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Direct Rear Visibility of Passenger Cars: Laser-Based Measurement Development and Findings for Late Model Vehicles

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16. Abstract

In 2007, NHTSA initiated an effort to examine the rear visibility characteristics of recent model year vehicles. Vehicle fields of view were measured using a male driver of 50th percentile height and a female driver of 5th percentile height. While data valuable for characterizing vehicle rear visibility were obtained, the areas visible to these individuals may not be representative of all drivers due to physical differences among individuals such as driver height, differences in body movement tendencies, and seating position preferences. Subsequently, NHTSA investigated ways to measure visibility vehicle rear fields of view in a more objective manner using a surrogate, mechanical "driver." The resulting measurement method used a dynamic laser-based fixture to simulate a 50th percentile male driver's line of sight.

This report describes an objective method for measurement of the area behind a vehicle that is directly visible to a driver. A dynamic laser-based fixture was developed to simulate the line of sight for a 50th percentile height male driver. The areas that would be visible using direct glances (i.e., areas visible using mirrors or rearview video systems were not considered) for a 29.4-inch-tall (i.e., approximately the height of a 1-year-old child) visual target were determined over an area 50 ft wide and 50 ft long centered behind the vehicle. This approach focusing on direct visibility allowed for the most direct assessment of the impact of the vehicle's exterior structural design on rear visibility. Using the developed method, the rear visibility characteristics of a set of 75 vehicles were measured.

Since a vehicle's structural features, such as pillars, may affect rear visibility, longitudinal rear sight distance was examined along the entire vehicle width. Eight distance values with respect to the vehicle's rear bumper were measured across the width of the vehicle. The "shortest minimum sight distance" was the longitudinal distance from the bumper, out of the eight values that was closest to the vehicle. The shortest minimum longitudinal rear sight distance for any of the measured vehicles was 0.5 ft for the 2008 Volkswagen New Beetle. The "longest minimum sight distance" was the longitudinal distance from the bumper, out of the eight values that was farthest from the vehicle. The longest minimum longitudinal rear sight distance was less than 50 ft for 32 of 75 vehicles measured; meaning 57 percent of measured vehicles had at least one of the eight longitudinal rear sight distance values listed as 50 ft. Longitudinal rear sight distance values reported do not exceed 50 ft since that was the extent of the longitudinal measurement field behind the vehicle. Average longitudinal rear sight distance, calculated as a mean of the eight individual longitudinal sight distance values, was shortest for passenger cars and longest for vans.

Direct-view rear blind zone areas were also assessed. Rear blind zone area values for measured passenger cars were smallest for passenger cars and largest for pickup trucks. Overall average blind zone areas within the 50-foot wide by 50-foot long measurement field for measured passenger cars ranged from 932 to 2010 square ft.

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EXECUTIVE SUMMARY

Backover crashes involve a person being struck by a vehicle moving in reverse. The victims of backing crashes are frequently young children and elderly persons. These crashes are likely to be the result of some combination of vehicle blind zones, drivers' inadequate visual scanning behavior, and drivers' expectation that no obstacles are present behind the vehicle. NHTSA has undertaken research to examine the first two of these contributing factors. A 2008 study of drivers' use of rearview video systems in naturalistic driving conditions provided information about drivers' eye glance behavior during backing maneuvers with and without a rearview video system. The study described in this report examined the rear visibility of current vehicles to determine what range of blind zone sizes exists, and to provide information that can be used to determine whether a link exists between blind zone size and backover crash incidence.

In attempting to understand the problem of crashes involving backing vehicles striking children, it makes sense to examine whether characteristics of the vehicles involved in the incidents contributed to the likelihood of the crash. The area around a vehicle that a driver can see (i.e., field of view or "FOV") is affected by the structural design of the vehicle. Vehicles having greater height and length are likely to have larger "blind zone" areas around them, contributing to the likelihood of unseen obstacles, which may include pedestrians.

This report describes measurement of the rear visibility characteristics of a set of 75 vehicles. The visibility of a 29.4-inch-tall (i.e., approximately the height of a 1-year-old child) visual target was determined over a 2500-square-foot area stretching 25 ft to either side of the vehicle's centerline and 50 ft back from the vehicle's rear bumper, as well as on either side of the vehicle aft of the vehicle's side rearview mirrors. A dynamic fixture using a laser (Light Amplification by Stimulated Emission of Radiation) light beam was used to simulate the line of sight for a 50th percentile height male driver for these measurements. The measurement procedure determined the areas that would be visible to a 50th percentile male driver using direct glances (i.e., areas visible using mirrors or rearview video systems were not considered). This approach allowed for the most direct assessment of the impact of the vehicle's exterior structural design on rear visibility.

Since the vehicle's structural features, such as pillars and head restraints, may affect rear visibility, longitudinal rear sight distance was examined along the entire width of the vehicle. Eight distance values with respect to the vehicle's rear bumper were determined across the width of the vehicle based on the measured rear visibility data. The "shortest minimum sight distance" was the longitudinal distance from the bumper, out of the eight values, that was closest to the vehicle. The "longest minimum sight distance" was the longitudinal distance from the bumper, out of the eight values, that was farthest from the vehicle. Average longitudinal rear sight distance was calculated as a mean of the eight individual longitudinal sight distance values.

Average longitudinal rear sight distances to a 29.4-inch-tall visual target were shortest for passenger cars and longest for vans. The shortest minimum longitudinal rear sight distance for any of the measured vehicles was 0.5 ft for the 2008 Volkswagen New

Beetle. The longest minimum longitudinal rear sight distance was less than 50 ft for 32 of 75 vehicles measured. For 57 percent of the 75 measured vehicles, at least one of the eight longitudinal rear sight distance values was listed as 50 ft. Longitudinal rear sight distance values reported do not exceed 50 ft since that was the extent of the longitudinal measurement field behind the vehicle.

Direct view rear blind zone areas were assessed over a 50-foot wide by 50-foot long measurement field centered behind the vehicle. Rear blind zone area values were found to be smallest for passenger cars and largest for pickup trucks, with the exception of the cargo van that was measured. Excluding the cargo van, which had a rear blind zone area of 2500 square ft and is not a passenger car, overall average blind zone areas within the 50-foot wide by 50-foot long measurement field ranged from 932 to 2010 square ft.

1.0 INTRODUCTION

Backover crashes involve a person being struck by a vehicle moving in reverse. The victims of backing crashes are frequently young children and elderly persons. Due to their short stature, children can be difficult for a driver to detect in a vehicle's rear blind zone. The area behind a vehicle that a driver cannot see is affected by structural design aspects of the vehicle, such as vehicle height and length, pillar width, and rear window dimensions. Poor rear visibility contributes to the likelihood of unseen obstacles, which may include pedestrians.

In 2007, NHTSA began examining the rear visibility characteristics of vehicles. The initial effort involved assessing what areas around a vehicle were visible to a male driver of 50^{th} percentile height (69.1 in.)[1] and a female driver of 5^{th} percentile height (59.8 in.) [1]. Valuable data describing the size of the area behind a vehicle that can be seen were obtained for a set of top-selling vehicles. While these measurements determined the actual degree of visibility afforded the particular drivers involved in the testing for the particular vehicles measured, the areas visible to these individuals may not be representative of all drivers of the same particular height. Individual differences amongst drivers can affect what areas surrounding a vehicle are visible. Physical characteristics of the driver such as torso breadth, physical flexibility (e.g., torso and neck rotational range), peripheral visual ability, and the presence of eye glasses all impact a driver's ability to glance toward the rear of the vehicle. Additional differences relating to how a driver chooses to position his or her body in the seat during backing (e.g., raising their body up from the seat pan to achieve a higher vantage point), driver preferences regarding seat adjustment, and mirror positioning may also affect rear visibility. Such individual differences may have affected these results of the 2007 effort. Based on a review of test data from the 2007 study, it is believed that the shorter driver used in that testing may have been less restricted in her body movements (i.e., leaned her body more) when attempting to view the visual target. As a result, for some vehicles, measures like minimum sight distance and average sight distance showed better results for some vehicles for the shorter female driver than for the taller male driver. To avoid such individualized effects on the measured visibility data, this subsequent visibility measurement effort investigated ways to make the measurements more objective, through the use of a surrogate, mechanical "driver." In anticipation of the passing of the Kids Transportation Act of 2007, NHTSA research sought to develop a more objective and repeatable measurement procedure, for potential use as part of a rear visibility standard.

1.1 Study Objectives

The objectives of this research included:

- Develop an objective, repeatable measurement procedure for assessing the rear visibility of a light vehicle.
- Measure the driver's rear field of view covering approximately 180 degrees around the rear of the vehicle for a number of current and recent models to assess the impact of vehicle size and exterior structure on rear visibility.
- Provide rear visibility data for use in computing rear visibility metrics that may be related to a vehicle's backing crash risk.

2.0 BACKGROUND

The study sought to develop a procedure for measuring vehicle rear and side visibility in an objective and repeatable manner. Existing objective methods of assessing rear visibility were reviewed to assess their suitability for this purpose.

2.1 SAE J1050

The Society of Automotive Engineers (SAE) has a Recommended Practice for “Describing and Measuring the Driver’s Field of View” (SAE J1050)[2] for determining the areas around a vehicle that a driver can see through direct vision (i.e., without the use of mirrors or another indirect vision device). The procedure appears to rely on the use either engineering drawings or three-dimensional computer models of manufactured vehicles as a basis for geometrically approximating what a driver should be able to see. Using standard driver eyepoints, the simulation allows the rotation of sight lines originating from the eyepoints to determine the areas that the driver should be able to see outside the vehicle. This approach for determining a vehicle’s visibility characteristics is theoretical. NHTSA’s approach for compliance testing is to test actual vehicles in relation to their ability to meet minimum requirements, rather than to rely solely on computer-based simulations of how the vehicle may perform in the real world.[1] Also, NHTSA is not aware of the degree of repeatability afforded by the SAE procedure.

2.2 Consumer Reports Linear Rear Blind Spot Measurement Method

The Consumer Reports publication publishes new vehicle reviews that include comments regarding the quality of a vehicle’s rear visibility. In their August 2006 report [3], they examined vehicles to determine the closest distance at which a 28-inch-tall object (approximating the height of a child less than 1 year old) could be detected behind a vehicle. During the evaluation, drivers were seated in the vehicle and asked to detect an object while it was moved outward from the rear of the vehicle along its centerline. The distance from the rear bumper at which the driver could detect the object was measured, and then these sight distances were published as consumer information.

For NHTSA’s purposes, a more comprehensive approach that best addresses backover crash risk would be to take multiple measurements across the rear of the vehicle. Examining sight distance across the entire width of the rear of the vehicle would provide data that show how rear visibility across the vehicle is affected by vehicle structural components. While the rear visibility information provided in the Consumer Reports publication is likely to be interesting to consumers, NHTSA believes that for the purposes of establishing regulatory requirements to improve rear visibility, a more comprehensive approach that is objective and repeatable is needed.

[1] We note that manufacturers may use methods, such as computer simulation, for their self-certification to our standards. However, when NHTSA conducts compliance tests, we test vehicles and equipment based on a specified test procedure that involves the actual vehicle.

2.3 Paine, Macbeth, and Henderson (2003)

Paine, Macbeth, and Henderson [4] in 2003 described a rear visibility measurement method that used a laser device mounted in the vicinity of where a driver's head would be located and to approximate a driver's sight line. The method also used an H-Point machine (SAE J826)[5], which provided a physical structure representing that of a 50th percentile adult male and a standardized grid of 200mm squares covering an area 1.8m wide by 15m long behind the vehicle to perform the measurements. The laser device was mounted on a camera tripod attachment head and bolted to the side of the H-Point machine's head form at approximately eye level. The test target was 24-inch-tall (600 mm) test cylinder having a 7.87 inch (200mm) diameter.

The Insurance Australia Group (IAG) developed "Visibility Assessment Criteria" [6, 7] for use in rating vehicles' rear visibility. The rating system considers actual directly visible area, possible visible area based on a minimum sight distance to a visual target, and gives credit to vehicles equipped with a rearview video system or rear parking sensor system.

- This study was sponsored by the Insurance Australian Group study and its test procedure was described as "both easily repeatable and standardized to enable accurate comparisons to be made between a range of vehicles."
- The authors stated that the resulting "visibility index" highlighted that vehicle design plays a major role in the rear visibility of vehicles.
- Design factors that influence rear visibility were noted to include:
  - High rear windows
  - High bootlid
  - Rear-mounted spare tires
  - Rear head restraints
  - Rear mounted brake lights
  - Rear mounted wipers
  - Rear spoilers.
- Vehicle configuration requirements for the Australian testing were as follows:
  - Position the grid behind the vehicle.
  - Position the front driver's seat in its lowest and furthest back position.
  - Place the H-Point device in the driver's seat and adjust the angle of the seat until the back of the H-Point device is at 25 degrees.
  - Ensure that all front and rear head restraints are in the fully down position.
  - Turn on the laser and direct the beam through the rear window of the vehicle.
  - Place the cylinder on the grid and determine whether the laser is visible. Record the result.
  - Repeat the prior step for all positions in the grid.
- Data were used to calculate ratings that considered a number of factors including:
  - The total visible area behind the vehicle
  - The visible distance across the rear of the vehicle
  - The presence of reversing aids such as proximity sensors and reversing cameras.

The IAG scheme considers the actual visible area within a 1.8-meter-wide (5.9 ft) by 15-meter-long (49.2 ft) area behind the vehicle to come up with a preliminary star rating. IAG star rating boundary values for this preliminary rating step are shown in Table 1. The “possible” visible area is then determined by using the minimum distance at which a 600-mm tall test object was visible and using the value to form a rectangular area over which an area is calculated. If the actual visible area is less than 85 percent of the possible visible area, then half of a star is subtracted from the preliminary rating. If the vehicle is equipped with a rearview video system or rear parking sensor system, half of a star is added to its rating.

Table 1. IAG Preliminary Star Rating Criteria for Measured Visible Area, A

Metric	Number of Stars	English
$A=0m^2$	0	$A=0ft^2$
$0<A<4.5m^2$	1	$0<A<48.44ft^2$
$4.5\leq A<9m^2$	1.5	$48.44\leq A<96.88ft^2$
$9\leq A<12.6m^2$	2	$96.88\leq A<135.63\ ft^2$
$12.6\leq A<16.2m^2$	2.5	$135.63\leq A<174.38ft^2$
$16.2\leq A<18.9m^2$	3	$174.38\leq A<203.44ft^2$
$18.9\leq A<21.6m^2$	3.5	$203.44\leq A<232.50ft^2$
$21.6\leq A<24.3m^2$	4	$232.50\leq A<261.56ft^2$
$24.3\leq A<27m^2$	4.5	$261.56\leq A<290.63ft^2$
$A=27m^2$	5	$A\geq 290.63ft^2$

While the rear visibility assessment method outlined by these researchers has some merit, some improvements could be made to increase the validity of the procedure. Possible improvements include using a more accurate eyepoint for location of the origin of the light beam to better simulate what a 50th percentile male would be able to see.

2.4 NHTSA 2007 Human-Based Rear Visibility Measurements

In 2007, NHTSA examined the rear visibility characteristics of 44 recent model light vehicles to determine what range of blind zone sizes exist in the current fleet [8]. These data also provided information that was later used to determine whether a link exists between blind zone size and backover crash incidence. Measured vehicles included the top 10 top-selling passenger cars and light trucks for calendar year 2006.

The visibility of a visual target was determined over a 6300 sq. ft. area stretching 35 ft to either side of the vehicle’s centerline and 90 ft back from the vehicle’s rear bumper. This large area was used to allow for the assessment of how visibility may change as distance from the vehicle increases and whether a smaller area may provide sufficient information.

The visual target used was a 29.4-inch-tall (approximately the height of a 1-year-old child) traffic cone with a red, circular reflector atop it. Rear visibility was measured for both a 50th percentile adult male driver (69.1 inches tall) and a 5th percentile adult female driver (59.8 inches tall). These driver sizes were chosen to acquire a range of visibility data in relation to driver height and because they have been used by other organizations in similar visibility tests. The areas over which the visual target was visually discernible using direct glances (i.e., looking out vehicle windows) and indirect glances (i.e., looking into side or center rearview mirrors) were determined.

While areas visible using mirrors or rearview video systems were measured and reported, these areas were not considered in the calculation of rear blind zone related metrics. Since all passenger vehicles have side mirrors and center rearview mirrors that are essentially the same, except for slight overall size differences, the key source of variability in rear visibility would be the structure of the vehicle's exterior body components. Therefore, the direct-view rear blind zone metric highlights the impact of a vehicle's structural characteristics on rear visibility.

To permit the comparison of rear visibility characteristics across different vehicles, several metrics for describing rear visibility were calculated. The two primary metrics used were direct-view rear blind zone area and average rear sight distance.

- Rear direct-view blind zone area is the area in total area in sq. ft. within a defined field behind the vehicle in which the visual target could not be seen by the driver by looking directly out the vehicle's windows.
- The second metric was average longitudinal rear sight distance. The distance at which the visual target could be seen by the driver was evaluated along eight lines extending longitudinally back from the rear of the vehicle and spanning the width of the vehicle. The average of these eight distance values was calculated.

- Study Findings:
  - We note that these values may not represent the average for the vehicle type categories since they were based on a small portion of the overall fleet.
  - Average rear blind zone areas ranged from 100 to 1440 sq. ft.
  - Direct-view rear blind zone areas for the vehicles measured were found to be smallest for a light passenger car (194 sq. ft.) and small pickup trucks (255 sq. ft.). (illustrated in figure 1 below)
  - Direct-view rear blind zone areas were largest for mid-size and larger SUVs (approximately 770-1057 sq. ft.), a full-size van (869 sq. ft.), and large pickup trucks (744 sq. ft.). (illustrated in figure 1 below)
  - Average direct-view longitudinal rear sight distances were found to be shortest for a light passenger car and small pickup trucks. (illustrated in figure 2 below)
  - Average direct-view longitudinal rear sight distances were longest for a full-size van (45 ft), and larger SUVs (35-43 ft), and large pickup trucks (34 ft) (illustrated in Figure 2 below)

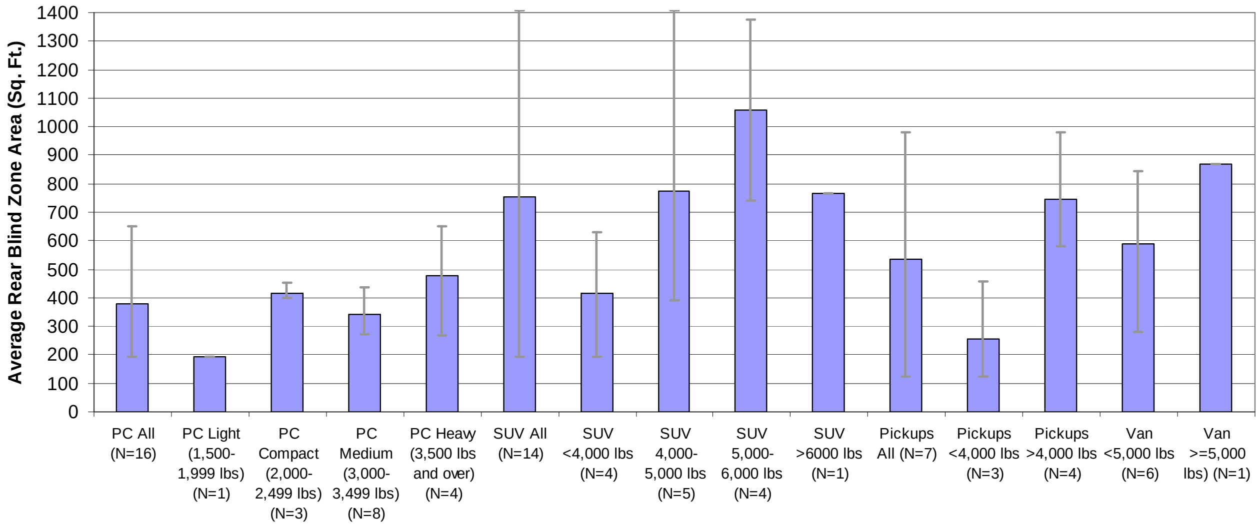

Figure 1. Vehicle Direct-View Rear Blind Zone Area by Vehicle Category and Curb Weight for a Measurement Field of 50-Foot Long by 60-Foot Wide. [8]

Note: Error bars show the range of values for each vehicle category.

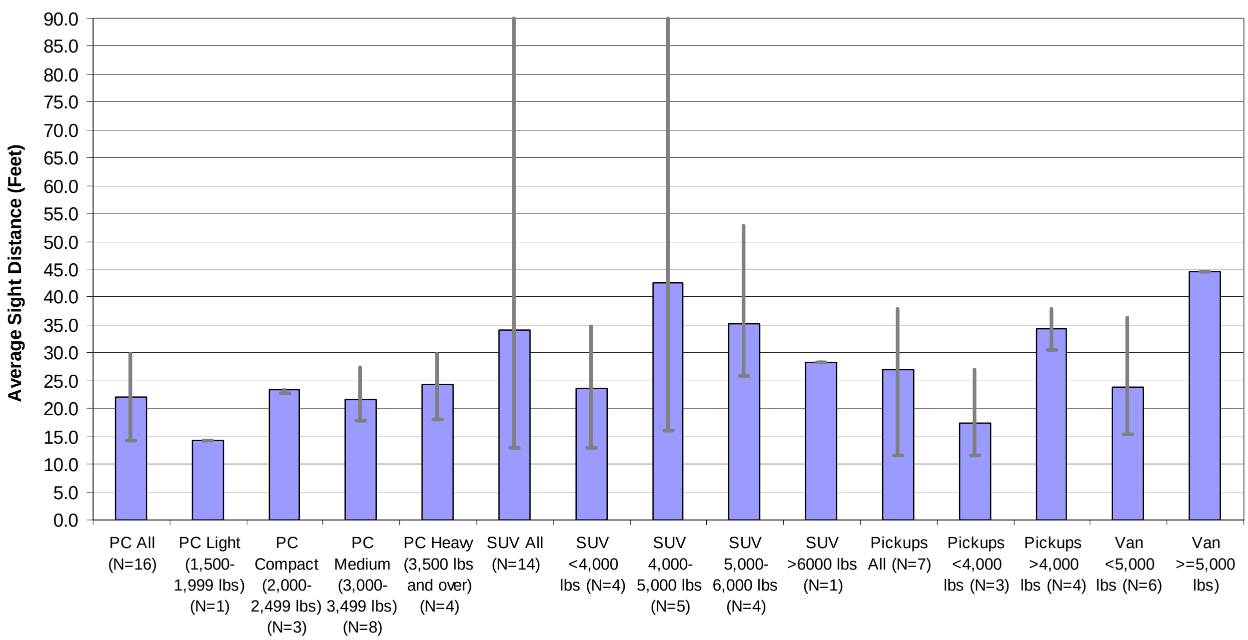

Figure 2. Vehicle Direct-View Average Rear Sight Distance by Vehicle Category and Curb Weight. [8]

Note: "PC" indicates "passenger car." Error bars show the range of values for each vehicle category.

NHTSA observed that physical characteristics among drivers can affect rear visibility. These characteristics include the occupant's torso breadth, physical flexibility (e.g., torso and neck rotational range), peripheral visual ability, and the presence of eye glasses. Additional differences relating to driver positioning while backing (e.g., raising the body up from the seat pan to achieve a higher vantage point), driver preferences regarding seat adjustment, and mirror positioning may also affect rear visibility. Based on a review of test data, it appears that the particular 5th percentile female driver involved in this testing may have been less restricted in her body movement (i.e., leaned or “craned” body more) when attempting to view the visual target. For example, for some vehicles the measured minimum sight distance and average sight distance values were better for the shorter driver than for the taller driver.

Based on the results of this effort, improvements to testing procedures (e.g., a surrogate, mechanical “driver”) may be warranted to improve the objectivity and repeatability of the data.

3.0 METHOD

This study sought to define a procedure for measuring vehicle rear and side visibility in an objective and repeatable manner.

3.1 Rear Visibility Measurement Method Development

A NHTSA compliance test is required to be repeatable and reproducible. Therefore, a visibility measurement method was desired that would yield results that would provide a valid approximation of those attainable with a 50th percentile adult male driver. As a result, NHTSA considered the known rear visibility measurement procedures and developed an alternative procedure based on them that provides a basis for an objective (based on eye position) approximation of what a 50th percentile driver should be able to see.

In 2003, Paine, Macbeth & Henderson described a method to approximate a driver's sight line using an H-point machine and laser pointing device. This method was designed to be easily repeatable and standardized to enable accurate comparisons between vehicles. NHTSA believes the rear visibility assessment method outlined by these researchers has merit and further refinement may be desirable for our purposes. For instance, a more accurate eye point for location of the laser beam would better simulate what a 50th percentile male would be able to see. NHTSA sought to improve upon several aspects of the measurement method including:

- Wider measurement field (better correlated with backing crash risk [9])
- More representative eyepoint (more valid representation of 50th percentile adult male eye location)
- More controlled and justifiable vehicle setup (for test consistency and repeatability)
- More efficient test object (conduct test more quickly and therefore cheaply)
- Efficient test conduct with dynamic laser (conduct test more quickly and therefore cheaply)

These points are described in detail below.

3.1.1 Size of Measurement Field

The test surface was a level, smooth surface large enough to position a vehicle on a coordinate system with a 50-foot wide by 50-foot long area behind the vehicle.

Using vehicle rear visibility data measured using human drivers from NHTSA's Light Vehicle Rear Visibility Assessment [8], an analysis of the correlation between rear visibility and backing crashes was performed [9]. The analysis showed that rear blind zone area measured over a field 50 ft long behind the vehicle and 60 ft wide (30 ft to either side of the vehicle's centerline), or 50 ft long behind the vehicle and 20 ft wide behind the vehicle (10 ft to either side of the vehicle's centerline), were both highly correlated with backing crash rate [9]. The facility in which measurements were conducted provided a 50-foot square area behind the vehicle over which measurements could be made without the vehicle having to be repositioned on the grid. This 50 ft long by 50 ft wide test area seemed appropriate to provide a symmetrical compromise between the two evaluated areas, while maintaining the 50-foot longitudinal dimension that was proven to be well correlated with backing crash risk. Furthermore, in the event that smaller areas might later be deemed acceptable, a subset of this 50-foot wide by 50-foot long area could always be focused on for analysis purposes.

3.1.2 Coarseness of the Measurement Field's Test Grid

NHTSA has used a measurement field covered by a test grid consisting of 1-foot squares. To date, NHTSA has created the grid using either 3-inch width tape applied to a level indoor floor surface, or paint of similar line thickness applied to an outdoor level paved surface. This level of grid detail has provided meaningful rear visibility data, and has been used to produce rear blind zone area data that have been successfully correlated with backing crash risk.

3.1.3 Use of an H-Point Machine to Simulate the Physical Structure of a 50th Percentile Male

To facilitate a repeatable test procedure, an H-Point machine, used by the agency for many other standards and representing a 50th percentile adult male was used in place of a human driver. The 50th percentile adult male approximates the midpoint for driver height, and has been selected by other organizations conducting similar visibility measurement research. An H-Point machine was selected to provide a standardized representation of the seated posture of an adult male driver. The H-point machine's standard configuration was modified to incorporate a fixture mounted in place of the device's neck to hold the laser devices in specific positions to correspond to selected eyepoints for a 50th percentile adult male driver (as described below).

3.1.4 Determination of Driver Eye Midpoint Locations

To determine the most appropriate location from which a laser used to simulate a driver's line of sight should originate, the eye locations of actual drivers were measured using photometric measurement. Three male drivers of 50th percentile height were asked to glance at an object outside a vehicle while they were photographed from two directions. This process was repeated for three vehicles: a minivan, an SUV, and a sedan.

To facilitate making photometric measurements, four rigid rulers were placed around the driver's seat location of a test vehicle for use in determining the distances from the eyes to reference points on the driver's seat. One ruler was horizontally oriented above the driver's head, two were vertically oriented and located behind the driver to the either side, and a fourth was positioned horizontally against the rear of the seat back. Two digital cameras on tripods, one to the right of the vehicle beside the front passenger's window and a second behind the vehicle, were positioned at approximately the same height as the driver's eye locations.

The 50th percentile male was seated in a vehicle's driver's seat with the seat belt on and asked to look at an object positioned outside the vehicle. For rear-looking glance postures in which the driver looked behind the vehicle by looking over his right or left shoulder, the object at which he was to focus his gaze was located approximately 25 ft behind the vehicle. For side-looking glance postures, the driver was asked to look out the window to that side.

Photometric measurements were taken from the rear and right (passenger) side of the vehicle. For each of the two rear-looking and two side-looking glance posture, the locations of the driver's eyes were measured. Eyepoint locations for the three drivers were used to calculate an average eyepoint location for each of the four postures. Finally, a midpoint between the average left and right eyepoints was measured for each of the four postures. These "midpoint" locations were used as the positions for laser devices used to simulate driver line of sight. The resulting eyepoints were as follows:

Table 2. Left-Right Eye Midpoint Locations for Posture of Driver Glancing Over His/Her Shoulder or Directly to Left and Right Sides

Glancing rearward over the:	Longitudinal (Distance forward of the head restraint face) (in.) (x)	Lateral Offset from the Center of the Seat (in.) (y)	Vertical with Respect to H-Point (in.) (z)
Left shoulder	3.5	-5.5	26.5*
Right shoulder	5.3	7.0	26.5*
Left window (-90 degrees from forward)	7.6	-5.5	26.5*
Right window (90 degrees from forward)	7.6	5.0	26.5*

*Note: Assumes that the distance from the seat pan to the H-Point is 3.6 inches.

3.1.5 Fixture Development

Two fixtures that would position the laser devices in a repeatable manner and attach to an H-Point machine were developed. One fixture held laser devices positioned at the two rear-looking eyepoint locations and a second fixture held laser devices positioned at the two side-looking eyepoint locations. With two laser devices per fixture, repositioning of the laser devices was not necessary in order to collect data for both left and right portions of the field of view. In addition, both laser devices in a fixture could be used at the same time to expedite data collection.

For each fixture, the two laser devices were connected to the mounting plate at the approximate point of origin of the light beam. They were mounted such that, while the points from which the laser light beam originated were held approximately constant, the bottom of the spinning laser device could be moved fore and aft, to change the pitch of the emanating light beams. To increase the speed with which measurements could be conducted, motors were connected to an arm attached to the bottom of the spinning laser devices to automatically pitch the devices about a horizontal axis.

Figure 3 shows the fixture used to simulate a 50th percentile male driver's line of sight when looking rearward over his left or right shoulders. Figure 4 shows a side view of the fixture used to simulate a 50th percentile male driver's line of sight when looking directly out the side windows.

Figure 3. Rear-Looking laser Fixture Used to Simulate the Line of Sight of a 50th Percentile Male Driver.

Figure 4. Side view of Side-Looking laser Fixture Used to Simulate the Line of Sight of a 50th Percentile Male Driver.

3.1.6 Test Object Height

The visual test object used in prior, human-based rear visibility measurements [8] was a 28-inch-tall traffic cone with a 3-inch diameter red, circular reflector sitting atop it. This height was based on the Center for Disease Control's (CDC) growth chart values for the 50th percentile child standing heights for a 1-year-old boy and 1-year-old girl (see Table 3), which were averaged [10,11], producing a height value of 29.4 inches. This height represents the youngest walking victims. Backover fatalities disproportionately affect children under 5 years old.

Table 3. 50th Percentile Child Height (CDC, 2000)

Age	**1**	2	3	4	5	6	7	8	9	10
Height - Girl	**29.125**	33.5	37.2	39.5	42.5	45.25	47.75	50.25	52.2	54.5
Height - Boy	**29.6**	34	37.5	40.25	43	45.5	48	50.5	52.5	54.5

The visual target for the current test effort was a device designed to simulate the previously used 29.4-inch-tall visual target, while taking advantage of the laser-based test method to increase test efficiency by incorporating use of a laser detector device.

In the prior measurements with a human driver, the driver was instructed to indicate when they could see the entire 3-inch reflector. The purpose of requiring the driver to report the test object as visible only when they could see the entire 3-inch diameter reflector was to ensure that the driver could see enough of the object to be able to correctly identify what the object was. To simulate a driver being able to see that much of a rear obstacle, the new target consisting of a laser detector mounted on a post was mounted such that the bottom of the laser detector's detection field was positioned at a height of 26.4 inches. As in prior testing, this object height was used to simulate that of a standing 1-year-old child.

3.1.7 Use of a laser Detector (in Lieu of a Visual Target)

To improve the efficiency of our test procedure, NHTSA used a different test object than was used in prior rear visibility measurements. The new test object incorporated a low power laser light detector that automatically produced an audible signal when the light beam intersected with the laser detector. Since laser light beams can be difficult to detect with the human eye, even in low light conditions, use of a low power laser light beam detector was believed to improve both the accuracy and speed of test conduct. The efficiency of test conduct with laser detectors could also be improved since the detectors automatically produced an audible signal when the light beam intersected the detector field.

The target was constructed with a commercial universal laser detector mounted vertically on a post. The base of the post was a 12-inch square of wood used to stabilize the fixture and center it within a 1-foot grid square. The target’s detection field was horizontally centered with respect to the post and base. To simulate a driver being able to see 3 inches of the top of a rear obstacle, as in prior human-based measurements, the new laser detector target was constructed with the detector mounted on a post and positioned such that the laser detector's detection field was horizontally centered and positioned at a vertical height ranging from 26.4 to 28.3 inches (the detector field’s height was 1.9 inches). Figure 5 presents an illustration of this target and how it compares to the previously used 3-inch reflector.

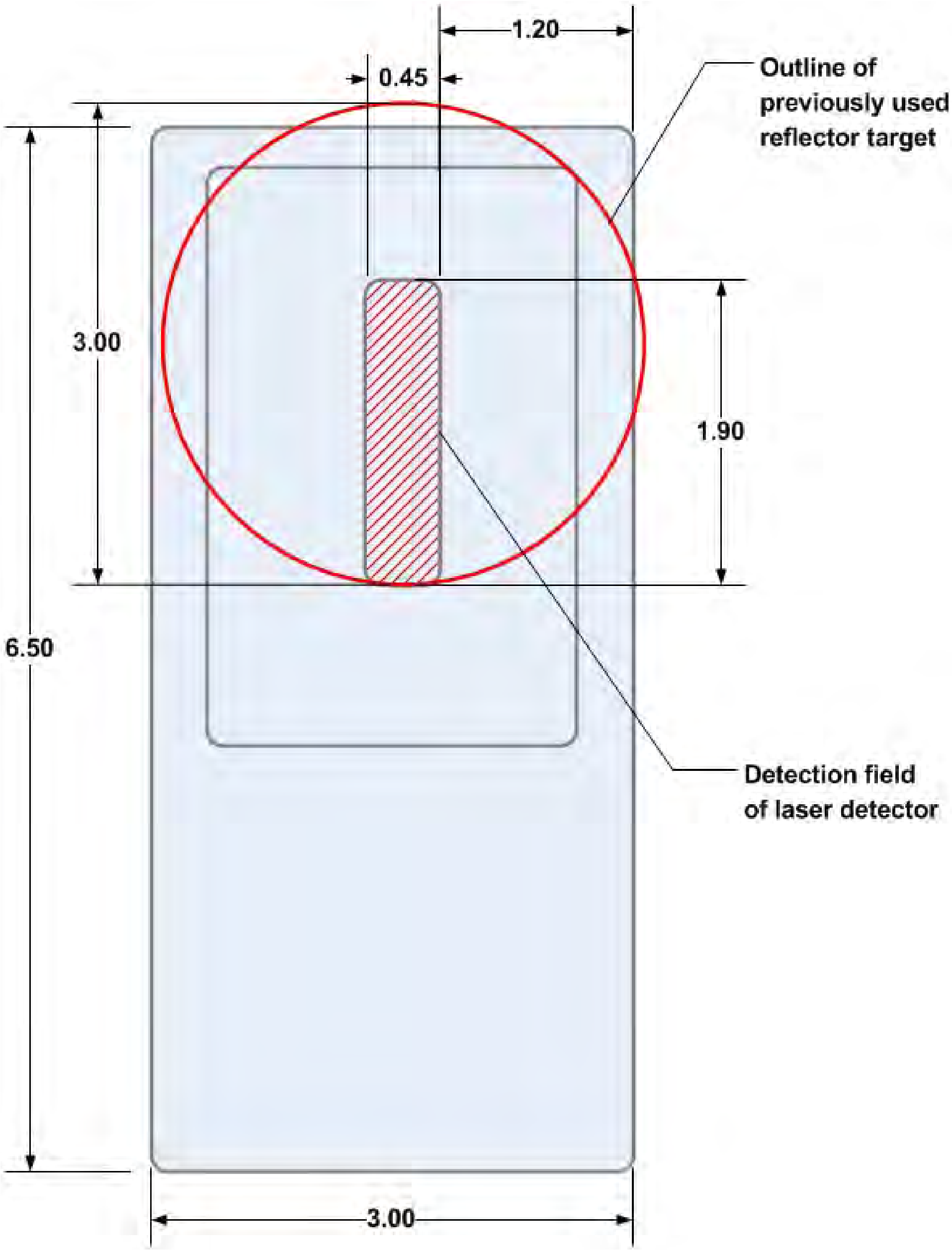

Figure 5. Illustration of Laser Detector Features with 3-Inch Reflector Overlaid for Comparison

An alternative approach, without a laser detector device, would be to rely on a test operator to visually confirm that the light beam contacted the test object within the detection area (e.g., 3-inch circular area at a height of 26.4 inches to 29.4 inches) while the test object was positioned within a particular location on the test grid. However, this approach may not produce the same level of repeatable results given the difficulty in detecting the light beam with the human eye and due to subjectivity in interpretation of a "successful" detection.

3.1.8 Vehicle Setup

To ensure a repeatable test procedure, several aspects of vehicle setup were specified. The following setup procedure addresses the relevant aspects that NHTSA believes are most important.

Fuel Tank – Ensure that the vehicle's fuel tank is filled to capacity, to provide a consistent fuel level (can affect vehicle pitch).

Vehicle Tires – The vehicle's tires should be confirmed to be of original equipment size and be set to their recommended inflation pressures (can affect vehicle pitch).

Vehicle Position on Test Grid – Position the vehicle on a flat, level test grid such that it is properly aligned (i.e., rear bumper flush with the '0' foot line, vehicle centered on the '0' longitudinal axis of the test grid).

- Ensure that the vehicle is accurately aligned on the grid. With one person in the vehicle and another standing off the edge of the grid in front of the vehicle, the test vehicle is slowly driven forward while the outside person directs the driver to a position with the vehicle centered on the grid. Next the spotter helps the driver line up the rear of the vehicle with the zero-foot line of the grid.
  - A plumb bob is hung from trunk or rear hatch latching mechanism at the centerline of the vehicle. Wheeled jacks are positioned around the tires and used to lift the vehicle off the ground to make fine adjustments to its position on the grid. The plumb bob is lined up with intersection of the center of the zero foot line and the Lateral center of the grid.
  - A plumb bob is hung at the center of the front bumper to confirm that the vehicle is perfectly aligned with the longitudinal axis of the grid.
  - The jacks are then removed. The plumb bobs are visually verified again to confirm that the vehicle position is still accurate and the vehicle is in its final testing position.

Vehicle Windows – The vehicle's windows should be closed, clean, and clear of obstructions (e.g., window stickers).

H-Point Device Configuration – Place the H-Point device in the driver's seat and adjust the seat as follows:

- Install the H-Point machine in the vehicle per the installation procedure outlined in SAE J826 [12].
- Adjust the driver's seat to the longitudinal adjustment position recommended by the manufacturer for a 50th percentile adult male as specified in Federal Motor Vehicle Safety Standard (FMVSS) Numbers 208 [13], 212 [14], 219 (partial)[15] and 301 [16] compliance testing. If this recommended adjustment setting is not available, position the seat at the midpoint of the longitudinal adjustment range. If no midpoint is selectable, then position the seat at the first notch rearward of the midpoint.
- Adjust the driver's seat to the vertical adjustment position recommended by the manufacturer for a 50th percentile adult male as specified in FMVSS Nos. 208, 212, 219 (partial), and 301 compliance testing. If this recommended adjustment

setting is not available, position the seat at the lowest point of all vertical adjustment ranges present.

- Use the H-Point machine to adjust the driver's seat back angle at the vertical portion of the H-Point machine's torso weight hanger to that recommended by the manufacturer for a 50th percentile adult male as specified in FMVSS 208, 212, 219 (partial), and 301 compliance testing. If this recommended adjustment setting is not available, adjust the seat-back angle to 25 degrees, as specified in SAE J826.
- Adjust the driver's seat head restraint such that the distance from the H-Point to the topmost point of the head restraint, as measured along a line parallel to the seat back, is 32.5 inches.[2] If a distance of 32.5 inches is not attainable given the adjustment range of the head restraint or detent positions, the closest detent position to that height should be used.
- Driver's seats with longitudinally adjustable head restraints should be positioned fully forward.

Vehicle Seat Positioning – Adjust all seats in positions other than the driver's as follows:

- Vehicles with standard stowable second or third row seats should have all seats in an upright, occupant-ready position. This configuration provides a consistent approach for rear seat positioning to avoid vehicle-to-vehicle test differences. If a vehicle is offered with an optional original equipment third row seat, the vehicle should be measured in this seating configuration to assess the vehicle's rear visibility characteristics in this worst-case condition.
- For seats with longitudinally adjustable head restraints, the restraint should be positioned at the midpoint of longitudinal adjustment.
- For seats with vertically adjustable head restraints, the restraint should be positioned in the lowest possible position. This configuration provides a consistent approach for head restraint positioning to avoid vehicle-to-vehicle test differences.
- For seats with an adjustable seat back angle, adjust the seat back angle to that recommended by the manufacturer for a driver's seat back angle position for a 50th percentile adult male as specified in FMVSS 208, 212, 219 (partial), and 301 compliance testing. If this recommended driver's seat back angle setting is not available, adjust the seat back angle to 25 degrees.
- Any rear seating position shoulder belts originating from the headliner (e.g., for use in rear center seating positions) should be latched into their receivers at the seat bight (i.e., the interface between the seat pan and the seat back).

3.1.9 Measurement Procedure

Once the vehicle had been properly set and the laser fixture has been set up, the measurements were conducted. To complete the rear visibility measurements, the laser devices may be manually or automatically maneuvered to pan the area behind the vehicle in both the vertical and horizontal directions. The vertical extent of the light

[2] This 32.5 inch measurement is based on sitting height of 36.3 inches for 50th percentile adult males aged 20 and over. See CDC website at: http://www.cdc.gov/nchs/about/major/nhanes/anthropometric_measures.htm.

beam movement shall extend from the lower edge of the rear window to the horizon. The horizontal range of laser motion shall permit the evaluation of the direct visibility of the test object as positioned within 1 foot of the rear bumper and 25 ft to both sides of the vehicle's centerline.

The test object was placed on the grid one time in each 1-foot square behind the vehicle. The test observer listened to determine whether the laser detector beeped to indicate that the detector field had been contacted by a light beam. The test object was considered visible if the laser detector beeped when the light beam intersected. An operator recorded this result and repeated this step for all positions in the grid.

3.2 Vehicles Measured

Vehicles were selected for measurement mainly based on 2007 sales volumes in the U.S. and to ensure an adequate range of vehicle body types and sizes. An attempt was also made to obtain a range of vehicle body types and sizes. Tables 4-5 lists the specific passenger car make/models that were measured. Tables 6-9 list the multi-purpose vehicles (MPV) that were measured.

Table 4. Vehicles Measured: Passenger Cars, Part 1

NHTSA NCAP Category	MY	Make	Model	Trim	Design Generation	Corporate Twins	Curb Weight (lbs)	Vehicle Dimensions		
								Length (in.)	Width (in.)	Height (in.)
PC Light (2,000-2,499 lbs)	2008	Hyundai	Accent	GLS 4-door, 1.6L DOHC, Automatic	2006+		2,403	168.5	66.7	57.9
PC Compact (2,500-2,999 lbs)	2008	Honda	Fit		2006-2008		2,514	157.4	66.2	60.0
PC Compact (2,500-2,999 lbs)	2008	Chevrolet	Aveo	LS 4-door, 1.6L DOHC, Automatic	2004+	Pontiac Wave	2,531	169.7	67.3	58.9
PC Compact (2,500-2,999 lbs)	2008	Ford	Focus	SE 4-door, 2.0L DOHC, Automatic	2000+		2,623	175.0	67.8	58.6
PC Compact (2,500-2,999 lbs)	2005	Saturn	Ion	"3", 4-door	2003-2007		2,692	185.0	67.0	57.0
PC Compact (2,500-2,999 lbs)	2008	Kia	Spectra	LX, 2.0L V4, 5-speed Manual	2004+		2,701	177.2	68.3	57.9
PC Compact (2,500-2,999 lbs)	2008	Nissan	Versa		2007+		2,722	169.1	66.7	60.4
PC Compact (2,500-2,999 lbs)	2008	Hyundai	Elantra	GLS, 2.0L DOHC, Automatic	2007+		2,747	206.8	77.8	70.3
PC Compact (2,500-2,999 lbs)	2003	Nissan	Sentra	4-door, Limited, 2.5L V4, Automatic	2007+		2,747	177.5	67.3	55.5
PC Compact (2,500-2,999 lbs)	2005	Volkswagen	Jetta	4-door, diesel			2,895	172.0	68.0	57.0
PC Compact (2,500-2,999 lbs)	2008	Toyota	Prius	Package #3	2004-2008		2,932	175.0	67.9	58.7
PC Compact (2,500-2,999 lbs)	2008	Mazda	Mazda3	Grand Touring 4-door, 2.3L DOHC I4, Automatic	2004+		2,959	177.6	69.1	57.7
PC Compact (2,500-2,999 lbs)	2009	Toyota	Matrix		2009+	Pontiac Vibe	2,965	171.9	69.5	61.0
PC Compact (2,500-2,999 lbs)	2008	Volkswagen	New Beetle	SE, 2.5L I5, Automatic	1998+		2,965	161.1	67.9	59.0
PC Compact (2,500-2,999 lbs)	2008	Dodge	Caliber	SE Plus, 2.0L V4 DOHC, Automatic	2007+		2,966	173.8	68.8	60.4

Table 5. Vehicles Measured: Passenger Cars, Part 2

NHTSA NCAP Category	MY	Make	Model	Trim	Design Generation	Corporate Twins	Curb Weight (lbs)	Vehicle Dimensions		
								Length (in.)	Width (in.)	Height (in.)
PC Medium (3,000-3,499 lbs)	2006	Chrysler	PT Cruiser	4-door, Touring Wagon, 2.4L V4	2001+		3,075	168.9	67.1	63.0
PC Medium (3,000-3,499 lbs)	2008	Volkswagen	GTI	2.0L I4, 6-speed Manual	2006+		3,100	165.8	69.3	58.4
PC Medium (3,000-3,499 lbs)	2009	Chevrolet	HHR	LT, 2.2L Ecotec, Automatic	2006+		3,155	176.2	69.1	63.1
PC Medium (3,000-3,499 lbs)	2008	Mazda	Mazda6	i, 4-door, 2.3L V4, Automatic	2003+		3,168	186.8	70.1	56.7
PC Medium (3,000-3,499 lbs)	2008	Ford	Fusion	I4 S, 2.3L I4, 5-speed Manual	2006+	Lincoln, MKZ, Lincoln Zephyr, Mercury Milan	3,181	190.2	72.2	57.2
PC Medium (3,000-3,499 lbs)	2009	Subaru	Legacy	2.5i / 9AD, 2.5L SOHC, Automatic	2005+		3,245	185.0	68.1	56.1
PC Medium (3,000-3,499 lbs)	2009	Hyundai	Sonata	GLS	2006+	Kia Optima	3,266	188.9	72.1	58.0
PC Medium (3,000-3,499 lbs)	2008	Volkswagen	Jetta	2.5 SE, 2.5L I5, Automatic	2005+		3,285	179.3	70.1	57.4
PC Medium (3,000-3,499 lbs)	2008	Honda	Accord	4-door LX-P, 2.4L V4, Automatic	2008+		3,298	194.1	72.7	58.1
PC Medium (3,000-3,499 lbs)	2008	Pontiac	G6	1SV sedan, 2.4L V4, Automatic	2005+		3,305	189.0	70.6	57.1
PC Medium (3,000-3,499 lbs)	2006	Volkswagen	Passat		2006+		3305	188.2	71.7	61.0
PC Medium (3,000-3,499 lbs)	2006	BMW	330i		2006+		3,417	178.2	71.5	58.0
PC Medium (3,000-3,499 lbs)	2007	Chevrolet	Monte Carlo	LS Coupe	2000-2007		3,461	196.7	72.9	55.8

Table 6. Vehicles Measured: Passenger Cars, Part 3

NHTSA NCAP Category	MY	Make	Model	Trim	Design Generation	Corporate Twins	Curb Weight (lbs)	Vehicle Dimensions		
								Length (in.)	Width (in.)	Height (in.)
PC Heavy (>=3,500 lbs)	2008	BMW	528i	3.0L V6, Automatic	2004+		3,505	191.1	72.7	57.8
PC Heavy (>=3,500 lbs)	2008	Toyota	Avalon	XLS, 3.5L DOHC, Automatic	2005+		3,570	197.6	72.8	58.5
PC Heavy (>=3,500 lbs)	2007	Lexus	ES350		2007+		3,580	191.1	71.7	57.1
PC Heavy (>=3,500 lbs)	2008	Hyundai	Azera	Limited, 3.8L DOHC V6, Automatic	2006+		3,629	192.7	72.8	58.7
PC Heavy (>=3,500 lbs)	2007	Ford	Five Hundred		2005-2007; 2008 Taurus	2005-2007 Mercury Montego; 2008+ Mercury Sable	3644	200.7	74.5	61.5
PC Heavy (>=3,500 lbs)	2008	Buick	Lucerne	CX, 3.8L V6, Automatic	2006+		3,764	203.2	73.8	58.0
PC Heavy (>=3,500 lbs)	2008	Dodge	Charger	SE Plus, 3.5L V6, Automatic	2006+	Chrysler 300	3,800	200.1	74.5	58.2
PC Heavy (>=3,500 lbs)	2008	Volvo	S80	3.2 A SR, 3.2L V6, Automatic	2007+		3,825	191.0	73.3	58.8
PC Heavy (>=3,500 lbs)	2005	Cadillac	STS		2005+		3858	196.3	72.6	57.6
PC Heavy (>=3,500 lbs)	2005	Chrysler	300	C	2005+	Dodge Charger	4,048	196.8	74.1	58.4
PC Heavy (>=3,500 lbs)	2009	Acura	RL		2005+		4,083	195.8	72.7	57.2

Table 7. Vehicles Measured: MPVs, Part 1

NHTSA NCAP Category	MY	Make	Model	Trim	Design Generation	Corporate Twins	Curb Weight (lbs)	Vehicle Dimensions Length (in.)	Vehicle Dimensions Width (in.)	Vehicle Dimensions Height (in.)
SUV <4,000 lbs	2009	Scion	XB	5-door, 2.4L DOHC, V4, Automatic	2008+		3,086	180.1	72.8	67.0
SUV <4,000 lbs	2005	Honda	CR-V		2002-2006		3,263	181.0	103.0	66.0
SUV <4,000 lbs	2008	Toyota	RAV4	4x4, 2.4L V4, Automatic	2006+		3,444	181.1	71.5	66.3
SUV <4,000 lbs	2008	Kia	Sportage	4x2, 2.0L I4, Automatic	2005+		3,527	171.3	70.9	66.7
SUV <4,000 lbs	2008	Ford	Edge	Limited AWD, 5-passenger, 3.5L V6, Automatic	2007+	Lincoln MKX	3,546	185.7	75.8	67.0
SUV <4,000 lbs	2007	Suzuki	Grand Vitara	4x4, 2.7L V6, Automatic	2006+		3,682	176.0	71.3	66.3
SUV <4,000 lbs	2008	Hyundai	Santa Fe	GLS, 2.7L DOHC, Automatic	2007+		3,793	184.1	74.4	67.9
SUV <4,000 lbs	2008	Saturn	Vue	XE FWD, 2.4L DOHC Ecotec, Automatic	2008+		3,825	180.1	72.8	67.0
SUV <4,000 lbs	2008	Infiniti	EX35	AWD Journey, 3.5L V6, Automatic	2008+		3,953	182.3	71.0	61.9
SUV <4,000 lbs	2008	Ford	Taurus X		2008+	Ford Freestyle	3,959	200.3	74.9	67.4
SUV 4,000-5,000 lbs	2008	Subaru	Tribeca	8TA, 3.6L DOHC, Automatic	2006+		4,129	191.5	73.9	66.4
SUV 4,000-5,000 lbs	2007	Dodge	Magnum	SXT 4-door Wagon, 3.5L V6, Automatic	2005+		4,164	197.7	74.1	59.3
SUV 4,000-5,000 lbs	2008	Jeep	Wrangler	Unlimited Sahara 4x4, 3.8L V6, Manual	2007+		4,297	184.4	73.9	
SUV 4,000-5,000 lbs	2008	Toyota	4Runner	SR5 4x4, 4.0L V6, Automatic	2003+		4,300	189.2	75.2	69.3

Table 8. Vehicles Measured: MPVs, Part 2

NHTSA NCAP Category	MY	Make	Model	Trim	Design Generation	Corporate Twins	Curb Weight (lbs)	Vehicle Dimensions Length (in.)	Width (in.)	Height (in.)
SUV 4,000-5,000 lbs	2005	Ford	Explorer		2002-2005	Mercury Mountaineer	4350	206.0	72.1	70.0
SUV 4,000-5,000 lbs	2006	Honda	Pilot	4WD EX LR, 3.5L V6, Automatic	2003+		4,425	188.0	77.5	71.3
SUV 4,000-5,000 lbs	2008	Mazda	CX-9	Grand Touring, AWD, 3.7L V6, Automatic	2007+		4,528	199.6	76.2	68.0
SUV 4,000-5,000 lbs	2008	Honda	CR-V	LX 4WD, Automatic	2007+		4,560	177.9	71.6	66.1
SUV 4,000-5,000 lbs	2007	Jeep	Commander				4,649	188.5	74.8	75.6
SUV 4,000-5,000 lbs	2008	Saturn	Outlook	FWD XR, 3.6L VVT V6, Automatic	2007+	Buick Enclave, GMC Acadia	4,722	200.7	78.2	69.9
SUV 5,000-6,000 lbs	2008	Chevrolet	Equinox	FWD LS, 3.4L V6, Ato	2005+	Pontiac Torrent	5,070	188.8	71.4	69.3
SUV 5,000-6,000 lbs	2007	Cadillac	Escalade		2007+	Chevrolet 1500 Tahoe, GMC 1500 Yukon	5,459	202.5	79.0	74.3
SUV 5,000-6,000 lbs	2008	Chevrolet	Trailblazer	2LT 4WD, Vortec 4.2L SFI I6, Automatic	2002+	Buick Ranier, GMC Envoy, Isuzu Ascender, Olds Bravada, Saab 9-7X	5,750	191.8	74.7	72.5
SUV 5,000-6,000 lbs	2008	Chevrolet	Avalanche	LT 4WD, 5.3L V8, Automatic	2007+	Cadillac Escalade EXT	5,803	221.3	79.1	76.6
SUV >=6000 lbs	2008	Jeep	Grand Cherokee	4x4 Limited, 5.7L Hemi, Automatic, 18x17.5 wheels, 245/60R18 OWL All Terrain Tires	2005+		6,100	188.0	72.6	68.9

Table 9. Vehicles Measured: MPVs, Part 3

NHTSA NCAP Category	MY	Make	Model	Trim	Design Generation	Corporate Twins	Curb Weight (lbs)	Vehicle Dimensions Length (in.)	Width (in.)	Height (in.)
SUV >=6000 lbs	2008	Chevrolet	Suburban	4WD 1/2 Ton LT, 5.3L V8 SFI Flex0Fuel, Automatic	2007+	Cadillac Escalade ESV, GMC 1500 Yukon XL	7,200	222.4	79.1	76.8
SUV >=6000 lbs	2008	Ford	Expedition	King Ranch EL 4x4, 7-passenger, 5.4L V8, Automatic, Captains Chairs KR	2007+		7,828	221.3	78.8	77.7
Van <5,000 lbs	2008	Dodge	Caravan	SE, 3.3L V6 OHV, Automatic	2008+	Chrysler Town & Country	4,321	202.5	76.9	68.9
Van <5,000 lbs	2005	Chevrolet	Uplander		2005-2007	Buick Terraza, Pontiac Montana SV6, Saturn Relay	4,470	204.3	72	72
Van <5,000 lbs	2007	Honda	Odyssey	Touring	2005+		4,678	201	77.1	70
Van >=5,000 lbs)	2008	Ford	Econoline	E250 Cargo van, 138" WB, 5.4L V8, Automatic	1997+		5,340	237	79.3	84.6
Pickups All	2008	Dodge	Dakota	Crew Cab SXT 4x2, 3.7L V6, Automatic	2005+		6,010	218.5	76.4	68
Pickups All	2008	Honda	Ridgeline	4WD, RTLNAV, 3.5L V6, Automatic	2006+		6,050	206.8	77.8	71.2
Pickups All	2008	GMC	Sierra	1500 2WD Reg Cab W/T, 4.8L V8, Automatic	2007+	Chevrolet 1500 Silverado	6,400	205.6	80	73.6
Pickups All	2008	Ford	F-150	4x4 Supercrew XLT 150" WB Styleside, 5.4L V8, Automatic	2004+	Lincoln Mark LT	6,950	235.8	78.9	73.5
Pickups All	2007	Chevrolet	Silverado		2007+	GMC 1500 Sierra	4,743	222.4	79.1	76.8

4.0 RESULTS

This section summarizes rear field of view measurement data for 75 late-model vehicles. Basic measures are presented including longitudinal rear sight distance and rear blind zone area.

4.1 Rear Field of View

For the sake of brevity within the body of the report, FOV data were summarized into tables and graphs presenting relevant characteristics of the data in the following sections. The actual measured FOV for the vehicles examined are presented graphically in Appendix A.

4.2 Longitudinal rear Sight Distances

Since the vehicle's structural features, such as pillars and head restraints, may affect rear visibility, longitudinal rear sight distance was examined along the entire rear of the vehicle. While most vehicle widths average approximately 6 ft, an 8-foot minimum measurement span width was used to encompass the width of any passenger vehicle measured. Therefore, eight distance values were measured perpendicularly out from the vehicle's rear bumper to the closest point at which the target was detected, as shown in Figure 6. These values, illustrated in Figure 6 by circles representing the visual target, were averaged for an individual vehicle to determine average longitudinal rear sight distance.

Figure 6 also illustrates the definitions of sight distance terms used here. "Shortest minimum sight distance" was the longitudinal distance from the bumper, out of the eight measured across the width of the vehicle that was closest to the vehicle. "Longest minimum sight distance" was the longitudinal distance from the bumper, out of the eight measured across the width of the vehicle that was farthest from the vehicle.

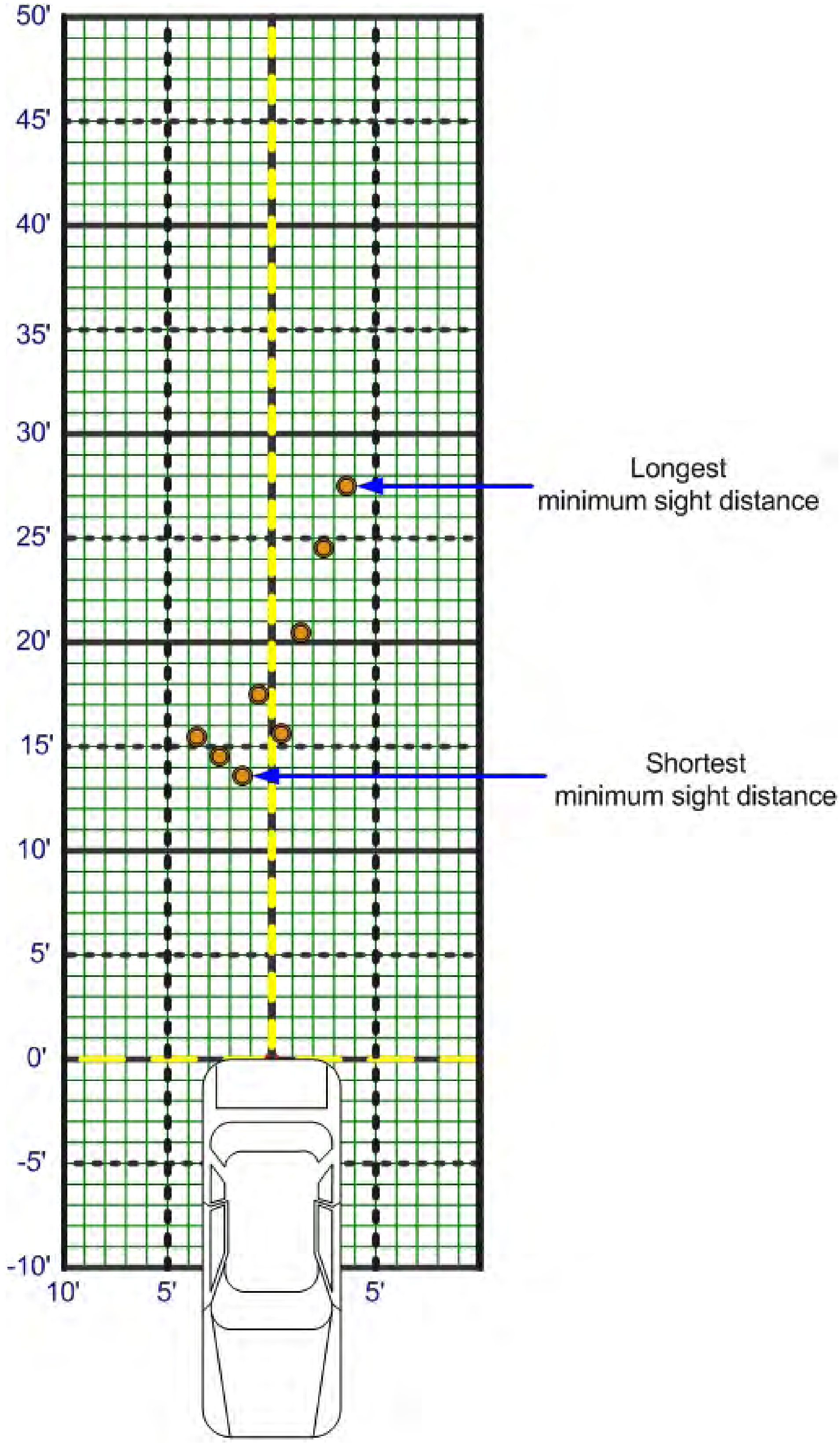

Figure 6. Illustration of Eight Rear Sight Distance Data Points Measured and Definition of Sight Distance Terms

The overall mean value of average longitudinal rear sight distance for the 75 vehicles was 34.7 ft (SD=9.38). Average longitudinal rear sight distance results are presented in Tables 10 and 11. The mean values of average longitudinal rear sight distance for each body type are presented in Table 12. The shortest average sight distance for an individual vehicle was 12.1 ft (2008 Toyota Prius). The actual longest average sight distance exceeded the longitudinal measurement range of 50 ft, and thus was not measurable due to the 50-foot longitudinal range of the test grid. For vehicles in which one or more of the eight sight distance values did not fall within the 50-foot measurement range behind the vehicle’s rear bumper, a value of 50 ft was substituted for that value. For this reason, longest minimum sight distance values listed in Tables 10 and 11 do not exceed 50 ft. Also because of the maximum 50-foot longitudinal measurement range, average rear sight distance values reported do not exceed 50 ft.

While 22 of 39 measured passenger cars had at least one of the eight rear sight distance data points that was beyond 50 ft (indicated by shaded table cells), no passenger car had all eight values that exceeded 50 ft. The passenger car with the longest average rear sight distance was a 2005 Saturn Ion (47.9 ft).

Twenty-one of the 36 measured multi-purpose vehicles had at least one of the eight rear sight distance data points that was beyond 50 ft (indicated by shaded table cells in the “longest minimum sight distance” column of Table 11). Four of the measured MPVs had all eight measured rear sight distance values exceed the range of 50 ft. For these four MPVs, showing an average sight distance value of 50 ft in Table 11, the actual average sight distance value was greater than the measurement limit of 50 ft.

Of measured values for shortest minimum rear sight distance, the 2008 Volkswagen New Beetle had the smallest value of any measured passenger car at 0.5 ft. The next smallest value for shortest minimum rear sight distance value was 10.5 ft, which was measured for the 2008 Honda Fit and 2008 Toyota Prius. The largest value of shortest minimum rear sight distance for any measured passenger car was 44.5 measured for the 2005 Saturn Ion. For MPVs, the 2008 Infiniti EX35 had the smallest value of minimum rear sight distance at 12.5 ft.

Table 10. Average Longitudinal Rear Sight Distance by Vehicle: Passenger Cars

Vehicle Category	MY	Make	Model	Average Sight Dist	Shortest Min. Sight Dist	Longest Min. Sight Dist
PC Light (2,000-2,499 lbs)	2008	Hyundai	Accent	25.3	16.5	37.5
PC Compact (2,500-2,999 lbs)	2008	Toyota	Prius	12.1	10.5	13.5
PC Compact (2,500-2,999 lbs)	2008	Volkswagen	New Beetle	13.8	0.5	48.5
PC Compact (2,500-2,999 lbs)	2003	Nissan	Sentra	17.4	12.5	26.5
PC Compact (2,500-2,999 lbs)	2008	Nissan	Versa	17.4	12.5	33.5
PC Compact (2,500-2,999 lbs)	2008	Honda	Fit	20.3	10.5	50.0
PC Compact (2,500-2,999 lbs)	2008	Dodge	Caliber	31.6	21.5	50.0
PC Compact (2,500-2,999 lbs)	2005	Volkswagen	Jetta	31.6	18.5	50.0
PC Compact (2,500-2,999 lbs)	2008	Chevrolet	Aveo	32.3	20.5	46.5
PC Compact (2,500-2,999 lbs)	2008	Kia	Spectra	32.3	19.5	50.0
PC Compact (2,500-2,999 lbs)	2008	Hyundai	Elantra	34.2	21.5	50.0
PC Compact (2,500-2,999 lbs)	2008	Mazda	3	36.1	27.5	50.0
PC Compact (2,500-2,999 lbs)	2008	Ford	Focus	36.6	32.5	40.5
PC Compact (2,500-2,999 lbs)	2009	Toyota	Matrix	40.1	28.5	50.0
PC Compact (2,500-2,999 lbs)	2005	Saturn	Ion	47.9	44.5	50.0
PC Medium (3,000-3,499 lbs)	2008	Volkswagen	GTI	19.8	15.5	24.5
PC Medium (3,000-3,499 lbs)	2008	Mazda	6	21.0	17.5	23.5
PC Medium (3,000-3,499 lbs)	2007	Chevrolet	Monte Carlo	22.4	16.5	27.5
PC Medium (3,000-3,499 lbs)	2006	Chrysler	PT Cruiser	24.0	15.5	31.5
PC Medium (3,000-3,499 lbs)	2008	Honda	Accord	33.5	18.5	46.5
PC Medium (3,000-3,499 lbs)	2009	Chevrolet	HHR	34.6	28.5	50.0
PC Medium (3,000-3,499 lbs)	2009	Hyundai	Sonata	35.6	24.5	50.0
PC Medium (3,000-3,499 lbs)	2006	BMW	330i	37.3	33.5	50.0
PC Medium (3,000-3,499 lbs)	2008	Volkswagen	Jetta	38.1	27.5	50.0
PC Medium (3,000-3,499 lbs)	2008	Pontiac	G6	39.5	34.5	50.0
PC Medium (3,000-3,499 lbs)	2006	Volkswagen	Passat	42.8	30.5	50.0
PC Medium (3,000-3,499 lbs)	2009	Subaru	Legacy	43.4	38.5	50.0
PC Medium (3,000-3,499 lbs)	2008	Ford	Fusion	45.7	40.5	50.0
PC Heavy (>=3,500 lbs)	2008	Volvo	S80	29.1	21.5	50.0
PC Heavy (>=3,500 lbs)	2008	Hyundai	Azera	29.6	22.5	35.5
PC Heavy (>=3,500 lbs)	2008	BMW	528i	29.8	22.5	43.5
PC Heavy (>=3,500 lbs)	2007	Ford	Five Hundred	29.9	20.5	42.5
PC Heavy (>=3,500 lbs)	2009	Acura	RL	34.4	30.5	38.5
PC Heavy (>=3,500 lbs)	2008	Dodge	Charger	35.9	27.5	47.5
PC Heavy (>=3,500 lbs)	2008	Toyota	Avalon	37.6	24.5	50.0
PC Heavy (>=3,500 lbs)	2005	Chrysler	300	38.3	25.5	50.0
PC Heavy (>=3,500 lbs)	2008	Buick	Lucerne	41.0	34.5	50.0
PC Heavy (>=3,500 lbs)	2005	Cadillac	STS	45.9	32.5	50.0
PC Heavy (>=3,500 lbs)	2007	Lexus	ES350	46.4	38.5	50.0

Table 11. Average Longitudinal Rear Sight Distance by Vehicle: Multi-Purpose Vehicles

Vehicle Category	MY	Make	Model	Average Sight Dist	Shortest Min. Sight Dist	Longest Min. Sight Dist
SUV <4,000 lbs	2005	Honda	CR-V	24.4	19.5	26.5
SUV <4,000 lbs	2008	Hyundai	Santa Fe	26.3	18.5	37.5
SUV <4,000 lbs	2008	Toyota	RAV4	28.0	26.5	29.5
SUV <4,000 lbs	2007	Suzuki	Grand Vitara	31.3	18.5	50.0
SUV <4,000 lbs	2008	Kia	Sportage	33.8	30.5	45.5
SUV <4,000 lbs	2008	Infiniti	EX35	34.5	12.5	50.0
SUV <4,000 lbs	2009	Scion	XB	37.7	29.5	50.0
SUV <4,000 lbs	2008	Ford	Edge	41.1	29.5	50.0
SUV <4,000 lbs	2008	Saturn	Vue	42.4	29.5	50.0
SUV <4,000 lbs	2008	Ford	Taurus X	43.9	28.5	50.0
SUV 4,000-5,000 lbs	2005	Ford	Explorer	19.0	14.5	23.5
SUV 4,000-5,000 lbs	2008	Toyota	4Runner	25.6	19.5	38.5
SUV 4,000-5,000 lbs	2008	Honda	CR-V	27.6	24.5	29.5
SUV 4,000-5,000 lbs	2007	Dodge	Magnum	27.8	25.5	37.5
SUV 4,000-5,000 lbs	2006	Honda	Pilot	36.6	22.5	50.0
SUV 4,000-5,000 lbs	2008	Jeep	Wrangler	38.1	21.5	50.0
SUV 4,000-5,000 lbs	2008	Mazda	CX-9	40.4	25.5	48.5
SUV 4,000-5,000 lbs	2008	Subaru	Tribeca	50.0	50.0	50.0
SUV 4,000-5,000 lbs	2007	Jeep	Commander	50.0	50.0	50.0
SUV 4,000-5,000 lbs	2008	Saturn	Outlook	50.0	50.0	50.0
SUV 5,000-6,000 lbs	2008	Chevrolet	Trailblazer	30.3	20.5	50.0
SUV 5,000-6,000 lbs	2007	Cadillac	Escalade	44.3	36.5	50.0
SUV 5,000-6,000 lbs	2008	Chevrolet	Equinox	48.5	43.5	50.0
SUV 5,000-6,000 lbs	2008	Chevrolet	Avalanche	48.8	47.5	50.0
SUV >=6000 lbs	2008	Jeep	Grand Cherokee	31.5	27.5	40.5
SUV >=6000 lbs	2008	Ford	Expedition	35.5	25.5	42.5
SUV >=6000 lbs	2008	Chevrolet	Suburban	46.9	32.5	50.0
Pickups	2008	Dodge	Dakota	25.6	22.5	37.5
Pickups	2008	Honda	Ridgeline	30.8	26.5	50.0
Pickups	2007	Chevrolet	Silverado	39.4	35.5	41.5
Pickups	2008	GMC	Sierra	43.6	42.5	45.5
Pickups	2008	Ford	F-150	49.6	48.5	50.0
Van <5,000 lbs	2008	Dodge	Caravan	25.5	22.5	32.5
Van <5,000 lbs	2005	Chevrolet	Uplander	41.9	35.5	50.0
Van <5,000 lbs	2007	Honda	Odyssey	42.1	28.5	50.0
Van >=5,000 lbs)	2008	Ford	Econoline (E-series)	50.0	50.0	50.0

Table 12. Average Longitudinal Rear Sight Distance by Vehicle Category

Model	Mean Average Sight Dist (ft)	Standard Deviation
PCs (N=39)	32.3	9.1
Van (<5,000 lbs) (N=3)	36.5	9.5
SUVs All (N=27)	36.8	9.1
Pickups All (N=5)	37.8	9.7
Van Heavy (>=5,000 lbs) (N=1)	50.0	N/A

Figure 7 summarizes average longitudinal rear sight distance values by vehicle type by taking an average over the individual vehicles' averages in each group. "Error bars" shown for each vehicle category in the chart indicate the range of average sight distance values within each vehicle category. For the vehicles measured, passenger cars had the greatest variability in rear sight distance of any body type (subject to the 50-foot cutoff). The range of measured average longitudinal rear sight distance values was greatest for the passenger car body type, at 35.8 ft. The range of average longitudinal rear sight distance values for the SUV body type was approximately as large, at 31 ft. For pickup trucks and vans, the values were 24 ft and 16.6 ft, respectively.

The trend in sight distance magnitude evident in Figure 7 indicates that SUVs, pickup trucks, and vans tend to have longer average rear sight distances than passenger cars. This trend was also evident in Figure 8 which presents a more detailed breakdown of vehicle groups by weight.

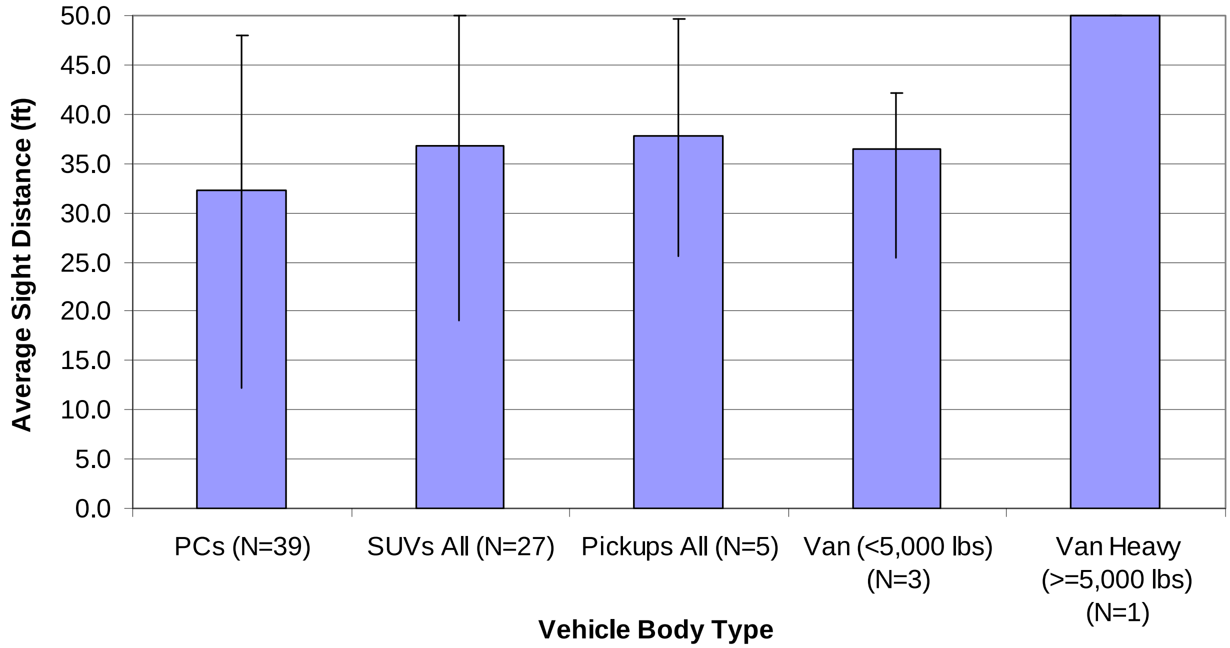

Figure 7. Average Longitudinal Rear Sight Distance Results by Vehicle Body Type

Note: Error bars show the range of values for each vehicle category.

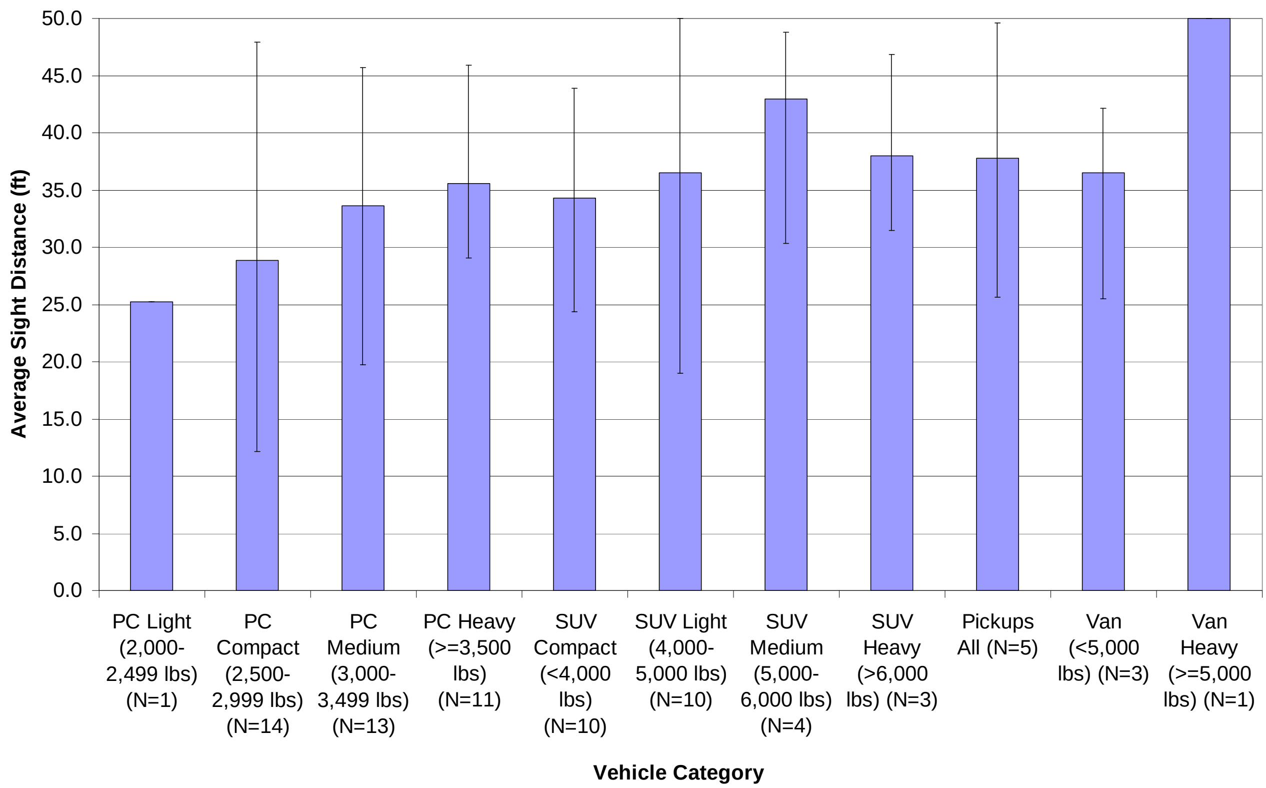

Figure 8. Average Longitudinal Rear Sight Distance Results by Vehicle Category

Note: Error bars show the range of values for each vehicle category.

Figure 9 presents the frequency distribution of average longitudinal rear sight distance values for the 75 vehicles measured. This figure shows that average longitudinal rear sight distance values fell largely within the range of 25 to 45 ft for all measured vehicles.

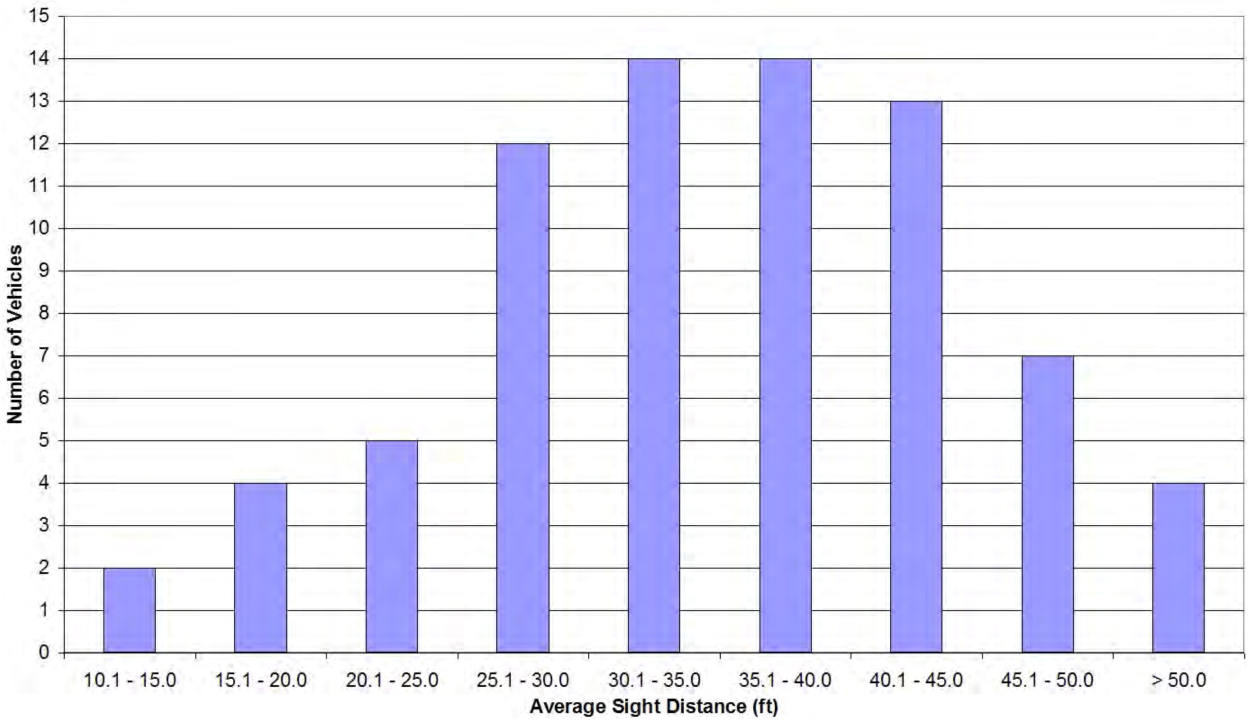

Figure 9. Frequency Distribution of Values for Longitudinal Rear Sight Distance – All Vehicles (N=75)

Figure 10 presents the frequency distribution of average longitudinal rear sight distance values for the 75 vehicles for passenger cars and multi-passenger vehicles separately. The average longitudinal rear sight distance was 32.3 ft (SD=9.1) for passenger cars measured (N=39) and 37.3 ft (SD=9.1) for MPVs measured (N=36). This figure shows that while the distribution for sight distance values of measured passenger cars was approximately normally distributed, the distribution of values for measured MPVs was somewhat skewed toward larger values of distance.

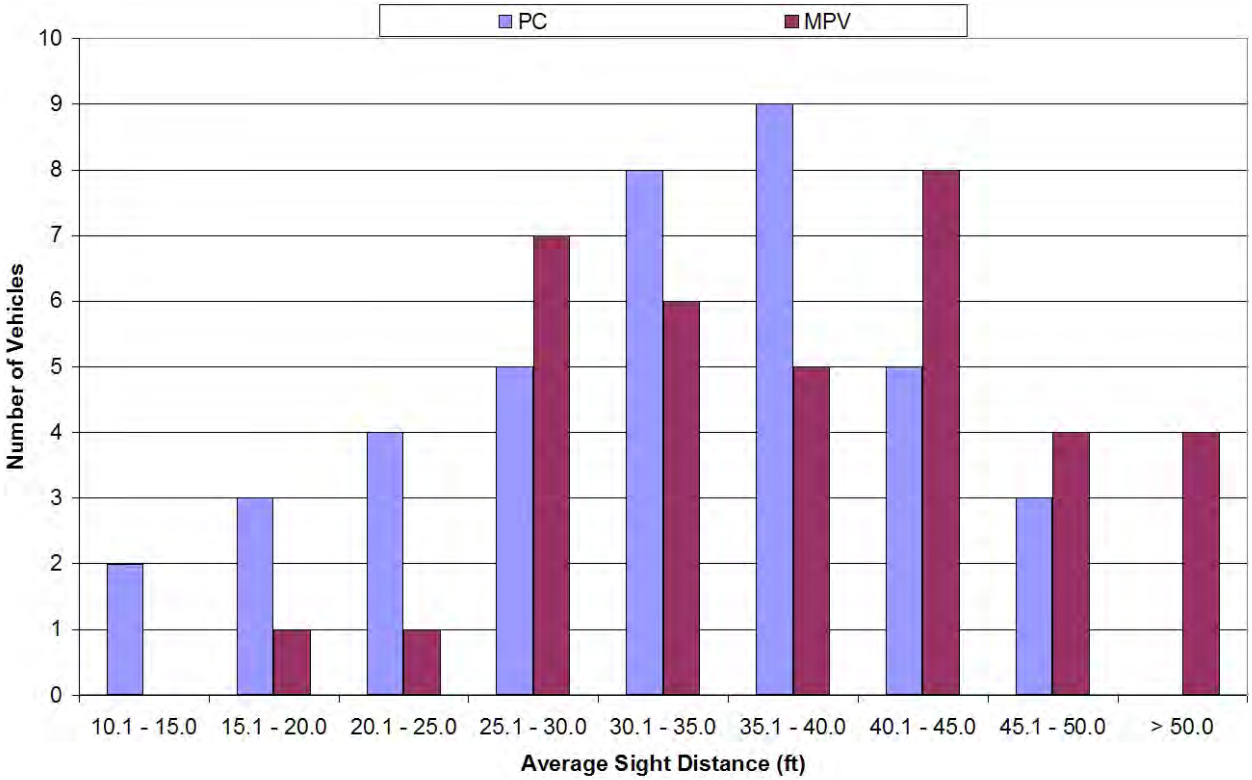

Figure 10. Frequency Distribution of Values for Longitudinal Rear Sight Distance – Passenger Cars (PC)(N=39) Versus MPVs (N=36)

4.3 Rear Blind Zone Areas

To permit the comparison of rear visibility characteristics across different vehicles, rear blind zone area was calculated. Rear blind zone area was defined as the sum of the horizontal area over which the visual target could not be seen. Rear blind zone area results presented in this section consider only those areas not visible by direct glances (i.e., areas visible using mirrors or rearview video systems were not considered in these calculations) in order to isolate the effect of vehicle structure on rear visibility.

Multiple calculations of blind zone area were computed. The first calculation of blind zone area summarizes blind spot data points over a 50 by 50 foot area representing the entire field over which vehicle rear visibility was measured in this study. The second calculation summarizes blind spot data points over a 50 by 20 foot area, representing an area approximately three vehicles wide. The third calculation summarizes blind spot data over a 50 by 8 foot area, representing an area approximately the width of one vehicle. Table 13 summarizes blind zone area results for passenger vehicles evaluated in this study and Table 14 summarizes results for MPVs.

Table 13. Rear Blind Zone Areas for Measured Passenger Cars

				Blind Zone Area (sq. ft.)		
NHTSA NCAP Category	MY	Make	Model	50' L x 50' W	50' L x 20' W	50' L x 8' W
PC Light (2,000-2,499 lbs)	2008	Hyundai	Accent	938	391	198
PC Compact (2,500-2,999 lbs)	2003	Nissan	Sentra	974	344	154
PC Compact (2,500-2,999 lbs)	2008	Nissan	Versa	1184	435	144
PC Compact (2,500-2,999 lbs)	2005	Volkswagen	Jetta	1227	666	249
PC Compact (2,500-2,999 lbs)	2008	Dodge	Caliber	1253	652	249
PC Compact (2,500-2,999 lbs)	2008	Honda	Fit	1384	491	161
PC Compact (2,500-2,999 lbs)	2008	Volkswagen	New Beetle	1388	477	155
PC Compact (2,500-2,999 lbs)	2008	Toyota	Prius	1415	642	257
PC Compact (2,500-2,999 lbs)	2008	Ford	Focus	1489	726	289
PC Compact (2,500-2,999 lbs)	2008	Mazda	Mazda3	1545	689	285
PC Compact (2,500-2,999 lbs)	2008	Kia	Spectra	1558	710	255
PC Compact (2,500-2,999 lbs)	2005	Saturn	Ion	1561	863	380
PC Compact (2,500-2,999 lbs)	2008	Hyundai	Elantra	1676	755	270
PC Compact (2,500-2,999 lbs)	2008	Chevrolet	Aveo	1685	671	255
PC Compact (2,500-2,999 lbs)	2009	Toyota	Matrix	1848	875	360
PC Medium (3,000-3,499 lbs)	2008	Mazda	Mazda6	932	376	164
PC Medium (3,000-3,499 lbs)	2006	Chrysler	PT Cruiser	1265	573	215
PC Medium (3,000-3,499 lbs)	2009	Hyundai	Sonata	1299	631	281
PC Medium (3,000-3,499 lbs)	2007	Chevrolet	Monte Carlo	1300	479	175
PC Medium (3,000-3,499 lbs)	2008	Volkswagen	GTI	1332	441	154
PC Medium (3,000-3,499 lbs)	2008	Pontiac	G6	1436	733	313
PC Medium (3,000-3,499 lbs)	2009	Chevrolet	HHR	1475	715	274
PC Medium (3,000-3,499 lbs)	2008	Honda	Accord	1499	742	264
PC Medium (3,000-3,499 lbs)	2006	BMW	330i	1546	788	318
PC Medium (3,000-3,499 lbs)	2008	Volkswagen	Jetta	1681	803	301
PC Medium (3,000-3,499 lbs)	2009	Subaru	Legacy	1689	866	344
PC Medium (3,000-3,499 lbs)	2006	Volkswagon	Passat	1693	852	339
PC Medium (3,000-3,499 lbs)	2008	Ford	Fusion	1825	878	363
PC Heavy (>=3,500 lbs)	2008	Hyundai	Azera	1167	494	233
PC Heavy (>=3,500 lbs)	2007	Ford	Five Hundred	1372	651	235
PC Heavy (>=3,500 lbs)	2008	Volvo	S80	1393	604	229
PC Heavy (>=3,500 lbs)	2009	Acura	RL	1547	641	271
PC Heavy (>=3,500 lbs)	2008	Dodge	Charger	1552	755	283
PC Heavy (>=3,500 lbs)	2008	BMW	528i	1584	756	234
PC Heavy (>=3,500 lbs)	2005	Chrysler	300	1619	816	303
PC Heavy (>=3,500 lbs)	2008	Buick	Lucerne	1620	792	325
PC Heavy (>=3,500 lbs)	2008	Toyota	Avalon	1704	819	298
PC Heavy (>=3,500 lbs)	2005	Cadillac	STS	1753	891	366
PC Heavy (>=3,500 lbs)	2007	Lexus	ES 350	1848	867	370

Table 14. Rear Blind Zone Areas for Measured Multi-Purpose Vehicles

				Blind Zone Area		
NHTSA NCAP Category	MY	Make	Model	50' L x 50' W	50' L x 20' W	50' L x 8' W
SUV Compact (<4,000 lbs)	2005	Honda	CRV	1217	545	191
SUV Compact (<4,000 lbs)	2008	Hyundai	Santa Fe	1350	528	206
SUV Compact (<4,000 lbs)	2008	Kia	Sportage	1408	639	266
SUV Compact (<4,000 lbs)	2008	Toyota	RAV4	1516	713	279
SUV Compact (<4,000 lbs)	2007	Suzuki	Grand Vitara	1547	760	252
SUV Compact (<4,000 lbs)	2009	Scion	XB	1625	820	298
SUV Compact (<4,000 lbs)	2008	Saturn	Vue	1625	839	337
SUV Compact (<4,000 lbs)	2008	Ford	Edge	1648	866	327
SUV Compact (<4,000 lbs)	2008	Infiniti	EX35	1668	641	274
SUV Compact (<4,000 lbs)	2008	Ford	Taurus X	1814	843	349
SUV Light (4,000-5,000 lbs)	2005	Ford	Explorer	1284	435	157
SUV Light (4,000-5,000 lbs)	2008	Jeep	Wrangler	1323	679	302
SUV Light (4,000-5,000 lbs)	2007	Dodge	Magnum	1369	619	218
SUV Light (4,000-5,000 lbs)	2008	Toyota	4Runner	1518	655	201
SUV Light (4,000-5,000 lbs)	2008	Honda	CR-V	1538	595	217
SUV Light (4,000-5,000 lbs)	2006	Honda	Pilot	1594	775	290
SUV Light (4,000-5,000 lbs)	2007	Jeep	Commander	1792	941	400
SUV Light (4,000-5,000 lbs)	2008	Subaru	Tribeca	1842	943	400
SUV Light (4,000-5,000 lbs)	2007	Mazda	CX9	1880	873	365
SUV Light (4,000-5,000 lbs)	2008	Saturn	Outlook	1955	956	400
SUV Medium (5,000-6,000 lbs)	2008	Chevrolet	Trailblazer	1268	602	239
SUV Medium (5,000-6,000 lbs)	2008	Chevrolet	Equinox	1805	877	387
SUV Medium (5,000-6,000 lbs)	2007	Cadillac	Escalade	1890	843	352
SUV Medium (5,000-6,000 lbs)	2008	Chevrolet	Avalanche	2010	923	387
SUV Heavy (<6,000 lbs)	2008	Jeep	Grand Cherokee	1411	674	248
SUV Heavy (<6,000 lbs)	2008	Ford	Expedition	1664	698	280
SUV Heavy (<6,000 lbs)	2008	Chevrolet	Suburban	1778	838	374
Pickups All	2008	Dodge	Dakota	1508	606	201
Pickups All	2007	Chevrolet	Silverado	1586	767	311
Pickups All	2008	Honda	Ridgeline	1650	652	255
Pickups All	2008	GMC	Sierra	1664	729	345
Pickups All	2008	Ford	F-150	1804	939	395
Van (<5,000 lbs)	2008	Dodge	Caravan	1174	595	200
Van (<5,000 lbs)	2005	Chevrolet	Uplander	1442	796	333
Van (<5,000 lbs)	2007	Honda	Odyssey	1812	874	335
Van Heavy (>=5,000 lbs)	2008	Ford	Econoline (E-series)	2500	1000	400

As the graph of rear blind zone area data in Figure 11 shows, the largest of the three blind zone measurement areas provides for a better “spread” of the data and facilitates an easier distinction between individual vehicle’s rear visibility. The overall range of values measured over the 50 by 50 foot area was 1562 ft, while the ranges measured over the 50 by 20 foot and 50 by 8 foot areas were 609 ft and 202 ft, respectively.

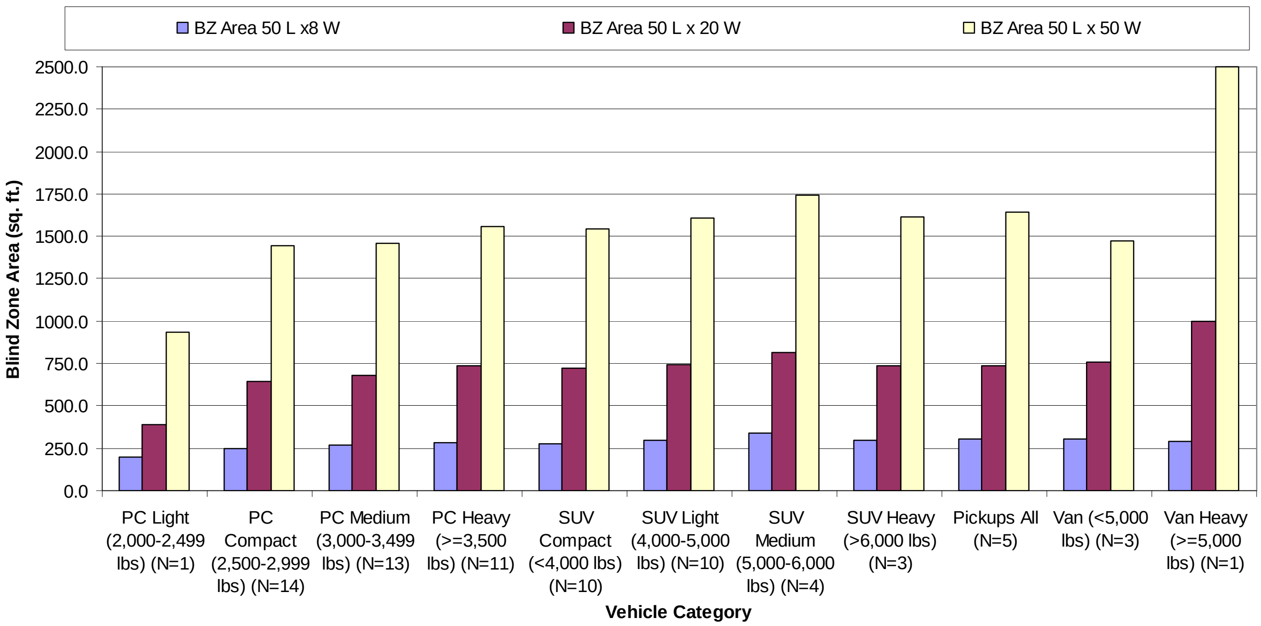

Figure 11. Rear Blind Zone (BZ) Area by Vehicle Category for Three Measurement Areas

Vehicles’ rear blind zone area results are summarized by body type in Table 15 below. Figure 12 shows average rear blind zone area by vehicle category and weight. These data show that average rear blind zone area tends to increase with increasing vehicle weight and size. Figure 13 illustrates these data down by vehicle body type. Overall average blind zone area for passenger cars was 1468.1 sq. ft. (SD=237) and for multi-purpose vehicles was 1624.4 sq. ft. (SD=263).

Table 15. Rear Blind Zone Area by Vehicle Body Type

Model	Mean Average Blind Zone Area (sq. ft.) Measure Over a 50 x 50 foot area	Standard Deviation
PCs (N=39)	1468.1	236.6
Van (<5,000 lbs) (N=3)	1476.0	320.4
SUVs All (N=27)	1626.9	211.2
Pickups All (N=5)	1676.0	109.4
Van Heavy (>=5,000 lbs) (N=1)	2500.0	N/A

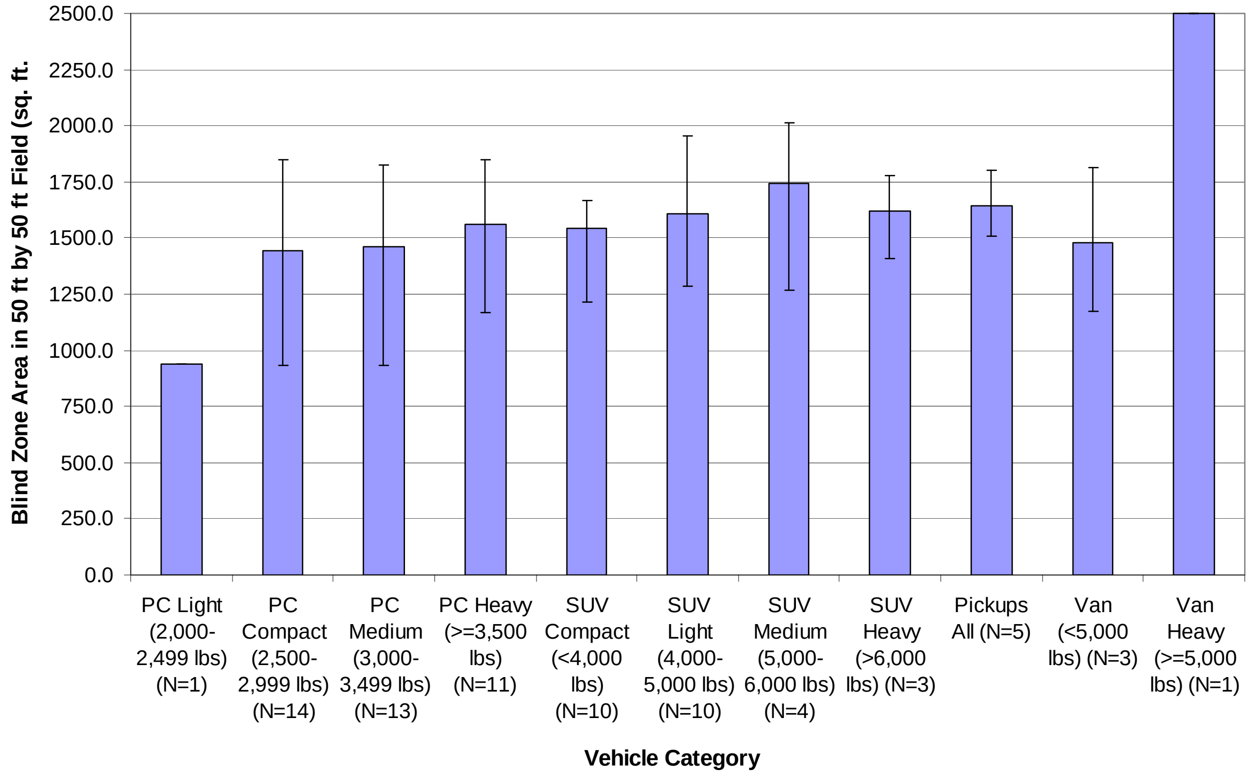

Figure 12. Rear Blind Zone Area Over a 50 ft by 50 ft Area by Vehicle Category

Note: Error bars show the range of values for each vehicle category.

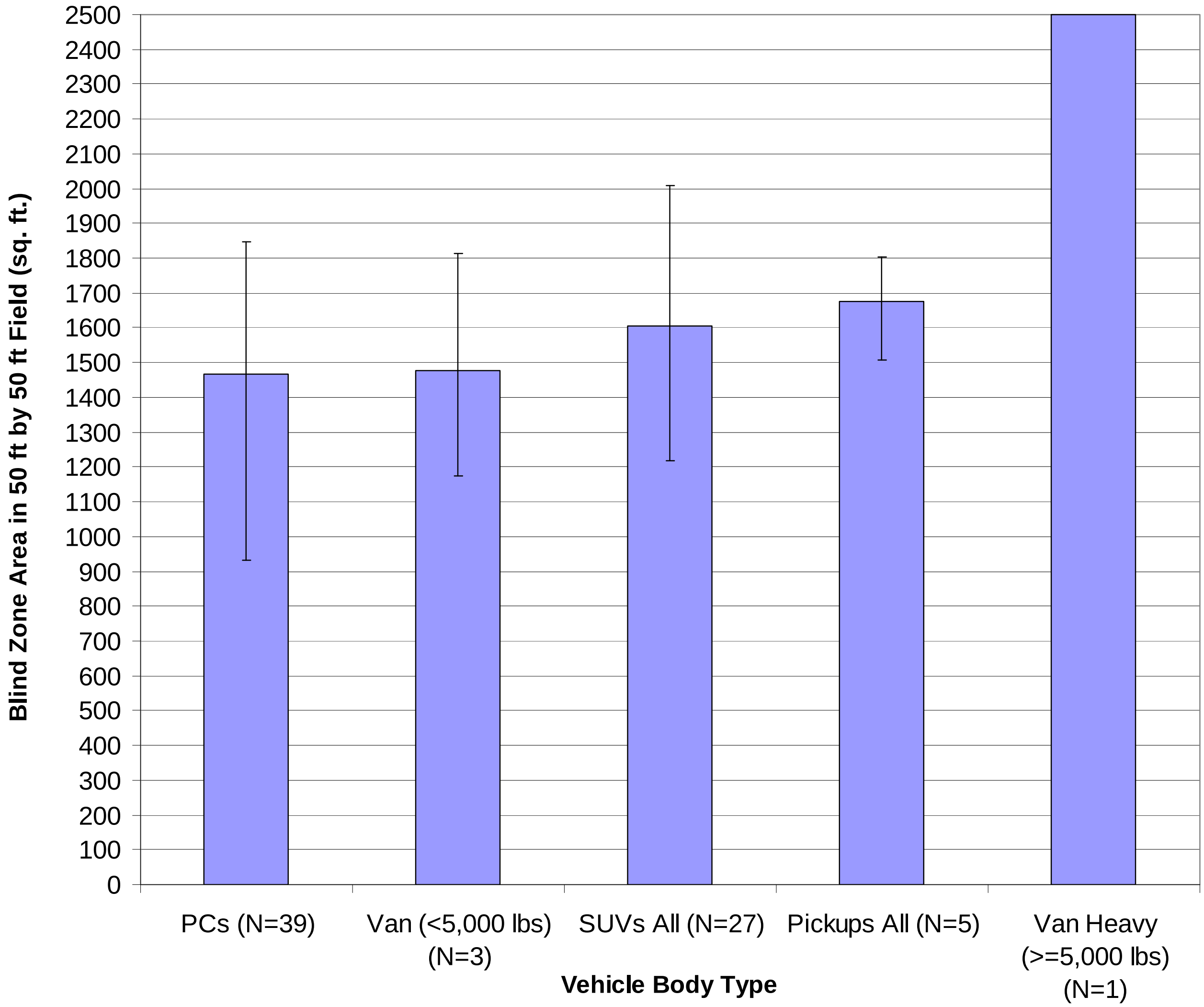

Figure 13. Rear Blind Zone Area Over a 50 ft by 50 ft Area by Vehicle Body Type

Note: Error bars show the range of values for each vehicle category.

The following two figures contain frequency distribution plots for all 75 measured vehicles as a whole (Figure 14) and separated into passenger cars and MPVs (Figure 15). Figure 14 shows that over half of the measured vehicles (42 of 75) have rear blinds zones within a 50 by 50 foot area behind the vehicle of 1500 sq. ft. or more. Figure 15 shows that MPVs as a group tend to have larger rear blind zone areas within a 50 by 50 foot area behind the vehicle than do passenger cars.

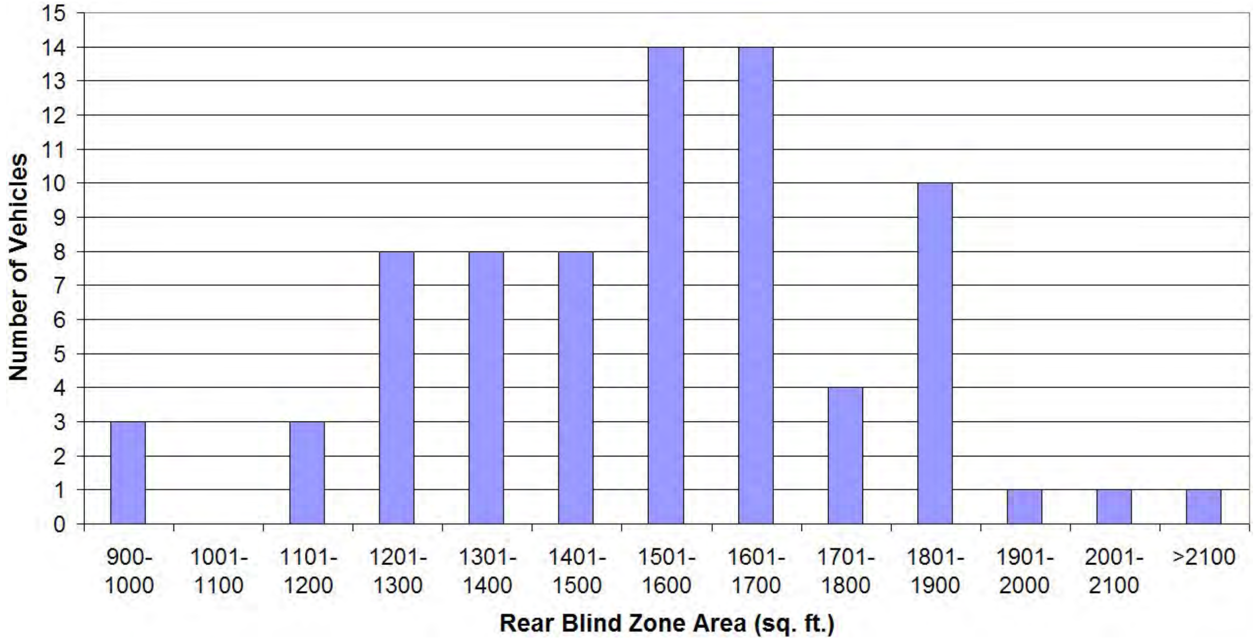

Figure 14. Frequency Distribution of Values for Rear Blind Zone Area Measured Over a Field 50 Ft Wide by 50 Ft Long – All Vehicles (N=75)

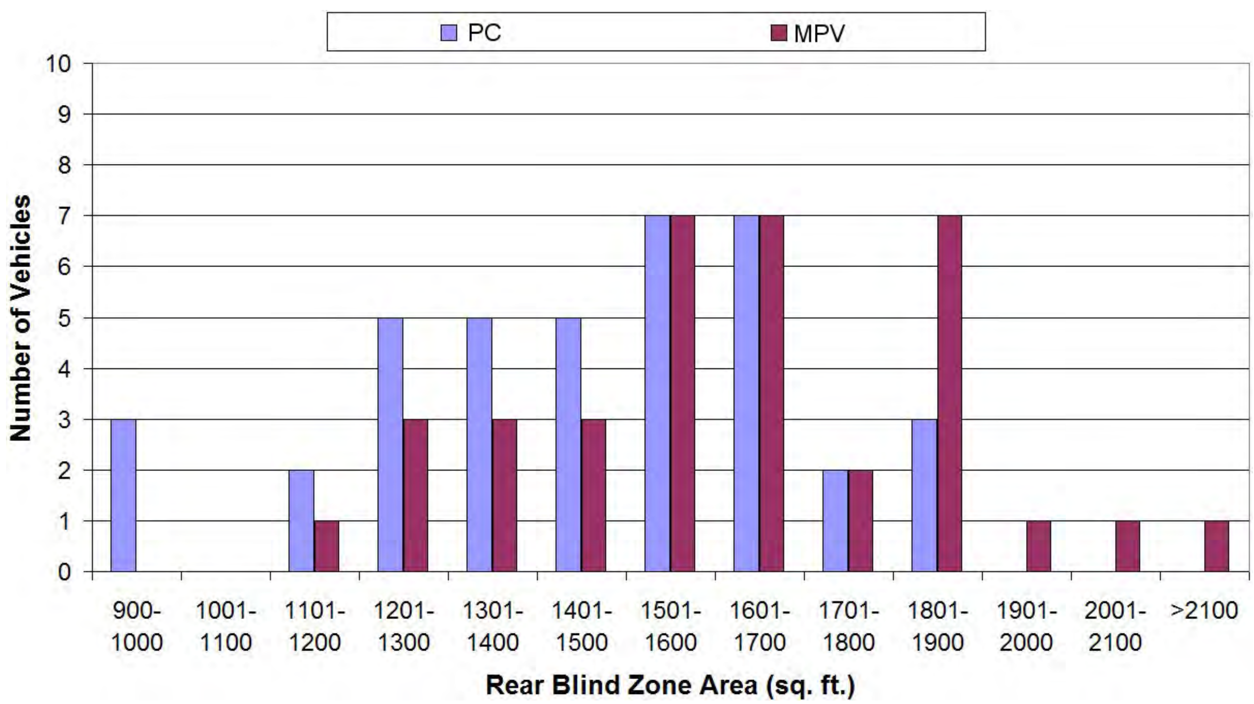

Figure 15. Frequency Distribution of Values for Rear Blind Zone Area Measured Over a Field 50 Ft Wide by 50 Ft Long – Passenger Cars (PC)(N=39) Versus MPVs (N=36)

4.4 Repeatability of Rear Visibility laser-Based Measurement Method

To assess the variability of this improved laser-based rear visibility test method, four test vehicles were measured using the laser-based rear visibility measurement protocol, including repositioning of the vehicles on the test grid. Results of these measurements are illustrated in Figure 16. As indicated in Table 16, the rear blind zone area data varied less than 3.2 percent of the measured value. This variability is believed to be due to the accuracy of positioning the vehicle on the test grid. The procedure for aligning the vehicle on the test grid for this study involved the alignment of the rear bumper with respect to the lateral grid axis. If the vehicle's alignment is checked to ensure that the vehicle's centerline is aligned with the longitudinal axis of the test grid, it is hypothesized that measurement variation could then be reduced to 2 percent or less.

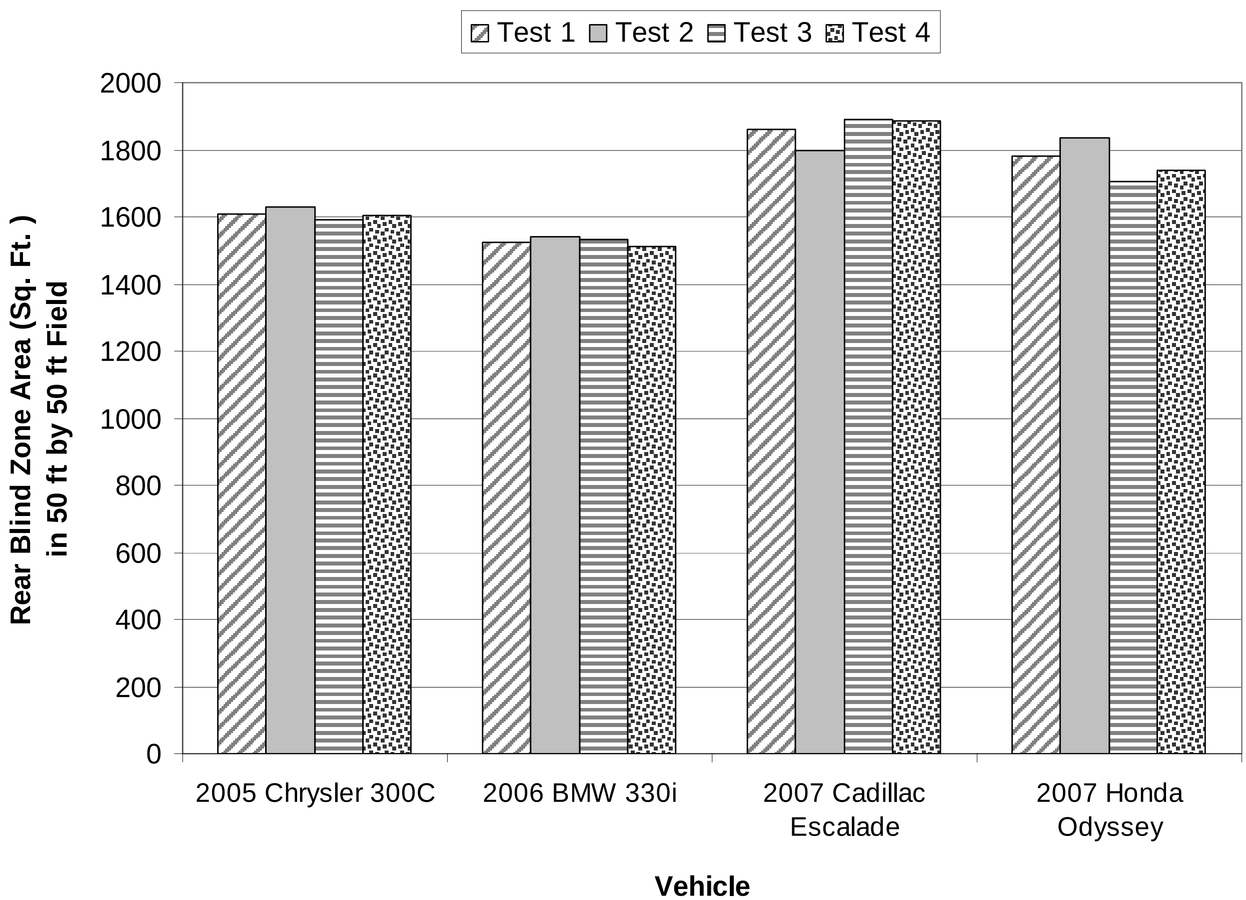

Figure 16. Rear Blind Zone Area Measurement Repeatability Results

Table 16. Rear Blind Zone Area Measurement Repeatability Results and Analysis

Vehicle	Test 1	Test 2	Test 3	Test 4	Avg	Std. Dev.	Min	Max	Range (Max-Min)	Std Dev / Avg
2005 Chrysler 300C	1608	1631	1590	1604	1608	17.0	1590	1631	41	1.1%
2006 BMW 330i	1523	1542	1533	1513	1528	12.5	1513	1542	29	0.8%
2007 Cadillac Escalade	1863	1800	1889	1887	1860	41.5	1800	1889	89	2.2%
2007 Honda Odyssey	1783	1834	1705	1739	1765	55.9	1705	1834	129	3.2%

4.5 Comparison of Rear Visibility Measurement Protocols

NHTSA compared rear visibility data for 18 vehicles that were measured using both the prior human-based and improved laser-based rear visibility measurement procedures to assess how the results compare (i.e., similar vehicle rankings, etc.). The data used for this comparison are summarized in Table 17.

Table 17. Human and laser Based Measurement Data Comparison

			Blind Zone Area		Blind Zone Area 50 L x 20 W		Average Sight Distance	
MY	Make	Model	Human 50 L x 60 W	Laser 50 L x 50 W	Human	Laser	Human	Laser
2006	BMW	330i	271	1546	221	788	18.1	40.0
2007	Cadillac	Escalade	1376	1890	688	843	48.5*	44.3
2005	Cadillac	STS	565	1753	436	891	29.8	45.9**
2005	Chevrolet	Uplander	718	1442	548	796	36.3	41.9**
2005	Chrysler	300	428	1619	312	816	29.9	38.3
2005	Ford	Explorer	391	1284	263	435	16.1	19.0
2007	Ford	Five Hundred	268	1372	253	651	18.0	29.9
2005	Honda	CRV	330	1217	304	545	17.3	24.4
2008	Honda	Fit	672	1384	418	491	21.1	20.3
2007	Honda	Odyssey	843	1812	579	874	28.1	42.1
2007	Jeep	Commander	1409	1792	829	941	90.0	50.0
2007	Lexus	ES 350	1115	1848	762	867	43.5	40.3
2007	Mazda	CX9	1326	1880	819	873	49.6	40.4
2005	Saturn	Ion	753	1561	579	863	36.4	47.9
2008	Subaru	Tribeca	1143	1842	693	943	37.4	50.0**
2008	Toyota	Prius	438	1415	235	642	11.0	12.1
2005	Volkswagen	Jetta	383	1227	342	666	23.9	31.6
2006	Volkswagen	Passat	422	1693	356	852	25.0	42.8**

* Noted averages include at least one individual longitudinal rear sight distance value that equaled or exceeded the limit of the measurement range of 90 ft. For individual longitudinal rear sight distance values that exceeded the measurement range in this study, a value of 90 ft was substituted.

** Noted averages include at least one individual longitudinal rear sight distance value that equaled or exceeded the limit of the measurement range of 50 ft. For individual longitudinal rear sight distance values that exceeded the measurement range in this study, a value of 50 ft was substituted.

Figure 17 illustrates the data presented in Table 17. The figure highlights the trend of the data produced by the two different measurement techniques to generally track each other. Blind zone area values measured using the laser-based method were consistently larger than those measured using a human driver. One possible reason for blind zone areas being smaller for the driver-based measurements could be that the driver's choice of seat position (i.e. longitudinal position and seat back angle) may have been different than that used for the standard position used for installation of the H-Point machine used to represent a 50th percentile male driver. In addition, the driver's ability to move their head and upper torso in order to better view the target was likely to have increased their ability to see the target over a greater area than was "visible" for the laser-based measurement method.

Despite the difference between the human-based and laser-based measured values, the laser-based method still provides an objective, repeatable means for assessing a vehicle's rear visibility and for comparing rear visibility amongst vehicles. Furthermore, an analysis of these two datasets [17] showed them to be correlated to a statistically significant degree. Based on these results and those of the repeatability testing, NHTSA's data suggests that the laser-based rear visibility measurement protocol is a valid and reliable method that can serve as an objective basis for assessment of vehicle's rear visibility characteristics.

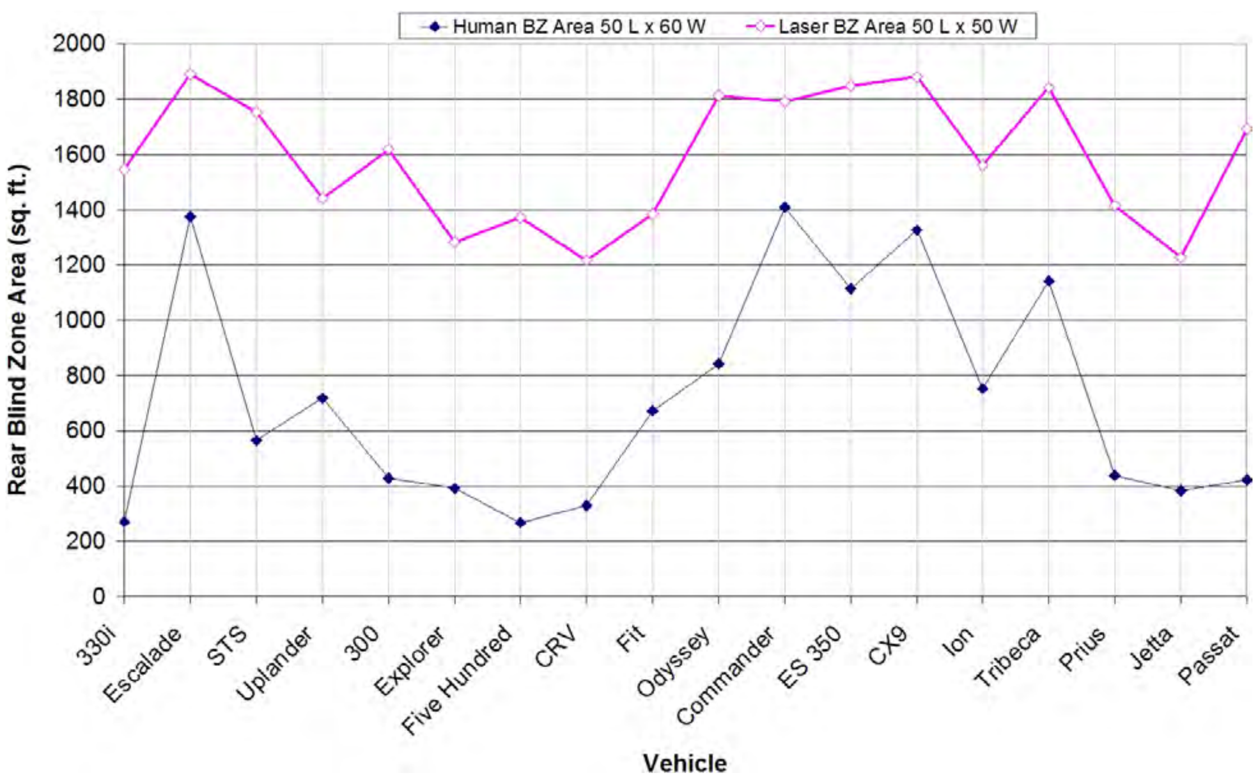

Figure 17. Illustration of Rear Blind Zone Data measured using a Human Driver Versus Those Measure Using a laser-Based Method.

5.0 SUMMARY

This report describes measurement of the rear visibility characteristics of a set of 75 vehicles. The visibility of a 29.4-inch-tall (i.e., approximately the height of a 1-year-old child) visual target was determined over a 2500-square-foot area stretching 25 ft to either side of the vehicle's centerline and 50 ft back from the vehicle's rear bumper, as well as on either side of the vehicle aft of the vehicle's side rearview mirrors. A dynamic laser-based fixture was used to simulate the line of sight for a 50th percentile height male driver for these measurements. The measurement procedure determined the areas that would be visible to a 50th percentile male driver using direct glances (i.e., areas visible using mirrors or rearview video systems were not considered). This approach allowed for the most direct assessment of the impact of the vehicle's exterior structural design on rear visibility.

Since the vehicle's structural features, such as pillars and head restraints, may affect rear visibility, longitudinal rear sight distance was examined along the entire width of the vehicle. Eight distance values with respect to the vehicle's rear bumper were determined across the width of the vehicle based on the measured rear visibility data. The "shortest minimum sight distance" was the longitudinal distance from the bumper, out of the eight values that was closest to the vehicle. The "longest minimum sight distance" was the longitudinal distance from the bumper, out of the eight values that was farthest from the vehicle. Average longitudinal rear sight distance was calculated as a mean of the eight individual longitudinal sight distance values.

Average longitudinal rear sight distances to a 29.4-inch-tall visual target were shortest for passenger cars and longest for vans. The shortest minimum longitudinal rear sight distance for any of the measured vehicles was 0.5 ft for the 2008 Volkswagen New Beetle. The longest minimum longitudinal rear sight distance was less than 50 ft for 32 of 75 vehicles measured, meaning 57 percent of measured vehicles had at least one of the eight longitudinal rear sight distance values listed as 50 ft. Longitudinal rear sight distance values reported do not exceed 50 ft since that was the extent of the longitudinal measurement field behind the vehicle.

Direct view rear blind zone areas were assessed over a 50-foot wide by 50-foot long measurement field centered behind the vehicle. Rear blind zone area values were found to be smallest for passenger cars and largest for pickup trucks, with the exception of the cargo van that was measured. With the exception of the cargo van that had a rear blind zone area of 2500 square ft, overall average blind zone areas within the 50-foot wide by 50-foot long measurement field ranged from 932 to 2010 square ft.

6.0 REFERENCES

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14. 49 CFR Sec. 571.212, Standard No. 212; Windshield mounting.
15. 49 CFR Sec. 571.219, Standard No. 219; Windshield zone intrusion.
16. 49 CFR Sec. 571.301, Standard No. 301; Fuel system integrity.
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7.0 APPENDICES

7.1 Vehicle Identification Numbers (VIN) for Vehicles Measured

Table 18. VIN Information for Passenger Cars Measured (last 5 digits redacted)

MY	Make	Model	Trim	VIN
2009	Acura	RL		JH4KB26639C0xxxxx
2006	BMW	330i		WBAVB335X6KSxxxxx
2008	BMW	528i	3.0L V6, Auto	WBANU53588CTxxxxx
2008	Buick	Lucerne	CX, 3.8L V6, Auto	1G4HD57298U1xxxxx
2005	Cadillac	STS		1G6DC67A1501xxxxx
2008	Chevrolet	Aveo	LS 4-door, 1.6L DOHC, Auto	KL1TD56628B1xxxxx
2009	Chevrolet	HHR	LT, 2.2L Ecotec, Auto	3GNCA23B99S5xxxxx
2007	Chevrolet	Monte Carlo	LS Coupe	2G1WJ1SK1792xxxxx
2005	Chrysler	300	C	2C3AA63H95H6xxxxx
2006	Chrysler	PT Cruiser	4-door, Touring Wagon, 2.4L V4	3A4FY58B06T2xxxxx
2008	Dodge	Caliber	SE Plus, 2.0L V4 DOHC, Auto	1B3HB28B78D7xxxxx
2008	Dodge	Charger	SE Plus, 3.5L V6, Auto	2B3KA43GX8H3xxxxx
2005	Ford	Five Hundred		1FAHP2410561xxxxx
2008	Ford	Focus	SE 4-door, 2.0L DOHC, Auto	1FAHP35N28W2xxxxx
2008	Ford	Fusion	I4 S, 2.3L I4, 5-speed manual	3FAHP06Z58R1xxxxx
2008	Honda	Accord	4-door LX-P, 2.4L V4, Auto	1HGCP26498A1xxxxx
2008	Honda	Fit		JHMGD38698S0xxxxx
2008	Hyundai	Accent	GLS 4-door, 1.6L DOHC, Auto	KMHCN46C58U2xxxxx
2008	Hyundai	Azera	Limited, 3.8L DOHC V6, Auto	KMHFC46F08A2xxxxx
2008	Hyundai	Elantra	GLS, 2.0L DOHC, Auto	KMHDU46D48U5xxxxx
2009	Hyundai	Sonata	GLS	5NPET46C49H4xxxxx
2008	Kia	Spectra	LX, 2.0L V4, 5-speed manual	KNAFE1210855xxxxx
2007	Lexus	ES 350		JTHBJ46G6720xxxxx
2008	Mazda	3	Grand Touring 4-door, 2.3L DOHC I4, Auto	JM1BK3231811xxxxx
2008	Mazda	6	i, 4-door, 2.3L V4, Auto	1YVHP80C385Mxxxxx
2003	Nissan	Sentra	4-door, Limited, 2.5L V4, Auto	3N1AB51A83L7xxxxx
2008	Nissan	Versa		3N1BC13E28L4xxxxx
2008	Pontiac	G6	1SV sedan, 2.4L V4, Auto	1G2ZF57B5842xxxxx
2005	Saturn	Ion	3', 4-door	1G8AL54F25Z1xxxxx
2009	Subaru	Legacy	2.5i / 9AD, 2.5L SOHC, Auto	4S3BL6167972xxxxx
2008	Toyota	Avalon	XLS, 3.5L DOHC, Auto	4T1BK36B78U3xxxxx
2009	Toyota	Matrix (Corolla)		2T1KU40EX9C0xxxxx
2008	Toyota	Prius	Package #3	JTDKB20U2834xxxxx
2008	Volkswagen	GTI	2.0L I4, 6-speed manual	WVWFD71K18W2xxxxx
2005	Volkswagen	Jetta	Auto, Diesel	3VWSR69M55M0xxxxx
2008	Volkswagen	Jetta	2.5 SE, 2.5L I5, Auto	3VWRM71K58M1xxxxx
2008	Volkswagen	New Beetle	SE, 2.5L I5, Auto	3VWRW31C98M5xxxxx
2006	Volkswagon	Passat		WVWGK73C56P1xxxxx
2008	Volvo	S80	3.2 A SR, 3.2L V6, Auto	YV1AS9822810xxxxx

Table 19. VIN Information for MPVs Measured

MY	Make	Model	Trim	VIN
2007	Cadillac	Escalade		1GYFK63887R1xxxxx
2008	Chevrolet	Avalanche	LT 4WD, 5.3L V8, Auto	3GNFK12338Gxxxxx
2008	Chevrolet	Equinox	FWD LS, 3.4L V6, Ato	2CNDL13F4863xxxxx
2007	Chevrolet	Silverado	Crew cab short bed; 2LT 2500 4wd	2GCEC13C9716xxxxx
2008	Chevrolet	Suburban	4WD 1/2 Ton LT, 5.3L V8 SFI Flex Fuel, Auto	3GNFK16318G1xxxxx
2008	Chevrolet	Trailblazer	2LT 4WD, Vortec 4.2L SFI I6, Auto	1GNDT13S6822xxxxx
2005	Chevrolet	Uplander		1GNDV03135D2xxxxx
2008	Dodge	Caravan	SE, 3.3L V6 OHV, Auto	2D8HN44H48R6xxxxx
2008	Dodge	Dakota	Crew Cab SXT 4x2, 3.7L V6, Auto	1D7HE38K38S5xxxxx
2007	Dodge	Magnum	SXT 4-door Wagon, 3.5L V6, Auto	2D4FV47VX7H6xxxxx
2008	Ford	Econoline (E-series)	E250 Cargo van, 138" WB, 5.4L V8, Auto	1FTNE24L28DAxxxxx
2008	Ford	Edge	Limited AWD, 5-passenger, 3.5L V6, Auto	2FMDK49C38BAxxxxx
2008	Ford	Expedition	King Ranch EL 4x4, 7-passenger, 5.4L V8, Auto, Captains Chairs KR	1FMFK185X8LAxxxxx
2005	Ford	Explorer		1FMZU72KI5ZAxxxxx
2008	Ford	F-150	4x4 Supercrew XLT 150" WB Styleside, 5.4L V8, Auto	1FTPW14V78FBxxxxx
2008	Ford	Taurus X		1FMDK02W18GAxxxxx
2008	GMC	Sierra	1500 2WD Reg Cab W/T, 4.8L V8, Auto	1GTEC14C68Z2xxxxx
2005	Honda	CR-V		JHLRD68515C0xxxxx
2008	Honda	CR-V	LX 4WD, Auto	5J6RE48338L0xxxxx
2007	Honda	Odyssey		5FNRL382X7B1xxxxx
2006	Honda	Pilot	4WD EX LR, 3.5L V6, Auto	2HKYF18656H5xxxxx
2008	Honda	Ridgeline	4WD, RTLNAV, 3.5L V6, Auto	2HJYK1658H5xxxxx
2008	Hyundai	Santa Fe	GLS, 2.7L DOHC, Auto, 4WD	5NMSG13DX8H1xxxxx
2008	Infiniti	EX35	AWD Journey, 3.5L V6, Auto	JNKAJ09F98M3xxxxx
2007	Jeep	Commander	4wd	1J8HG58287C6xxxxx
2008	Jeep	Grand Cherokee	4x4 Limited, 5.7L Hemi, Auto, 18x17.5 wheels, 245/60R18 OWL All Terrain Tires	1J8HR58258C2xxxxx
2008	Jeep	Wrangler	Unlimited Sahara 4x4, 3.8L V6, manual	1J4GA59148L5xxxxx
2008	Kia	Sportage	4x2, 2.0L I4, Auto	KNDJF7243875xxxxx
2008	Mazda	CX9	Grand Touring, AWD, 3.7L V6, Auto	JM3TB38A2801xxxxx
2008	Saturn	Outlook	FWD XR, 3.6L VVT V6, Auto	5GZER237X8J2xxxxx
2008	Saturn	Vue	XE FWD, 2.4L DOHC Ecotec, Auto	3GSCL33P68S6xxxxx
2009	Scion	XB	5-door, 2.4L DOHC, V4, Auto	JTLKE50E3910xxxxx
2008	Subaru	Tribeca	8TA, 3.6L DOHC, Auto	4S4WX91D4844xxxxx
2007	Suzuki	Grand Vitara	4x4, 2.7L V6, Auto	JS3TD9417742xxxxx
2008	Toyota	4Runner	SR5 4x4, 4.0L V6, Auto	JTEBU14R28K0xxxxx
2008	Toyota	RAV4	4x4, 2.4L V4, Auto	JTMBD33V7851xxxxx

7.2 Appendix A: Graphical Plots of FOV Data

This section contains graphical plots of data for the 75 vehicles measured using the laser-based apparatus to simulate the line of sight of a 50th percentile male driver. Field of view graphical plots show vehicle perimeters to the nearest foot. Table 20 below contains the legend for these plots.

Table 20. Legend for field of view plots

■	Vehicle perimeter
▲	Exterior rearview Mirror
○	Driver location
▣	Location **visible** via direct glance
	Location ***not*** **visible** via direct glance

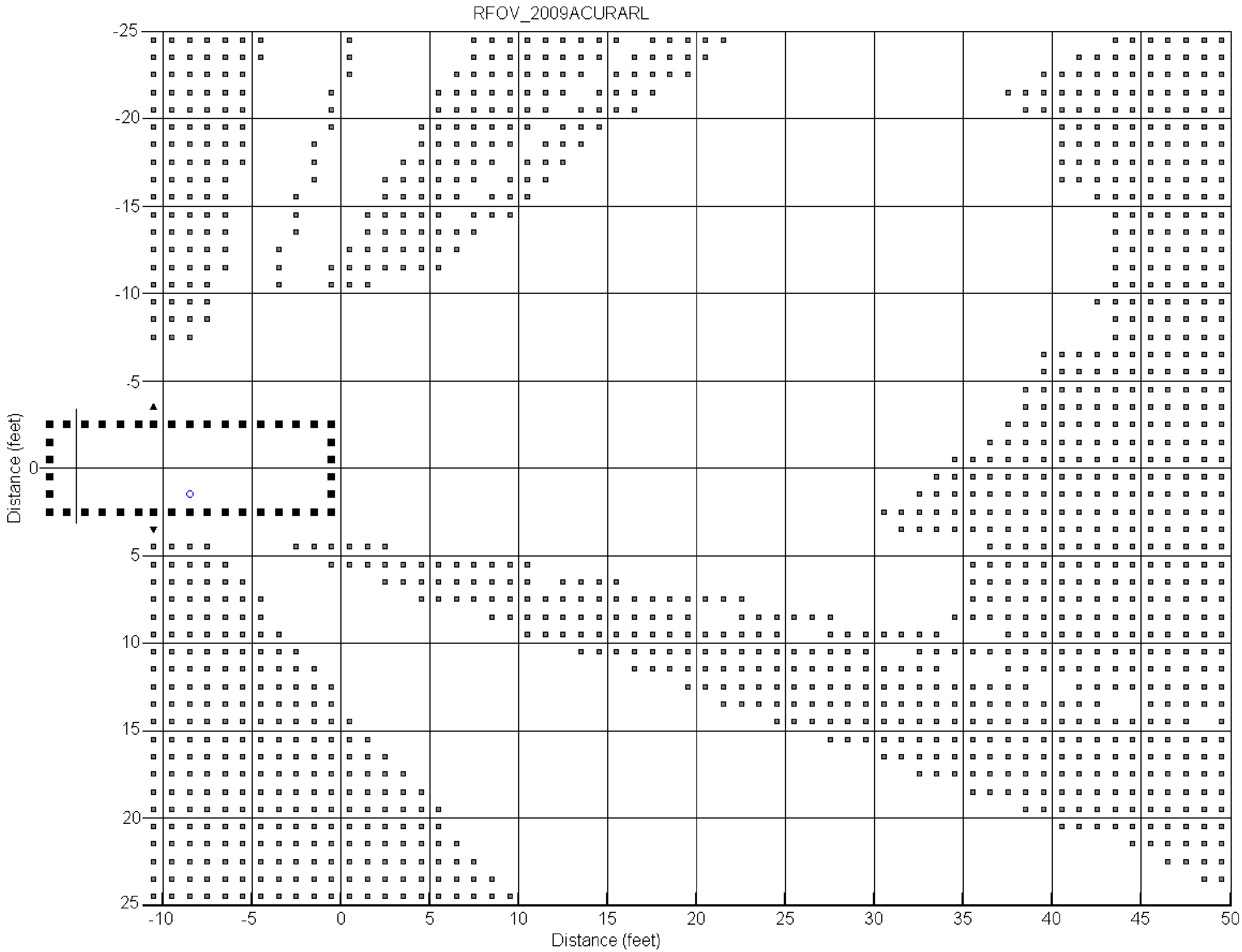

Figure 18. 2009 Acura RL Rear Field of View Data Plot

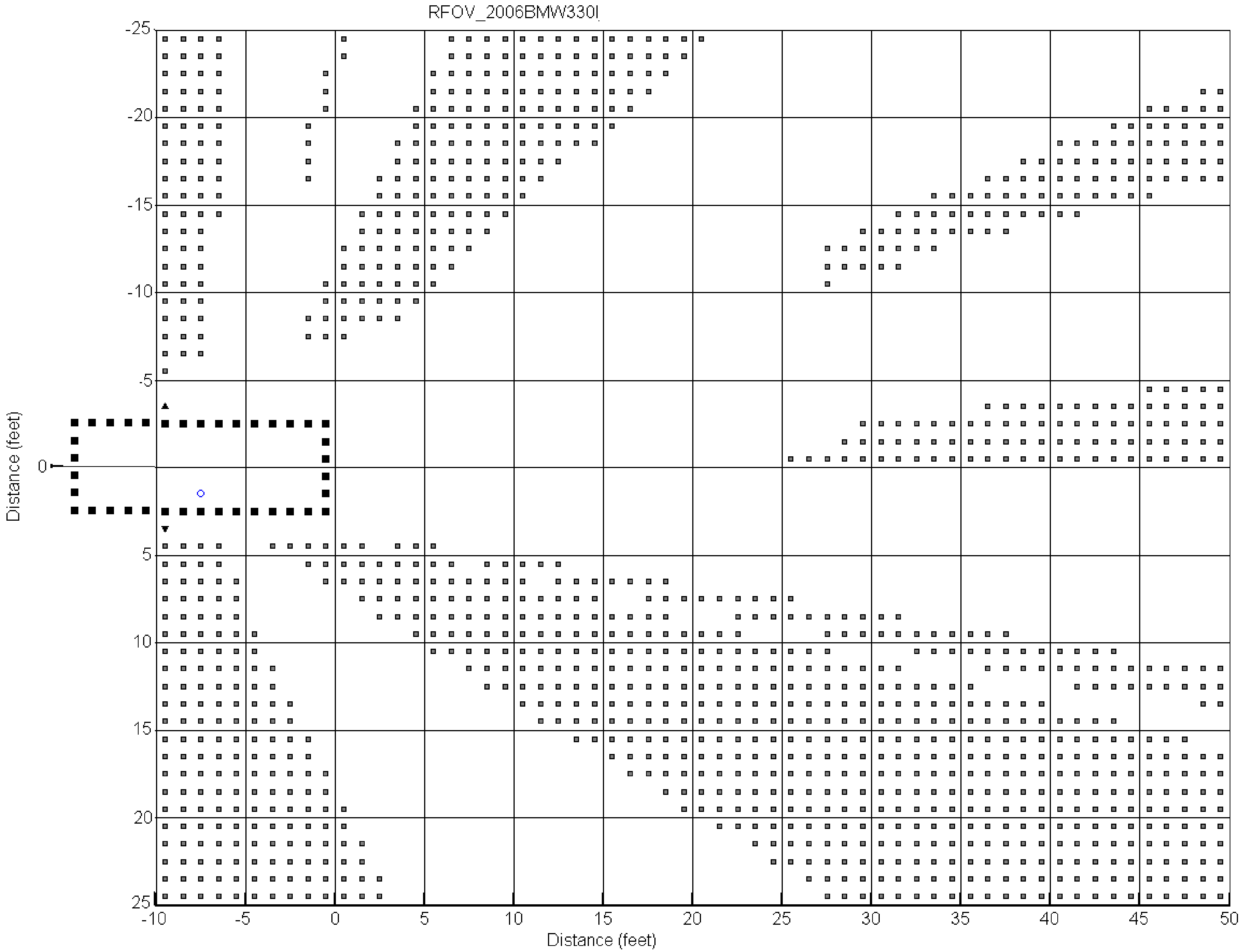

Figure 19. 2006 BMW 330i Rear Field of View Data Plot

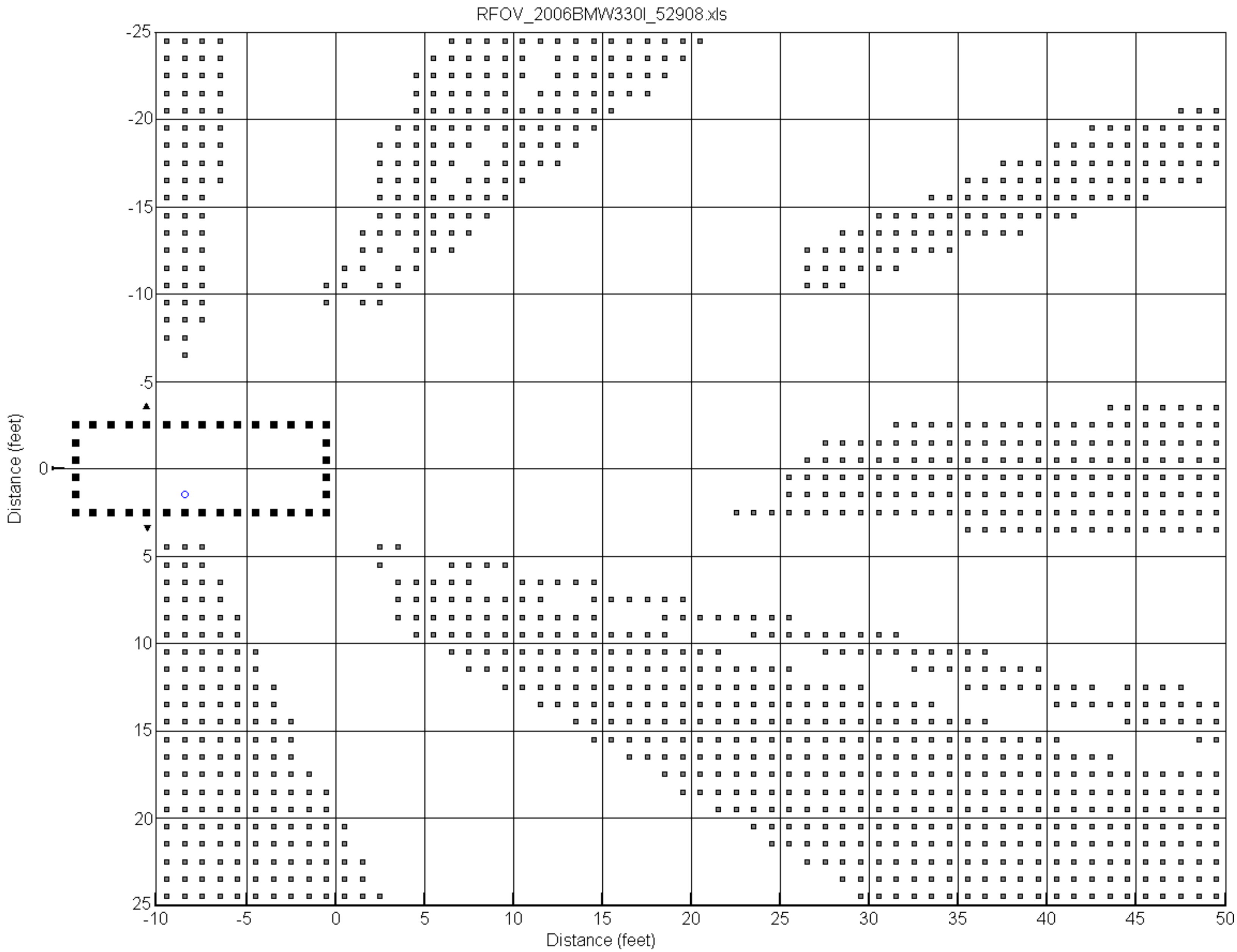

Figure 20. 2008 BMW 528i Rear Field of View Data Plot

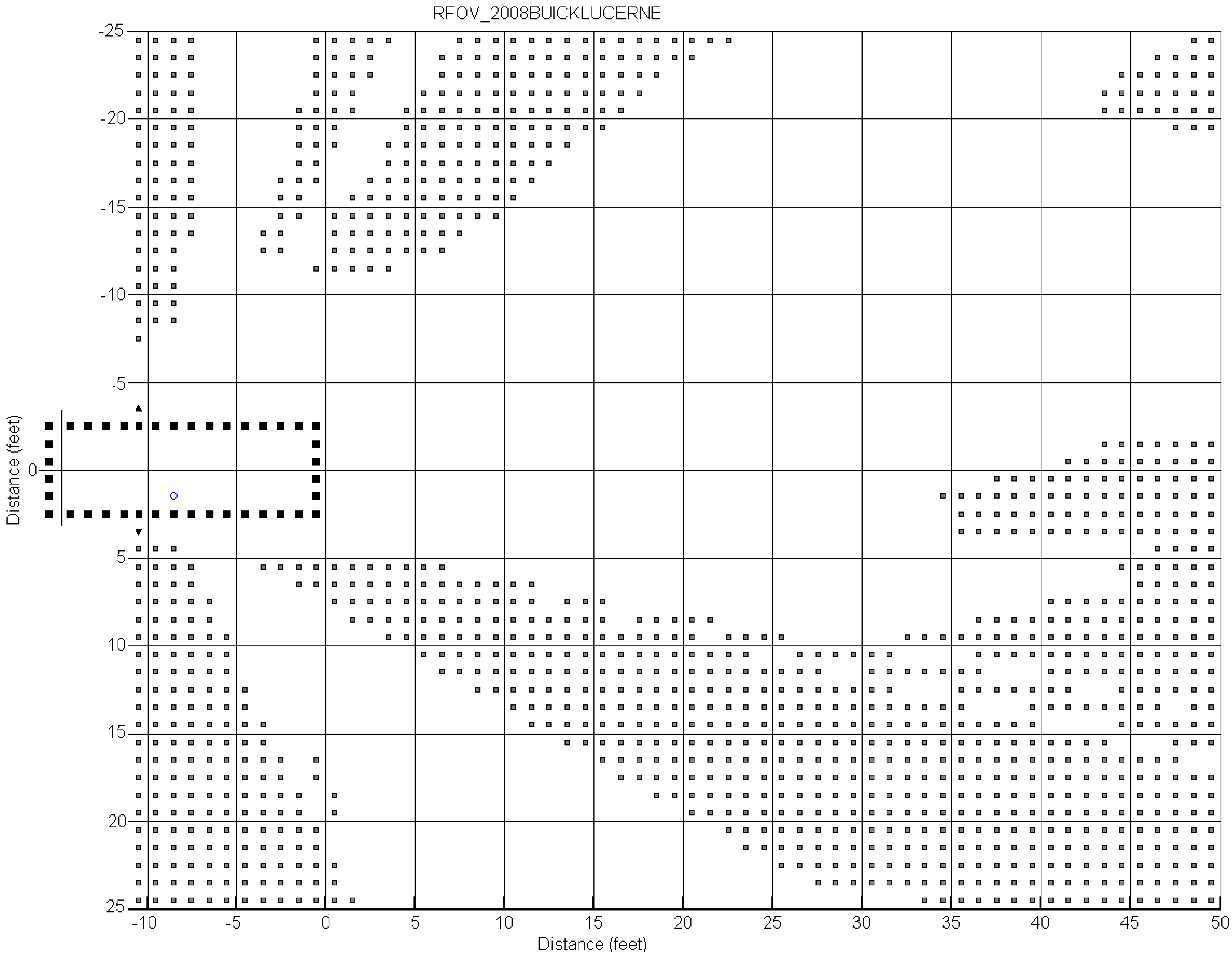

Figure 21. 2008 Buick Lucerne Rear Field of View Data Plot

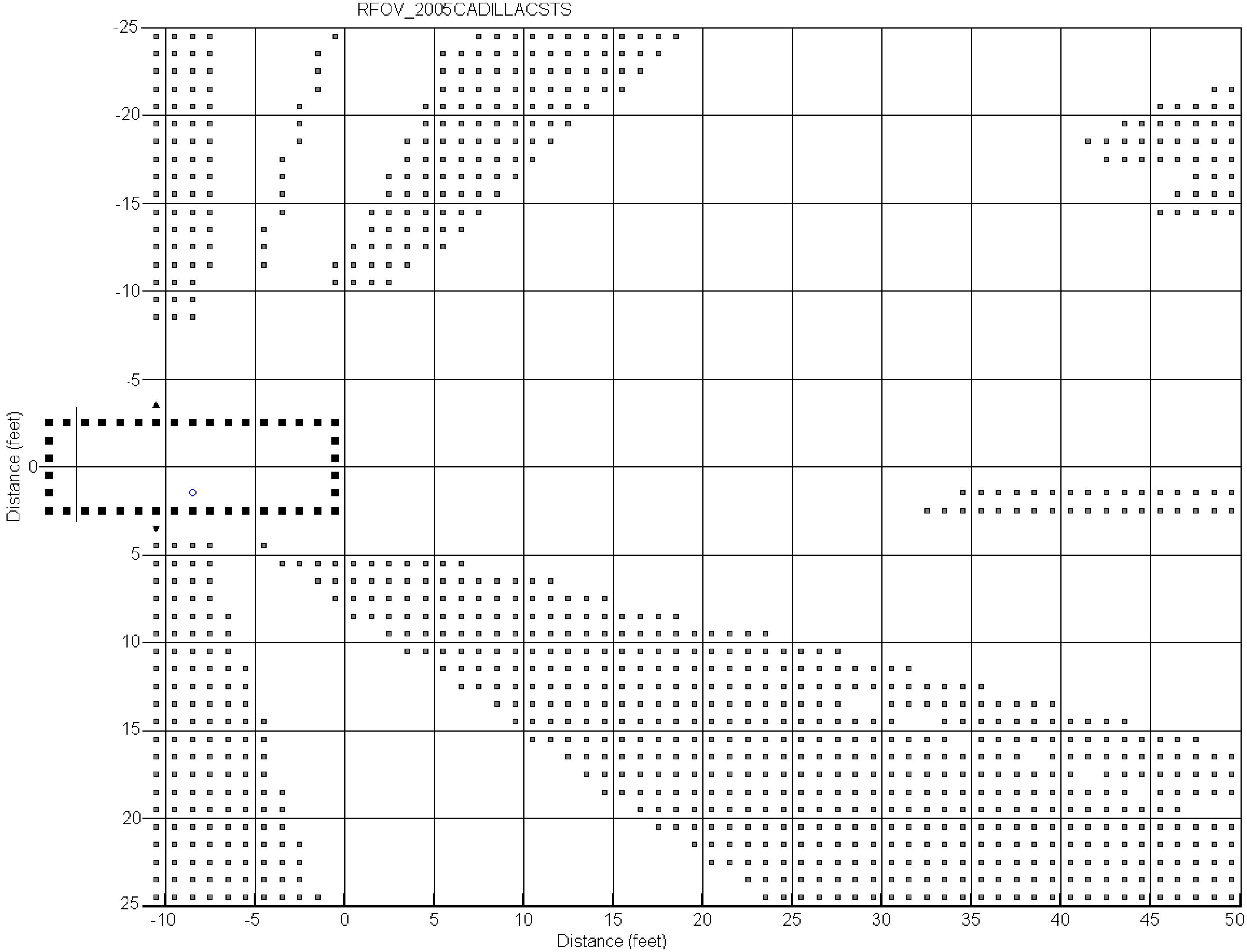

Figure 22. 2005 Cadillac STS Rear Field of View Data Plot

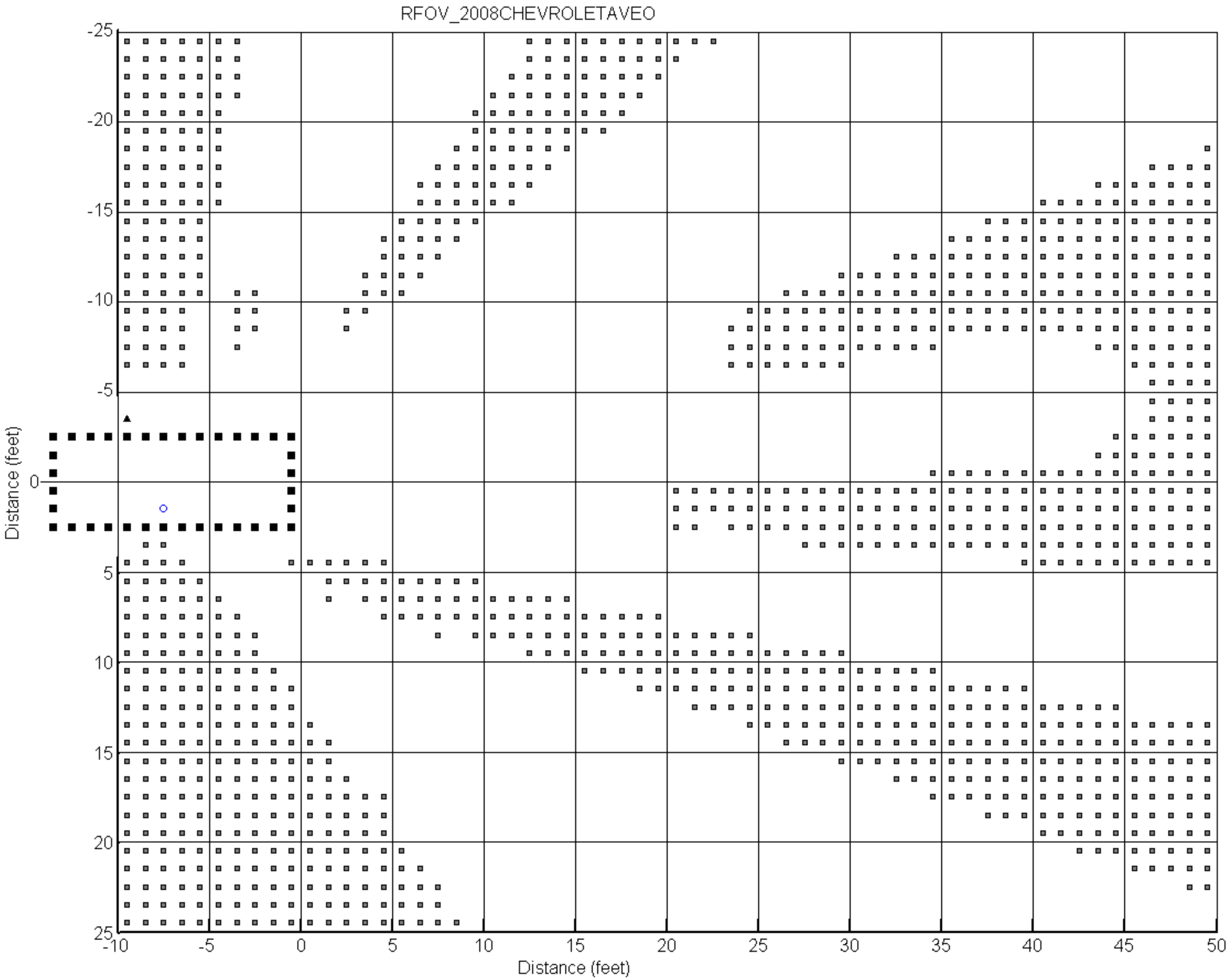

Figure 23. 2008 Chevrolet Aveo Rear Field of View Data Plot

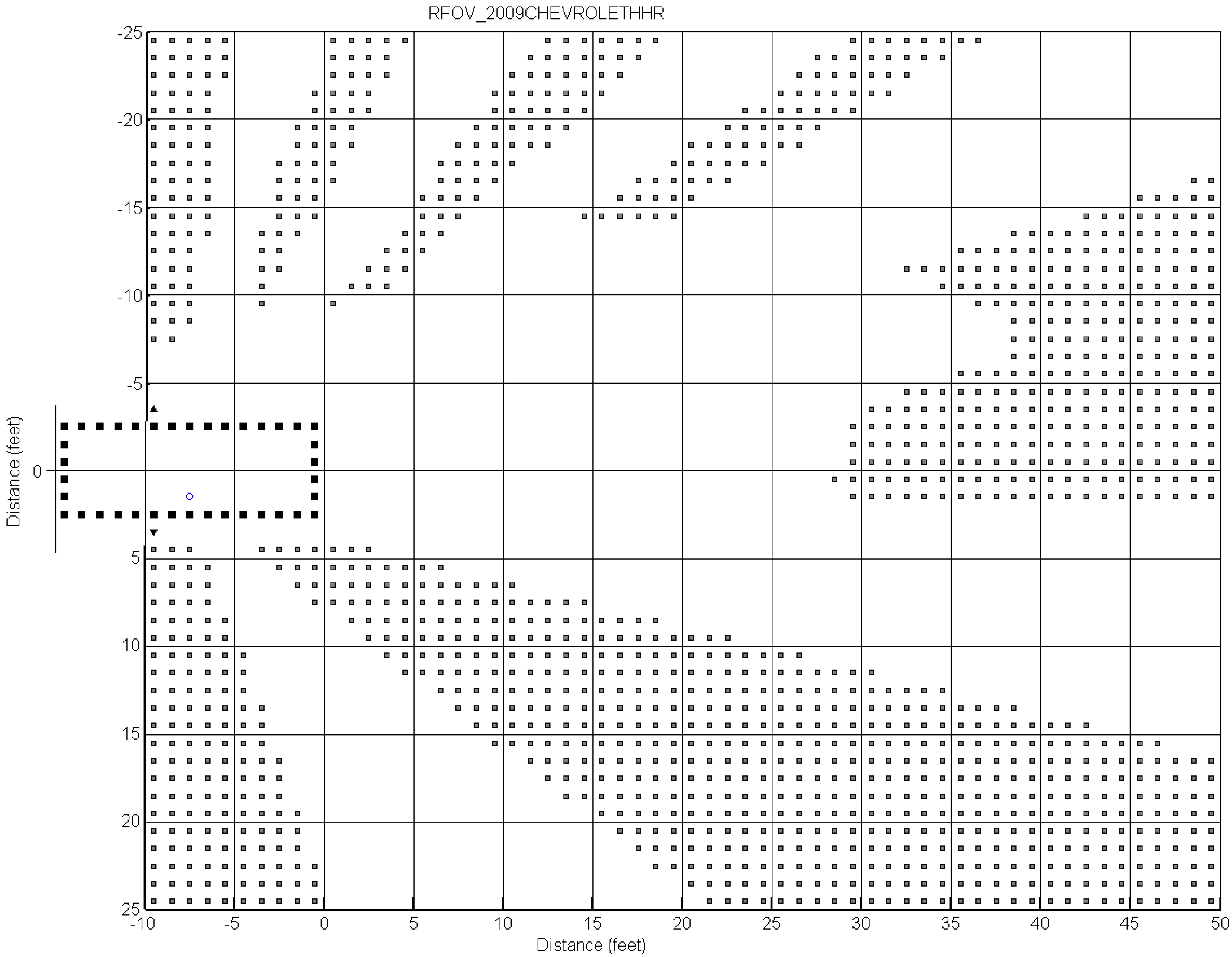

Figure 24. 2009 Chevrolet HHR Rear Field of View Data Plot

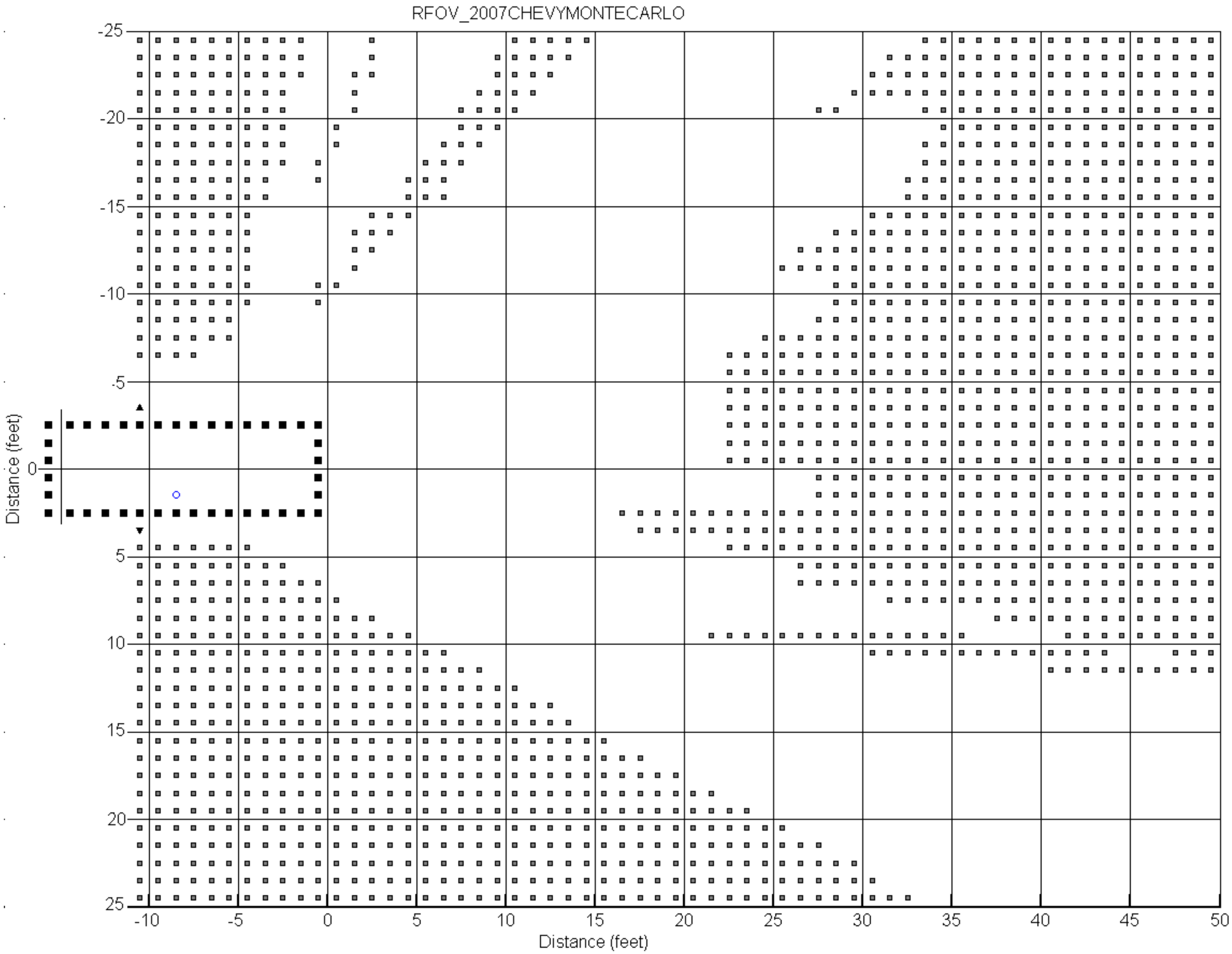

Figure 25. 2007 Chevrolet Monte Carlo Rear Field of View Data Plot

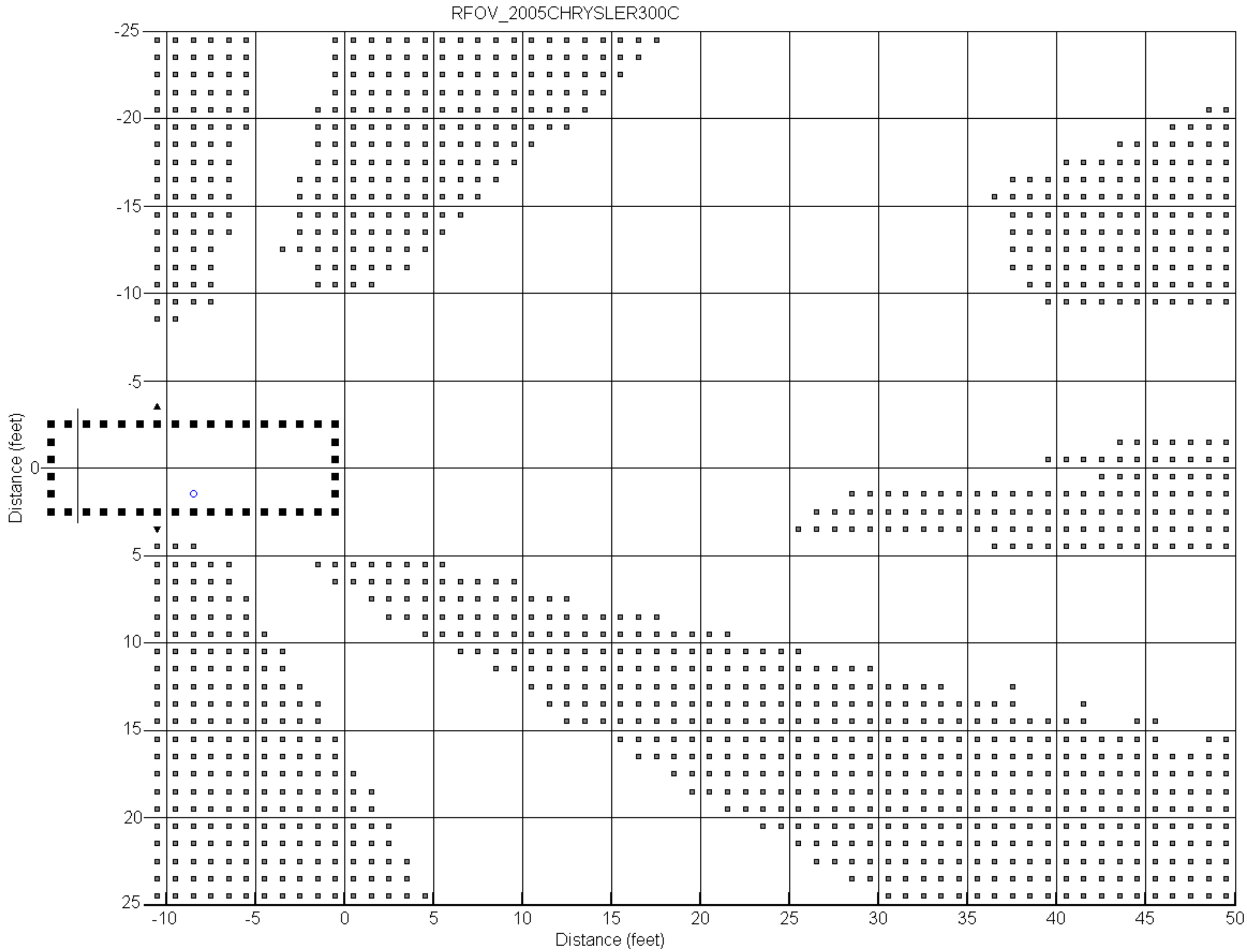

Figure 26. 2005 Chrysler 300C Rear Field of View Data Plot

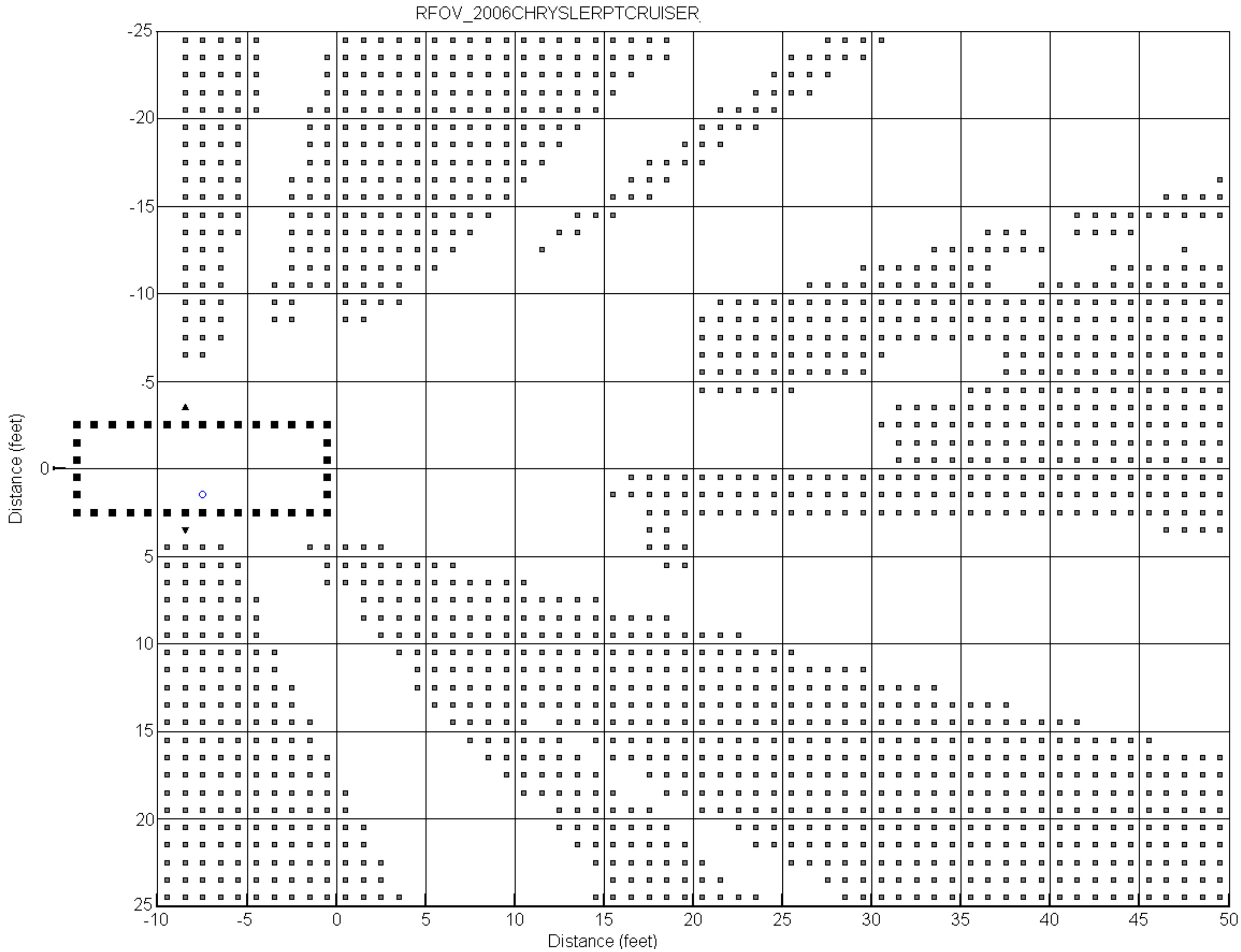

Figure 27. 2006 Chrysler PT Cruiser Rear Field of View Data Plot

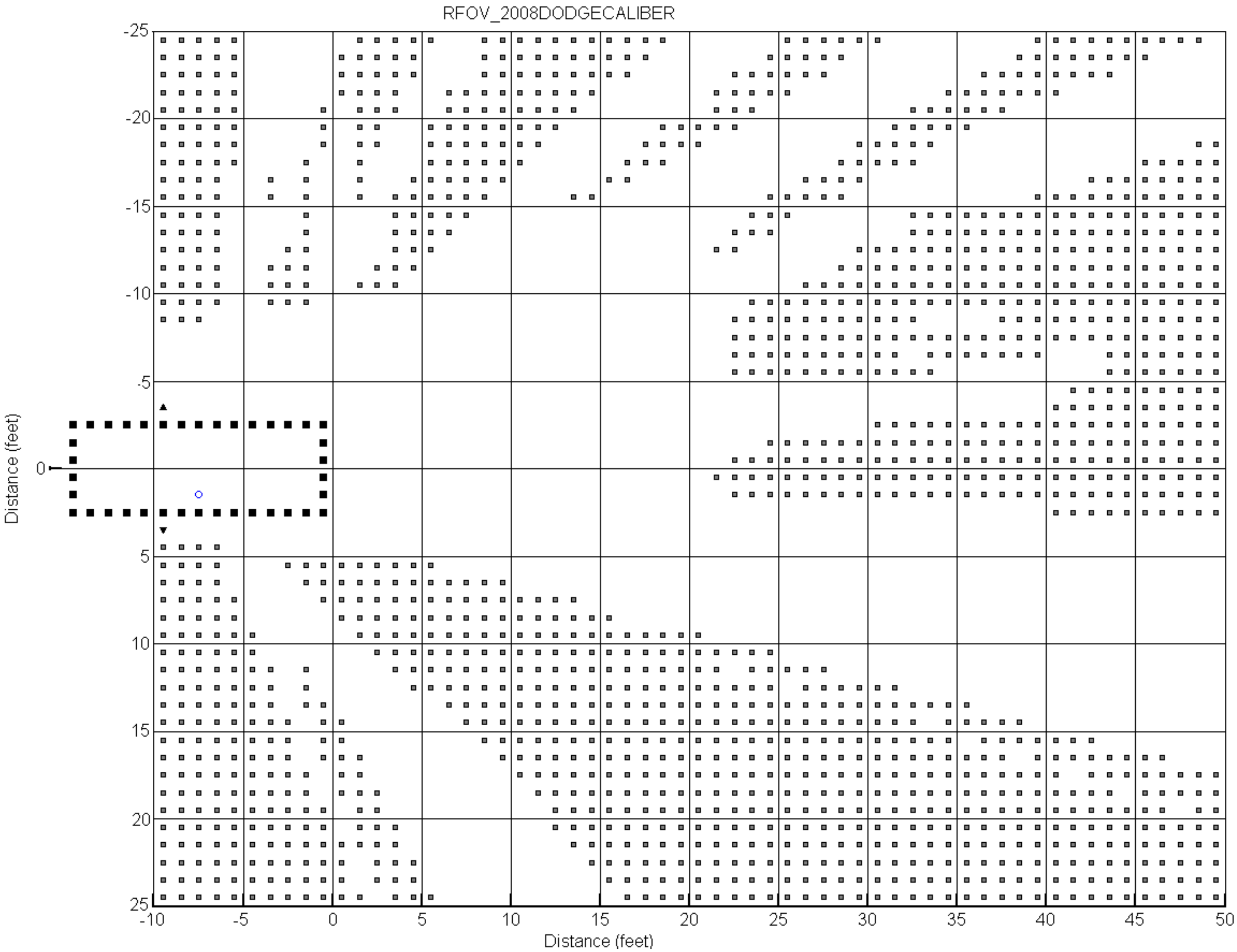

Figure 28. 2008 Dodge Caliber Rear Field of View Data Plot

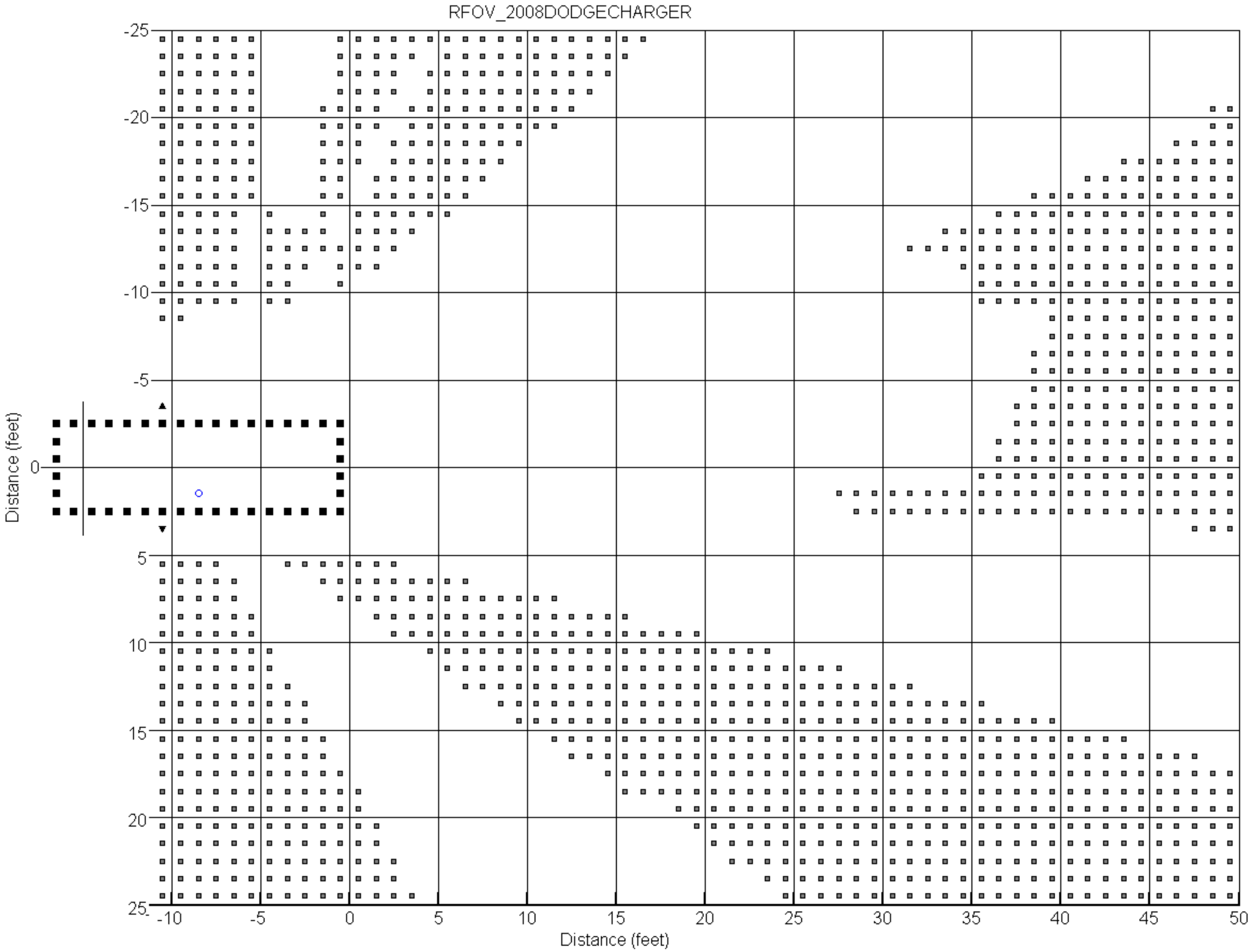

Figure 29. 2008 Dodge Charger Rear Field of View Data Plot

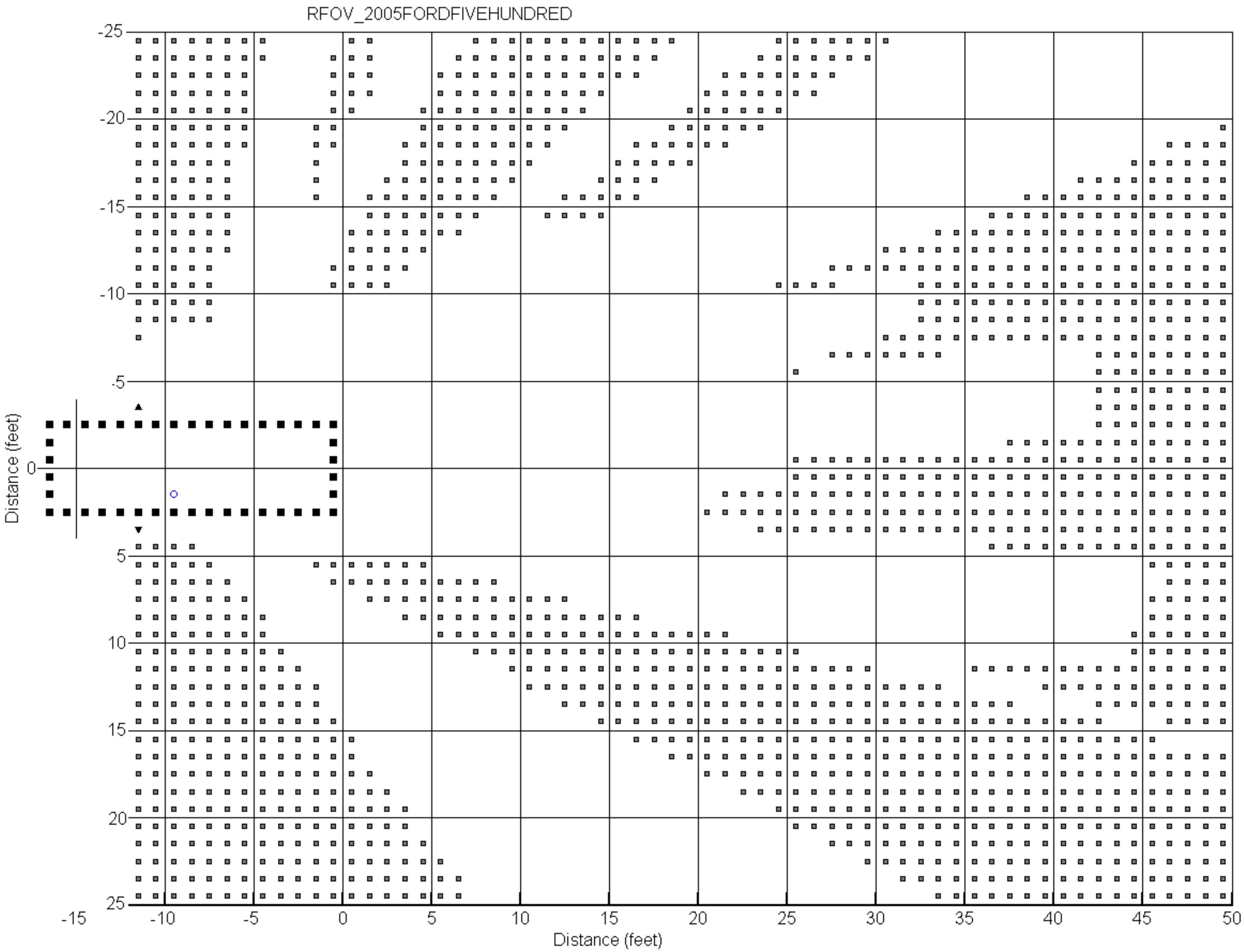

Figure 30. 2005 Ford Five Hundred Rear Field of View Data Plot

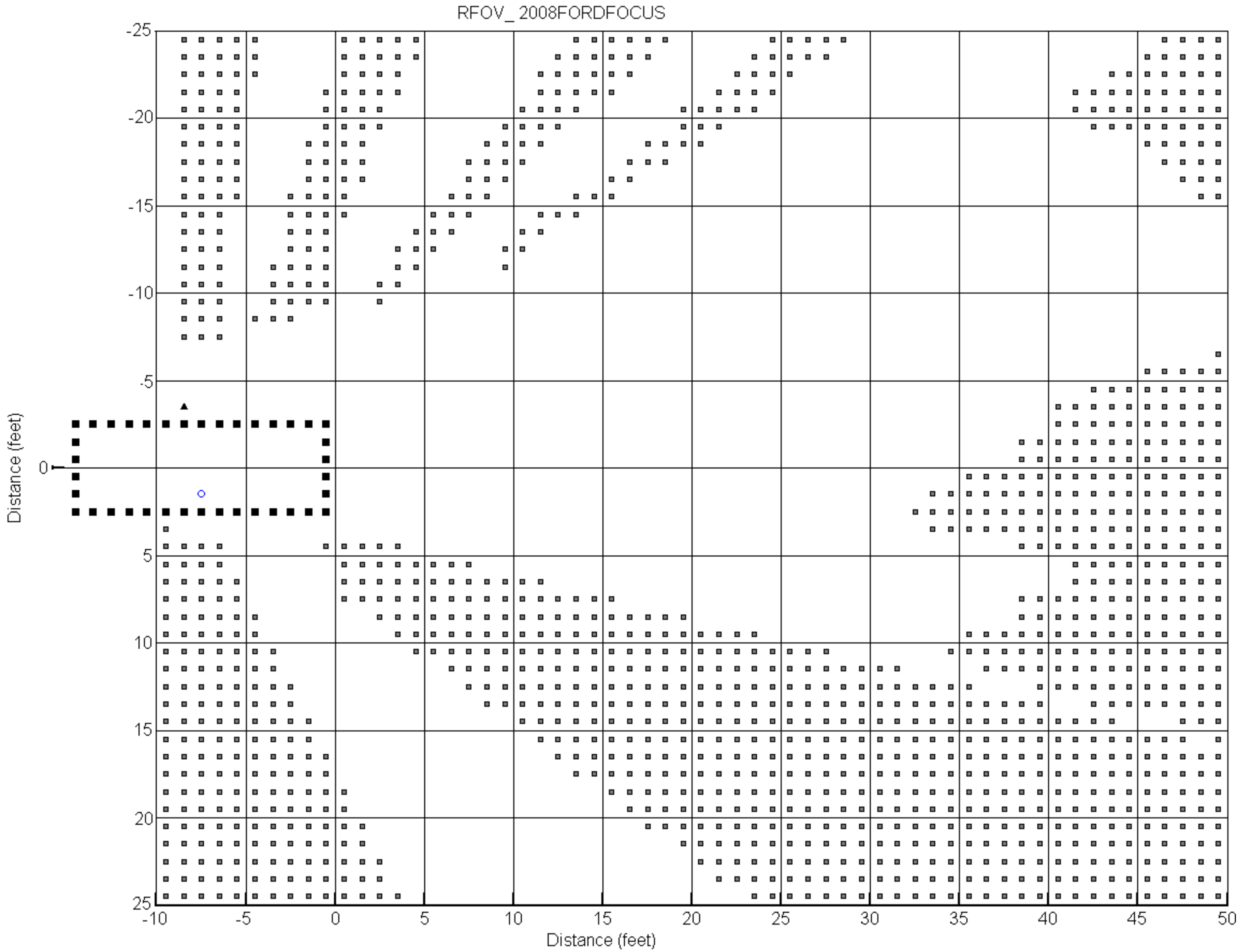

Figure 31. 2008 Ford Focus Rear Field of View Plot

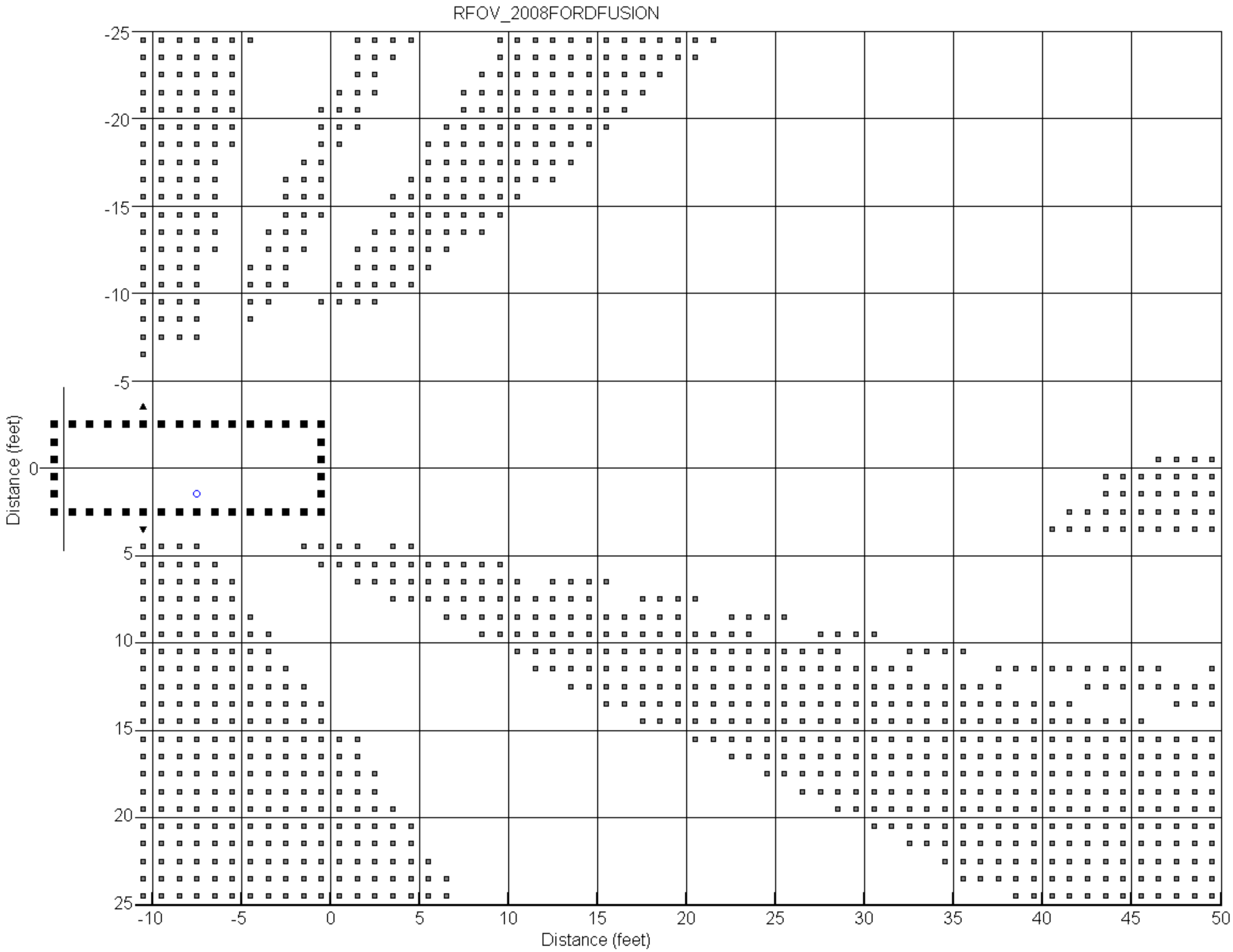

Figure 32. 2008 Ford Fusion Rear Field of View Data Plot

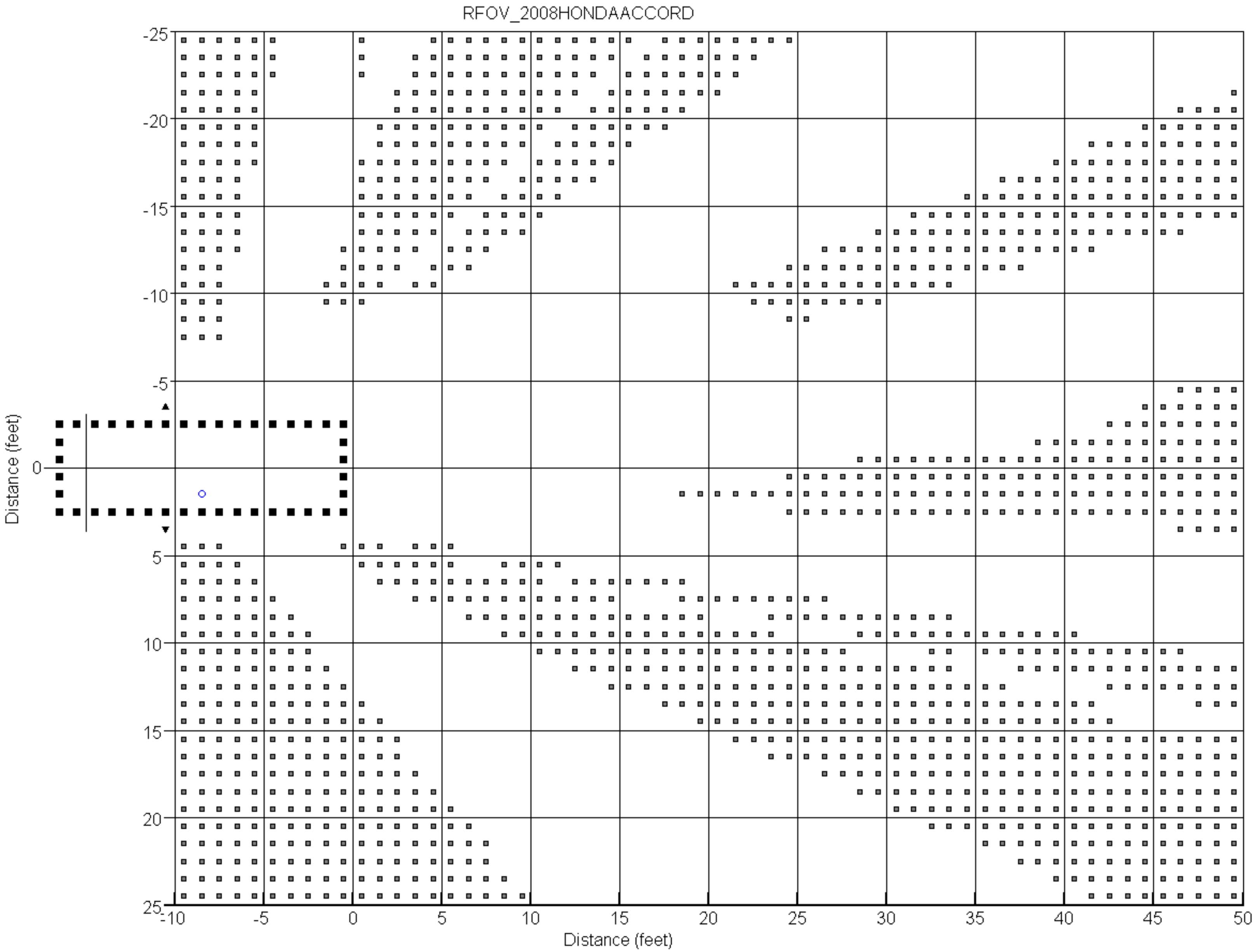

Figure 33. 2008 Honda Accord Rear Field of View Data Plot

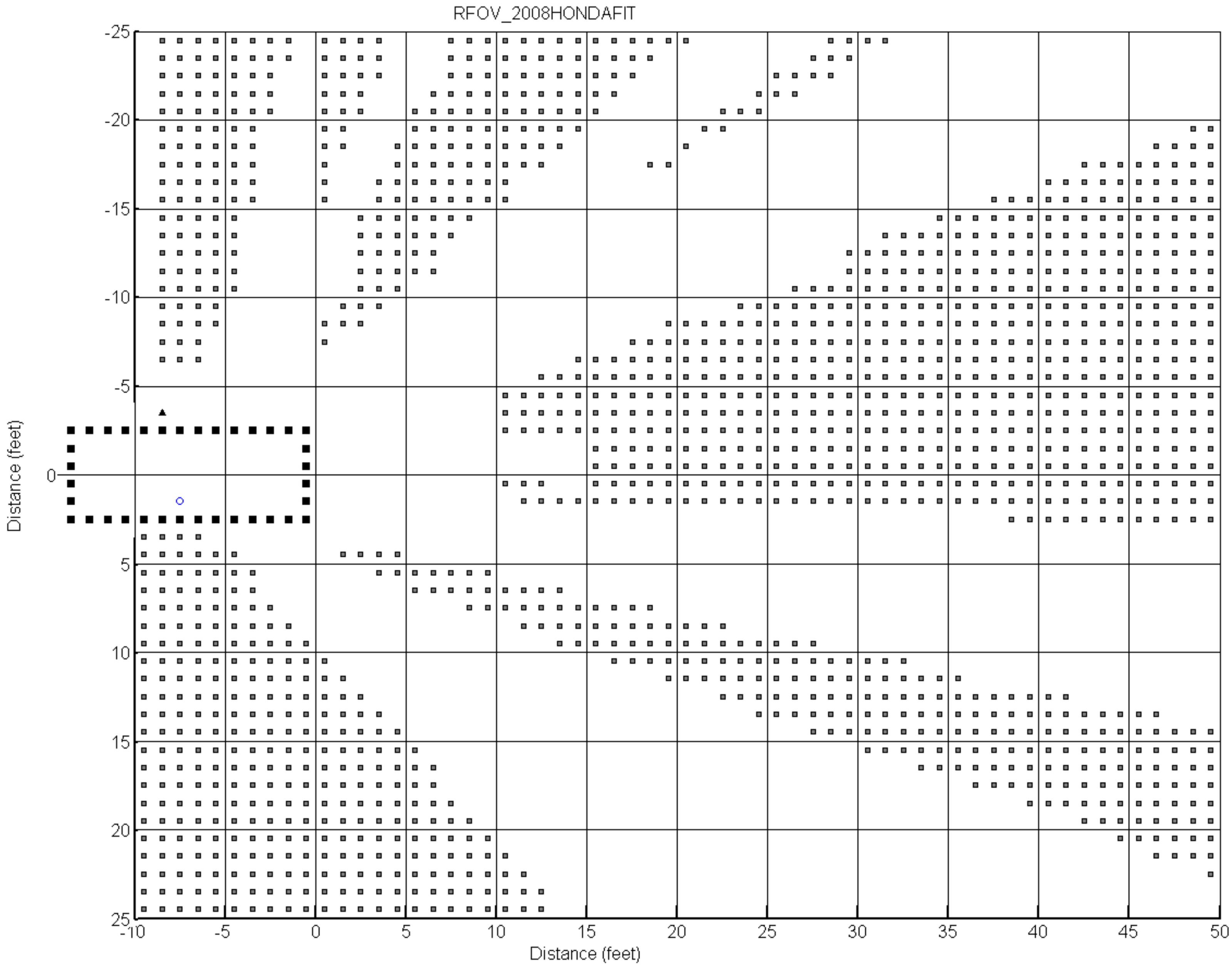

Figure 34. 2008 Honda Fit Rear Field of View Data Plot

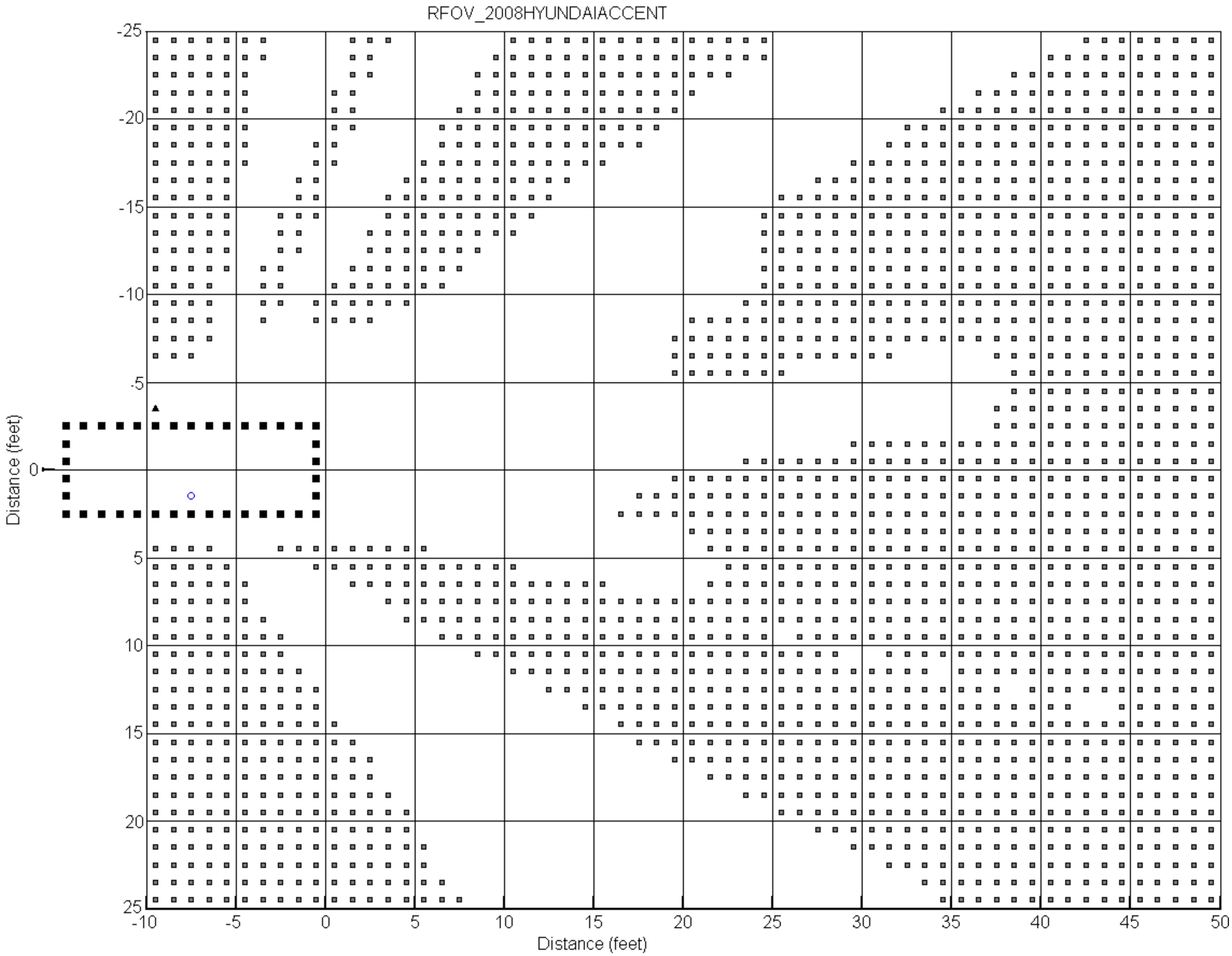

Figure 35.   2008 Hyundai Accent Rear Field of View Data Plot

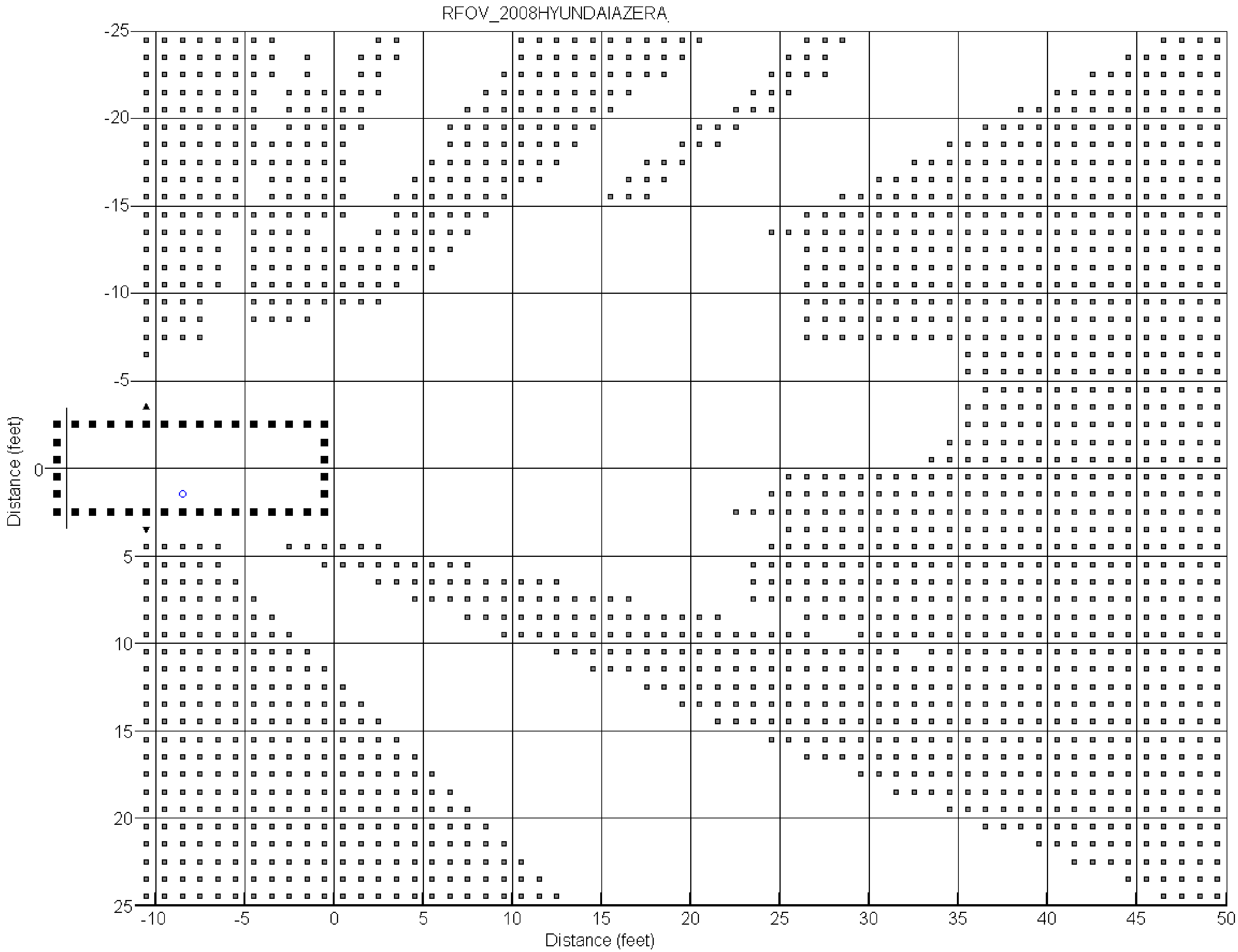

Figure 36. 2008 Hyundai Azera Rear Field of View Data Plot

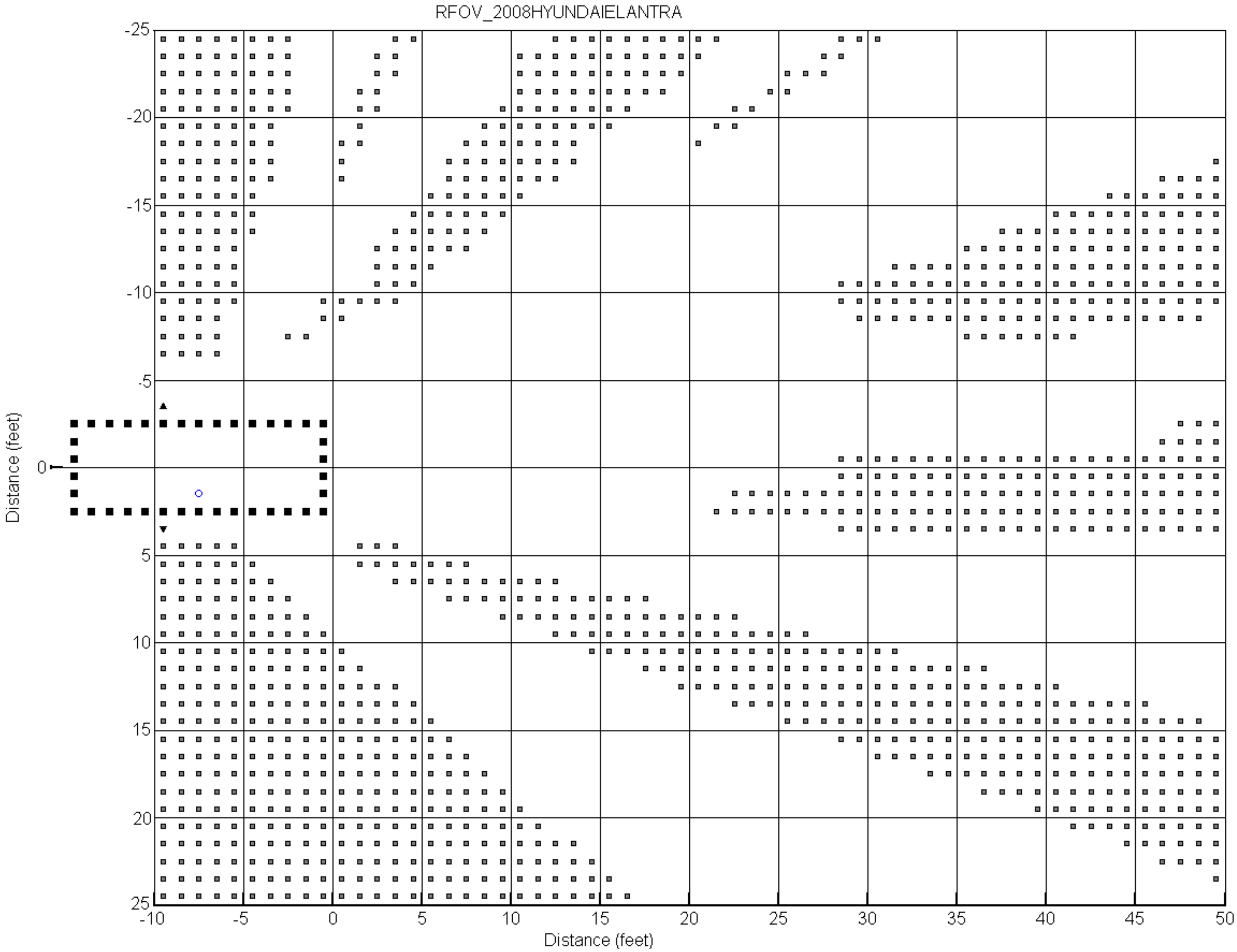

Figure 37. 2008 Hyundai Elantra Rear Field of View Data Plot

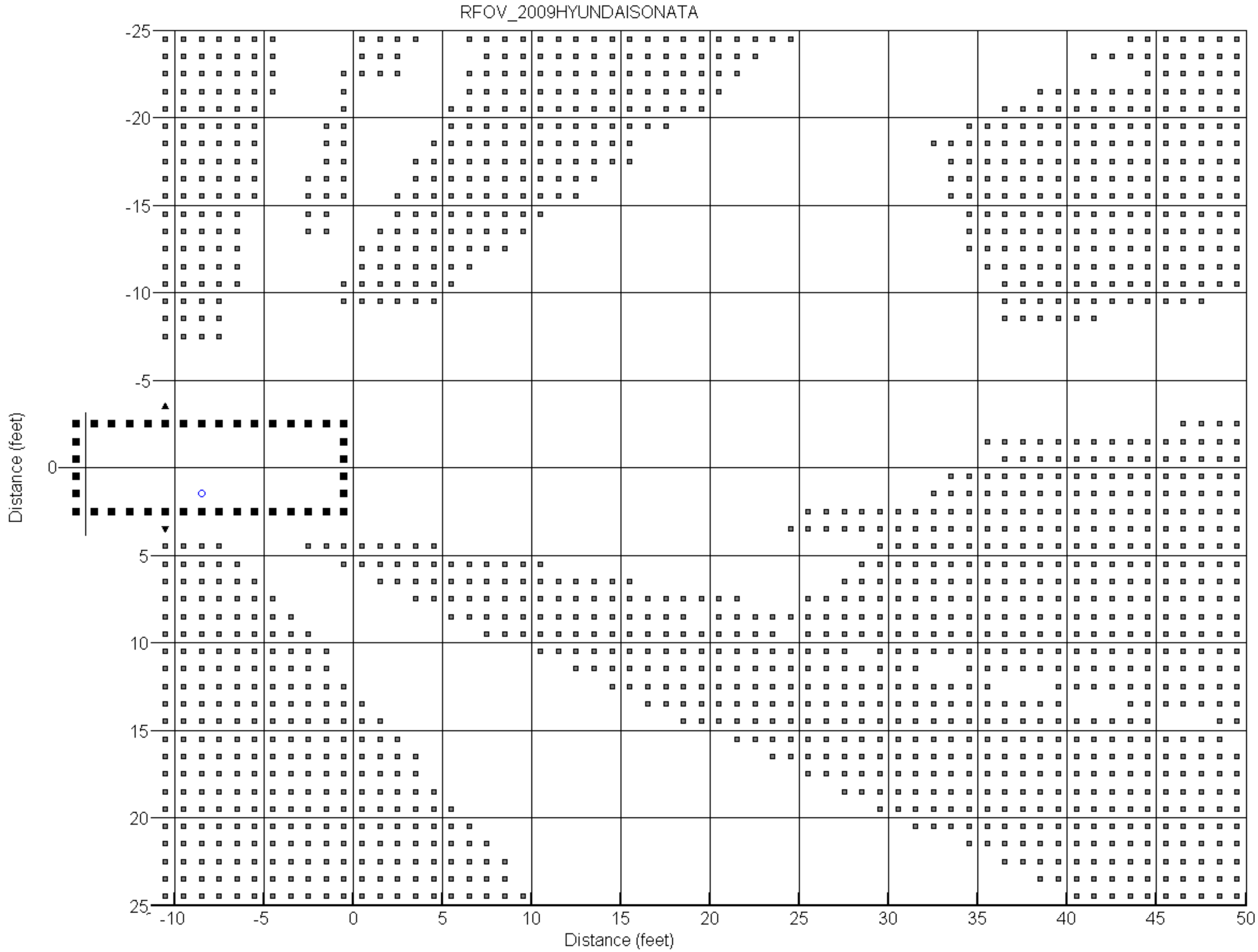

Figure 38. 2009 Hyundai Sonata Rear Field of View Data Plot

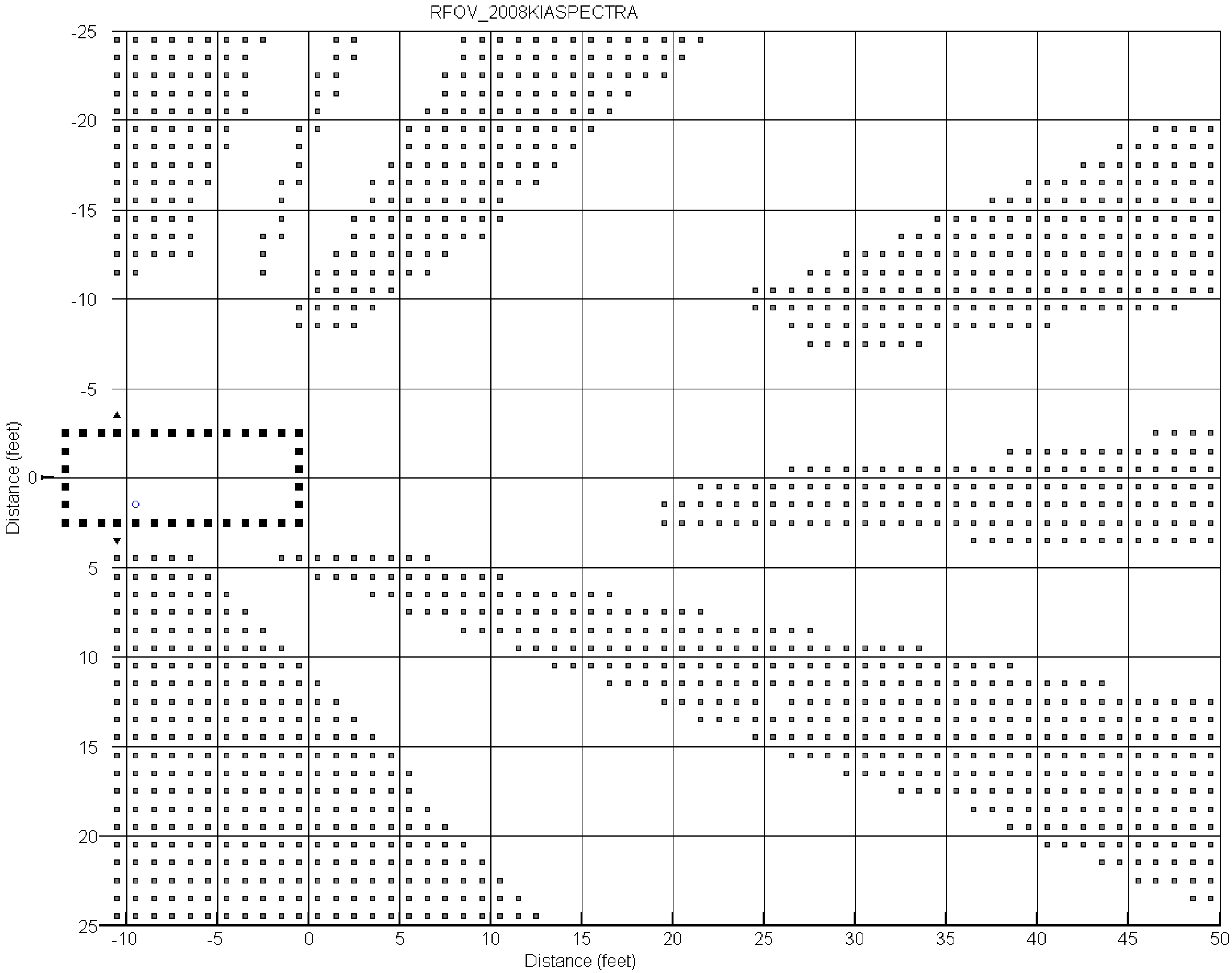

Figure 39. 2008 Kia Spectra Rear Field of View Data Plot

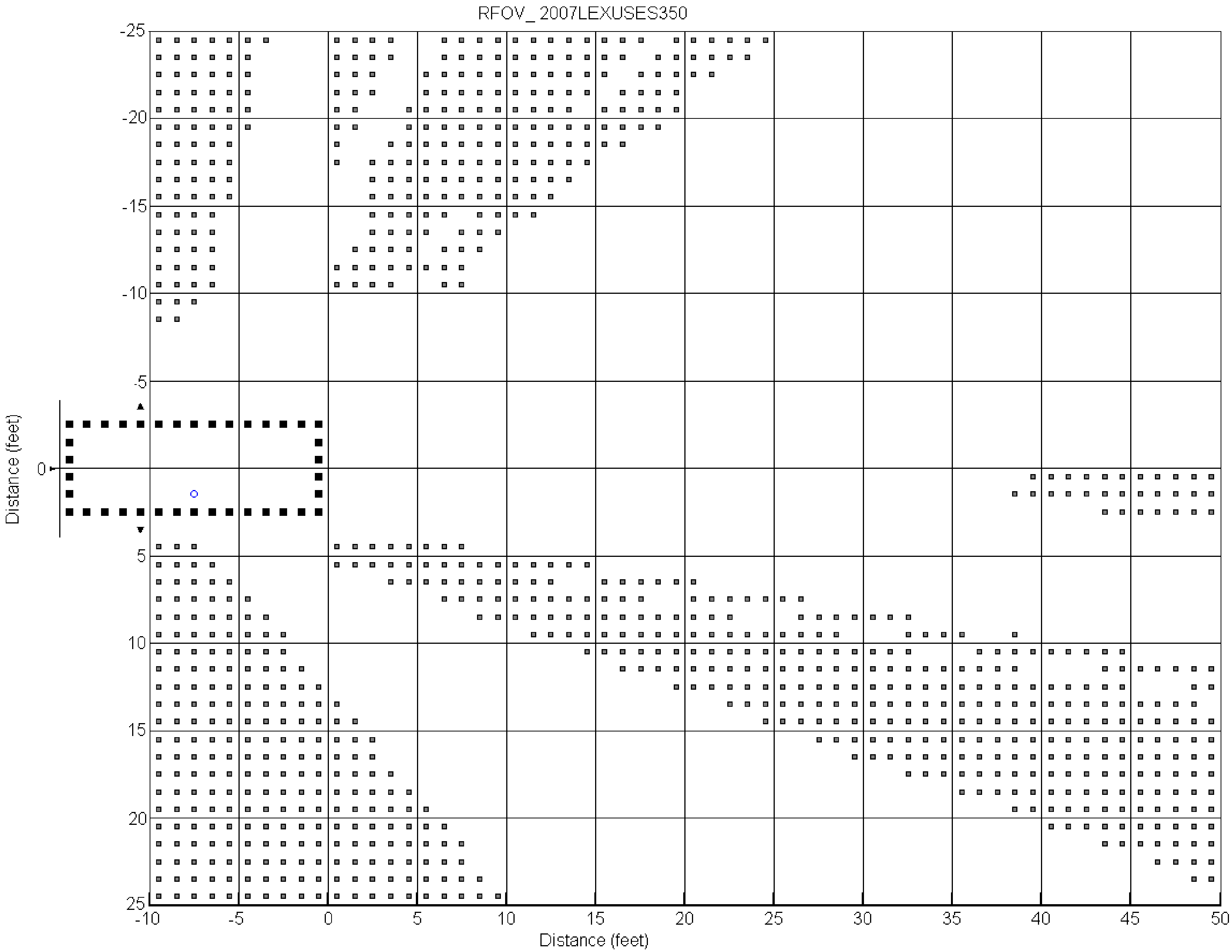

Figure 40. 2007 Lexus ES 350 Rear Field of View Data Plot

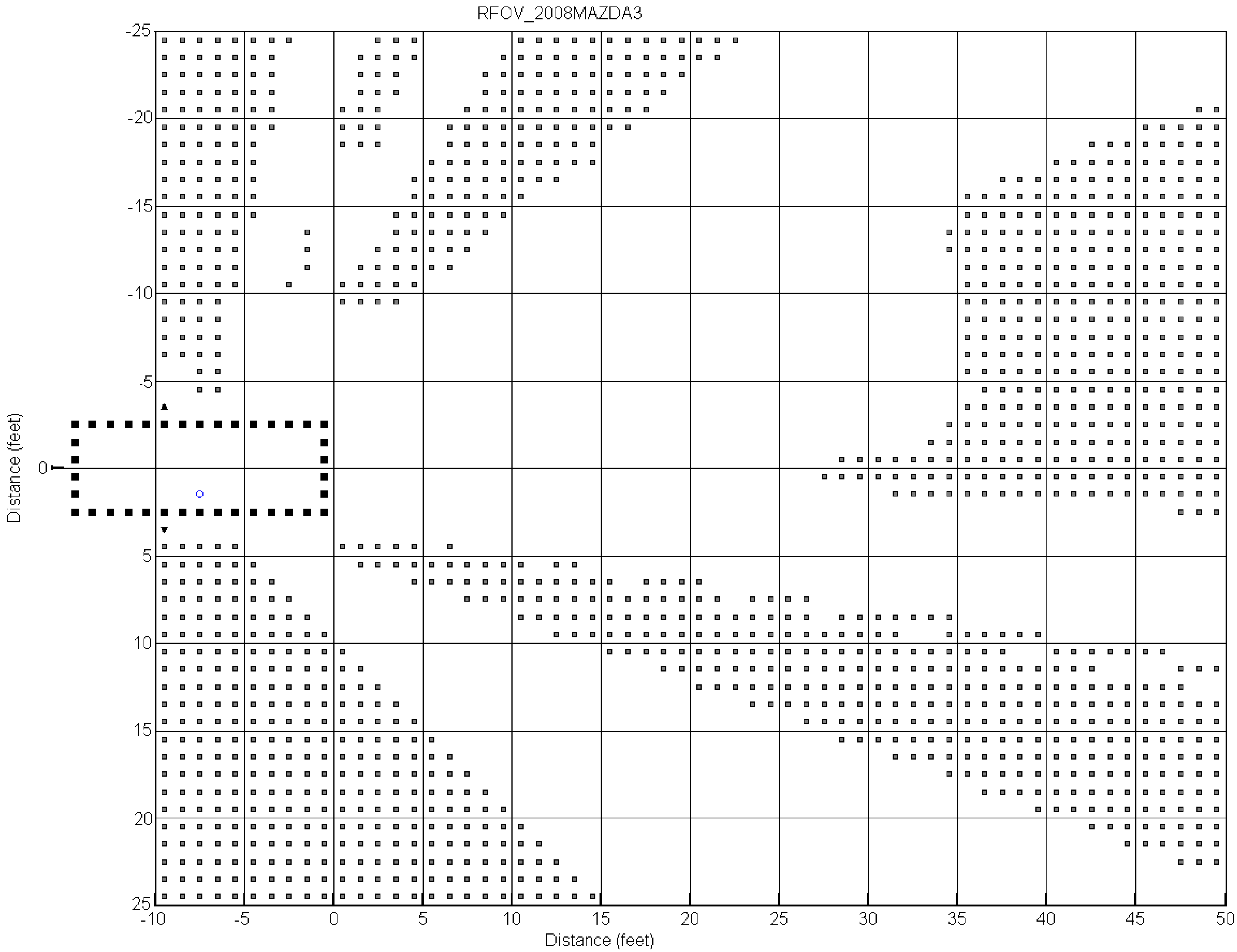

Figure 41. 2008 Mazda 3 Rear Field of View Data Plot

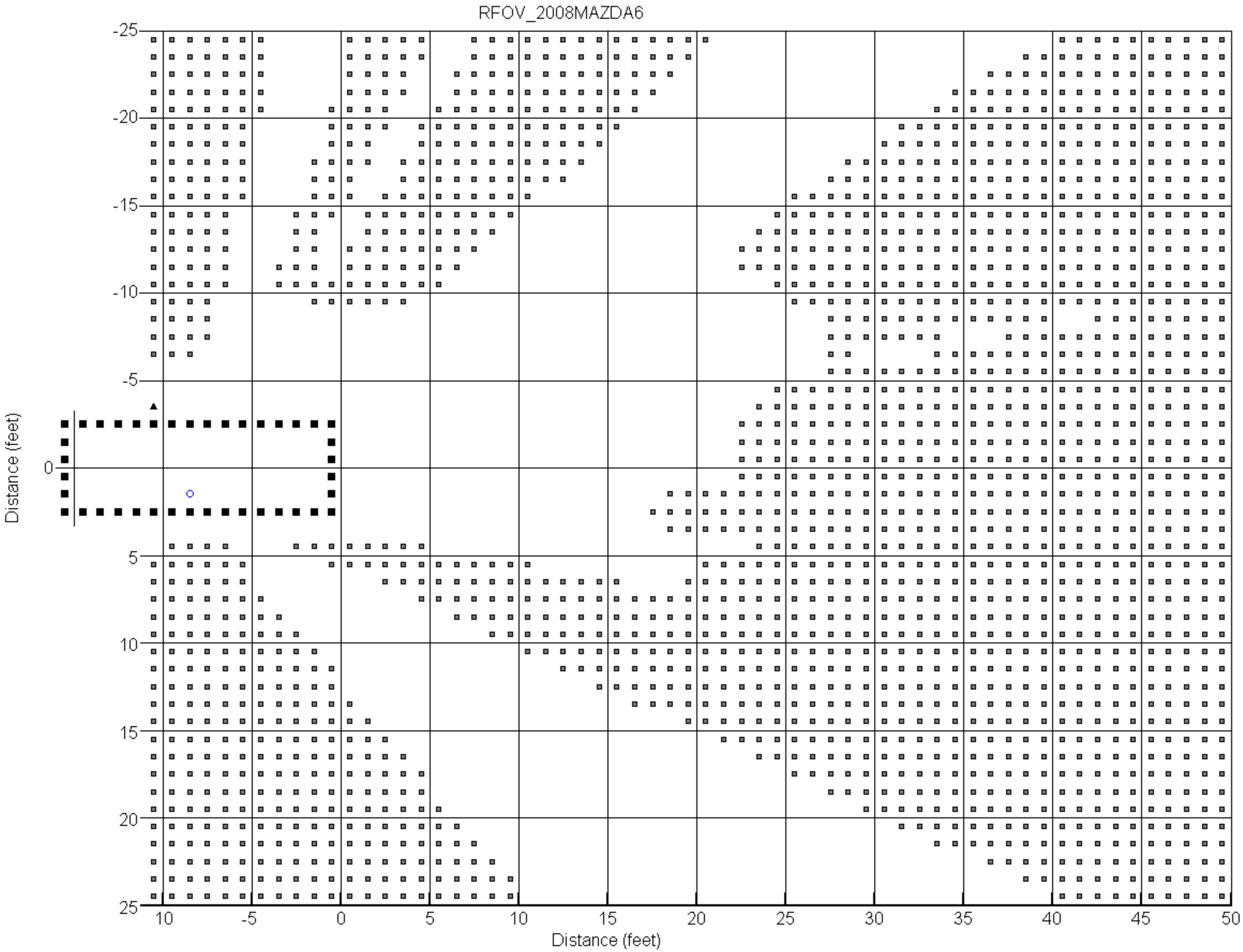

Figure 42. 2008 Mazda 6 Rear Field of View Data Plot

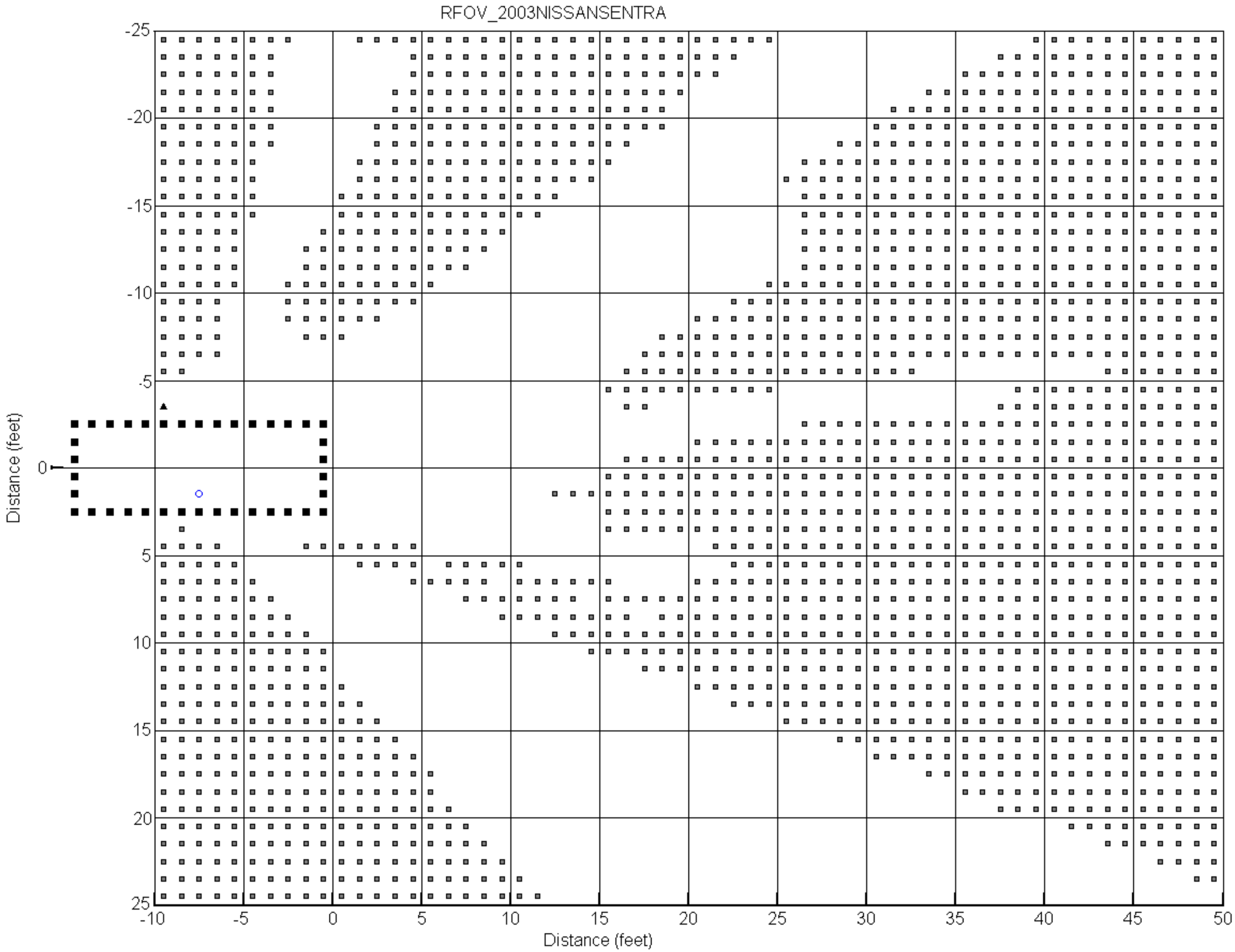

Figure 43. 2003 Nissan Sentra Rear Field of View Data Plot

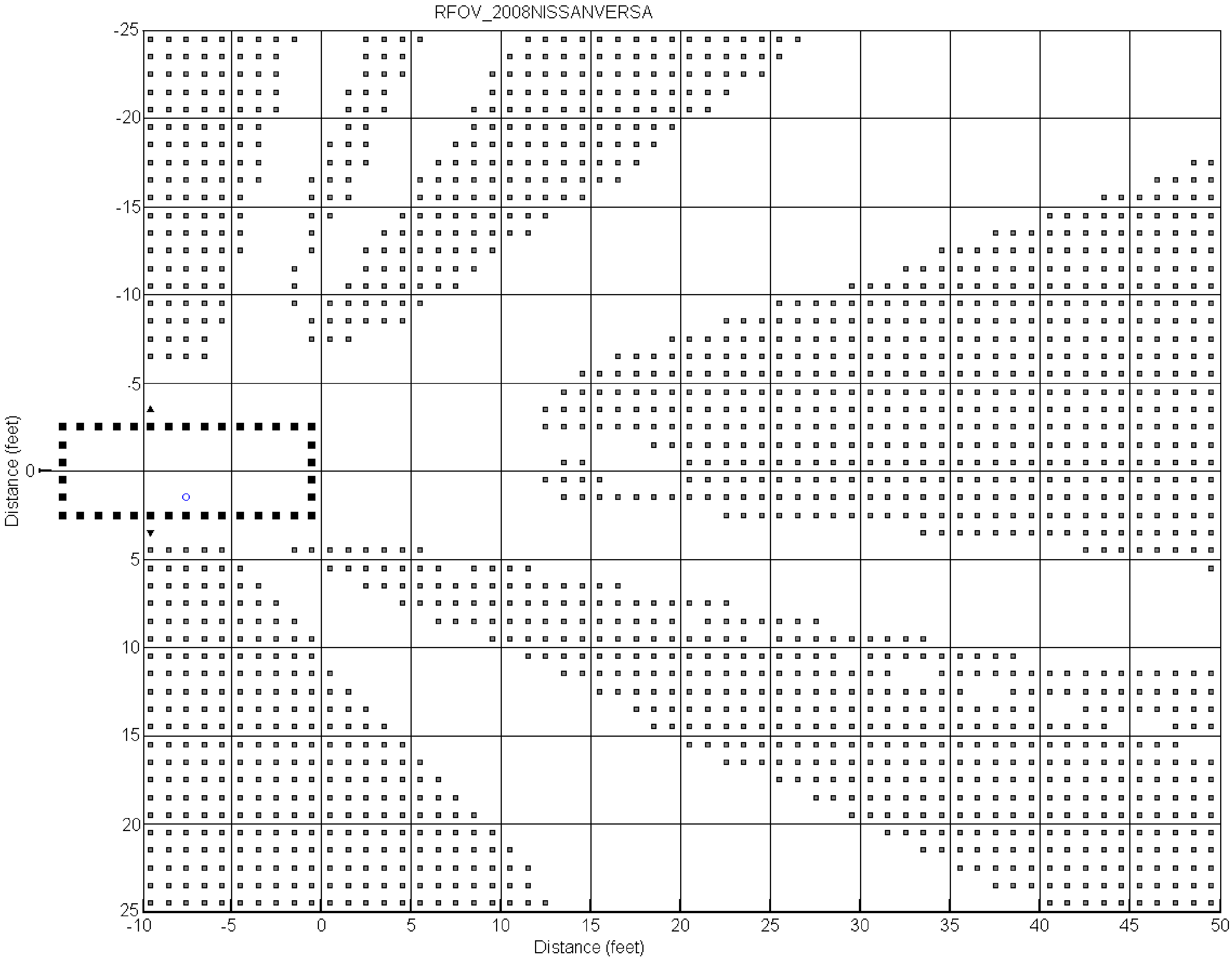

Figure 44. 2008 Nissan Versa Rear Field of View Data Plot

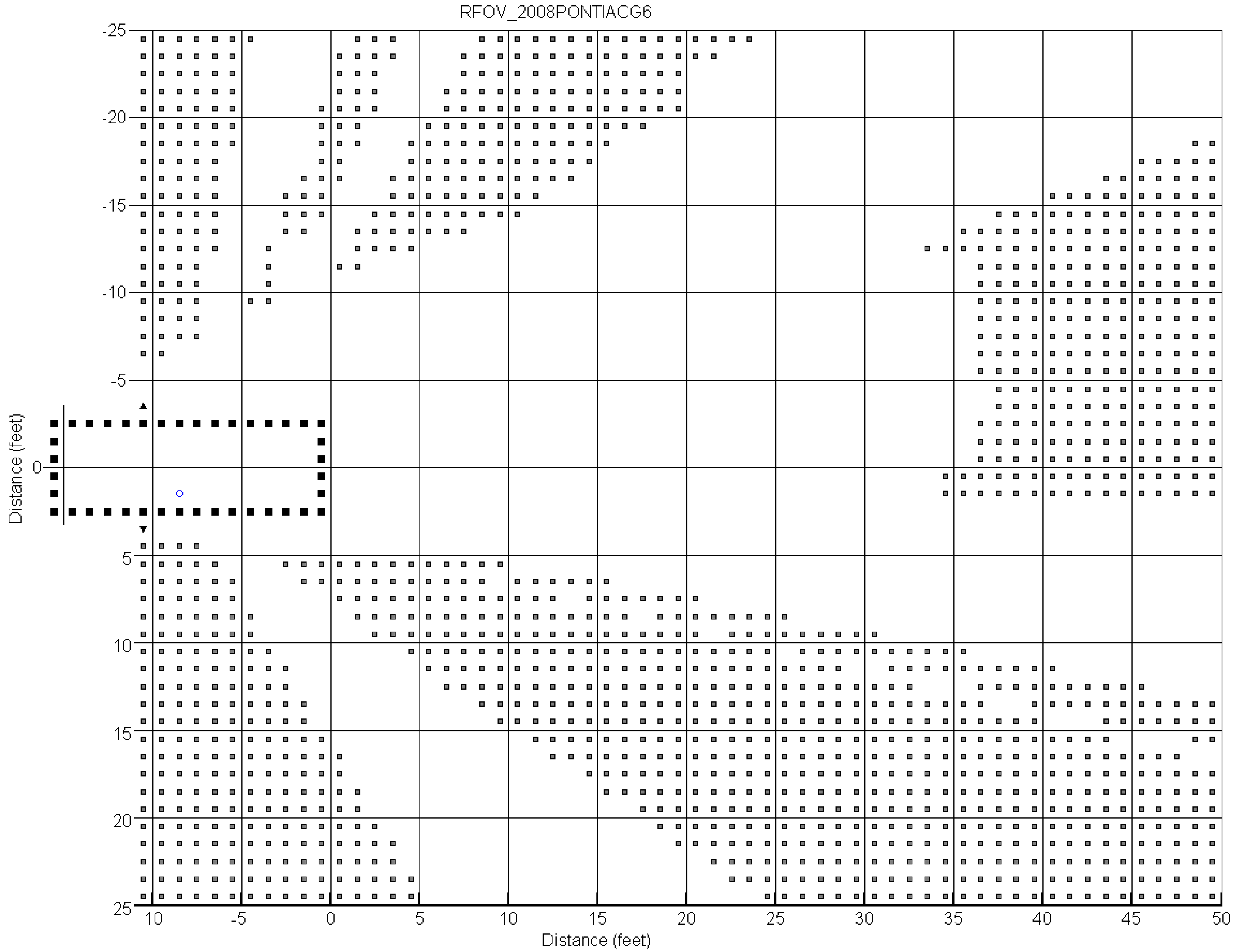

Figure 45. 2008 Pontiac G6 Rear Field of View Data Plot

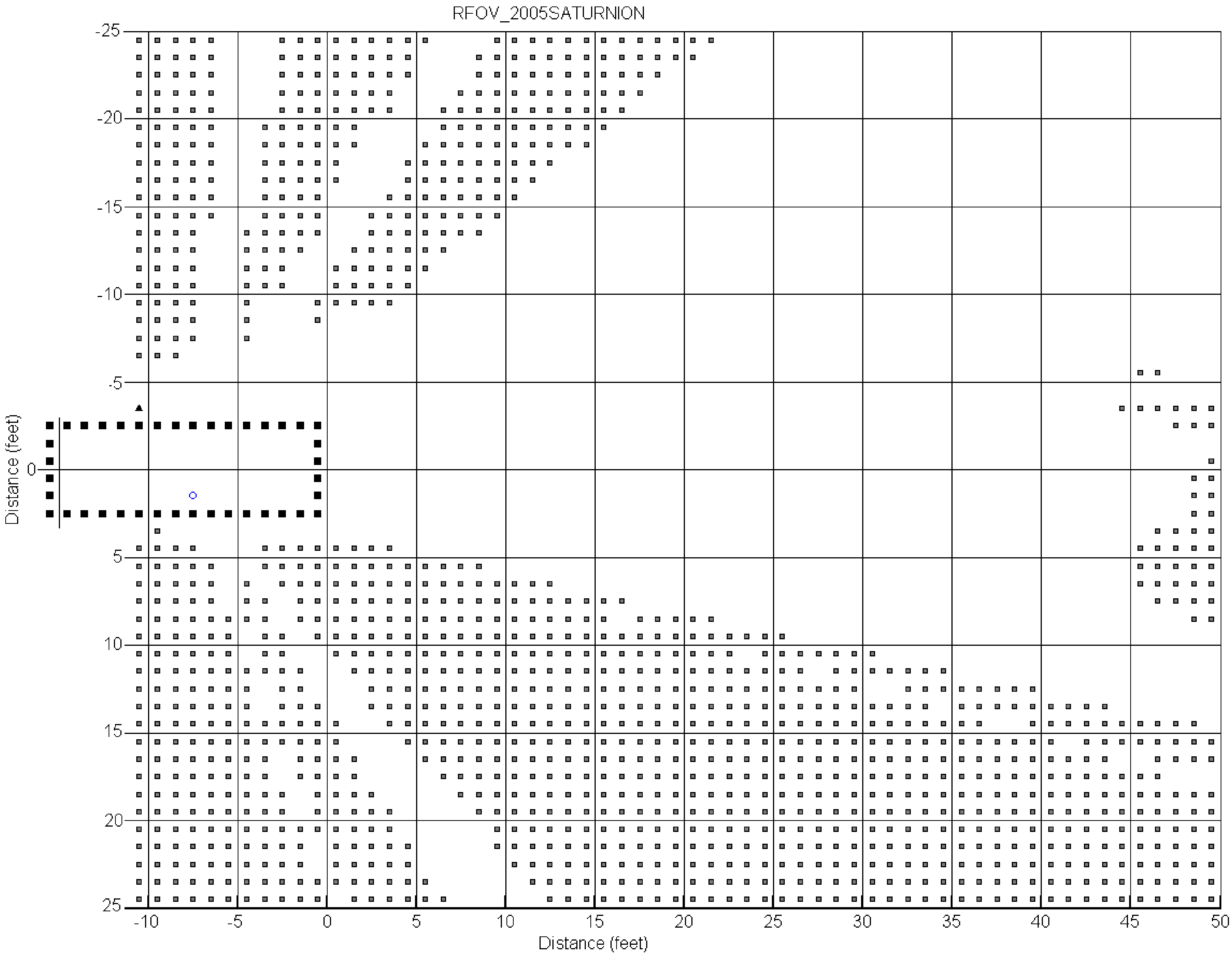

Figure 46. 2005 Saturn Ion Rear Field of View Data Plot

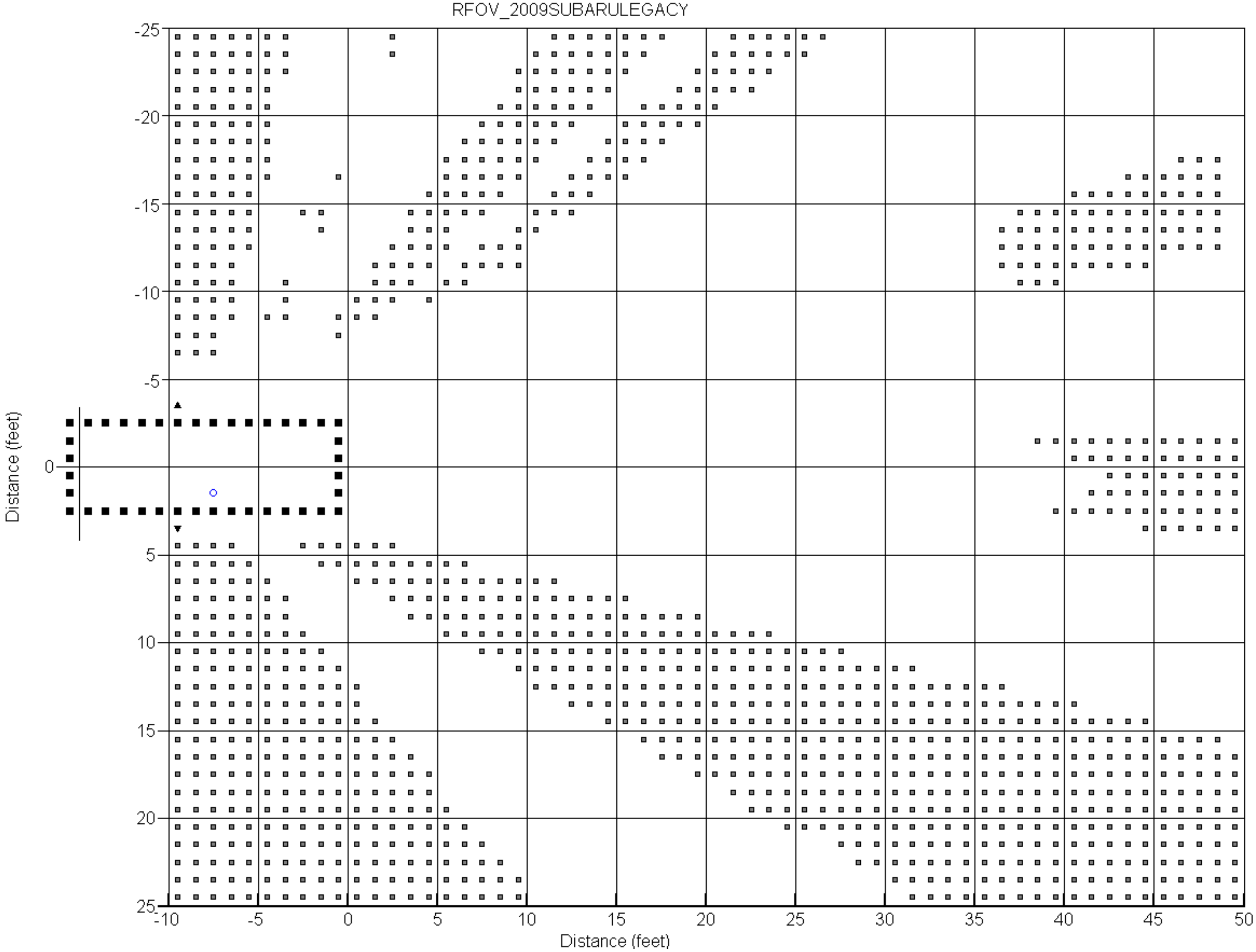

Figure 47. 2009 Subaru Legacy Rear Field of View Data Plot

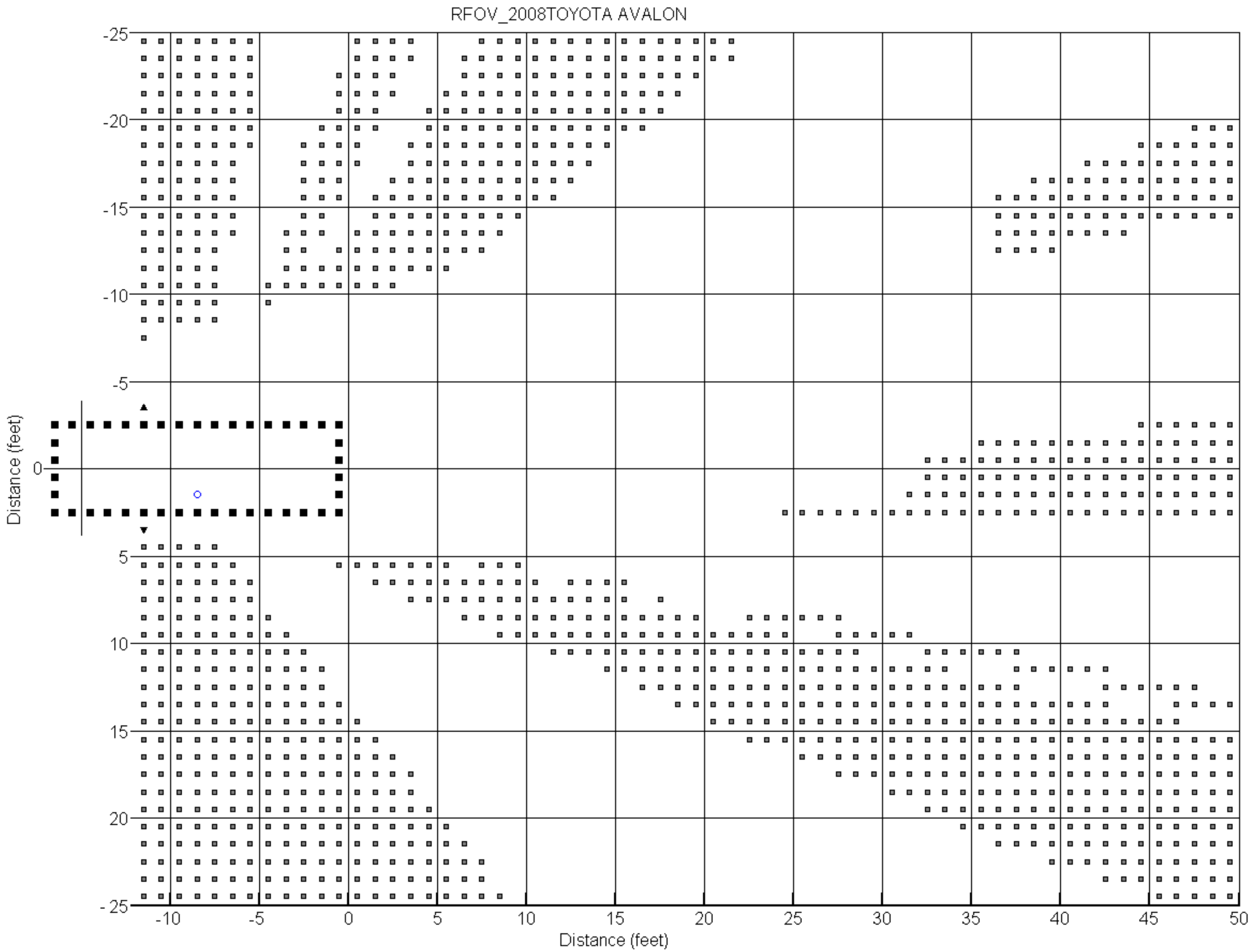

Figure 48. 2008 Toyota Avalon Rear Field of View Data Plot

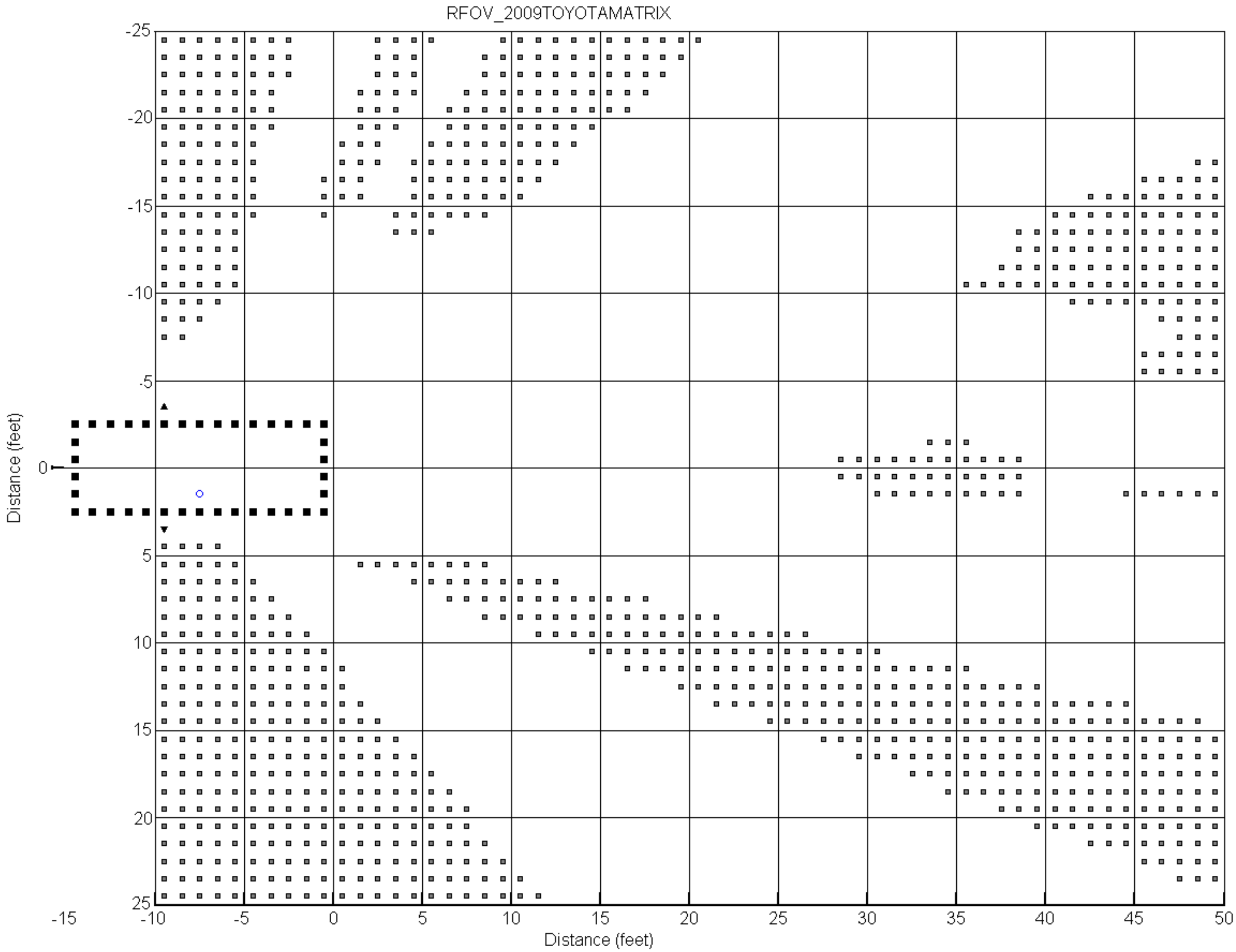

Figure 49. 2009 Toyota Matrix Rear Field of View Data Plot

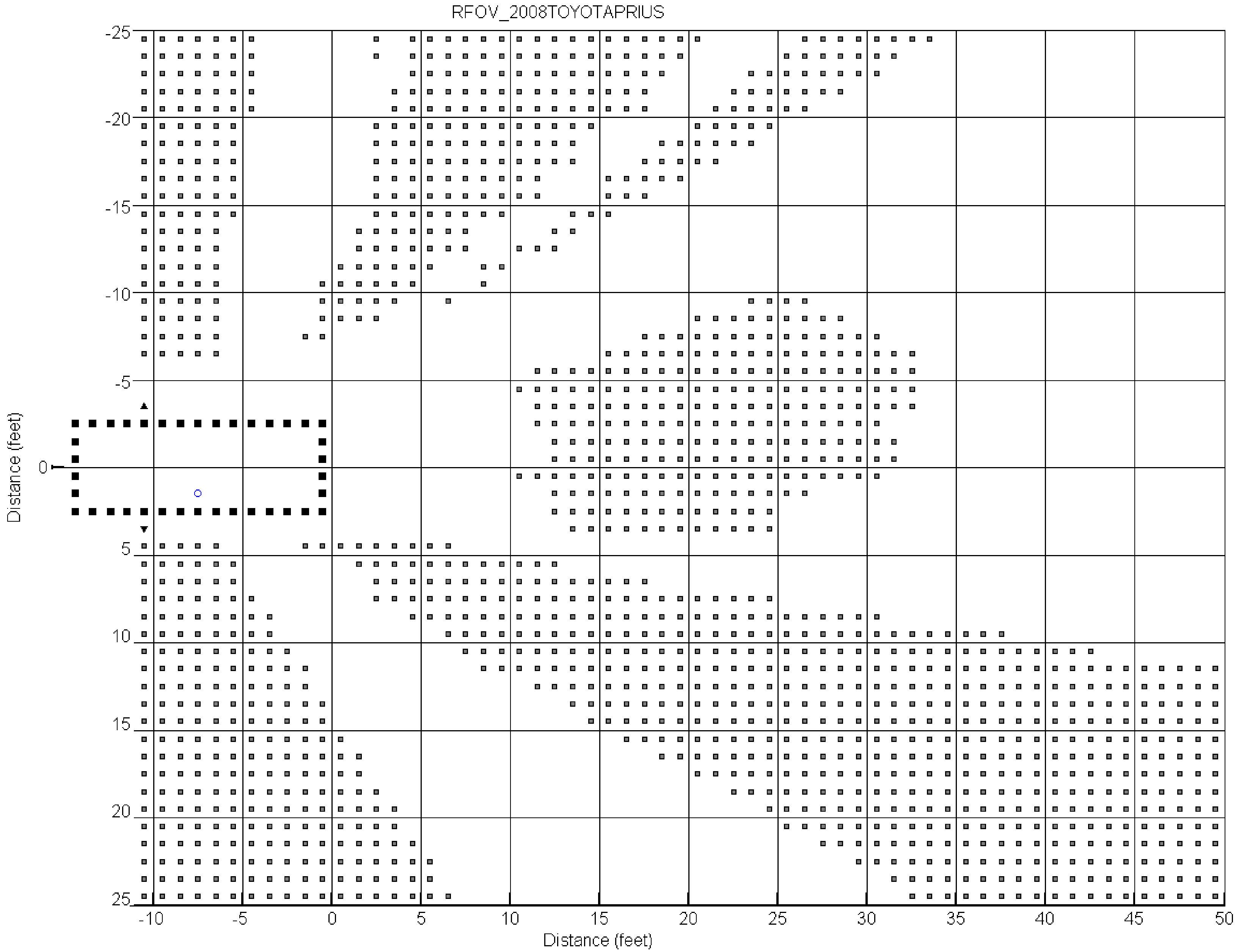

Figure 50. 2008 Toyota Prius Rear Field of View Data Plot

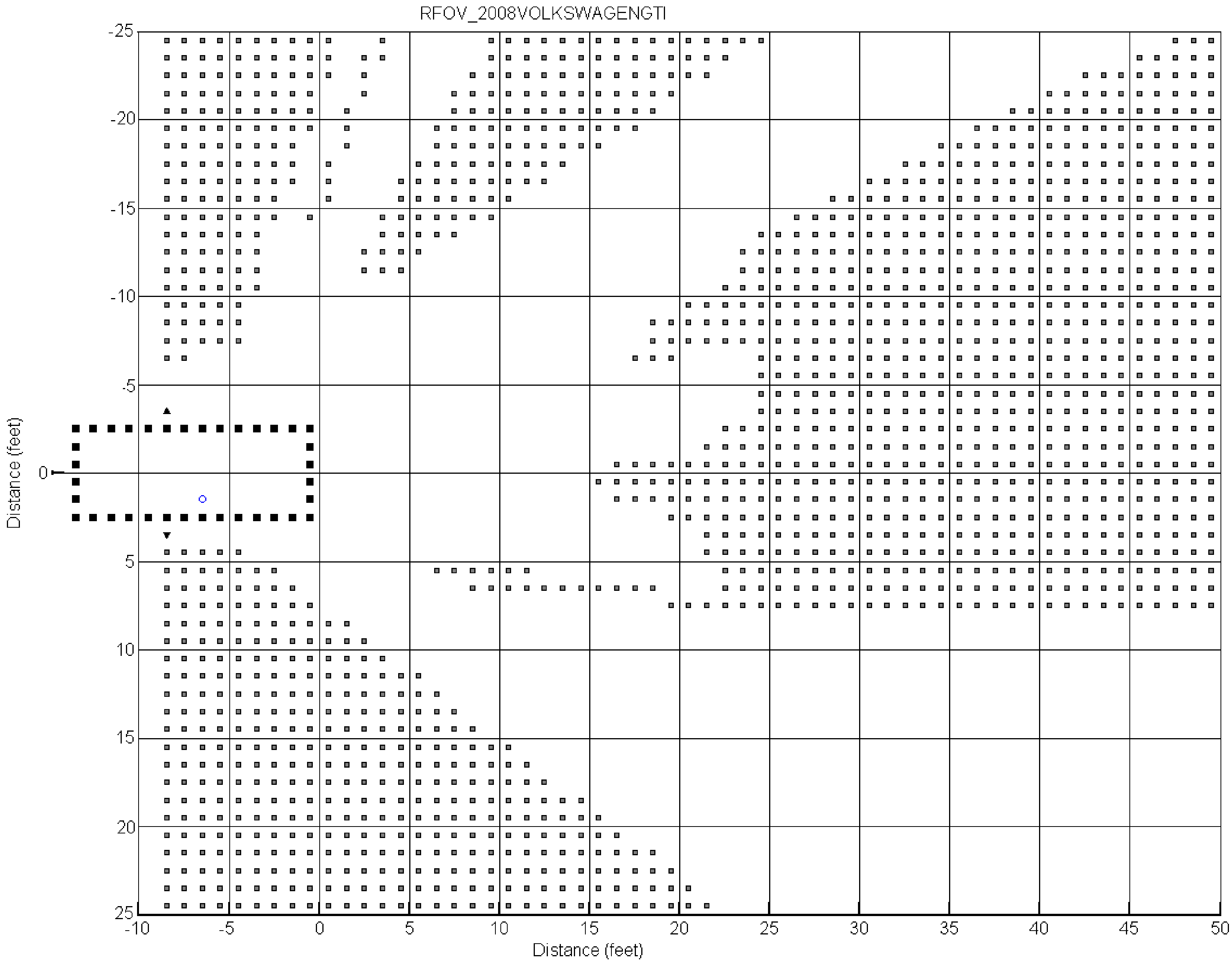

Figure 51. 2008 Volkswagen GTI Rear Field of View Data Plot

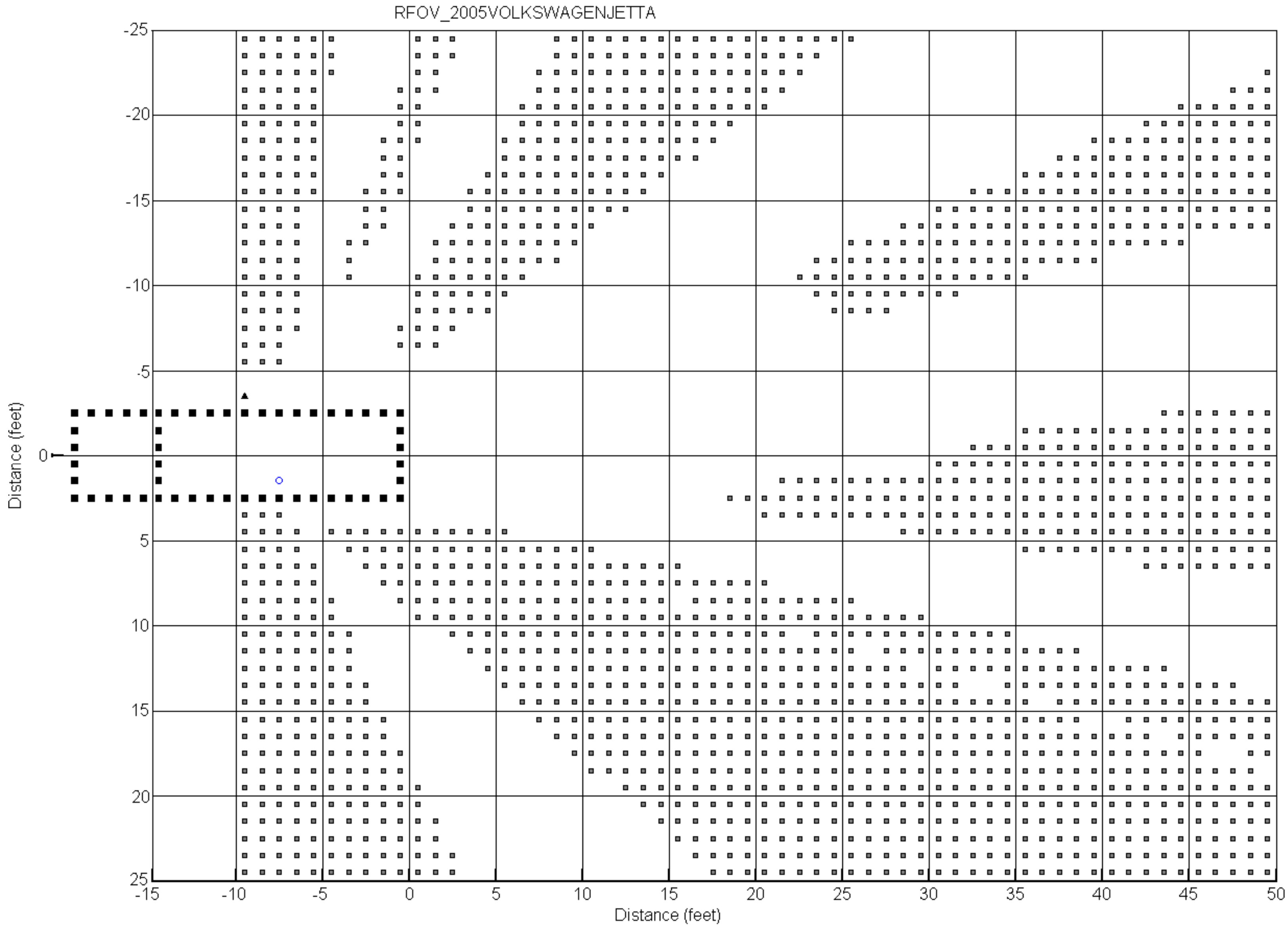

Figure 52. 2005 Volkswagen Jetta Rear Field of View Data Plot

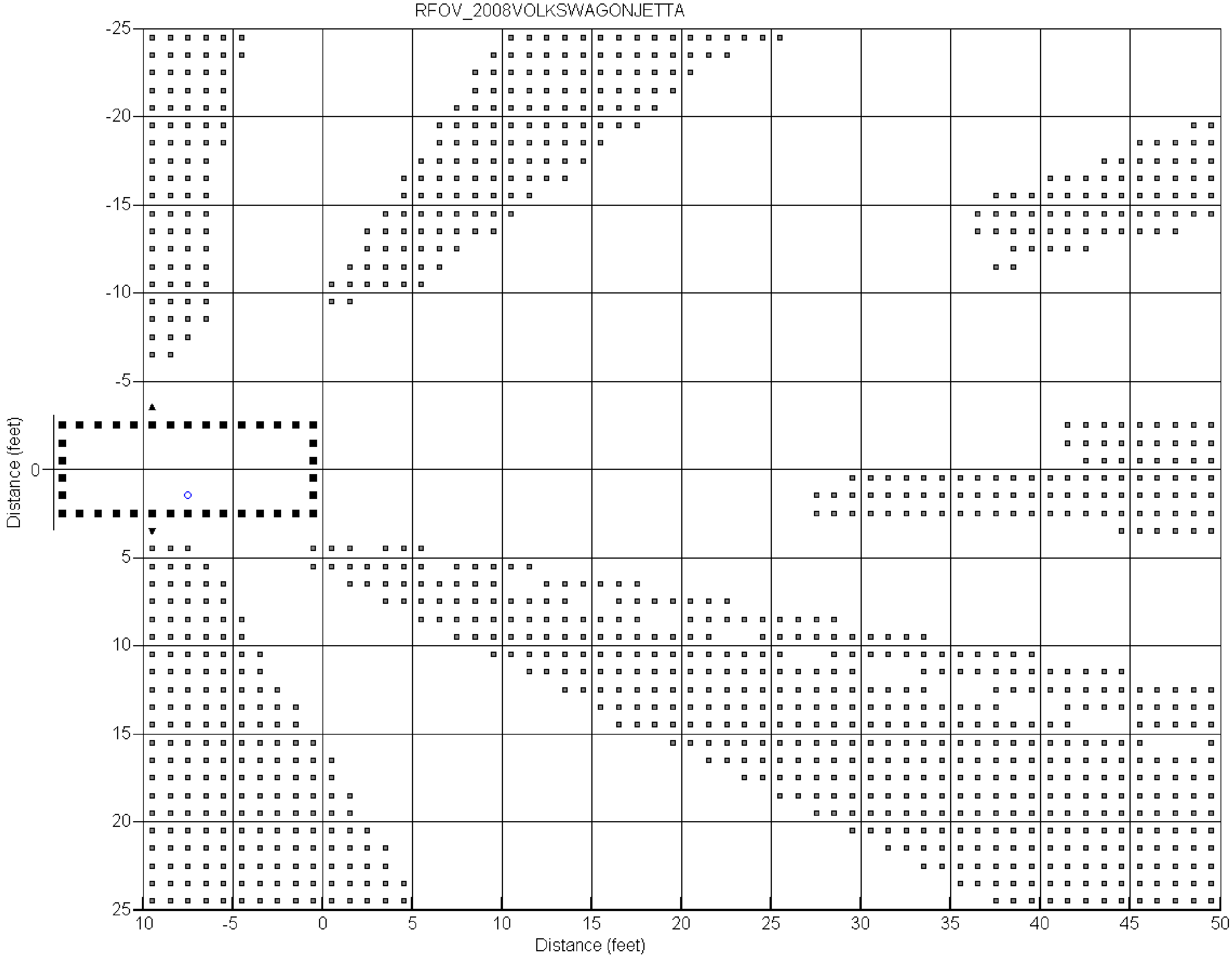

Figure 53. 2008 Volkswagen Jetta Rear Field of View Data Plot

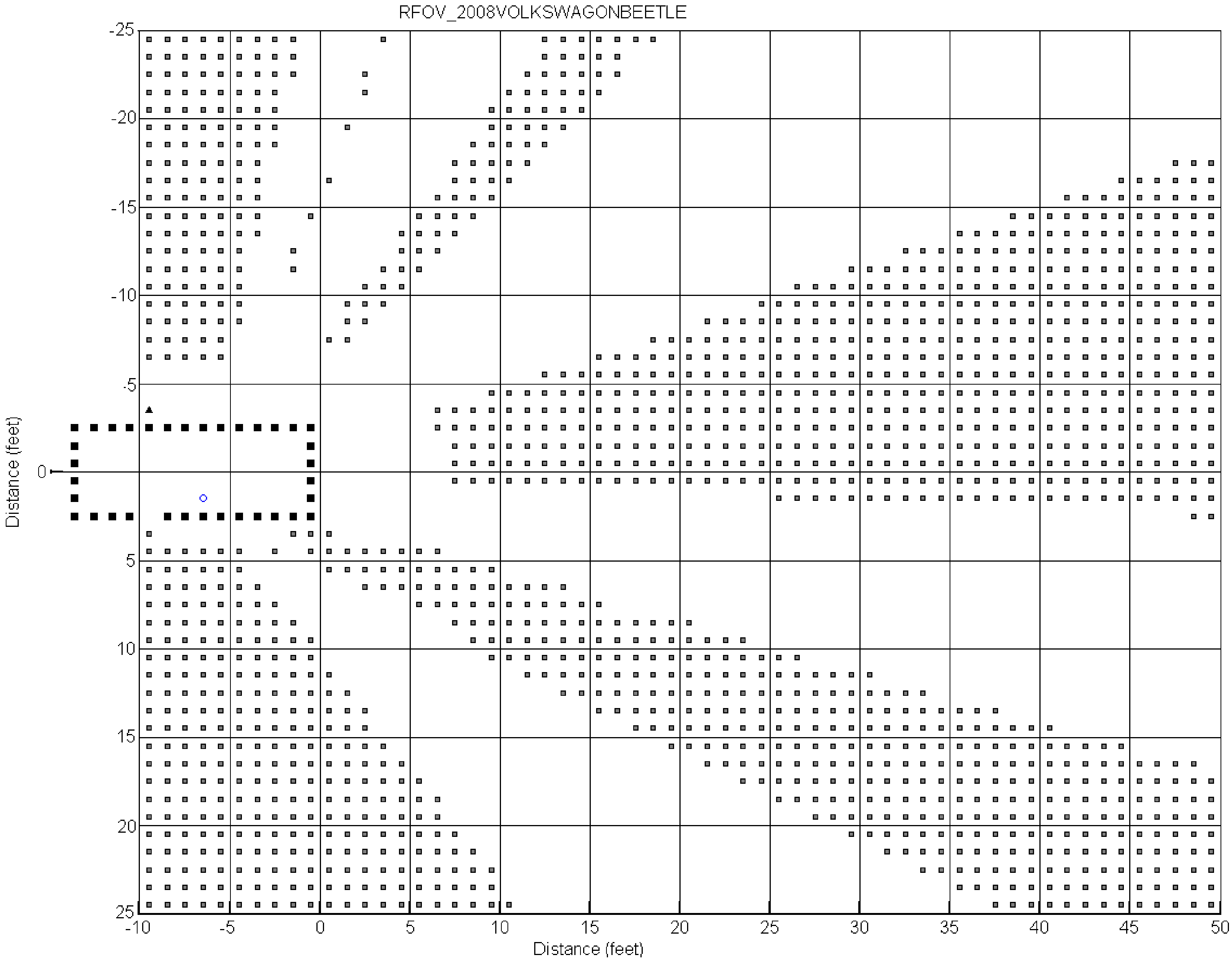

Figure 54. 2008 Volkswagen New Beetle Rear Field of View Data Plot

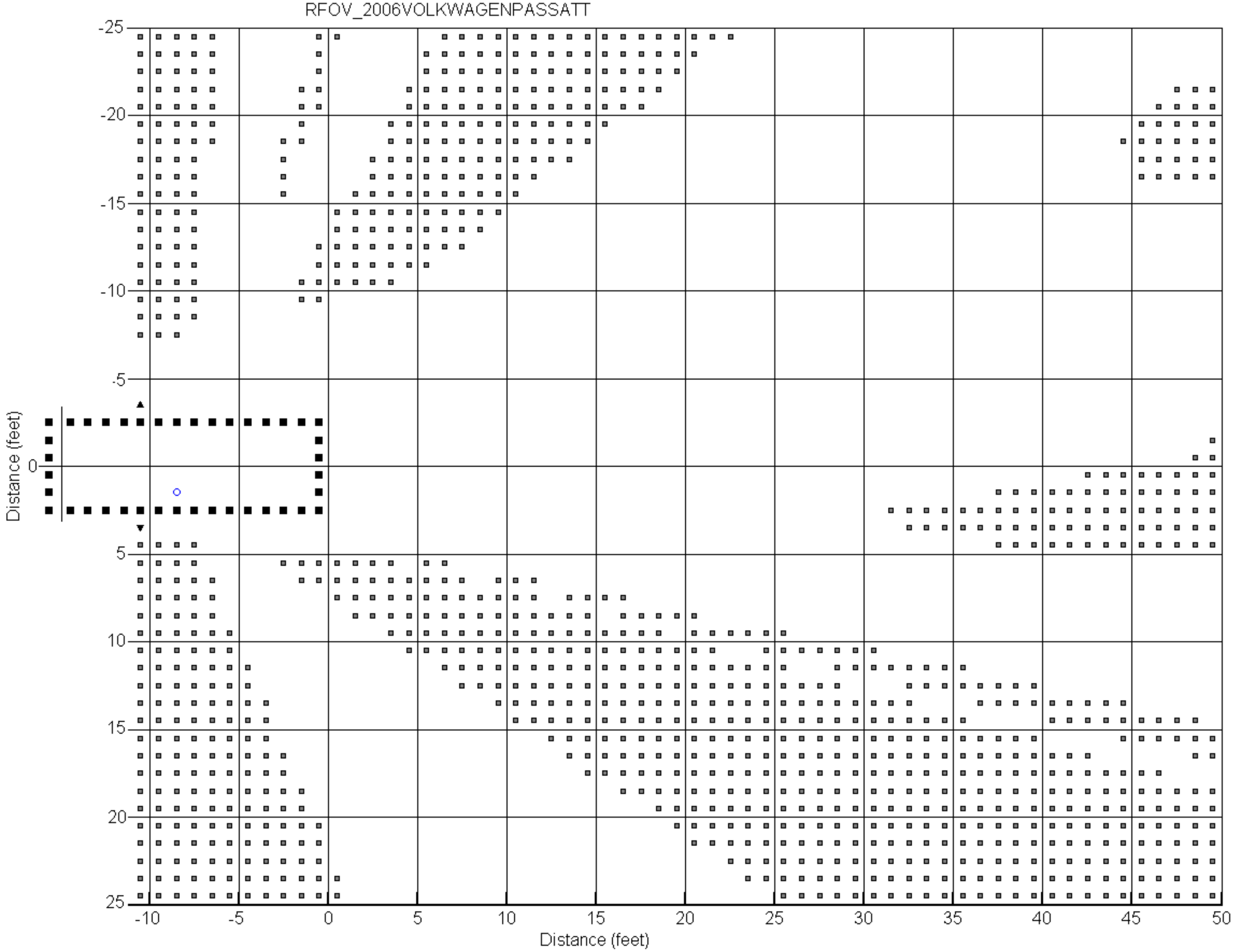

Figure 55. 2006 Volkswagen Passat Rear Field of View Data Plot

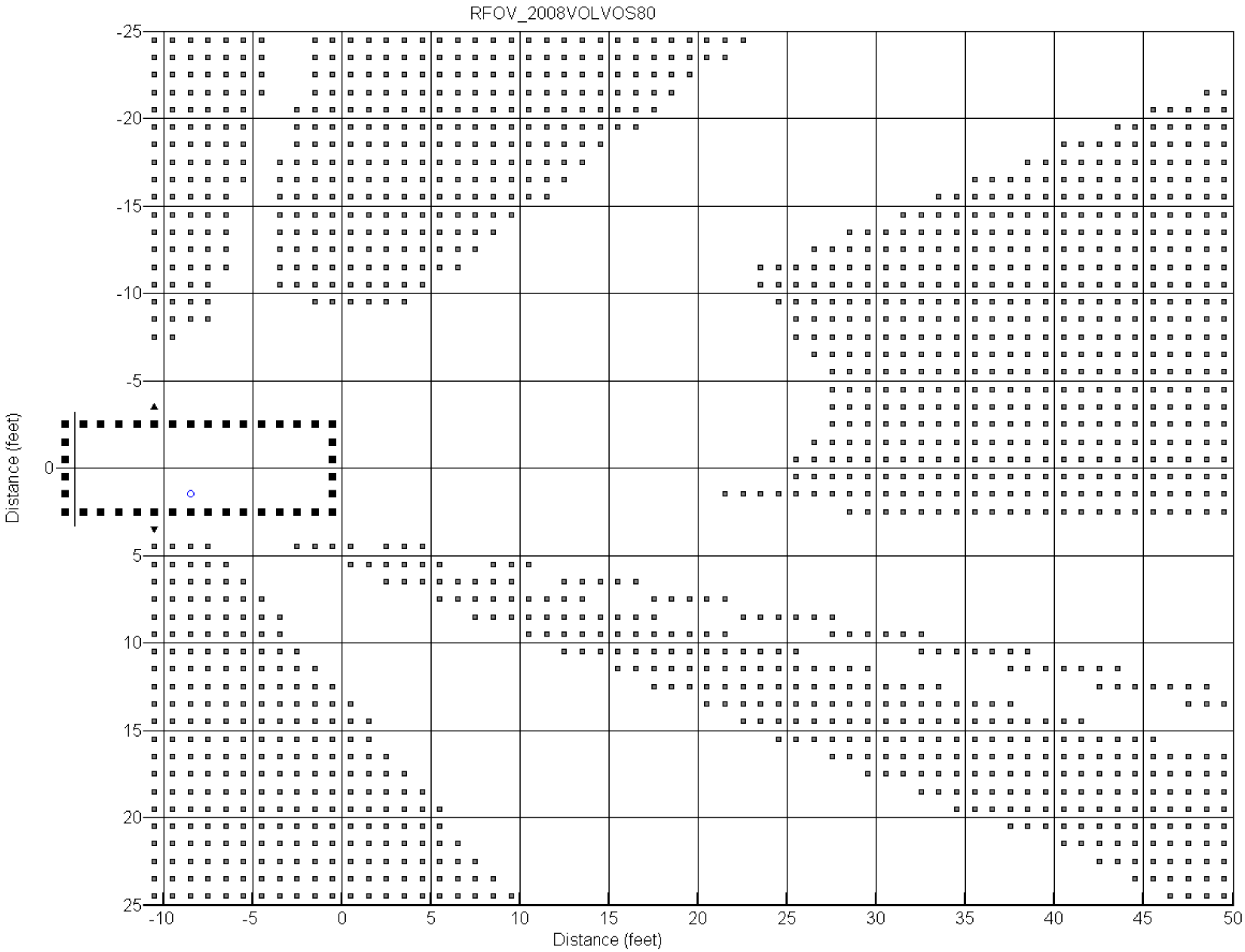

Figure 56. 2008 Volvo S80 Rear Field of View Data Plot

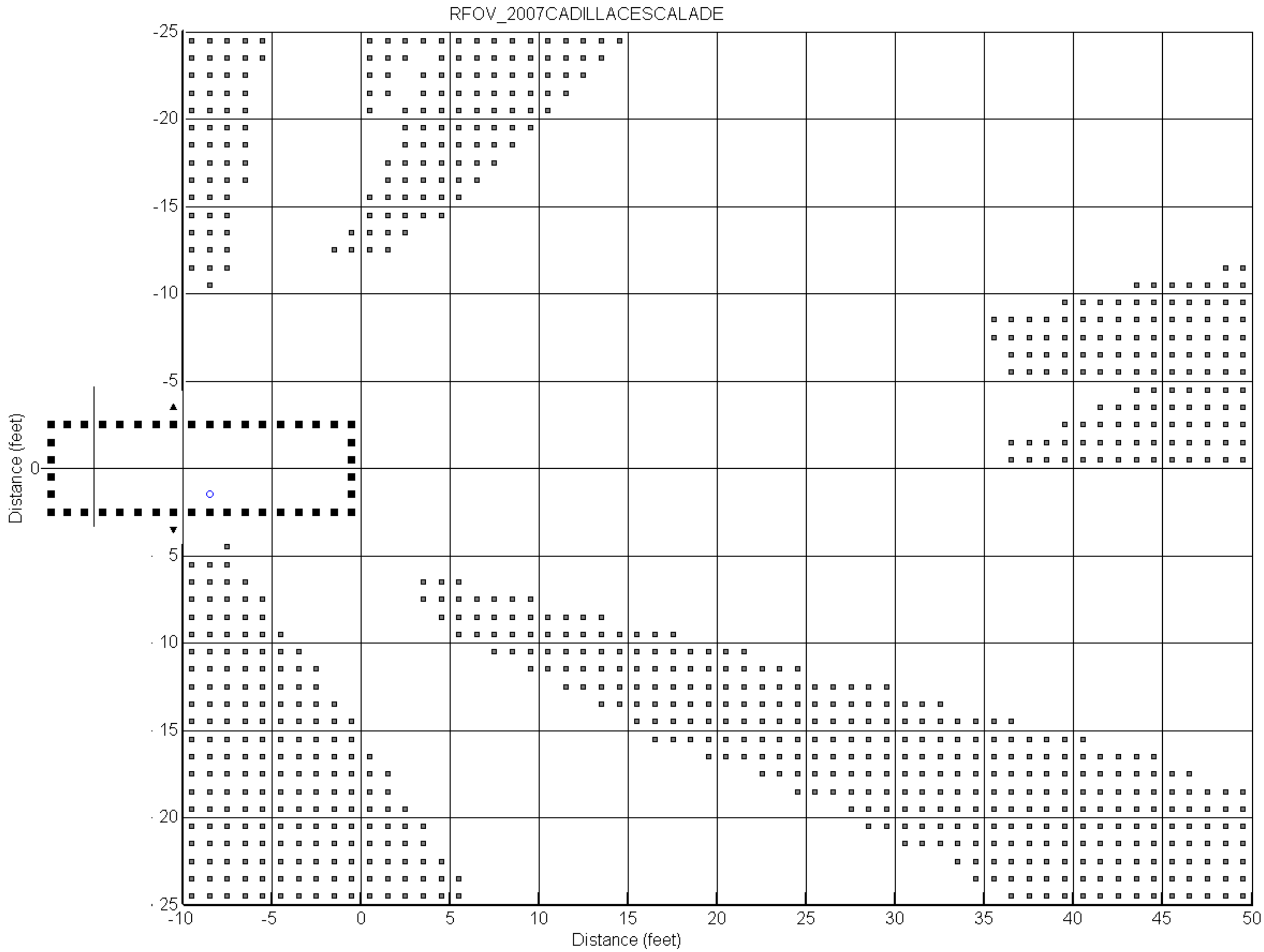

Figure 57. 2007 Cadillac Escalade Rear Field of View Data Plot

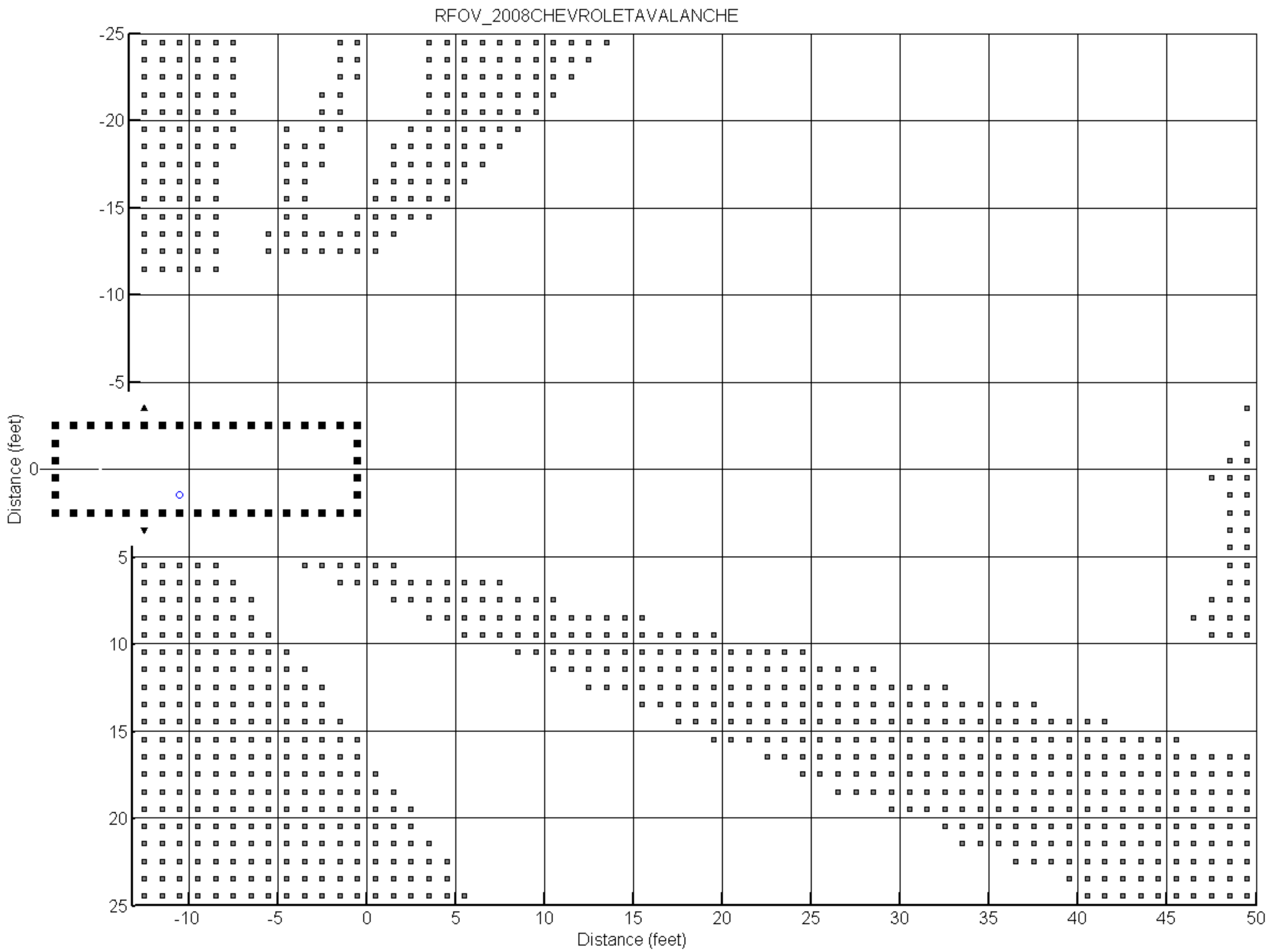

Figure 58. 2008 Chevrolet Avalanche Rear Field of View Data Plot

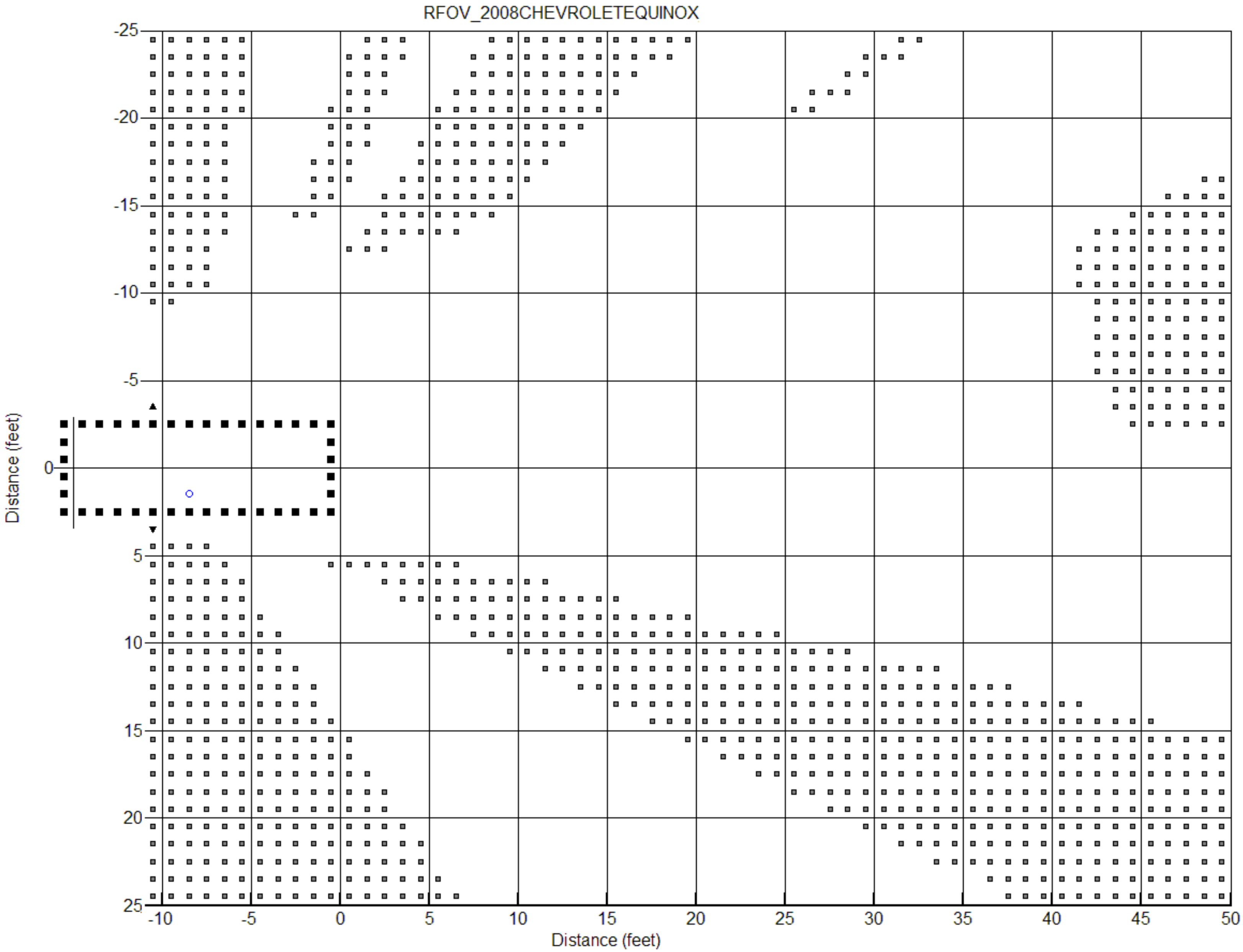

Figure 59. 2008 Chevrolet Equinox Rear Field of View Data Plot

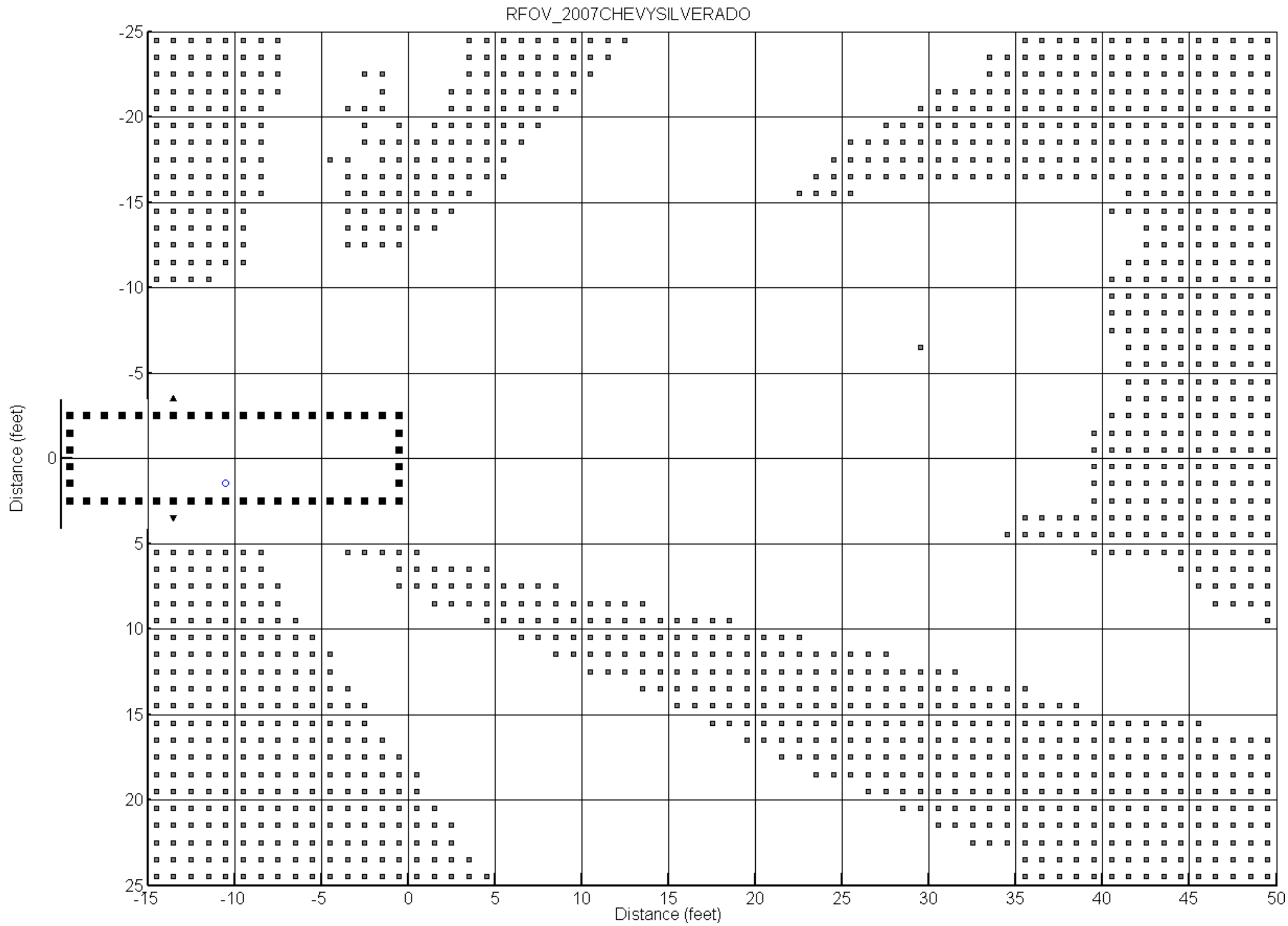

Figure 60. 2007 Chevrolet Silverado Rear Field of View Data Plot

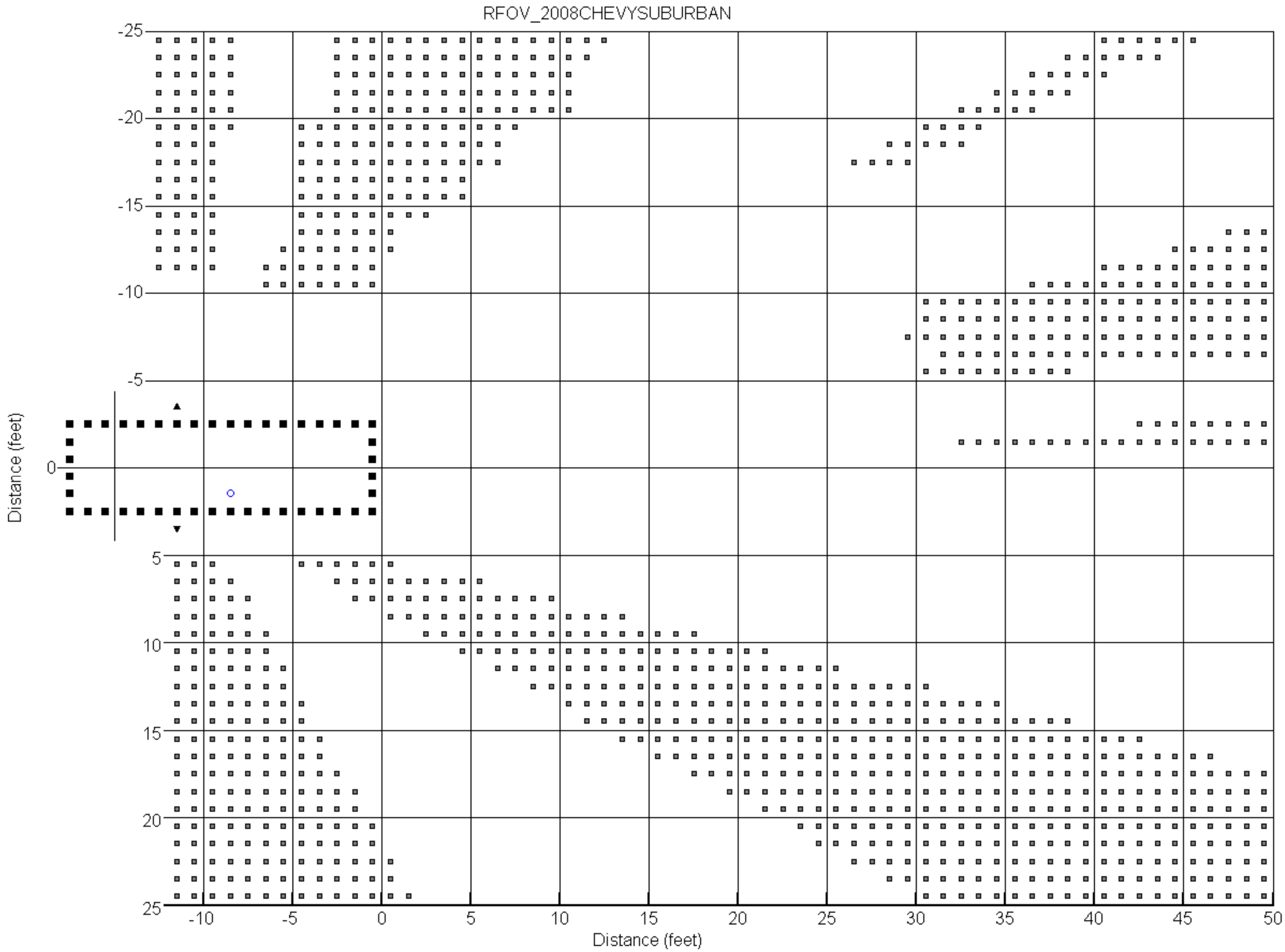

Figure 61. 2008 Chevrolet Suburban Rear Field of View Data Plot

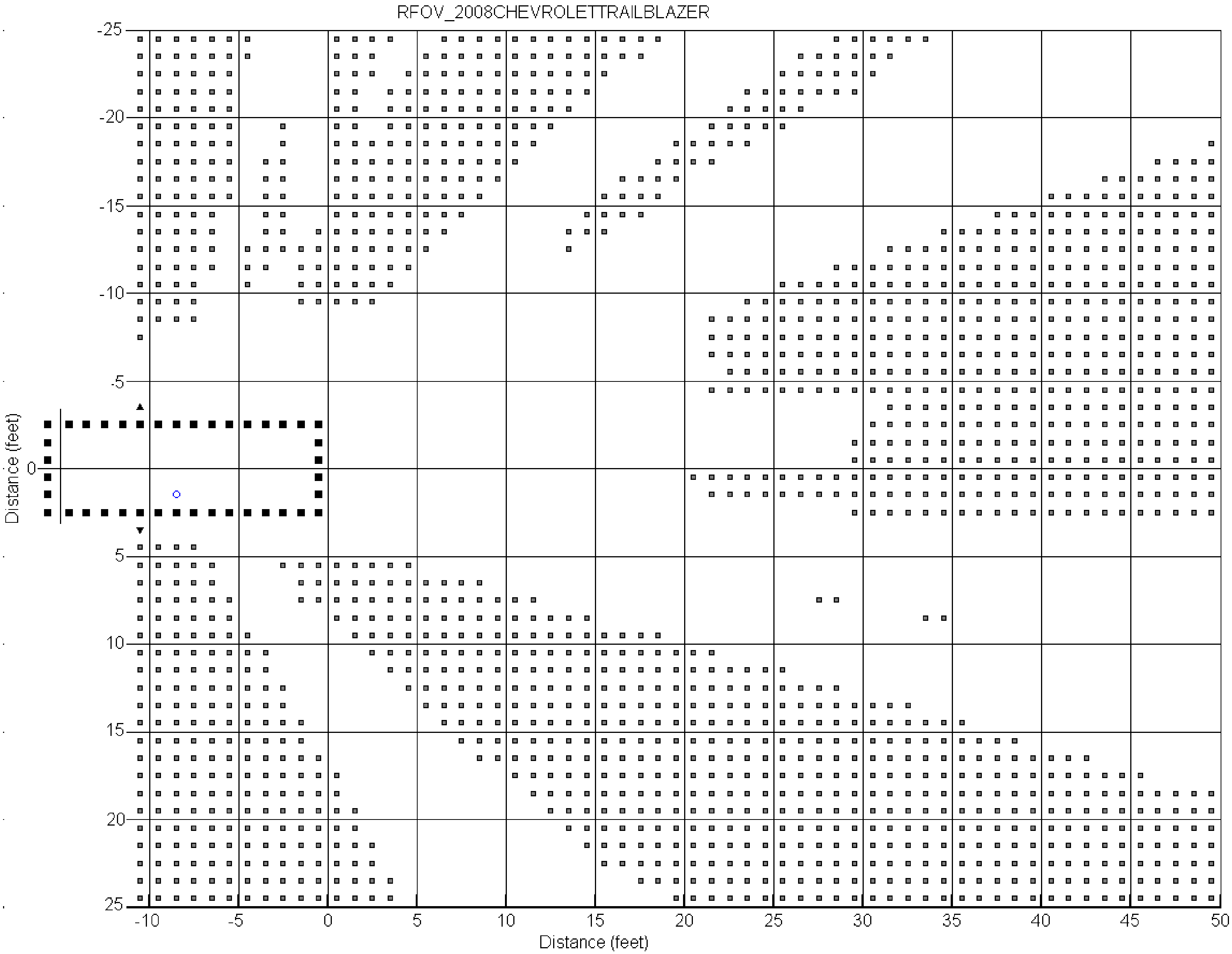

Figure 62. 2008 Chevrolet Trailblazer Rear Field of View Data Plot

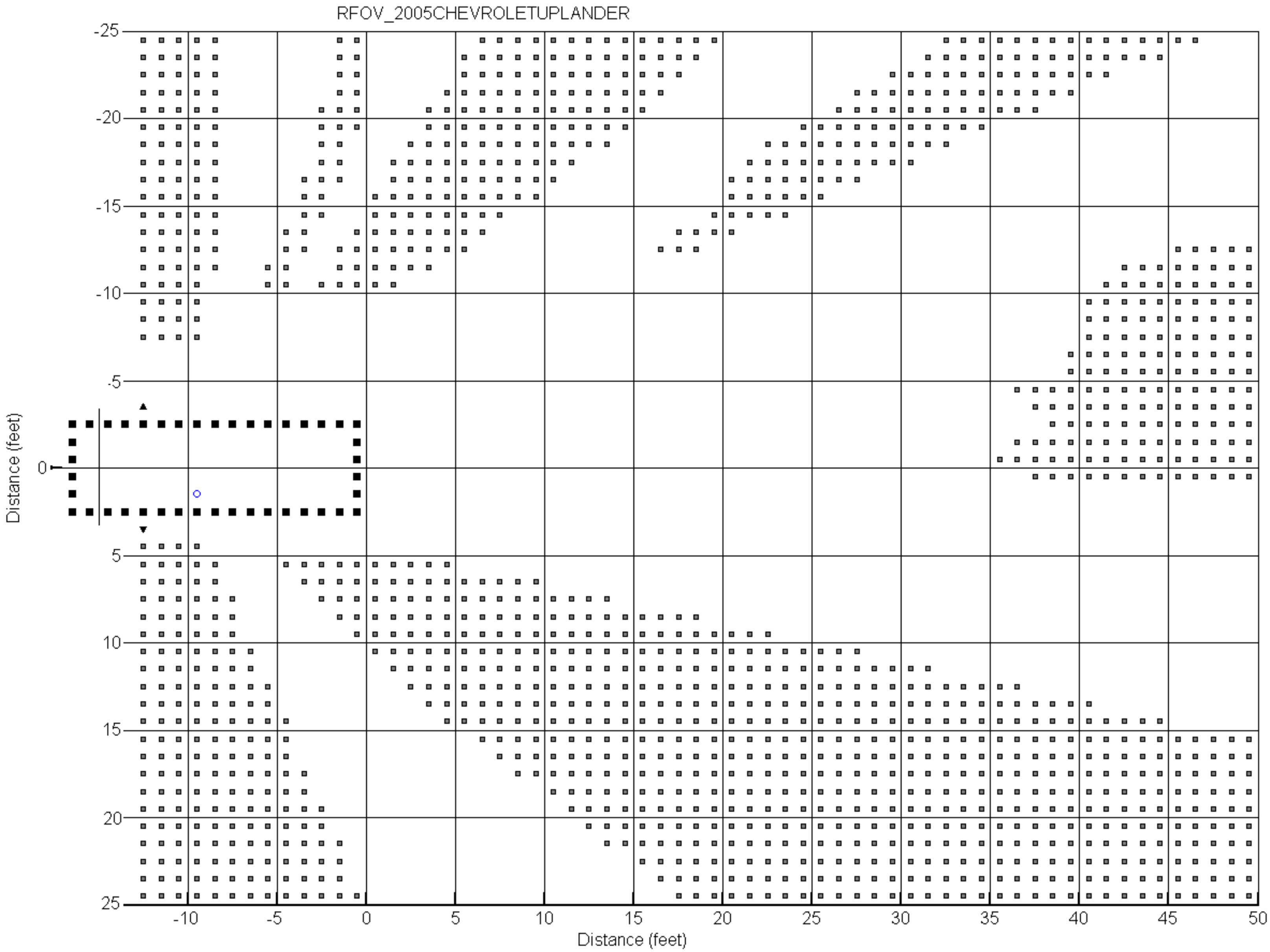

Figure 63. 2005 Chevrolet Uplander Rear Field of View Data Plot

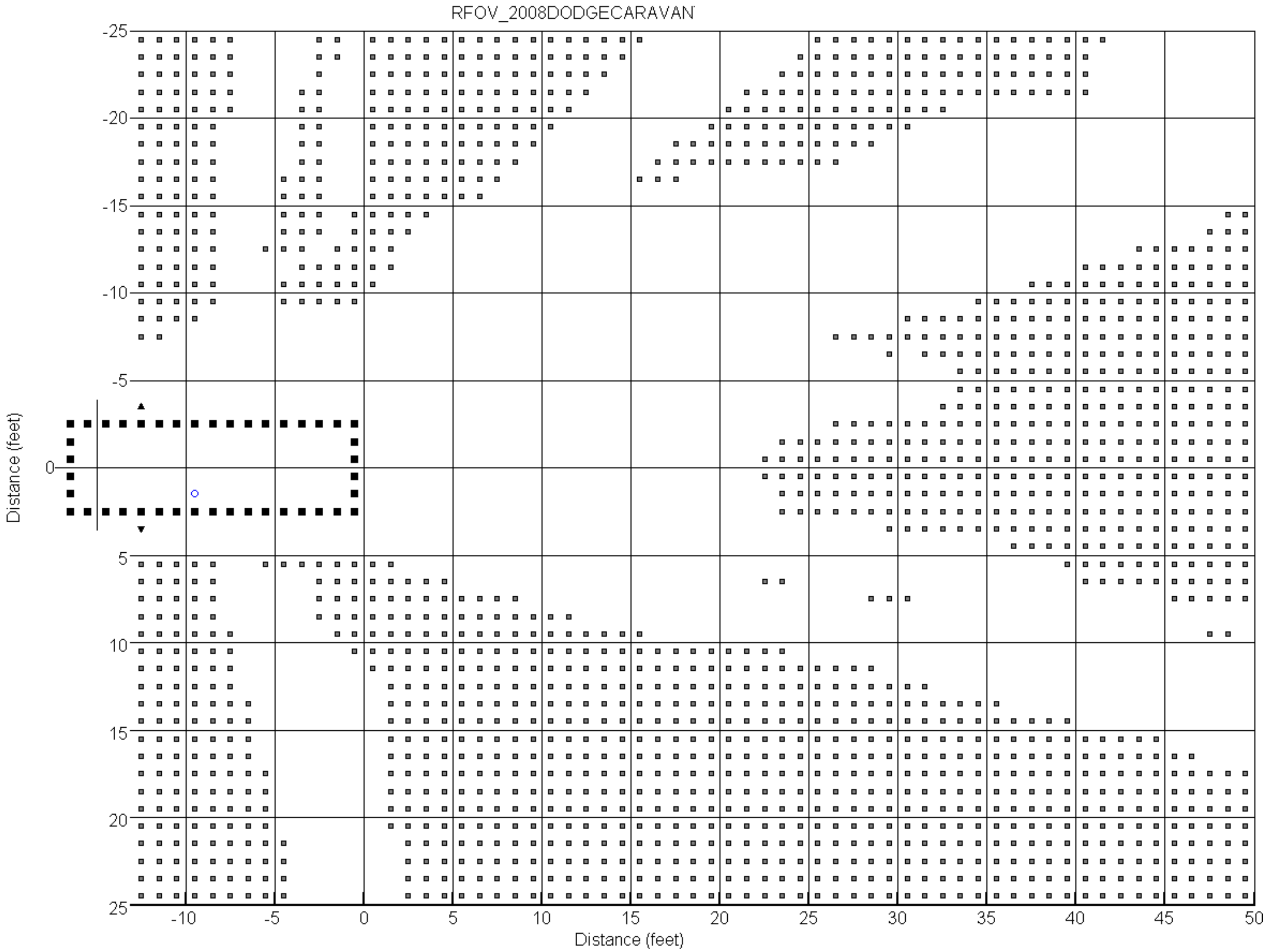

Figure 64. 2008 Dodge Caravan Rear Field of View Data Plot

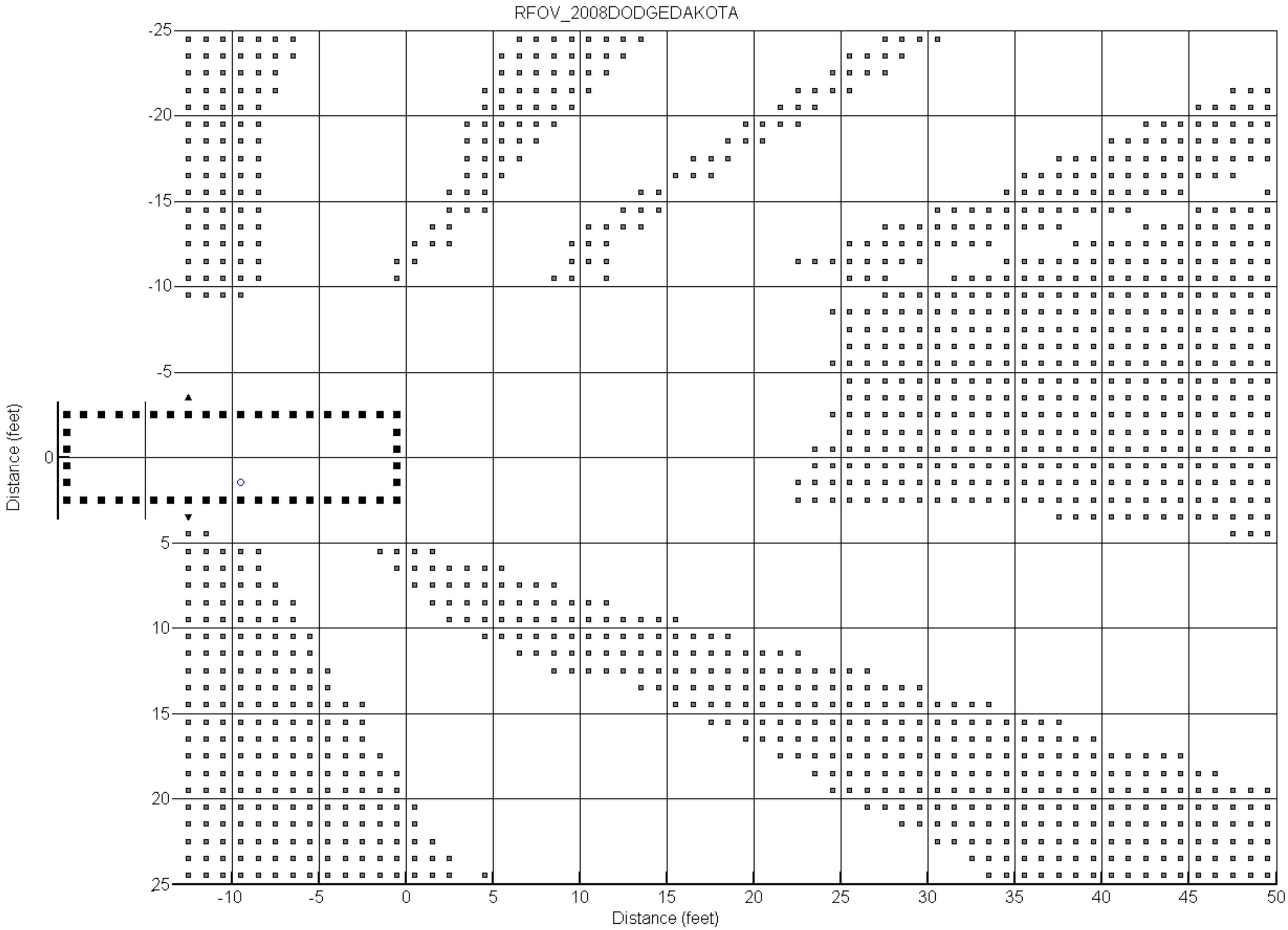

Figure 65. 2008 Dodge Dakota Rear Field of View Data Plot

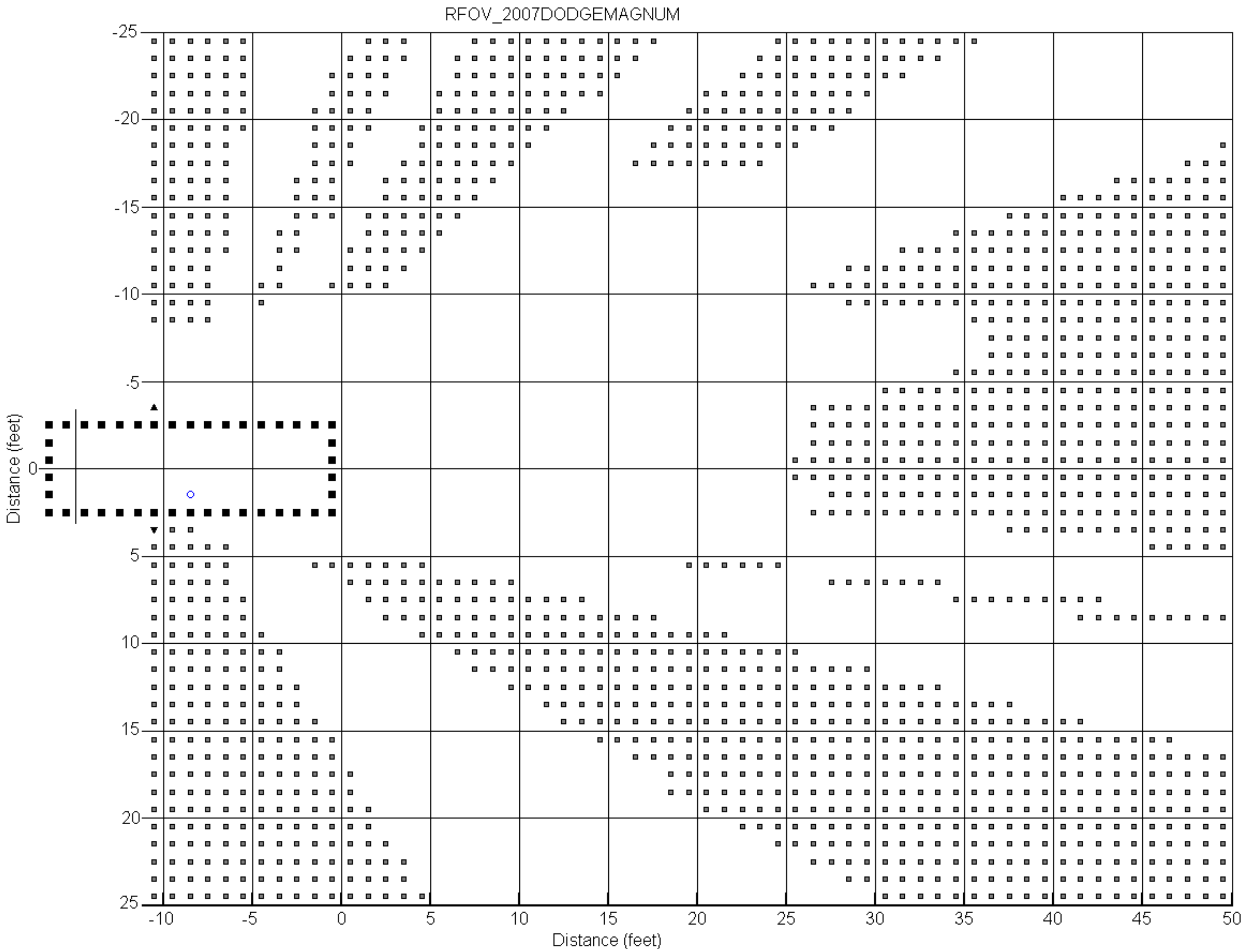

Figure 66. 2007 Dodge Magnum Rear Field of View Data Plot

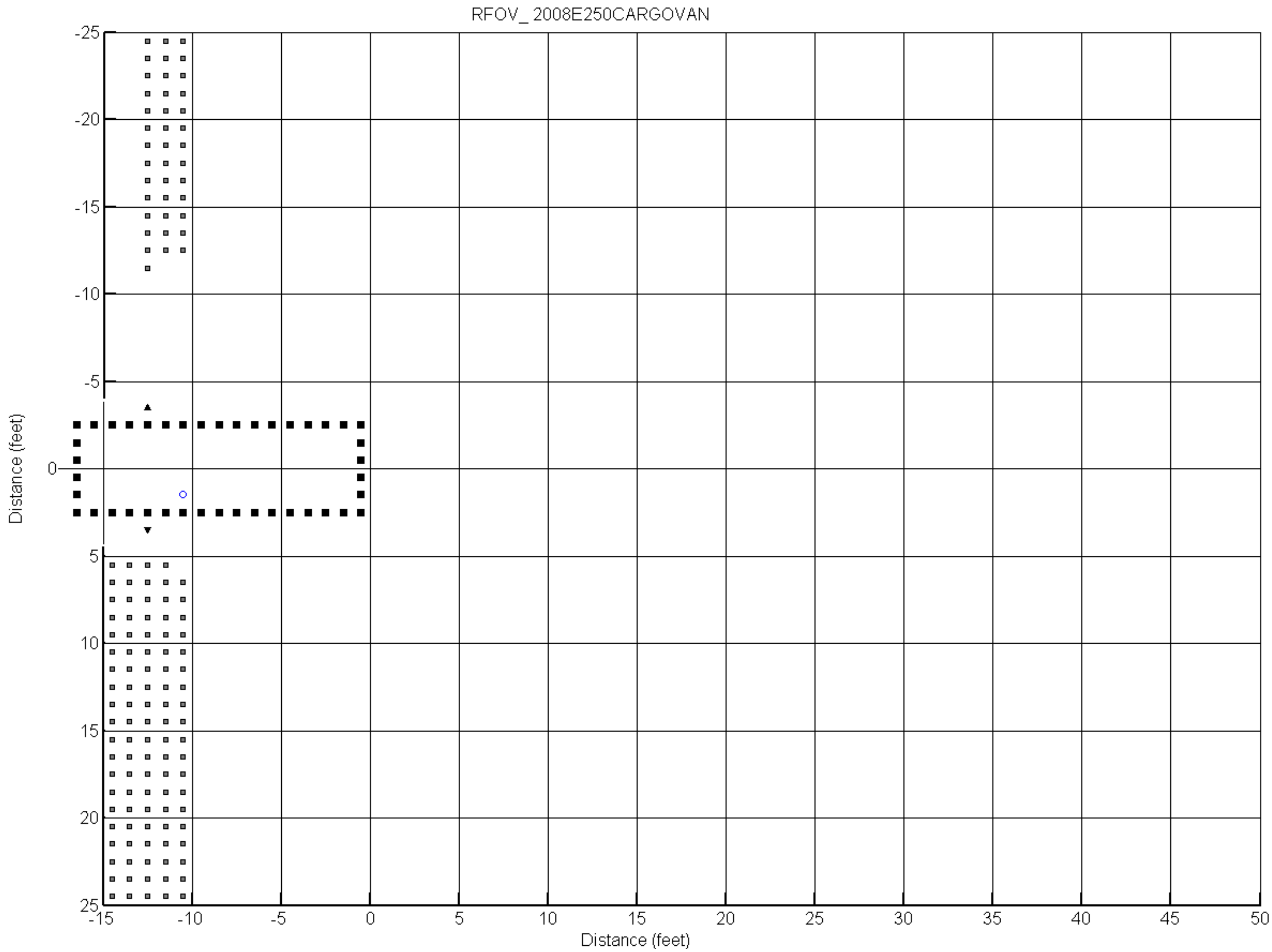

Figure 67. 2008 Ford E250 Cargo Van Rear Field of View Data Plot

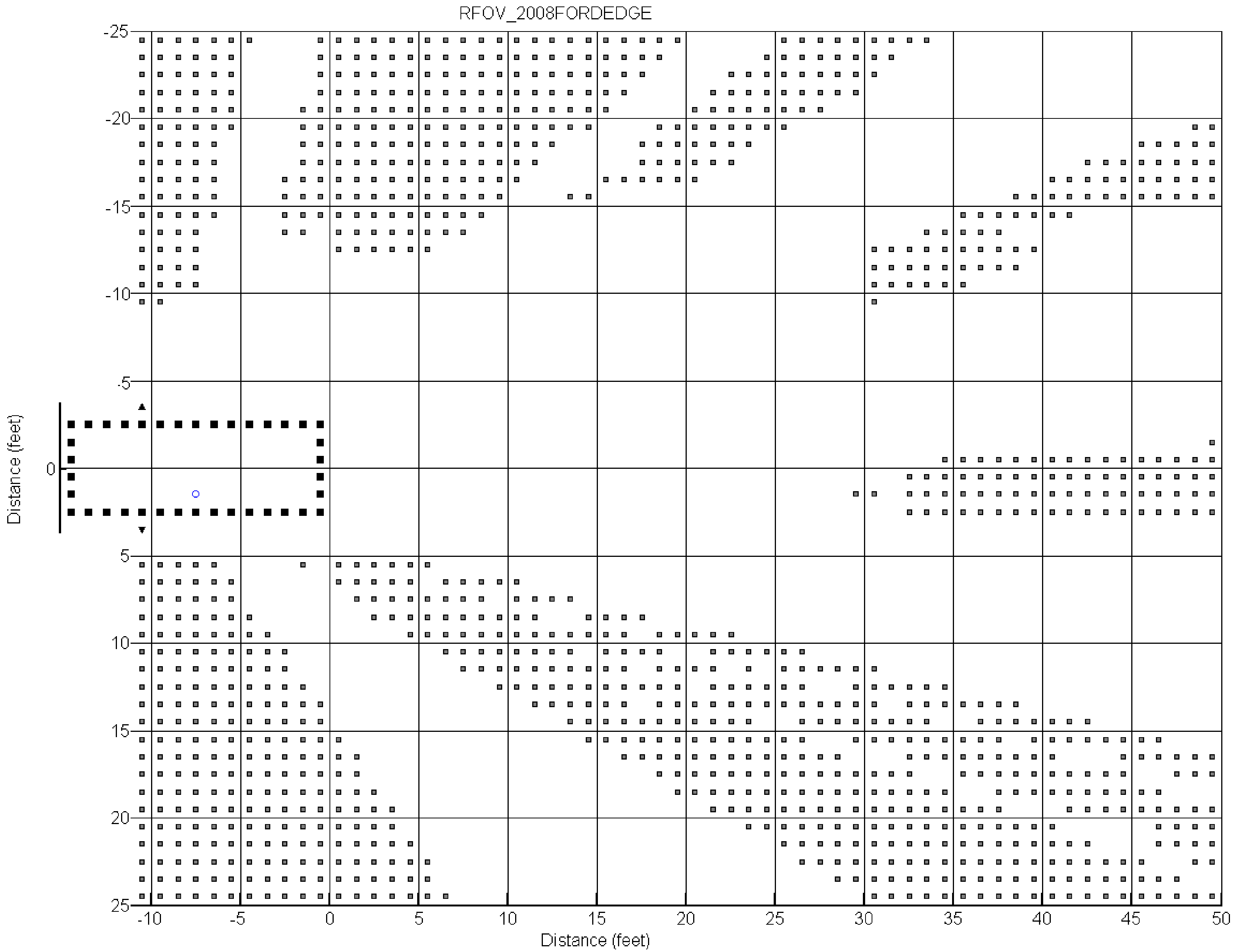

Figure 68. 2008 Ford Edge Rear Field of View Data Plot

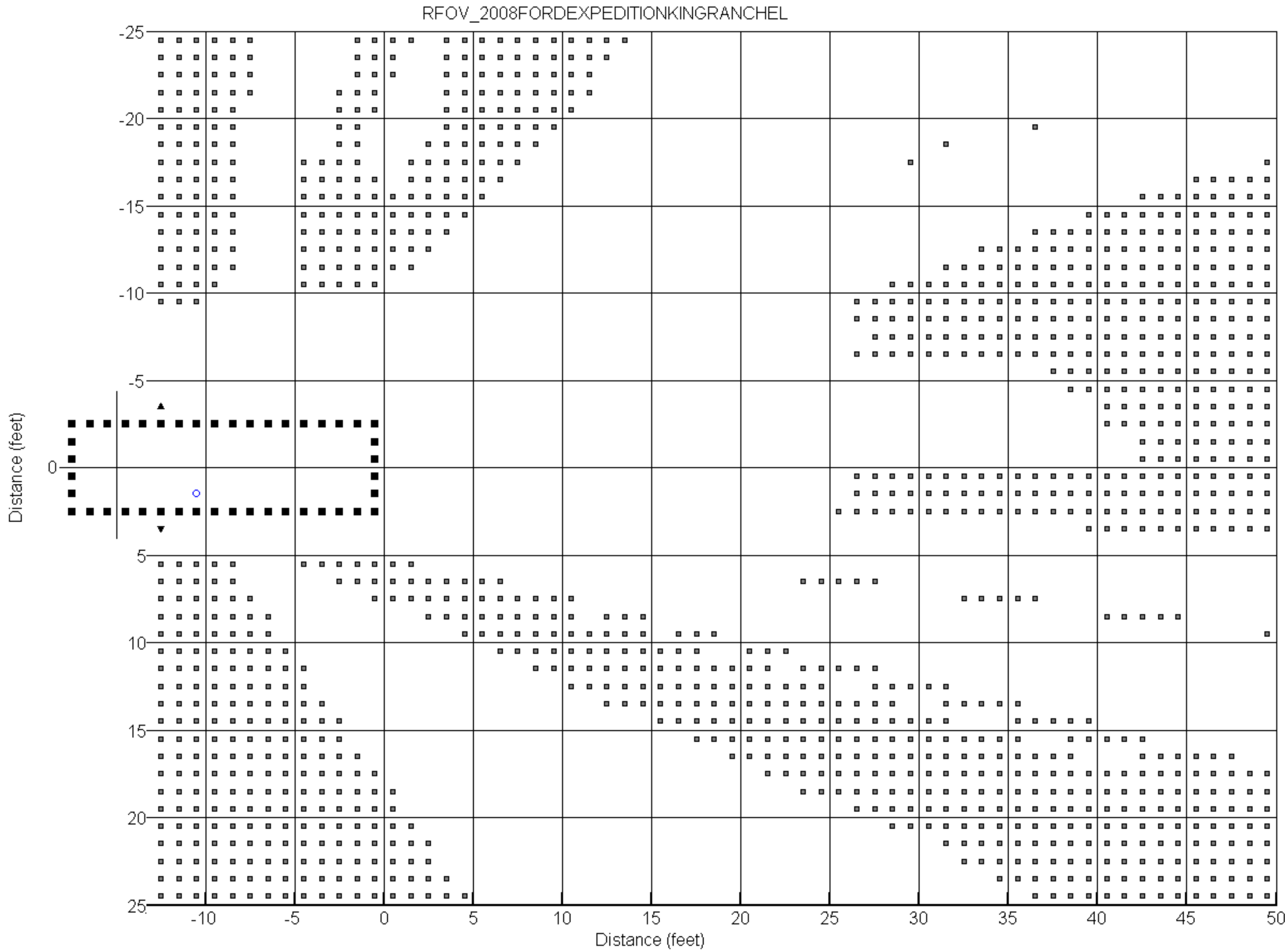

Figure 69. 2008 Ford Expedition Rear Field of View Data Plot

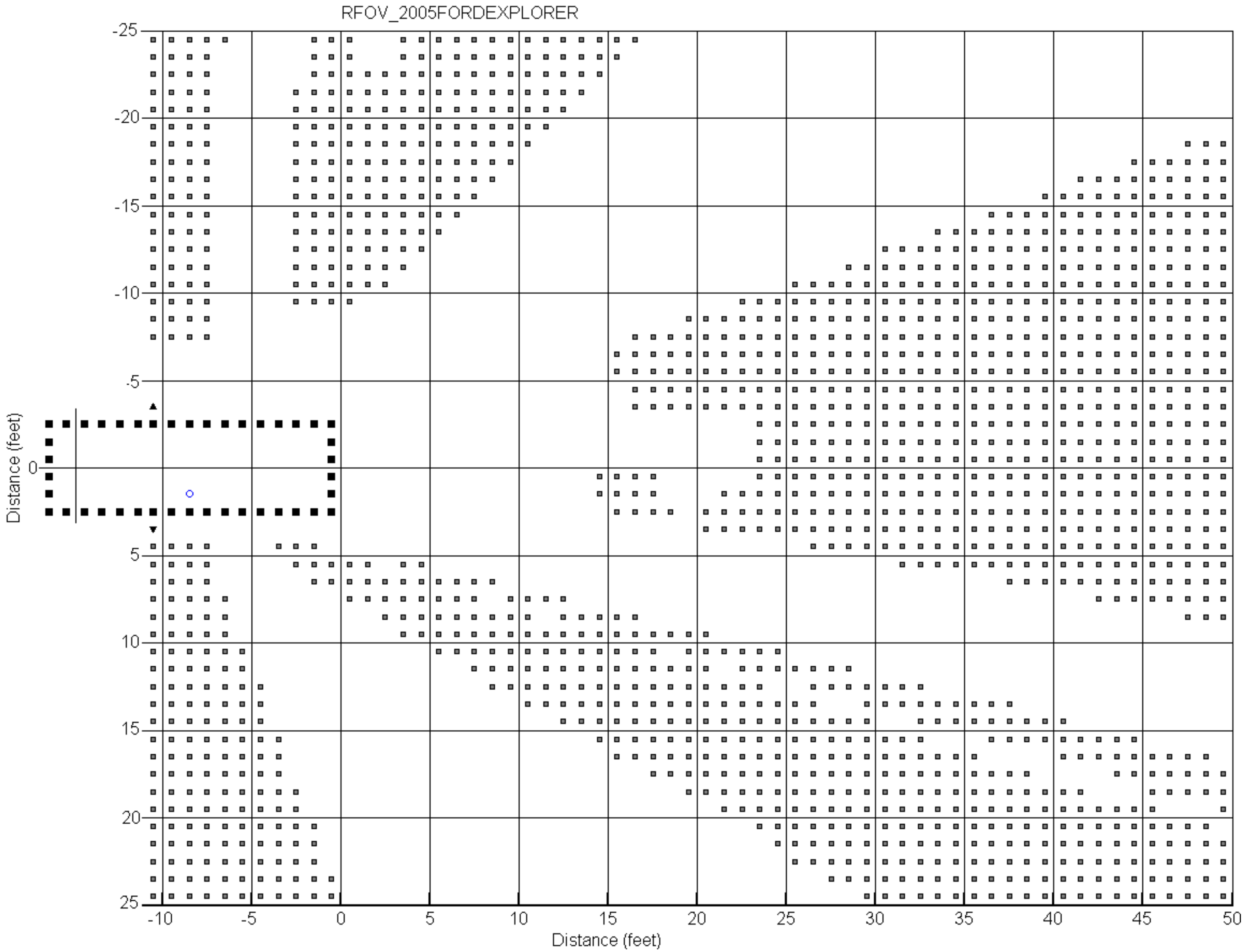

Figure 70. 2005 Ford Explorer Rear Field of View Data Plot

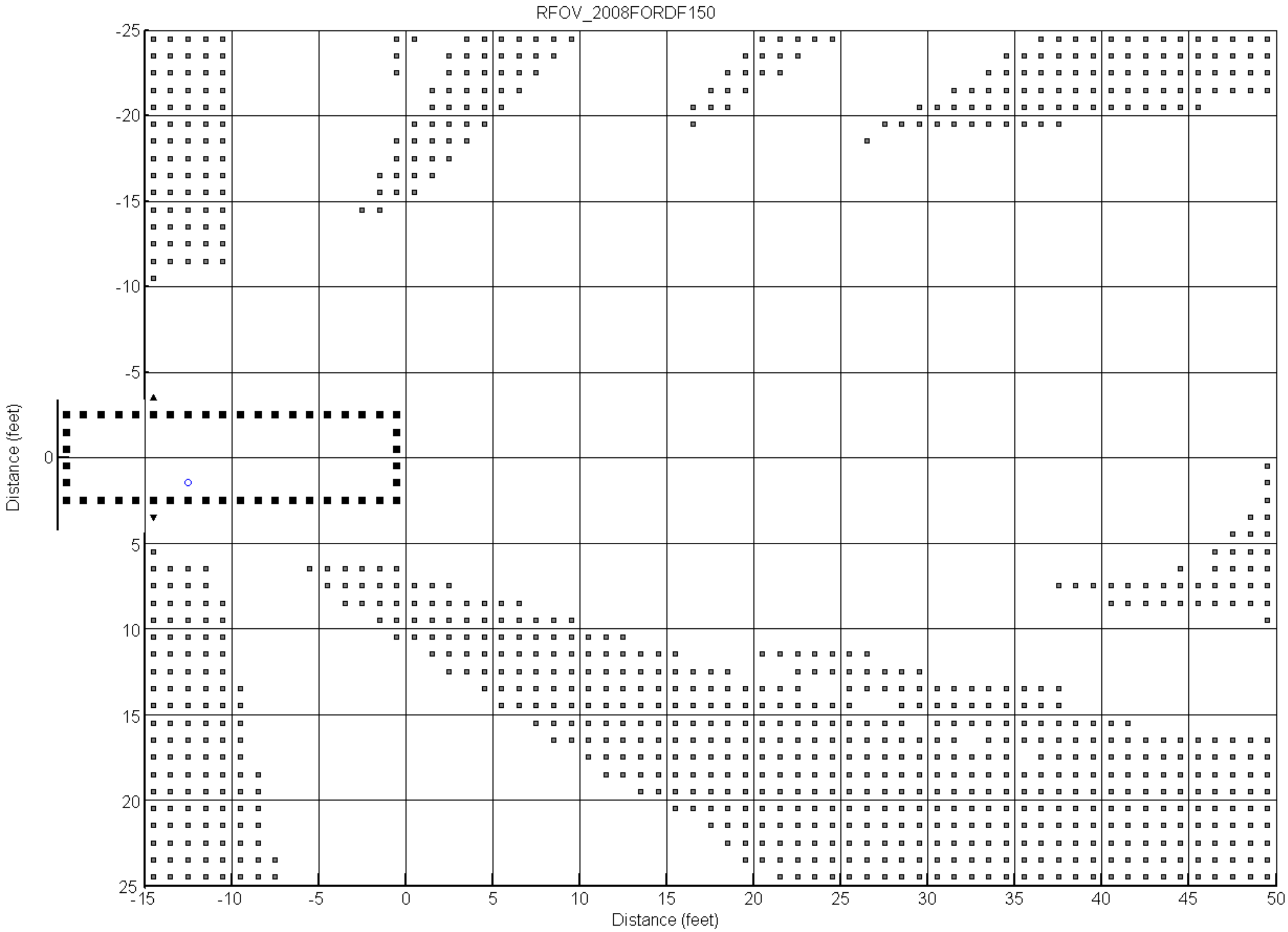

Figure 71. 2008 Ford F-150 Rear Field of View Data Plot

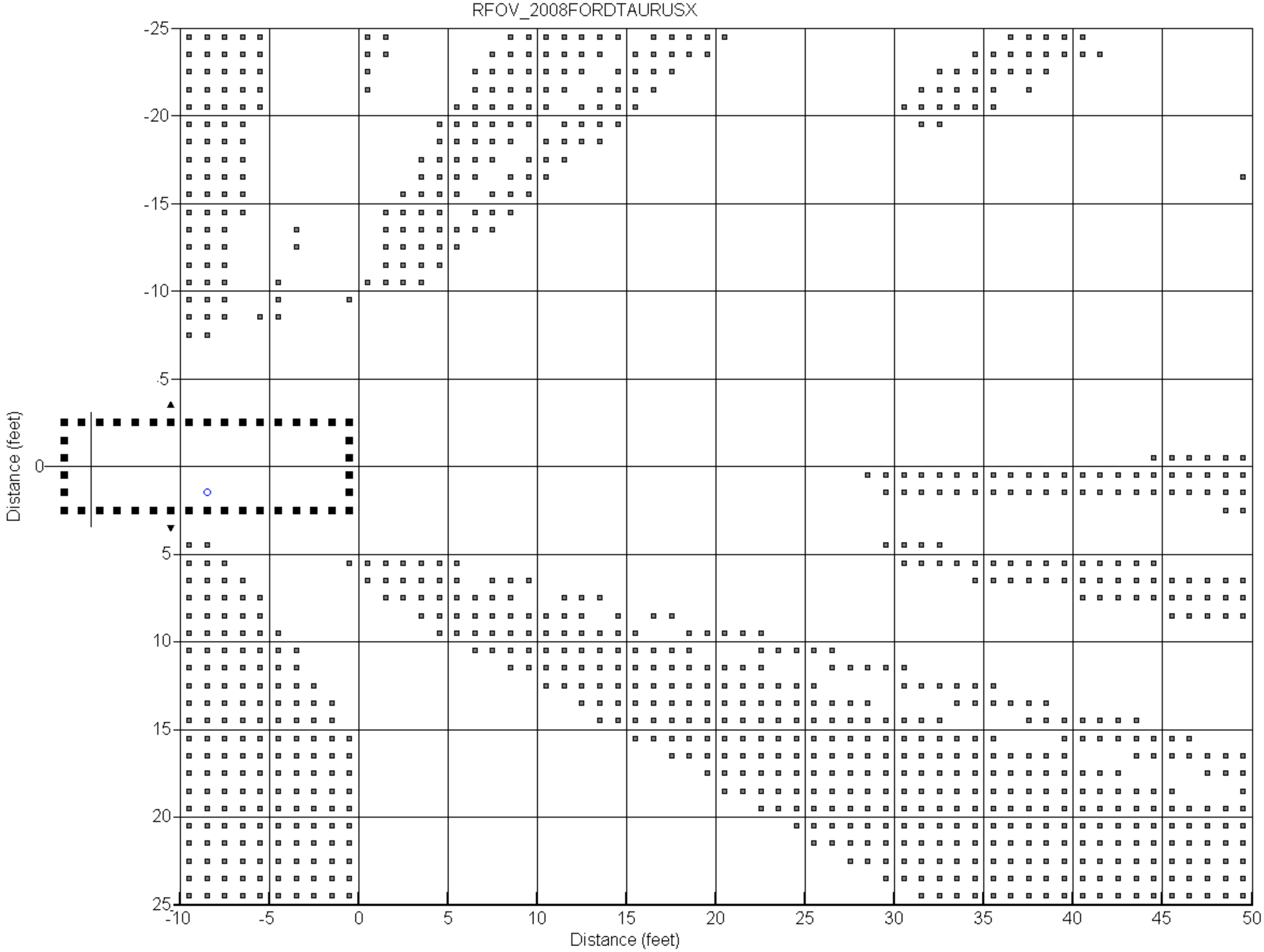

Figure 72. 2008 Ford Taurus X Rear Field of View Data Plot

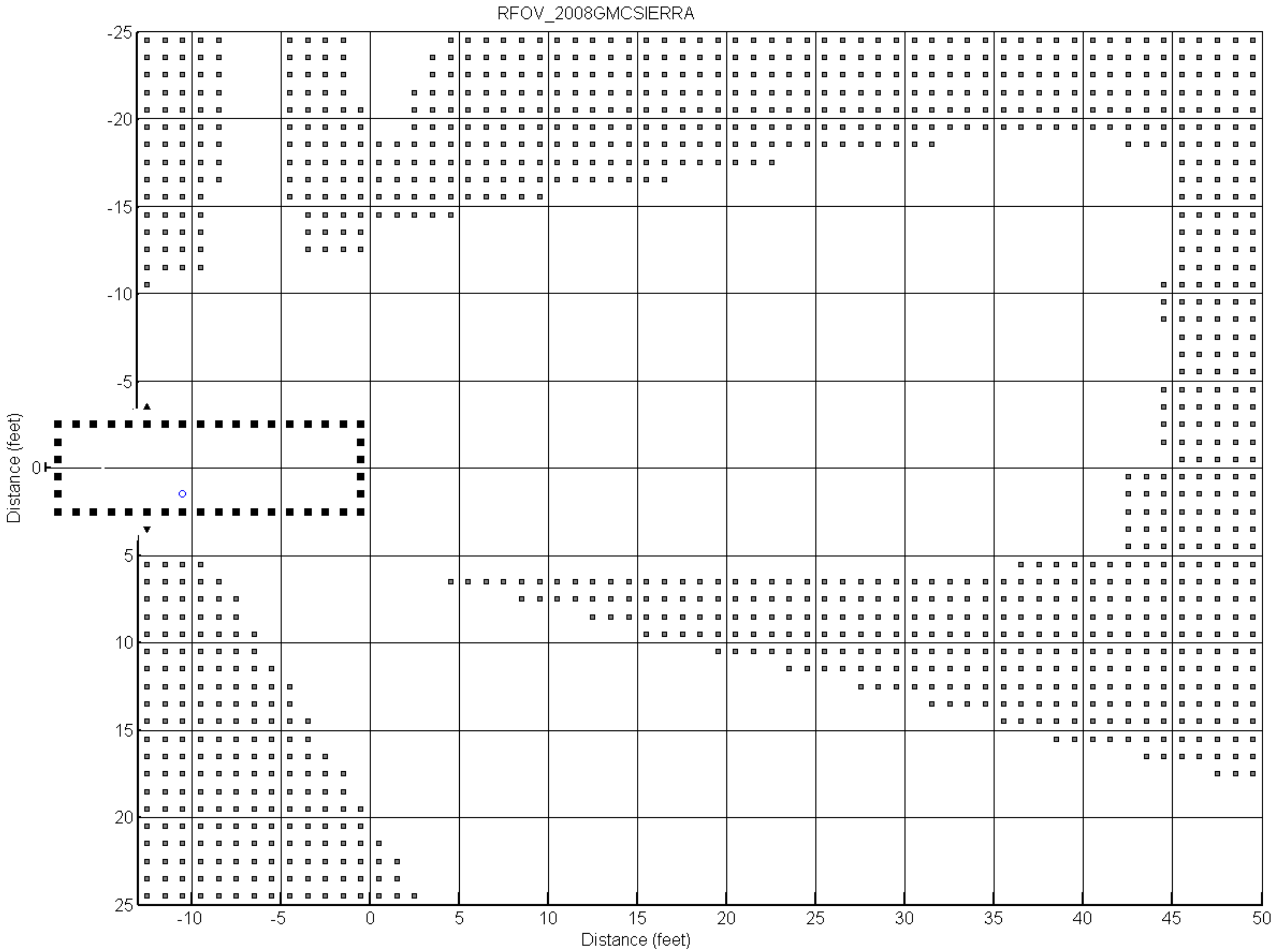

Figure 73. 2008 GMC Sierra Rear Field of View Data Plot

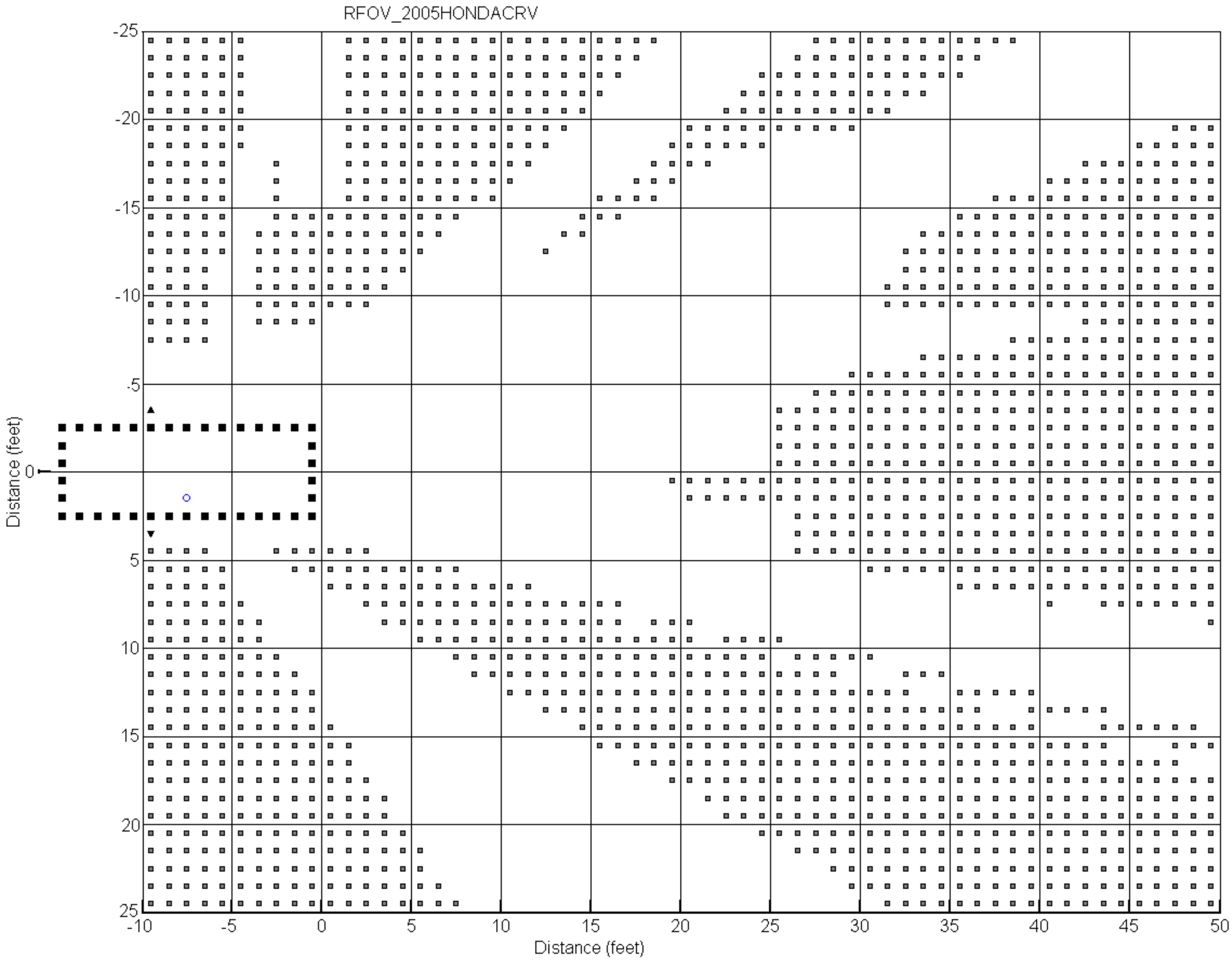

Figure 74. 2005 Honda CR-V Rear Field of View Data Plot

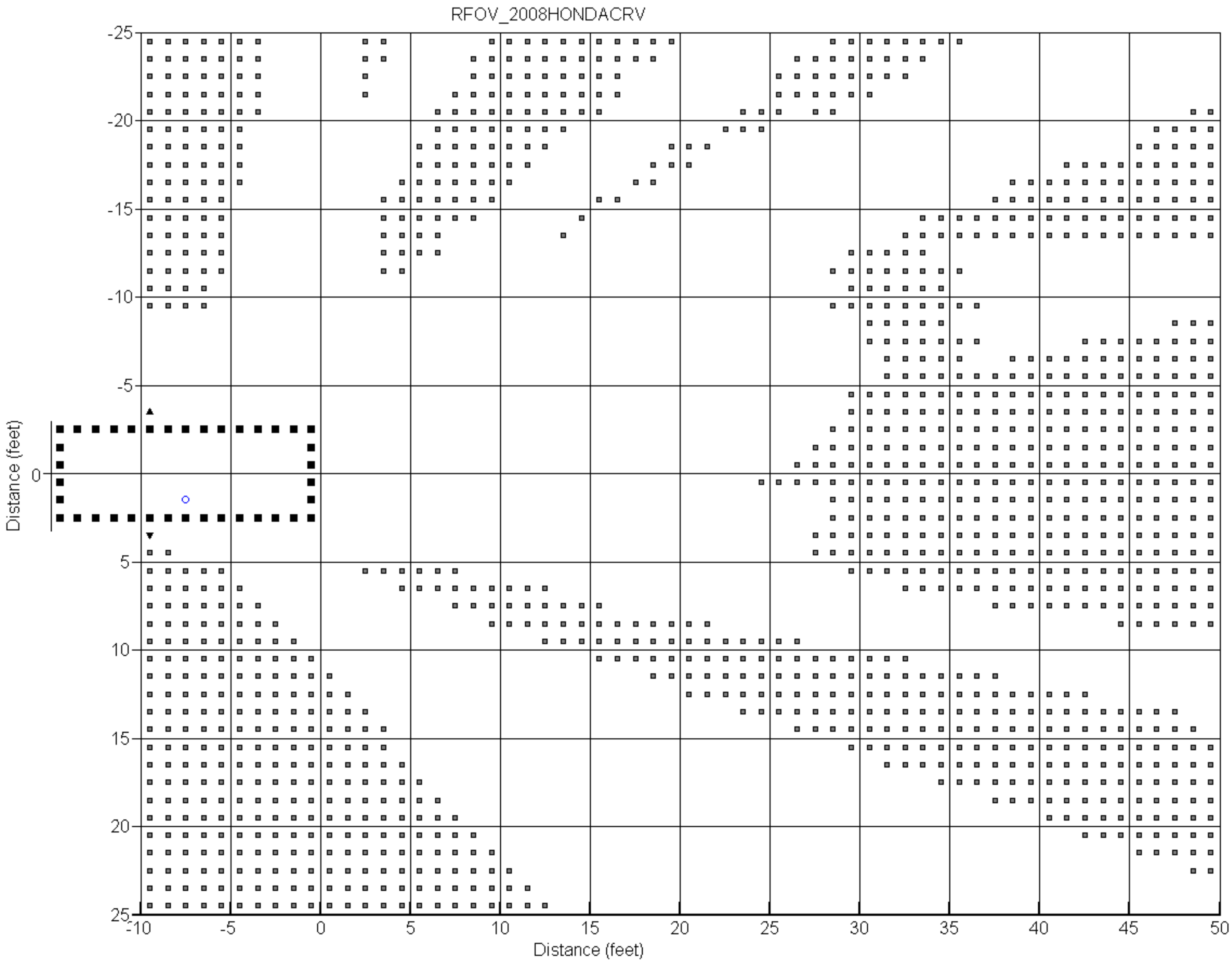

Figure 75. 2008 Honda CR-V Rear Field of View Data Plot

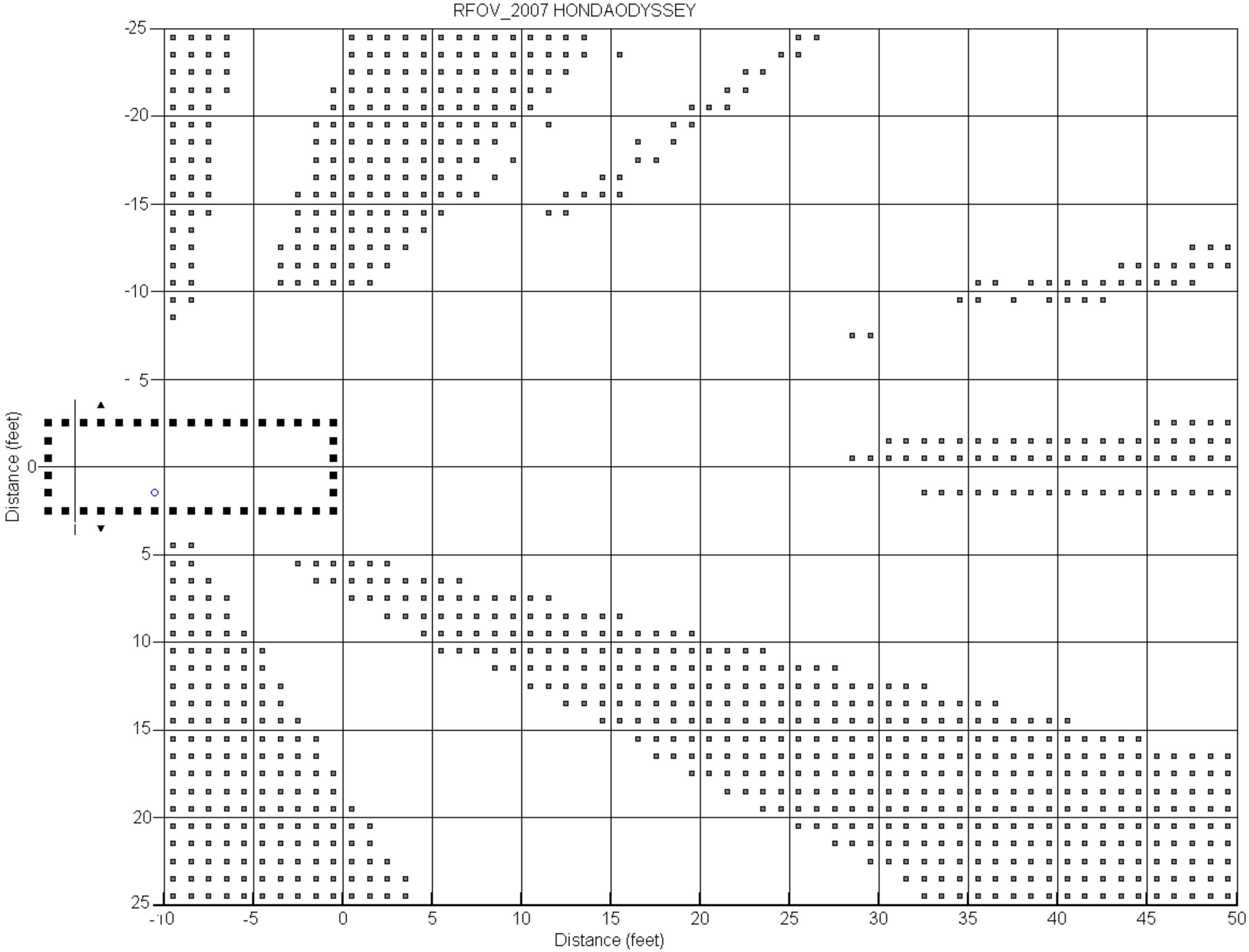

Figure 76. 2007 Honda Odyssey Rear Field of View Data Plot

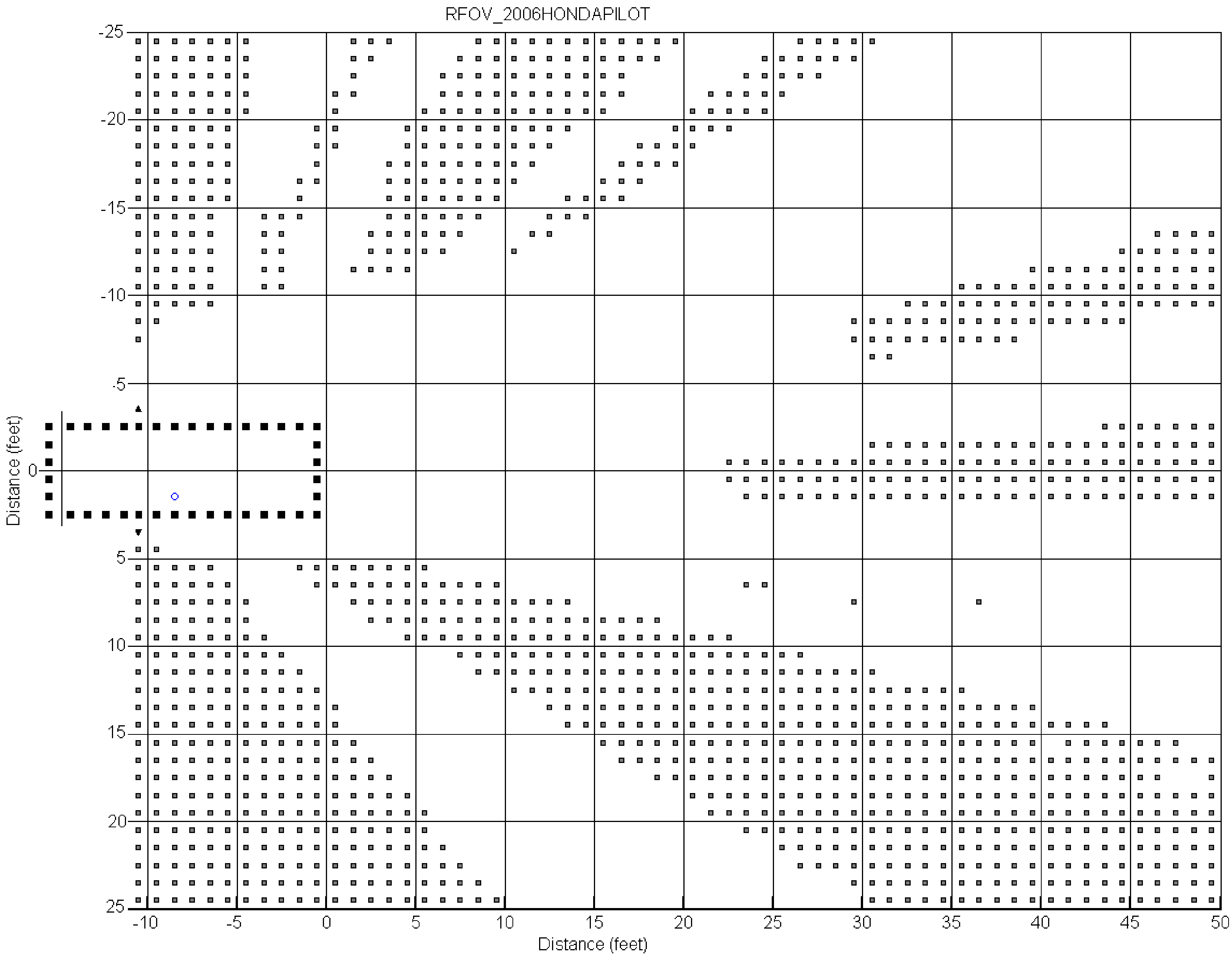

Figure 77. 2006 Honda Pilot Rear Field of View Data Plot

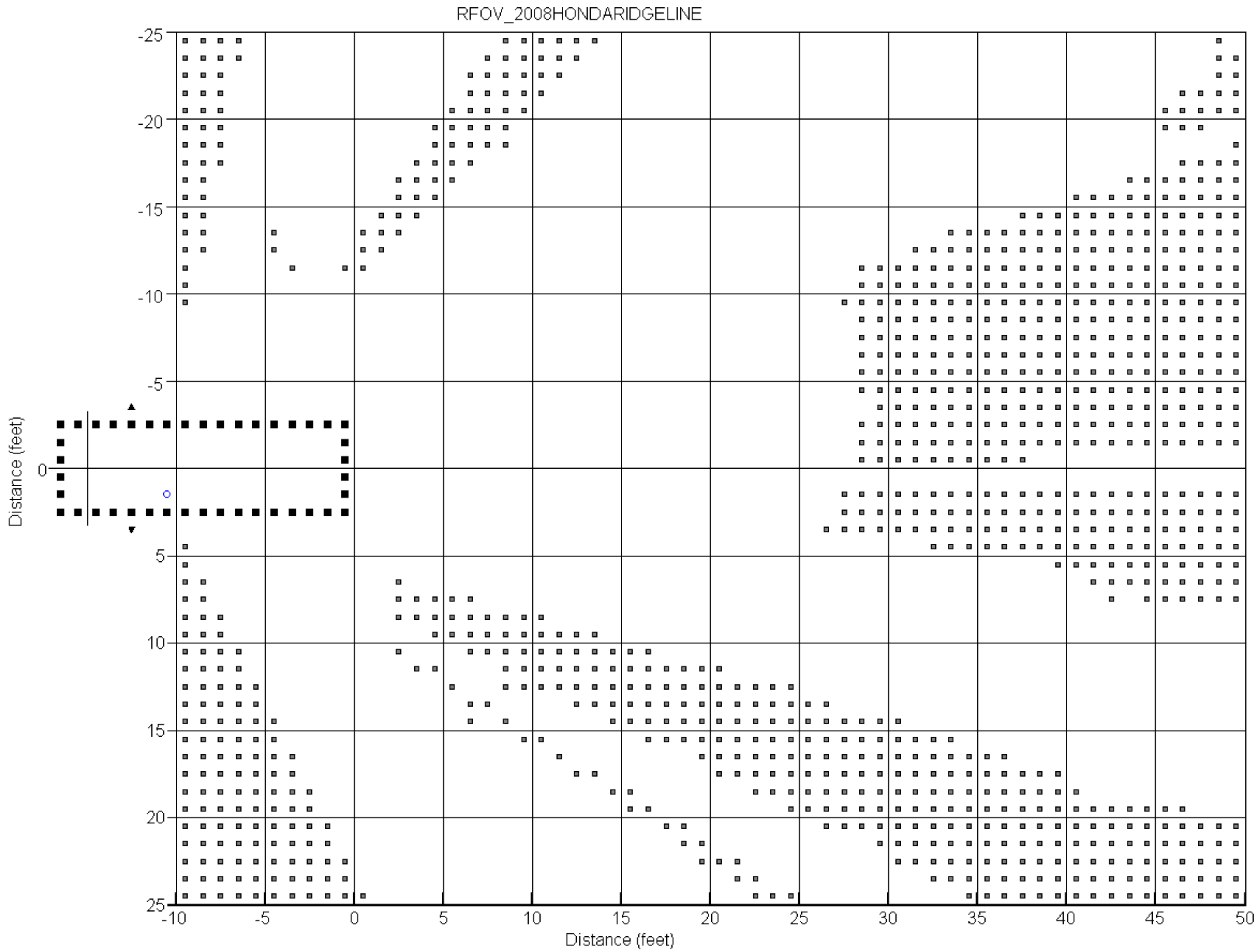

Figure 78. 2008 Honda Ridgeline Rear Field of View Data Plot

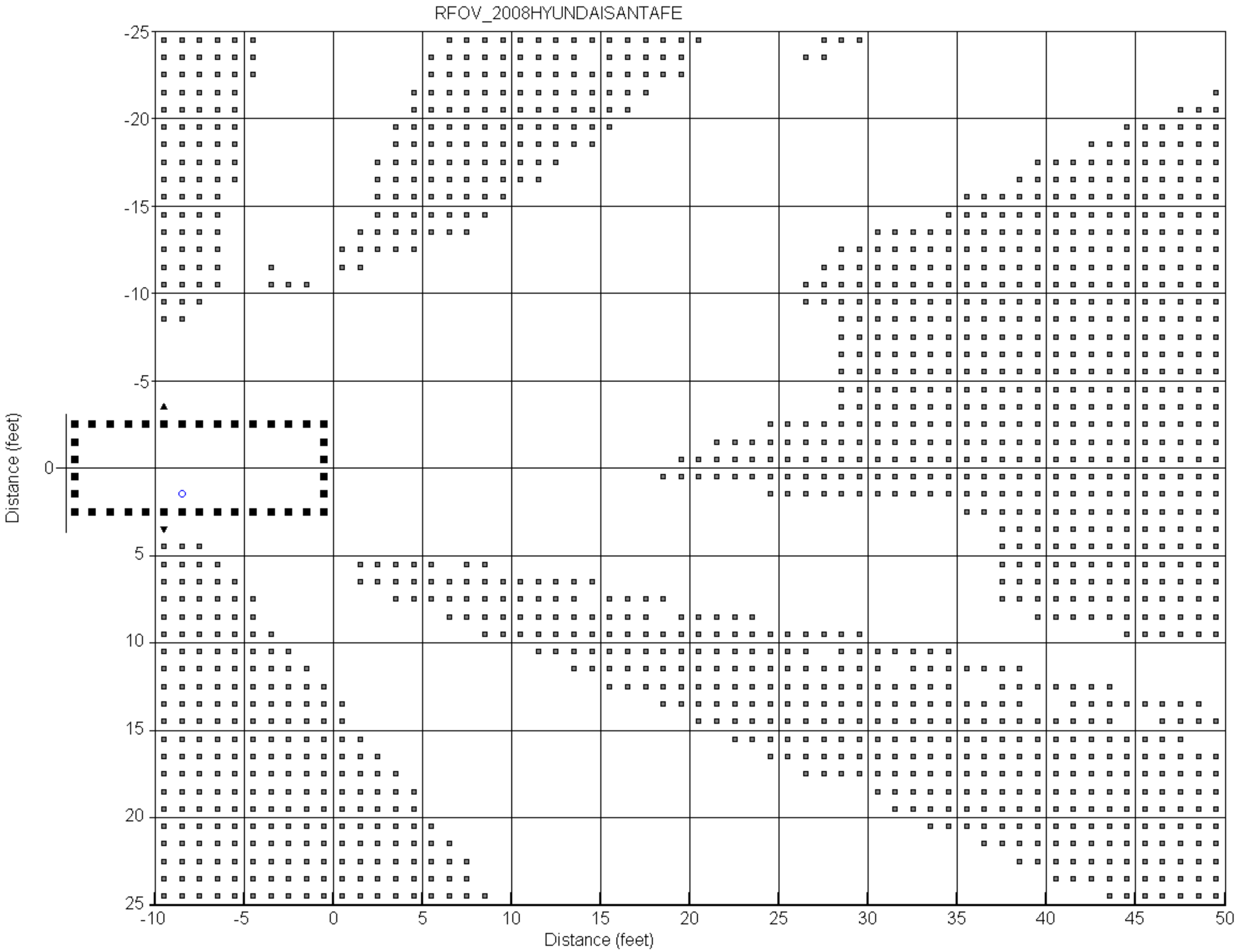

Figure 79. 2008 Hyundai Santa Fe Rear Field of View Data Plot

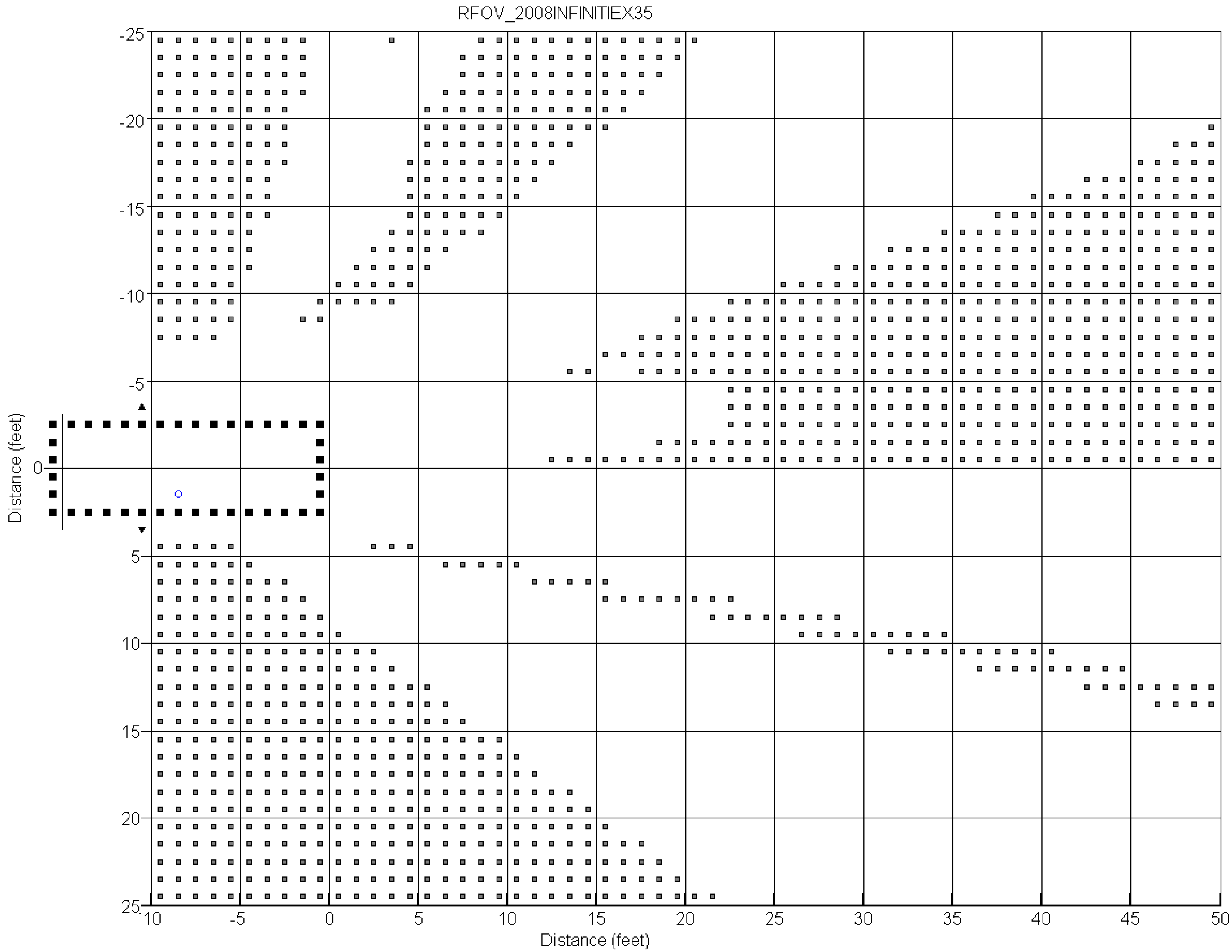

Figure 80. 2008 Infiniti EX35 Rear Field of View Data Plot

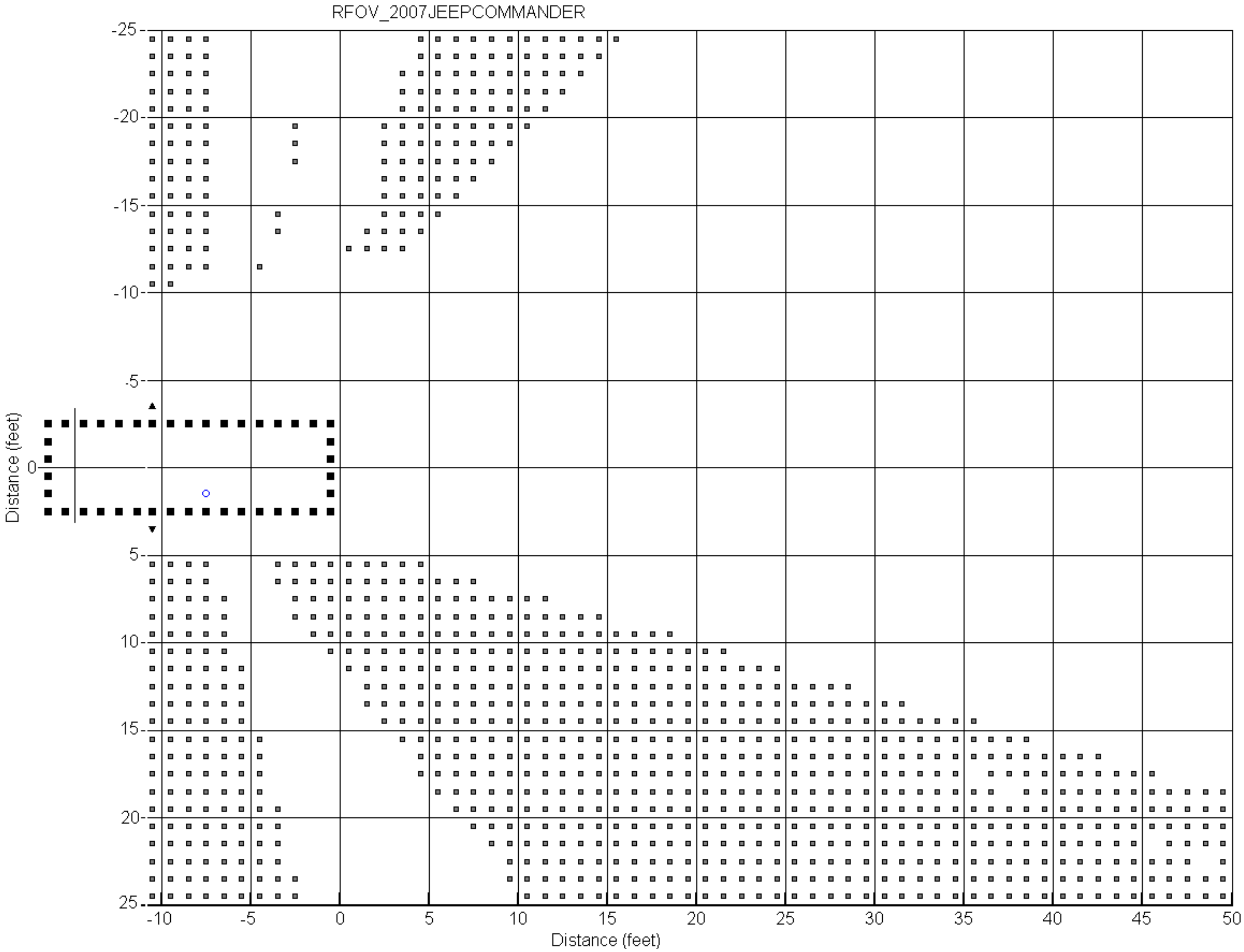

Figure 81. 2007 Jeep Commander Rear Field of View Data Plot

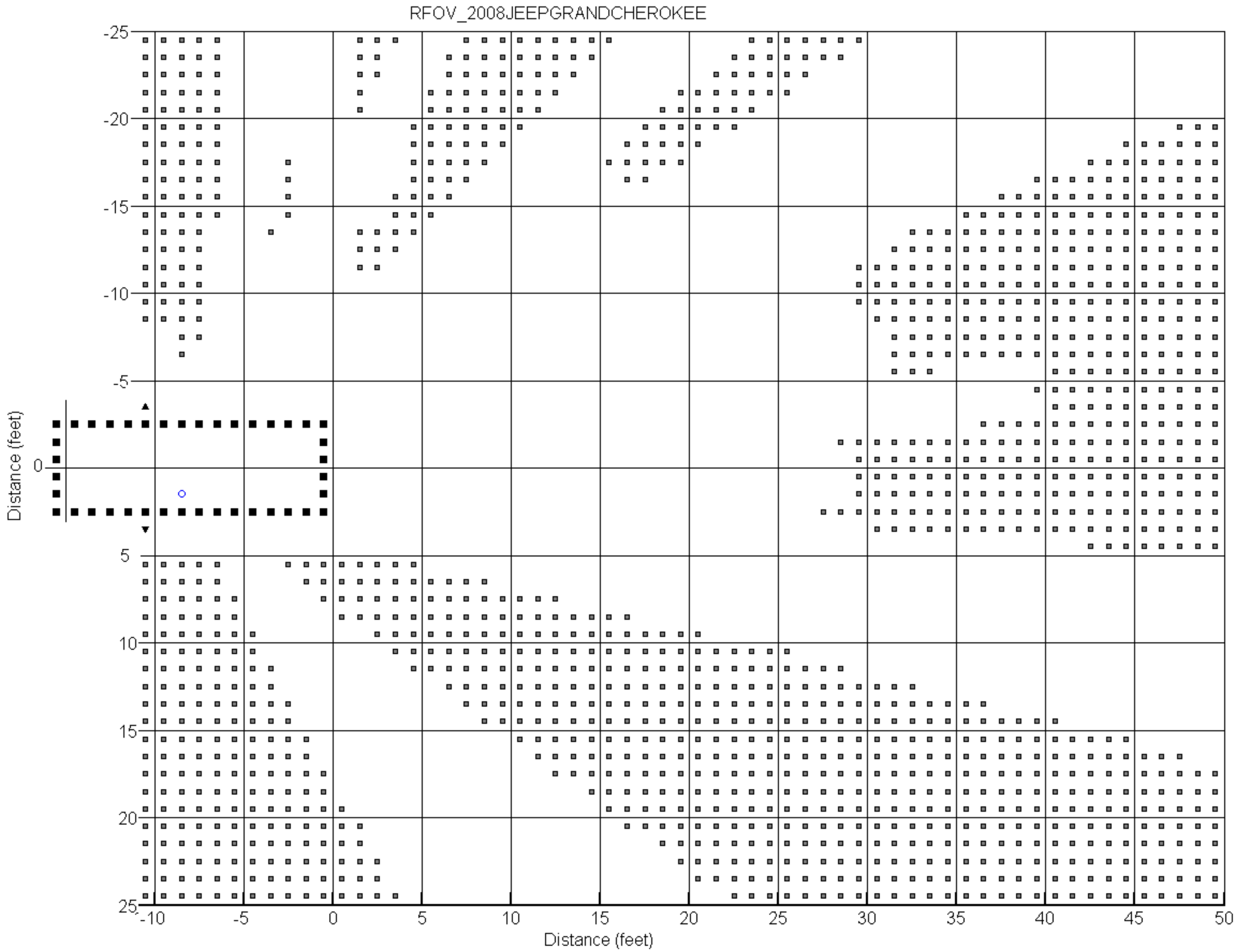

Figure 82. 2008 Jeep Grand Cherokee Rear Field of View Data Plot

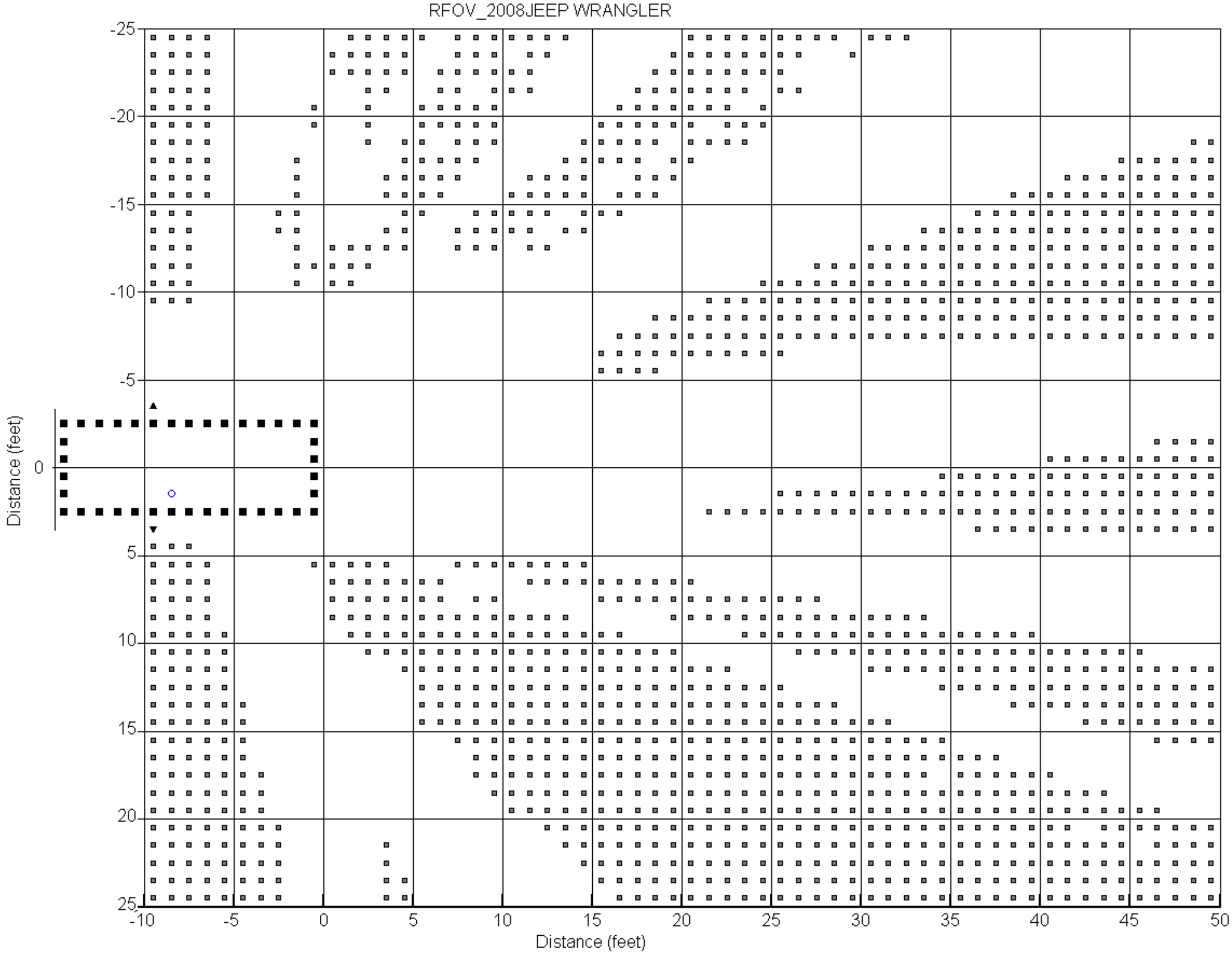

Figure 83. 2008 Jeep Wrangler Rear Field of View Data Plot

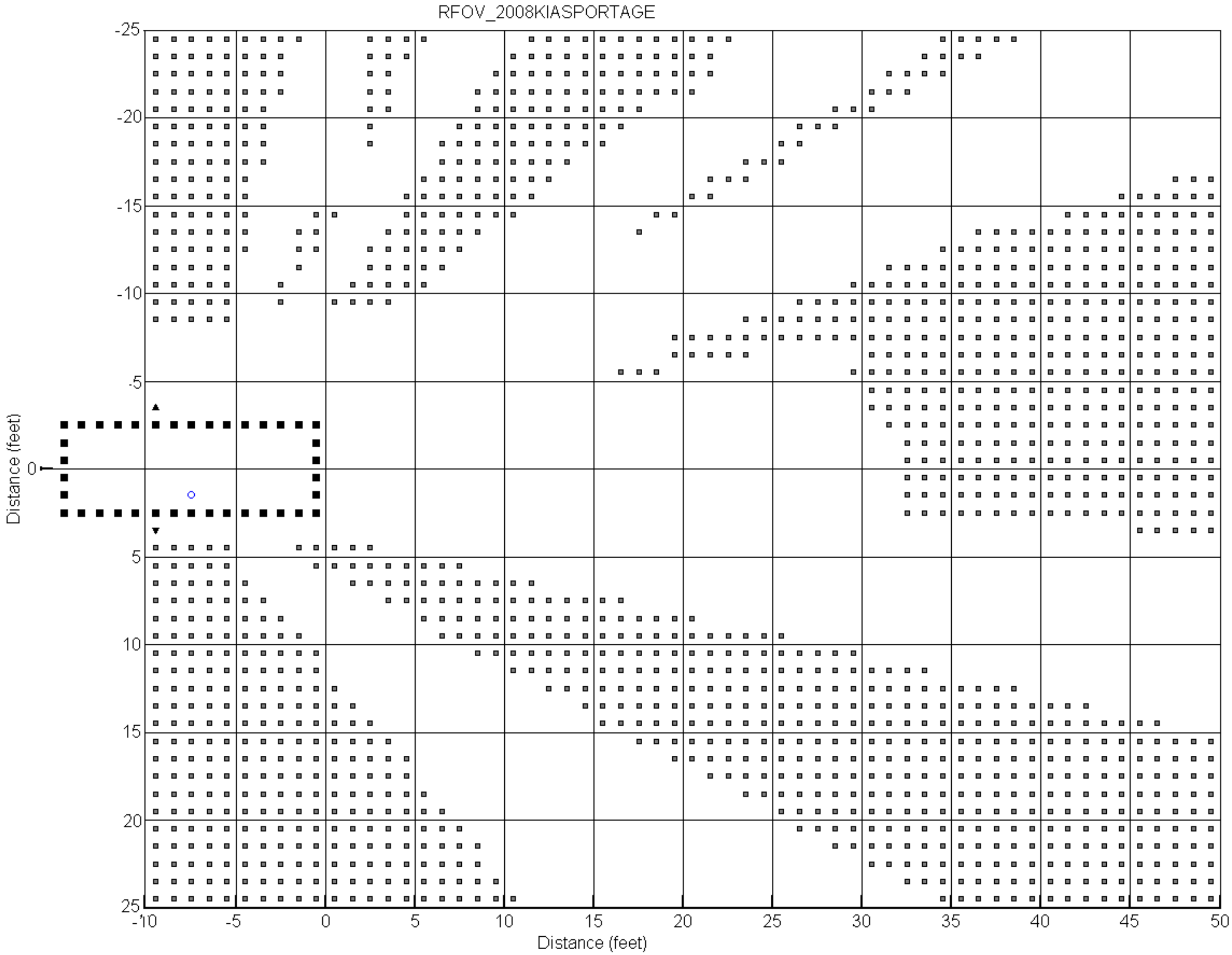

Figure 84. 2008 Kia Sportage Rear Field of View Data Plot

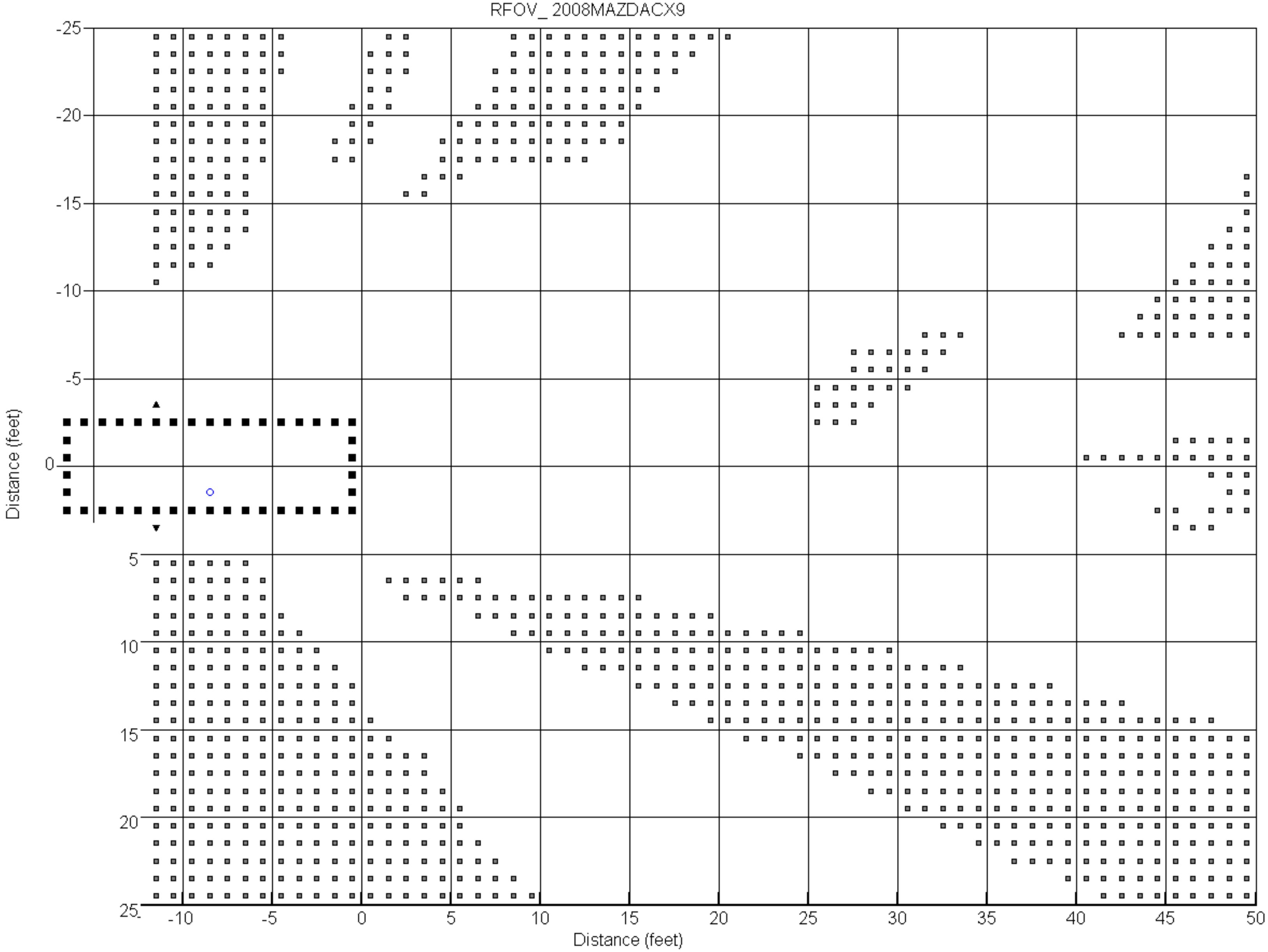

Figure 85. 2008 Mazda CX9 Rear Field of View Data Plot

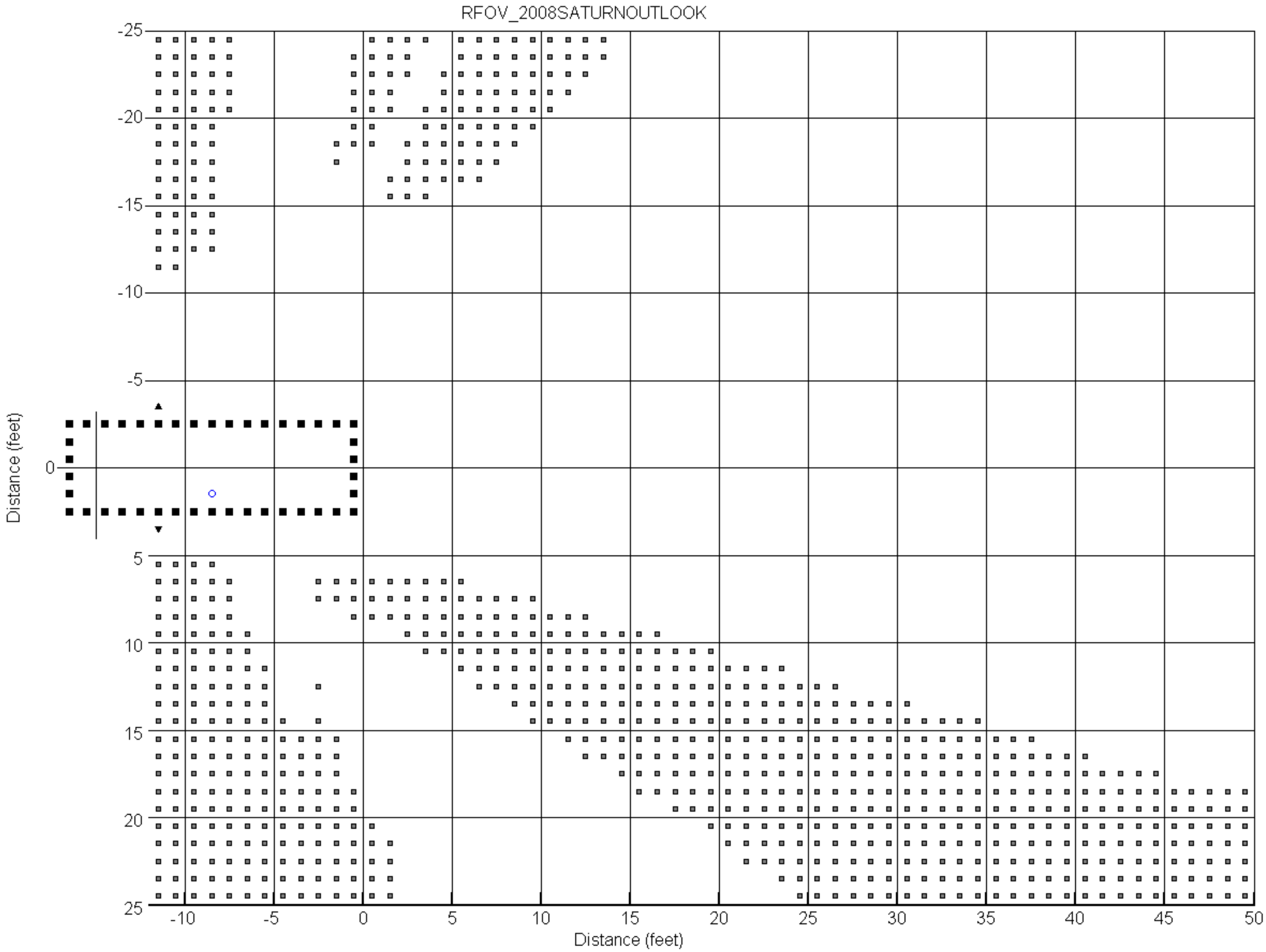

Figure 86. 2008 Saturn Outlook Rear Field of View Data Plot

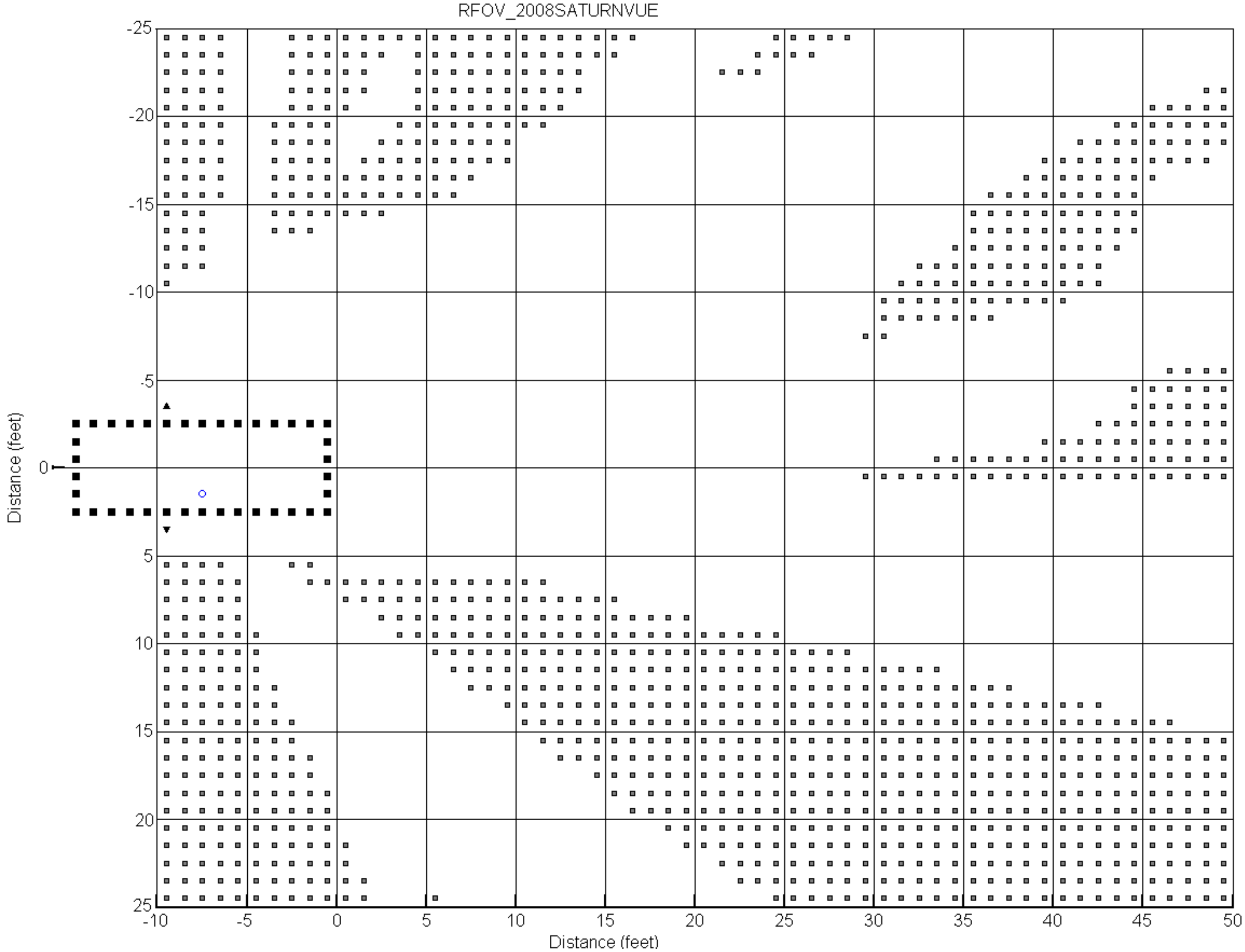

Figure 87. 2008 Saturn Vue Rear Field of View Data Plot

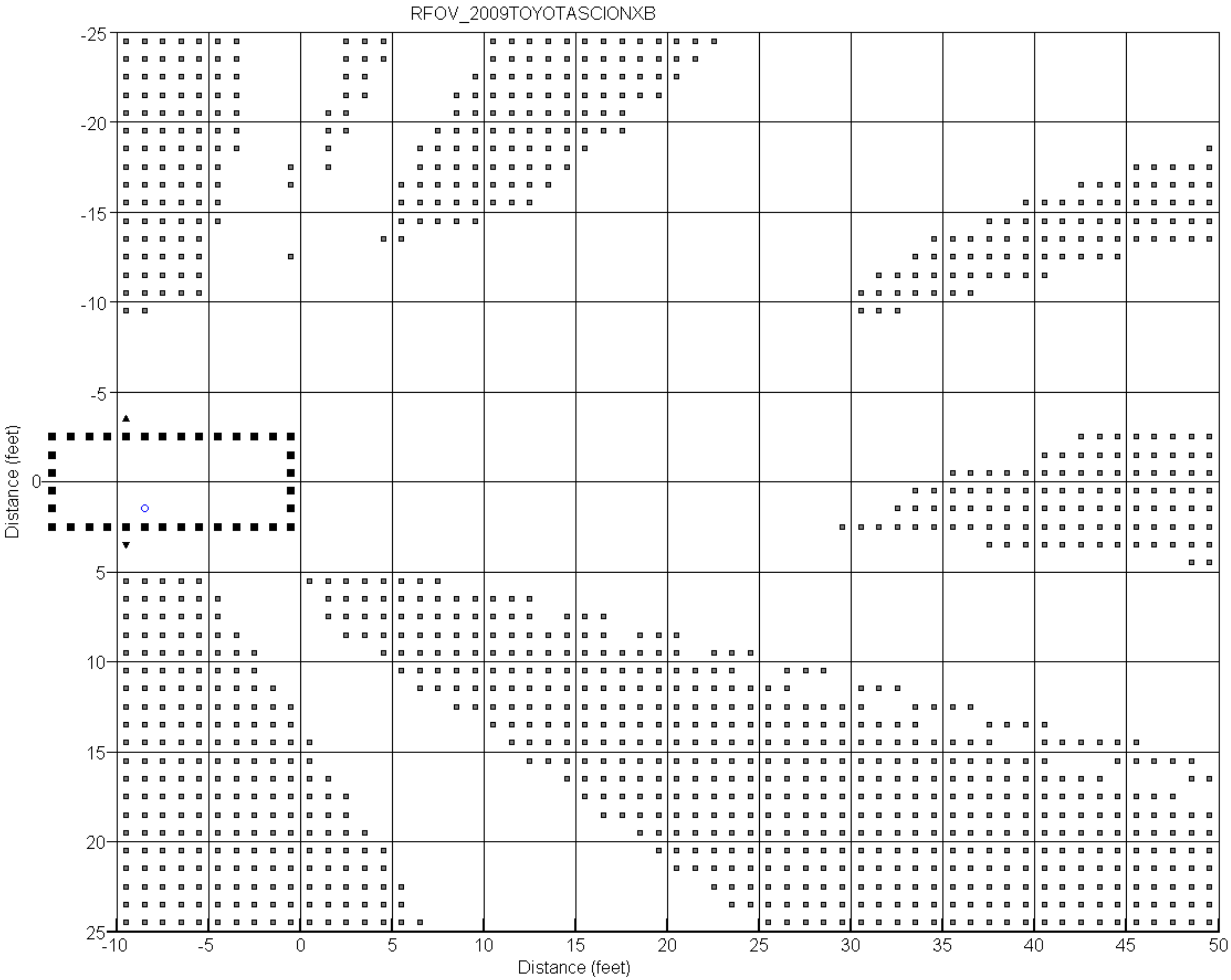

Figure 88. 2009 Scion xB Rear Field of View Data Plot

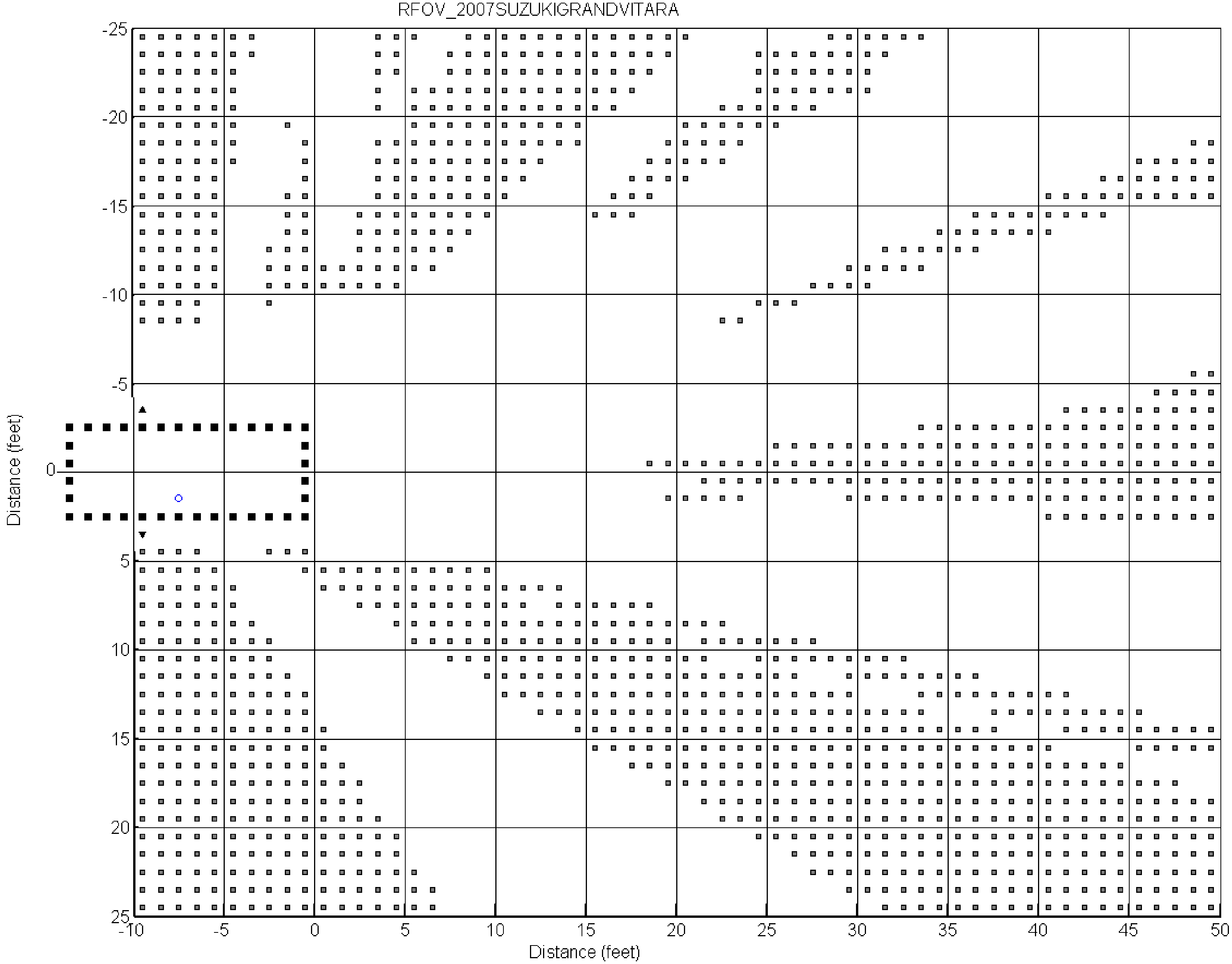

Figure 89. 2007 Subaru Grand Vitara Rear Field of View Data Plot

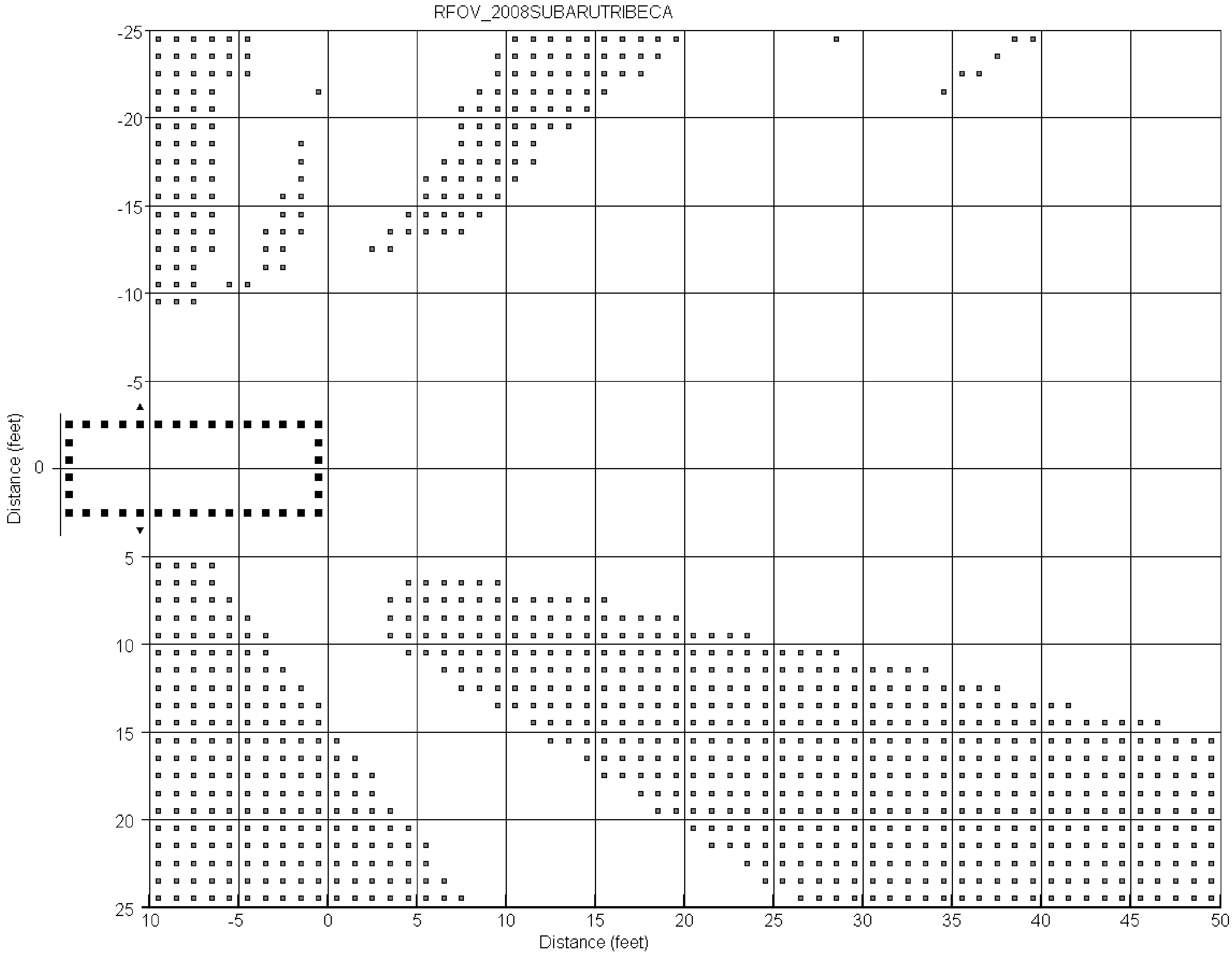

Figure 90. 2008 Subaru Tribeca Rear Field of View Data Plot

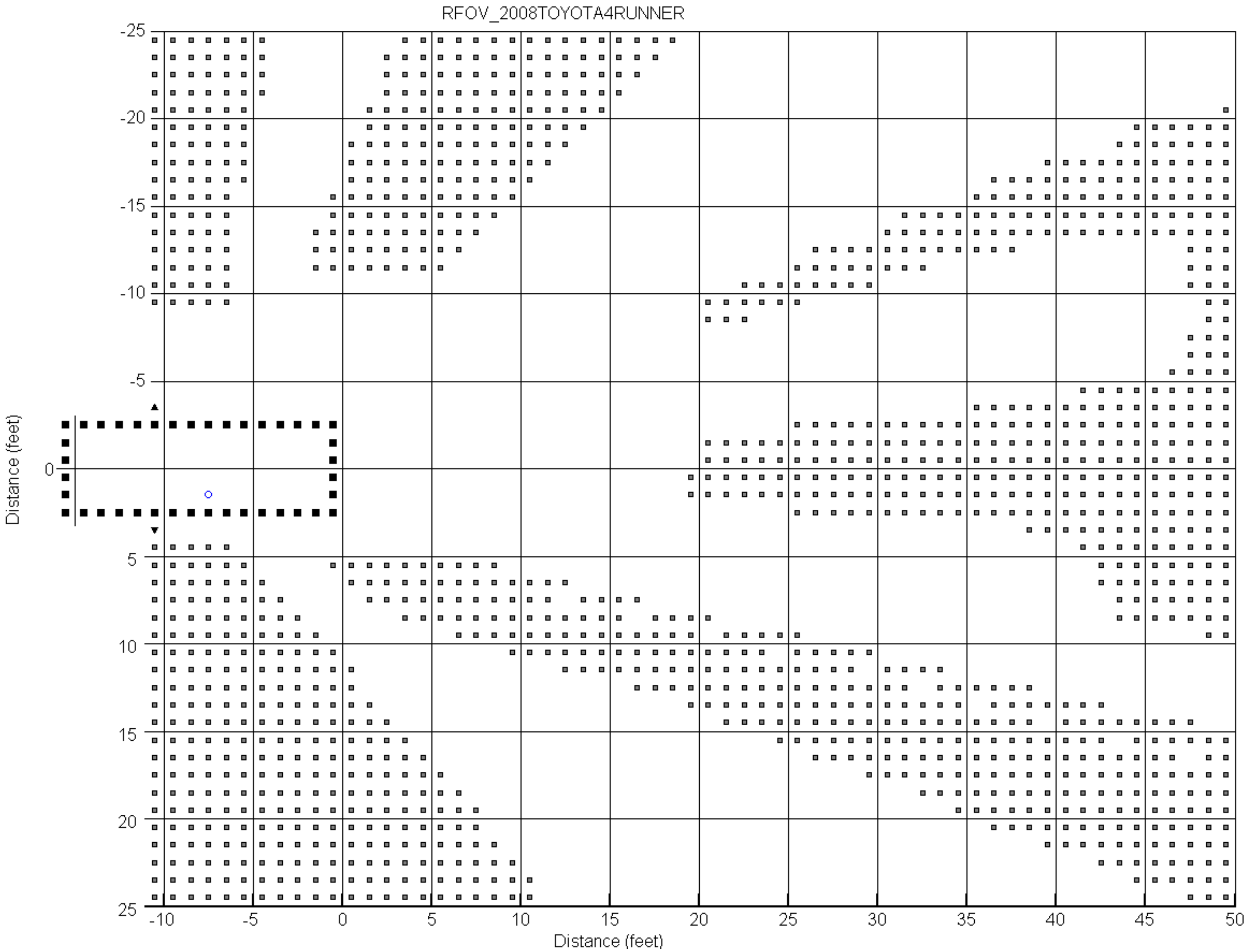

Figure 91. 2008 Toyota 4Runner Rear Field of View Data Plot

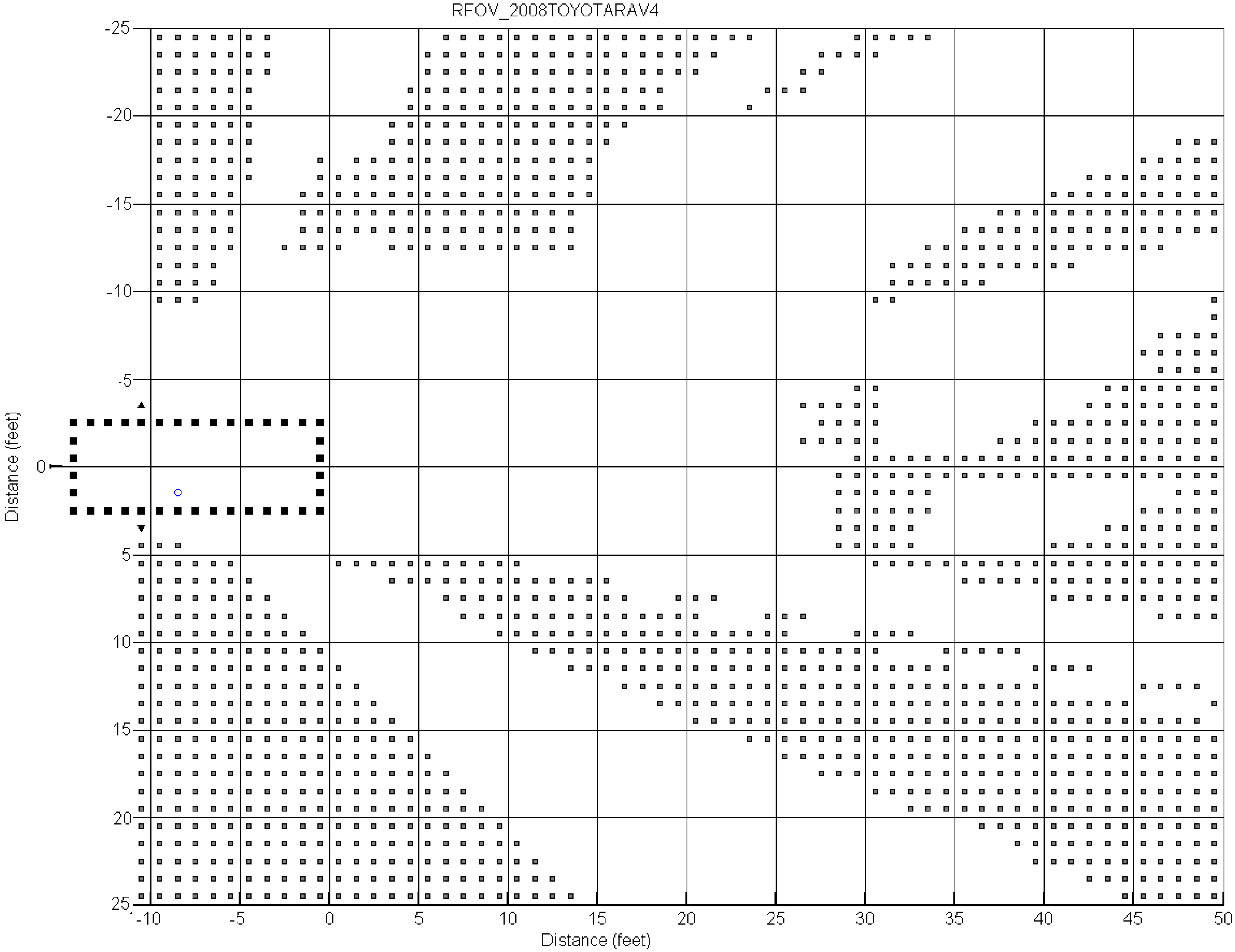

Figure 92. 2008 Toyota RAV4 Rear Field of View Data Plot