the right), detections (shown in red) are obtained using a STAP AMF metric and object level change detection. The blue bands indicate the portion of the AOI where the technique was applied. With STAP, detections are now seen at the predicted Durango location despite the competing clutter.

The mission CPI in Figure 11 and Figure 12 is centered 3 seconds before the end of the scenario. The red box is to indicate the Durango's Doppler-shifted location in the image and the blue box is to indicate the Durango's actual location in the image. As shown in Figure 12, the estimated Durango image location highlights the errors that can result from geolocation using GPS data.

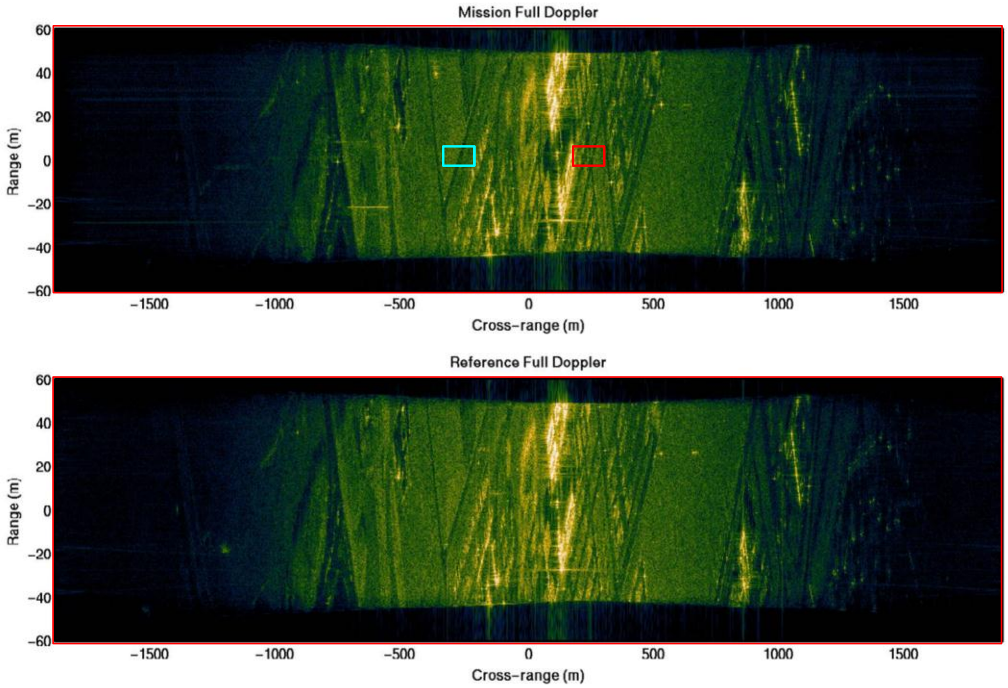

Figure 11 Full-Doppler images of the mission and reference pass formed at 3 seconds before the end of the scenario. Blue box indicates actual target location. Red box indicates location of target's Doppler-shifted energy.

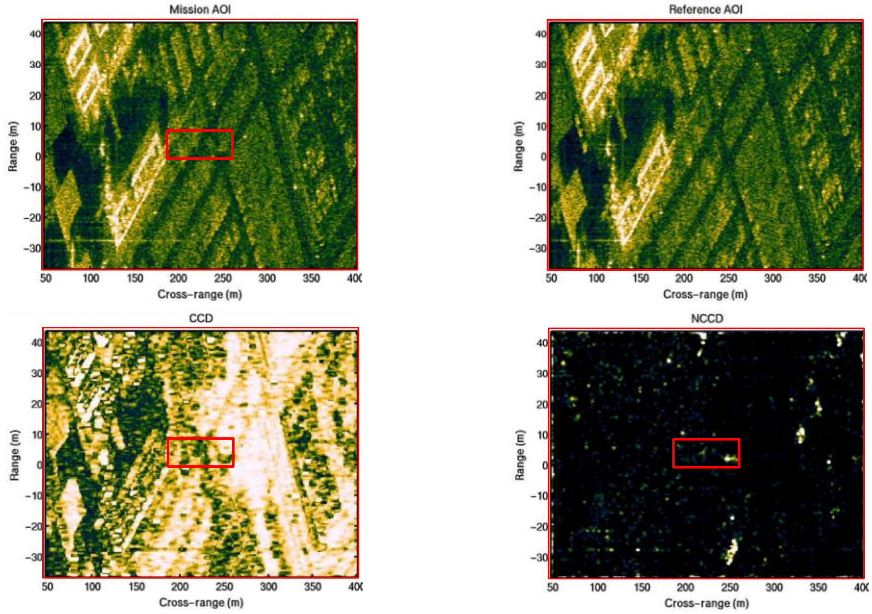

Figure 12 Combining the mission pass AOI (top left) and corresponding reference pass AOI (top right) to yield a coherent change image (bottom left) and non-coherent change image (bottom right). The estimated Durango image location (center of the red box) highlights the errors that can result from geolocation using GPS data.

To request a copy of the data set, visit the AFRL/RYA Sensor Data Management System (SDMS) Public Website https://www.sdms.afrl.af.mil/main.php.

5. SUMMARY

This document describes a challenge problem whose scope is the detection, geolocation, tracking and ID of moving vehicles from a set of X-band SAR data collected in an urban environment. The purpose of releasing this Gotcha GMTI Data Set is to provide the community with X-band SAR data that supports the development of new algorithms for SAR-based GMTI. To focus research onto specific areas of interest to AFRL, a number of challenge problems are defined.

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