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16. Abstract

This report describes a study in which the rear visibility characteristics of a set of 44 vehicles were measured. The visibility of a visual target consisting of a 29.4-inch-tall traffic cone (i.e., approximately the height of a 1-year-old child) was determined over a 6300-square-foot area stretching 35 feet to either side of the vehicle's centerline and 90 feet back from the vehicle's rear bumper. Rear visibility was measured for both a 50th percentile male driver (69.1 inches tall) and a 5th percentile female driver (59.8 inches tall). The areas over which the visual target was visually discernible using direct glances and indirect glances (i.e., using mirrors) was determined.

Direct view (i.e., using glances out windows, not using mirrors) rear sight distances values taken in 1-foot increments across the back of vehicles were measured. The average of the eight distance values across the rear of the vehicle was then calculated. Direct-view rear sight distances were found to be shortest for small pickup trucks, compact SUVs, and compact passenger cars. Average rear sight distances were longest for a full-size van (45 feet), mid-size (44 feet) and large SUVs (≥ 34 feet), and large pickup trucks (35 feet).

Rear, direct view blind zone areas for the vehicles measured were found to be smallest for small pickup trucks, compact passenger cars, and mid-size passenger cars. Direct view rear blind zone areas were largest for full-size vans, large and mid-size SUVs, large pickup trucks. Average blind zone sizes by vehicle types ranged from 100 square feet (small pickup trucks) to 1440 square feet (large SUVs).

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EXECUTIVE SUMMARY

Backover crashes involve a person being struck by a vehicle moving in reverse. Tragically, the victims of backing crashes are frequently young children. 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 will provide 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 exist and 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 some characteristic 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 44 vehicles. The vehicles were chosen based on 2006 U.S. sales by make/model, the results of August 2006 blind spot testing by Consumers' Union, results-to-date of NHTSA's Special Crash Investigation (SCI) focused on backover crashes, and vehicle body type and size.

The visibility of a visual target was determined over a 6300-square-foot area stretching 35 feet to either side of the vehicle's centerline and 90 feet back from the vehicle's rear bumper. 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 male driver (69.1 inches tall) and a 5th percentile female driver (59.8 inches tall). The areas over which the visual target was visually discernible using direct glances and indirect glances (i.e., using side and center rearview mirrors) were determined.

Results for rear sight distance for the particular visual target used showed that average direct view rear longitudinal sight distances were shortest for small pickup trucks, compact SUVs, and compact passenger cars. Average rear sight distances were longest for full-size vans (45 feet), mid-size SUVs (44 feet), large SUVs (≥ 34 feet), and large pickup trucks (35 feet).

To permit the comparison of rear visibility characteristics across different vehicles, several rear blind zone area calculations were made. The blind zone area calculations considered only those areas not visible by direct glances (i.e., areas visible using mirrors or rearview video systems were not considered in these calculations). The rationale for this was that since all passenger vehicles have side mirrors and center rearview mirrors that are essentially the same, the key source of variability in the rear visibility afforded a driver would be the structure of the vehicle’s body and interior components (e.g., rear head restraints). Therefore, these data highlight the direct rear visibility of vehicles resulting from their structural characteristics.

Direct view rear blind zone areas were found to be smallest for small pickup trucks, compact passenger cars, and mid-size passenger cars. Direct view rear blind zone areas were largest for full-size vans, large and mid-size SUVs, and large pickup trucks. Average blind zone sizes by vehicle types ranged from 100 square feet (small pickup trucks) to 1440 square feet (large SUVs).

1.0 INTRODUCTION

Backover crashes involve a person being struck by a vehicle moving in reverse. Tragically, the victims of backing crashes are frequently young children. Due to their short stature, children can be difficult to detect in a vehicle's rear blind zone.

In 2006, the National Highway Traffic Safety Administration (NHTSA) published a report to Congress documenting an examination of the safety problem of motor vehicle backover crashes involving pedestrians and the evaluation of available technologies that might help to reduce them [1]. This "Vehicle Backover Avoidance Technology Study" report described the problem from a number of angles, including related demographics, circumstances surrounding backover crashes, the frequency of involvement of different vehicle types, and rear visibility in different vehicle types. In terms of vehicle types, this report stated that "several analyses have found that minivans, pickup trucks and sport utility vehicles (SUVs) have a higher involvement rate in backover crashes than passenger cars." While greater exposure of these vehicle types to the presence of children and other pedestrians around them when backing is a plausible contributing factor to these crashes, poor rear visibility is also a plausible factor.

1.1 Backover Crashes and Vehicle Type

In attempting to understand the problem of crashes involving backing vehicles striking children, it makes sense to examine whether some characteristic 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) is affected by the structural design of the vehicle. Interior vehicle components, such as head restraints, can impact rear visibility. Exterior qualities of vehicles, such as vehicle height and length, pillar width, and rear window height, are also likely to impact rear visibility. Poor rear visibility contributes to the likelihood of unseen obstacles, which may include pedestrians.

Pinkney, et. al estimated injury incidence due to driveway backover incidents for four classes of vehicles [2]. They examined driveway backover events that occurred in Utah over the 6-year-period of 1998 to 2003. Figure 1 [2] illustrates their findings regarding the average incidence of injuries due to backing vehicles striking children. Compared to passenger cars, these data show statistically significant higher injury rates for pickup trucks (53 percent higher) and vans (240 percent higher). The study found that pickup trucks and vans were more likely to cause incapacitating injuries to children in backover incidents. Both increased exposure to children and poor rear visibility of pickup trucks, SUVs, and vans may contribute to the observed increased likelihood of a backover crash for these vehicle types.

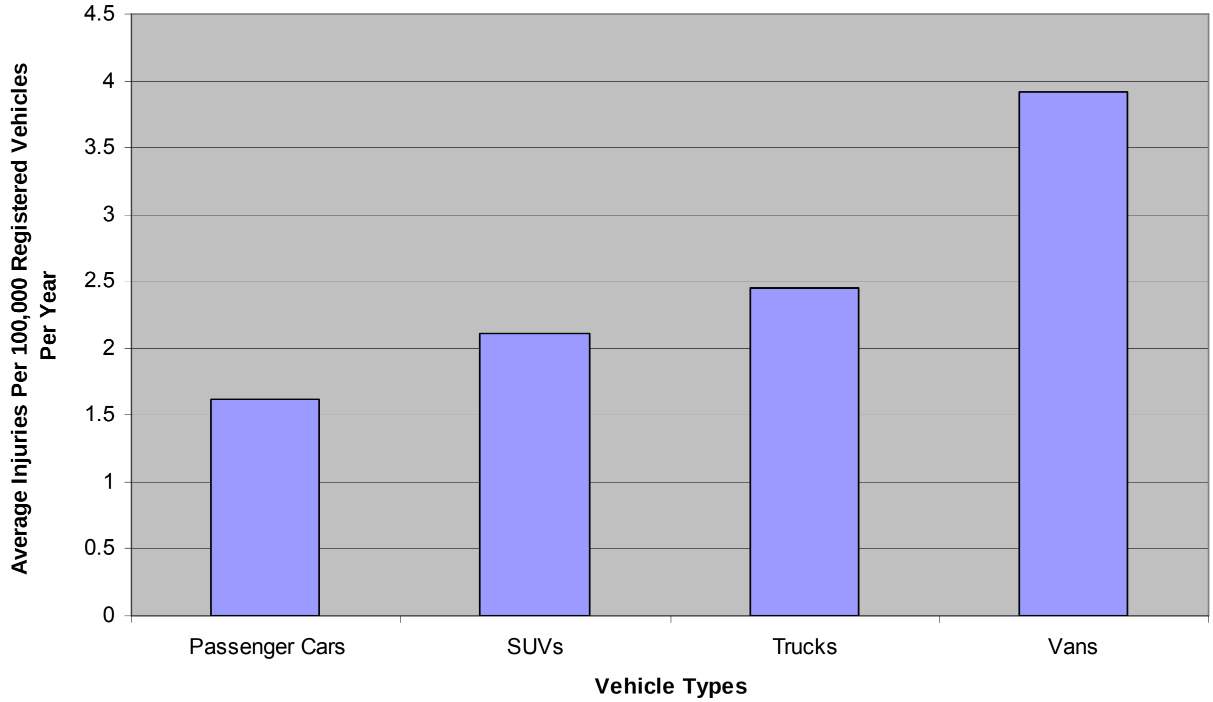

Figure 1. Average Injury Incidence Per 100,000 Registered Vehicles Per Year in Utah for 1998 to 2003

1.2 Rear Visibility and Vehicle Type

A logical hypothesis about the incidence of backover crashes with child pedestrians would be that the worse a vehicle's rear visibility, the larger the risk of involvement in a backover crash. To this end, some organizations have set out to measure the rear visibility of vehicles and, in particular, the area in which rear obstacles cannot be seen.

All vehicles have areas behind them which are not visible to the driver directly or in the vehicle's mirrors. Such an area could obscure the driver's visibility of small children [1]. The term, "blind spot," has been used to refer to the area behind a vehicle that is not visible to the driver. To characterize blind spots, single values of distance to a visible object have been used. This type of vehicle blind spot measurement has been conducted by Consumer Reports [3] in the United States. Paine, Macbeth & Henderson [4] in Australia measured blind spot length and area. In 2006, NHTSA went beyond a single "spot" value to measure the distance to view an object of specified height across an area of at least 20 feet wide by 50 feet long behind the vehicle [5]. Descriptions of these efforts follow.

1.2.1 Consumer Reports Blind Spot Testing

Consumer Reports examined vehicles to determine the closest distance at which a 28-inch-tall traffic cone could be detected behind a vehicle. Actual drivers were seated in the vehicle and the distance from the rear bumper at which they could detect the top of a centrally located 28-inch-tall traffic cone was measured. The heights of the subject drivers were 68 inches and 61 inches. The cone's height approximated the height of a child less than 1 year old [6, 7].

The Consumer Reports data show several patterns. As expected, rear visibility is better for taller drivers than for shorter drivers. The average rear blind spot length across all vehicles tested was 14 feet for a taller driver (68 inches) and 23 feet for a shorter driver (61 inches).

Blind spot data were examined by vehicle type. The Consumer Reports data (Figure 7) show that the longest blind spots were found for pickup trucks, followed by minivans and SUVs [1]. While the data indicate that sedans, on average, had a blind spot that was 2 feet smaller than that of SUVs (Sedans 21 feet, SUVs 23 feet), some sedans were found to have worse rear visibility than some SUVs.

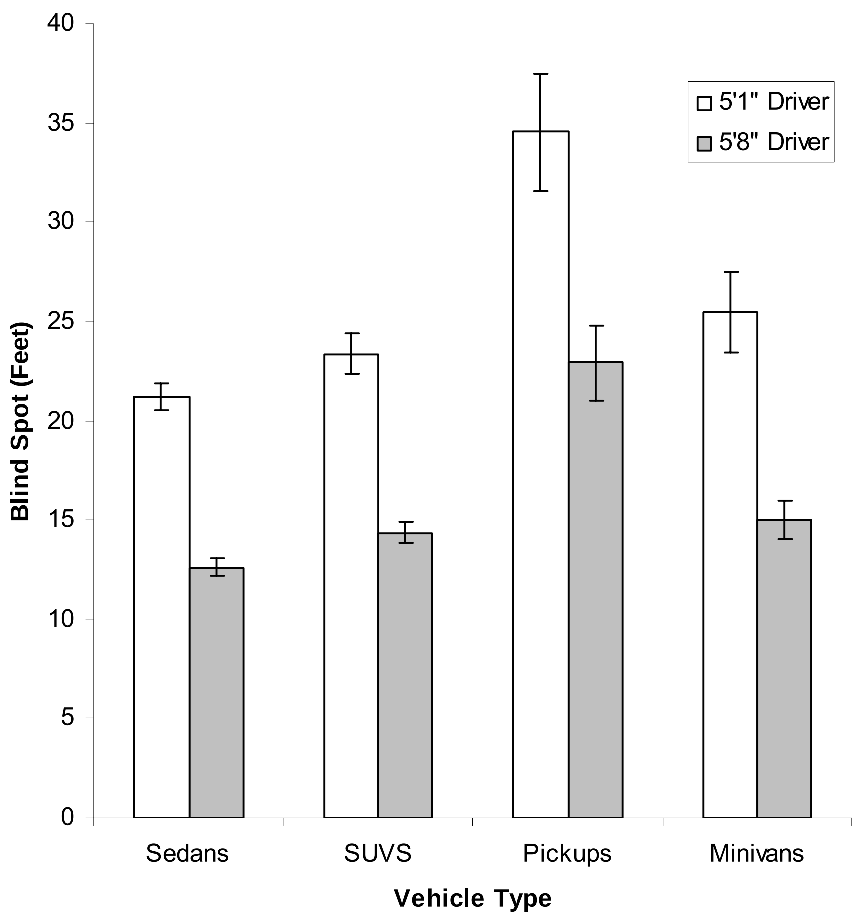

Figure 2. Consumer Reports Blind Spot Ratings by Vehicle Type

Note: Y error bars representing Standard Error of the Mean

1.2.2 Paine et al. Blind Spot Testing

In the Insurance Australian Group study, Paine, Macbeth & Henderson [4] used a measuring device representing an approximately 50th percentile male to detect a centrally located 24-inch-tall (600 mm) test cylinder having a 7.87 inch (200mm) diameter. The cylinder size approximated the height of a child less than 1 year old [6, 7].

Overall, this research found the vehicles examined to have an average blind spot length of 23 feet [1]. Large cars were found to have longer blind spots than SUVs (refer to as “4WDs”), pickups (Utilities) and minivans (People Movers), as shown in Figure 3. While these results seem contrary to those of Consumer Reports, differences in vehicle styling in these different markets may be responsible.

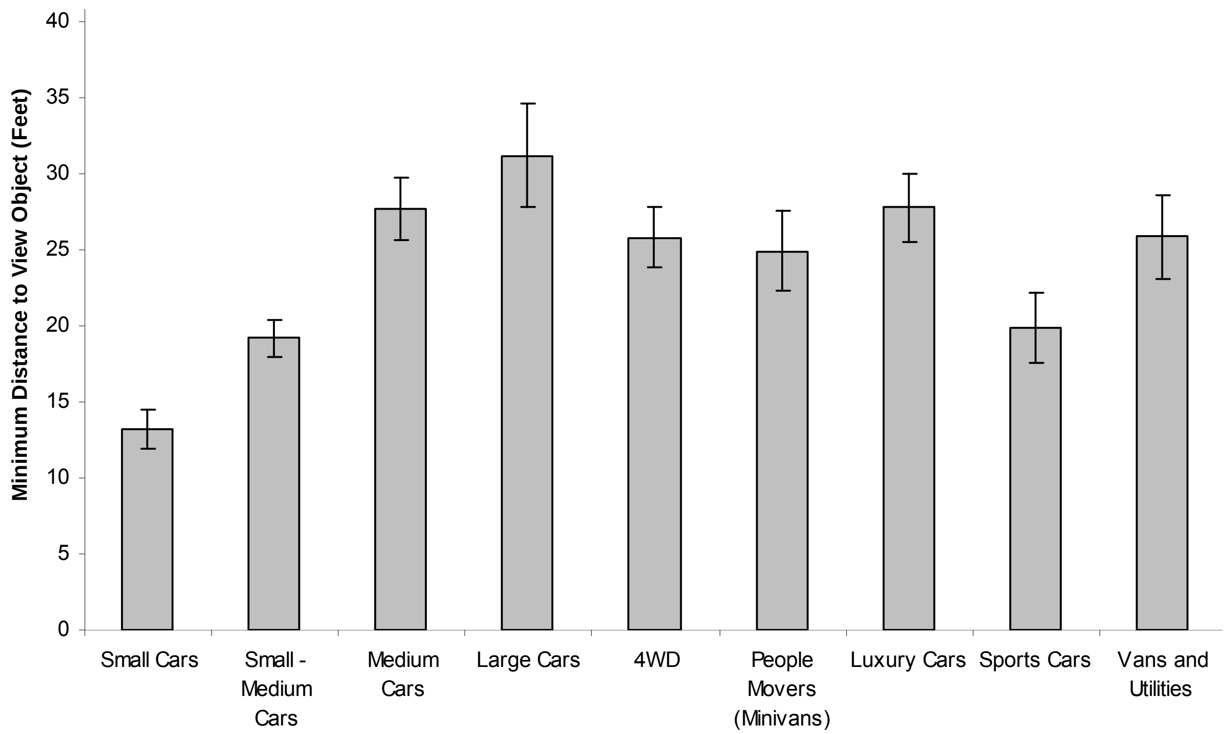

Figure 3. Visibility Distances by Vehicle Type [4; Paine, et al., 2003]

Note: Y error bars represent Standard Error of the Mean

1.2.3 NHTSA Rear Visibility Research

In support of 2006 congressionally mandated research to examine technologies for preventing backover crashes, vehicles acquired by NHTSA for rear parking aid system testing were also examined for their rear visibility [5]. The method used was similar to that used by Consumer’s Union [3]. A 28-inch-tall traffic cone was placed behind the vehicle, and the minimum distance at which the top of the cone could be seen via direct view (i.e., glancing out the window) or center rearview mirror glance by the driver was noted.

Side rearview mirrors were not used in this particular set of visibility tests, although it is possible to see some areas behind the vehicle using mirrors. Some of the vehicles used in this research (e.g., 2006 BMW 330i and 2005 Nissan Quest) had left-side, rearview mirrors that tilted downward when the vehicle transmission was placed in reverse gear.

While this shift of the mirror permits the driver to see more of the area directly adjacent to the vehicle (e.g., such as for viewing pavement marking lines when backing into a parking space), it nearly eliminates the ability of this mirror to show objects behind the vehicle. In addition, side rearview mirrors are also subject to a greater range of driver preferences in adjustment that affect field of view. Thus, to simplify testing and analysis, side rearview mirrors were not used in this field of view testing.

For each vehicle, minimum sight distance values were recorded for a 10-foot span across the rear of the vehicle. A maximum distance of 100 feet from the rear bumper of the vehicle was used. Drivers of two heights were used for these measurements, a 5th percentile female and a 50th percentile male driver. During testing, the subject sat in the driver's seat and wore the seat belt. Table 1 presents sight distance values obtained for the 50th percentile male driver. In this table, column headings indicate a distance in feet from the centerline from the perspective of a person looking toward the rear of the vehicle. Therefore, '5L' would indicate a position 5 feet left of the centerline on the passenger side of the vehicle. For cases in which the 28-inch cone was not visible within 100 feet, "-" is listed.

Table 1. Sight Distance for a 50th Percentile Male Driver Viewing a 28-inch Traffic Cone (ft)

	Vehicle	**5L**	**4L**	**3L**	**2L**	**1L**	**CL**	**1R**	**2R**	**3R**	**4R**	**5R**
Direct Glance (e.g., glance over the shoulder)	2006 BMW 330i	71	70	71	66	64	23	20	19	18	20	20
	2007 Cadillac Escalade	-	-	-	99	89	31	32	32	41	35	31
	2005 Infiniti FX35	28	21	19	45	24	22	17	21	22	19	19
	2005 Lincoln Navigator	59	52	52	50	49	46	44	48	49	49	51
	2005 Nissan Quest	41	40	38	37	36	33	21	19	22	33	33
	2003 Toyota 4Runner	22	18	23	25	19	17	16	17	18	18	21
Center Rearview Mirror Glance	2006 BMW 330i	37	26	22	22	23	26	26	21	22	23	29
	2007 Cadillac Escalade	46	35	36	35	34	37	35	31	32	37	46
	2005 Infiniti FX35	38	32	24	19	18	22	19	18	19	22	31
	2005 Lincoln Navigator	42	45	39	38	39	42	43	37	45	44	45
	2005 Nissan Quest	37	36	26	24	34	36	30	25	37	38	37
	2003 Toyota 4Runner	22	24	17	18	22	23	19	18	18	20	21

Data showed that neither driver could see the 28-inch cone using direct glances within 15 feet of the rear of the vehicle for any of the vehicles examined. Using the center rearview mirror, the 28-inch cone could not be seen closer than 17 feet from the rear of any vehicle.

Figure 4 [1] graphically presents the direct glance sight distance data for the 50th percentile male driver. This graph emphasizes that the largest variability in sight distance was observed for the 2007 Cadillac Escalade. For three of the six vehicles, visibility on the left side of the vehicle was noticeably worse than that on the right side. While these visibility ratings for six vehicles of mixed body type cannot be considered representative of the vehicle fleet, they do illustrate how rear visibility can vary across vehicles. These data also illustrate that a single data point cannot fully capture the true picture of rear visibility for most vehicles.

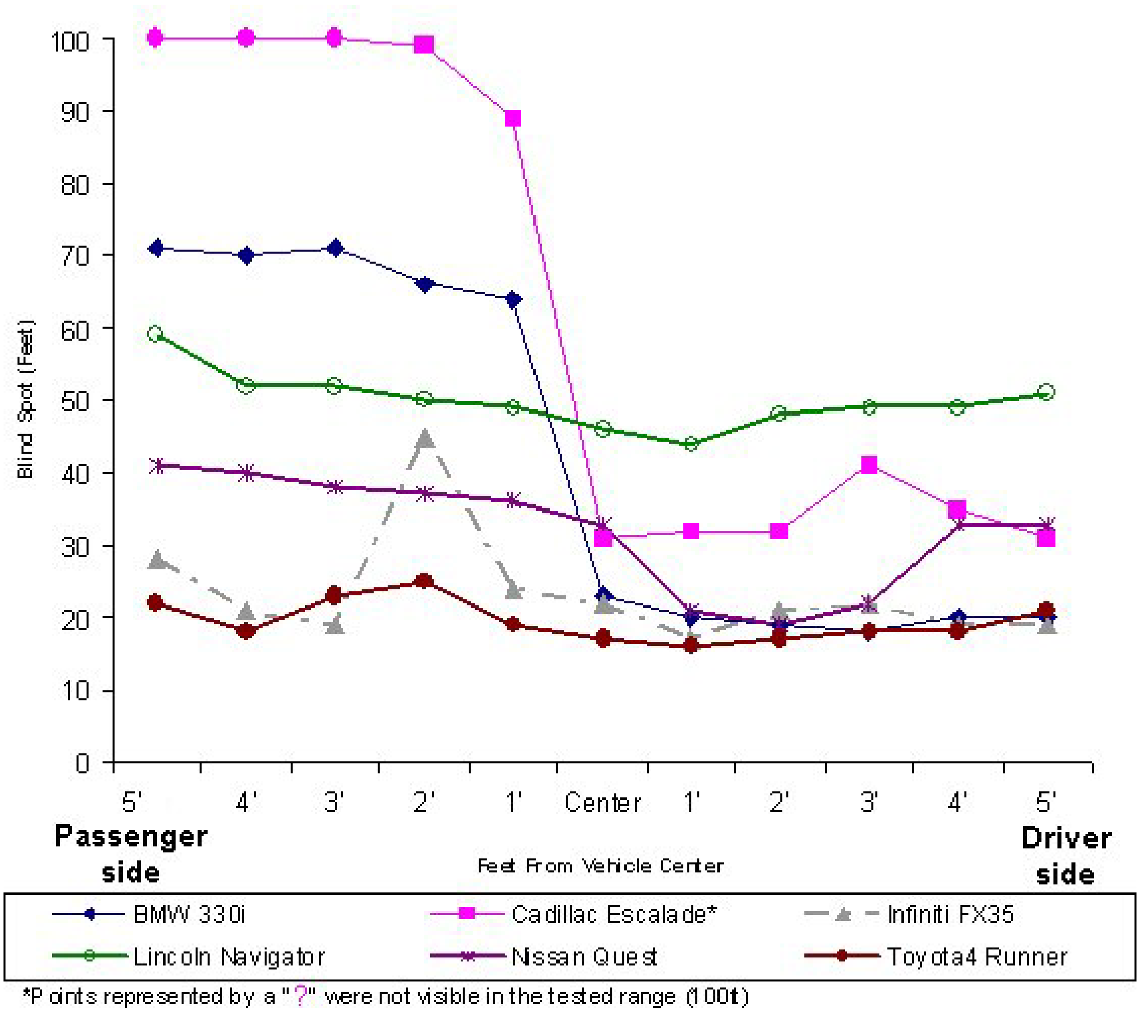

Figure 4. Sight Distance of a 50th Percentile Male Driver Viewing a 28-inch-tall Cone

1.3 Study Objectives

To gather more information about the impact of vehicle size and structure on rear visibility, NHTSA set out to measure the rear visibility of a number of current model vehicles. This rear visibility measurement effort sought to examine more than just a blind spot, but the entire rear field of view for a field covering approximately 180 degrees around the rear of the vehicle. Within this field, “blind zones,” consisting of a two-dimensional area over which a rear object is not visible to a driver, could be identified. The rear fields of view of a set of 44 contemporary vehicles of multiple sizes (e.g., compact, mid-size, full-size, SUV, minivan) were measured. These field of view (FOV) data are hoped to provide information useful in determining the degree to which rear visibility may contribute to the incidence of backover crashes. The results of this effort could also be released to the public to assist vehicle buyers in understanding visibility aspects of vehicle design that may not be easily discerned during a test drive.

2.0 METHOD

This section outlines the methods for vehicle field of view measurement and for the selection of vehicles for measurement.

2.1 Vehicle Selection

The factors impacting the selection of vehicles included 2006 U.S. sales by make/model, the results of August 2006 blind spot testing by Consumers' Union, results-to-date [8] of NHTSA's Special Crash Investigation (SCI) focused on backover crashes, and vehicle body type and size. Based on these criteria, the resulting set of selected vehicles includes the top 10 selling vehicles of 2006 for the U.S. (Source: Automotive News)[9] and four of the top 20 selling cars in the U.S. in 2006 (Source: Automotive News)[9]. Using Consumer Reports' August 2006 blind spot data, an attempt was made to include a balance of vehicles having both relatively "large" and "small" rear blind spots. Since preliminary results of the SCI examination of backover crashes has shown a high involvement of large pickup trucks, additional vehicles of this type were included in this rear visibility measurement effort. Lastly, vehicles were chosen to span the range of body types and sizes by including two of each variety for most vehicle types/sizes. Table 2 lists the specific make/modes that were measured.

Table 2. Vehicles Assessed, by Type

Type	Year	Make	Model	Trim
Compact Car	2006	BMW	330i	4-door
Compact Car	2007	Chevrolet	Cobalt	Coupe
Compact Car	2007	Honda	Civic	4-door EX
Compact Car	2007	Toyota	Corolla	4-door S Sedan (with spoiler)
Compact Car	2007	Toyota	Yaris	4-door Sedan
Mid-size Car	2005	Cadillac	STS	Sedan
Mid-size Car	2005	Chevrolet	Malibu	Maxx, Same as 07 Body Style
Mid-size Car	2006	Ford	Taurus	4-door
Mid-size Car	2007	Honda	Accord	4-door, EX
Mid-size Car	2007	Nissan	Altima	2.5 S
Mid-size Car	2007	Pontiac	Grand Prix	Sedan
Mid-size Car	2005	Subaru	Forrester	Station Wagon
Mid-size Car	2007	Toyota	Camry	4-door LE V6 Sedan
Mid-size Car	2006	Volkswagen	Passat	
Large Car	2007	Chevrolet	Impala	4-door
Large Car	2005	Chrysler	300C	4-door
Large Car	2007	Ford	Five Hundred	4-door
Compact SUV	2008	Ford	Escape	XLT
Compact SUV	2005	Honda	CR-V	2WD
Compact SUV	2005	Infiniti	FX35	4-door, Rearview Video
Mid-size SUV	2005	Ford	Explorer	4WD
Mid-size SUV	2007	Honda	Element	
Mid-size SUV	2007	Jeep	Commander	4x4, 4-door
Mid-size SUV	2007	Nissan	Xterra	S-V6 4x4
Mid-size SUV	2007	Toyota	FJ Cruiser	4x4
Large SUV	2007	Cadillac	Escalade	Rearview Video
Large SUV	2007	Chevrolet	Tahoe	2WD
Large SUV	2006	Dodge	Durango	2WD
Large SUV	2007	Ford	Expedition	2WD
Large SUV	2003	Hummer	H2	4x4, 4-door
Small Pickup	2007	Ford	Ranger	2WD XLT, Super King Cab
Small Pickup	2007	Nissan	Frontier	4x4 CC SE (Crew Cab Long Bed)
Small Pickup	2006	Toyota	Tacoma	4x2
Large Pickup	2005	Chevrolet	Silverado	2500HD, Crew Cab Short Bed 2WD
Large Pickup	2007	Dodge	Ram	1500
Large Pickup	2006	Ford	F-150	4x4, 4-door Extended Cab
Large Pickup	2007	Toyota	Tundra	SR5 4WD, Ext. Cab Short Bed
Minivan	2005	Chevrolet	Uplander	2WD, Standard wheelbase
Minivan	2007	Ford	Freestar	
Minivan	2007	Honda	Odyssey	Touring, Rearview Video
Minivan	2007	Kia	Sedona	EX
Minivan	2006	Mercury	Monterey	
Minivan	2006	Toyota	Sienna	LE
Full-size Van	2004	GMC	Savana	

2.2 Data Collection Procedure

Field of view was measured with the vehicle positioned on a flat test surface covered with a grid of 1 ft squares. Both directly viewable areas (by glancing out a window) and indirectly viewable areas (by glancing at side or center rearview mirrors) were assessed.

To provide comprehensive information regarding a driver's ability to see objects surrounding the vehicle during backing, both rear and side fields of view were measured (i.e., rear 180 degrees defined by the plane of the driver's forward-facing body. Visibility of the visual target was assessed for a longitudinal distance of 90 feet aft and up to 10 feet forward of the vehicle's rear bumper and 35 feet laterally to either side of the vehicle's centerline, as shown in Figure 5. Visibility of the specified visual target was assessed for each 1-foot-square in the shown test grid.

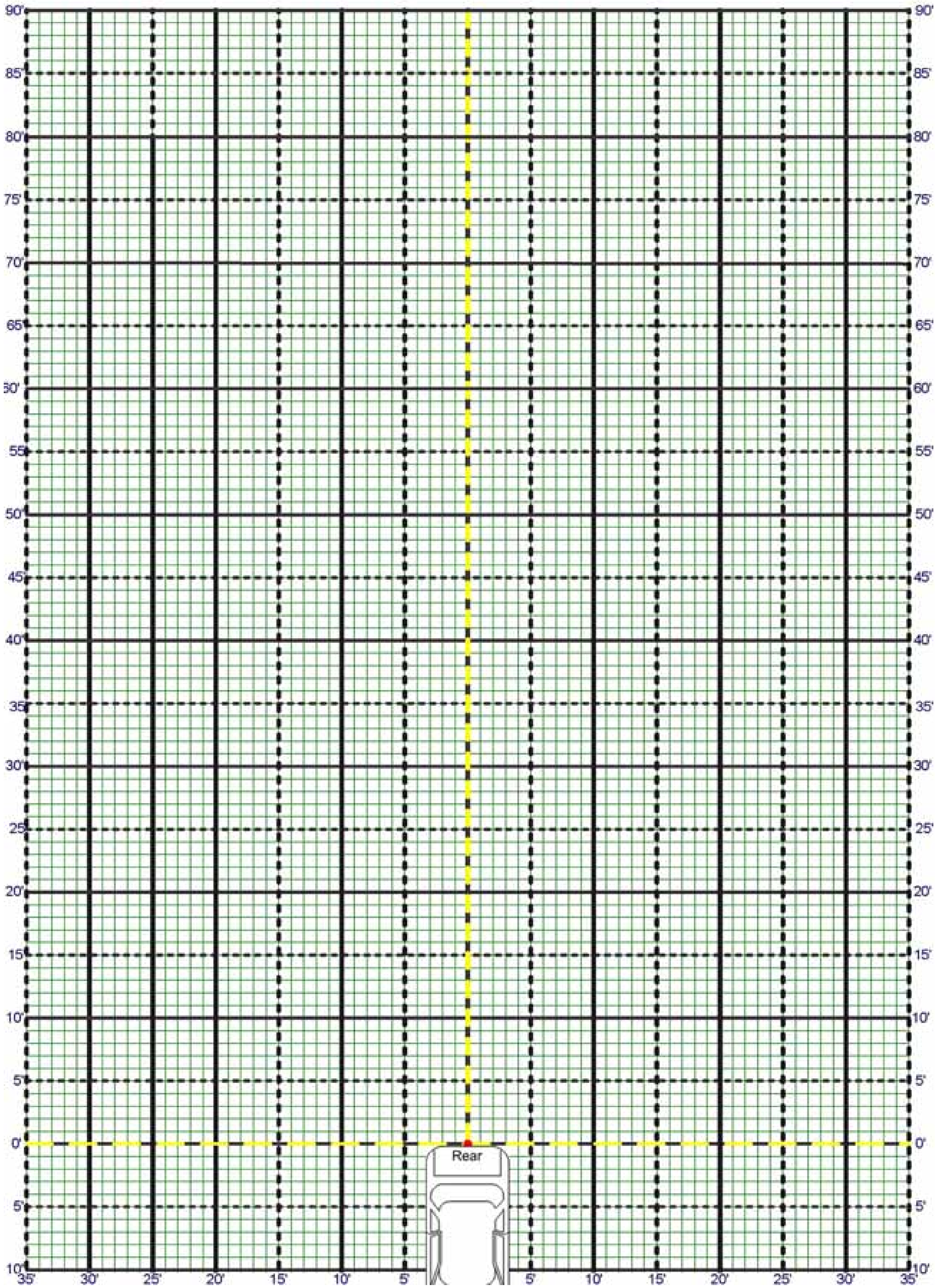

Figure 5. Illustration of Field of View Range Measured

The visual target was a 28-inch-tall traffic cone with a 3-inch in diameter red, circular reflector sitting atop it. The combined height of the cone and reflector was 29.4 inches to simulate that of a standing 1-year-old child. To determine this height, the Center for Disease Control's (CDC) growth chart values for the 50th percentile child standing height for a 1-year-old boy and 1-year-old girl (see Table 3) were averaged [6, 7]. Thus, the visual target used presented a nearly "worst-case scenario" in terms of object height since it approximated the height of the youngest backover victims. The breadth of the reflector was somewhat smaller than that of the average 1-year-old child's head (5 in.)[9].

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

Measurements were made with one person (the 'driver') in the vehicle's driver's seat reporting whether or not they could see the reflector and a second person moving the visual target and manually recording whether or not the target could be seen at each location on the grid. The visual target was considered "visible" if the driver could see the entire reflector mounted atop the traffic cone.

Drivers of two different heights were used: a 5th percentile female (59.8 in.) [11] and a 50th percentile male (69.1 in.)[11] having normal vision. The drivers rested their weight fully on the driver's seat pan and positioned their feet as close as possible to where they would be during driving. The subjects wore lap and shoulder restraints. The driver's seat and head restraint positions were adjusted to positions appropriate for his or her height. The driver adjusted the side rearview mirrors such that the side of the car was slightly visible in the mirror, to aid in ensuring that mirrors were set similarly for all vehicles. (Note that not including any view of the vehicle's side in the side view mirror would make it more difficult to know if the mirror was set to a particular angle.) Head restraints for unoccupied seats were in their lowest possible (stowed) position. Any folding rear seats were in their upright (occupant-ready) positions. The vehicle's windows were clean and clear of obstructions (e.g., window stickers).

Once the vehicle and driver were properly positioned, the FOV assessment began. A member of the research staff placed the cone in a square and the driver said whether or not they could see the reflector. The responses were recorded manually on a data sheet by the person outside the vehicle. After the entire FOV had been mapped, the data were entered into a spreadsheet program for plotting and computation of summary metrics.

3.0 RESULTS

This section summarizes rear field of view measurement data for 44 late-model vehicles. Basic measures are presented, such as the minimum distance at which an object was visible behind the vehicle. In addition, other summary metrics were calculated in an attempt to find a representative “figure of merit” to allow the discrimination of good versus poor rear visibility.

3.1 Rear Field of View

For the sake of brevity within the body of the report, FOV data were summarized into tables presenting relevant characteristics of the data. These tables are presented in the following sections. The actual measured FOV for the vehicles examined are presented graphically in Appendix A. While these FOV plots illustrate areas visible in each vehicle’s mirrors, the discussion of results focuses on direct glances, since these are more directly tied to the structure of the vehicle.

3.2 Rear Longitudinal Sight Distances

Since the vehicle’s structural features, such as pillars and head restraints, may affect rear visibility, rear longitudinal sight distance was examined along the entire rear of the vehicle. While most vehicle widths average approximately 6 feet, an 8-foot minimum measurement span width was used to encompass the width of any passenger vehicle measured. Therefore, 8 distance values were measured perpendicularly out from the vehicle’s rear bumper, as shown in Figure 6.

Figure 6 also illustrates the definitions of sight distance terms used. “Shortest minimum sight distance” was the longitudinal distance from the bumper, out of the 8 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 8 measured across the width of the vehicle that was farthest from the vehicle. To get the centerline sight distance, the two longitudinal distance values immediately adjacent to the centerline were averaged.

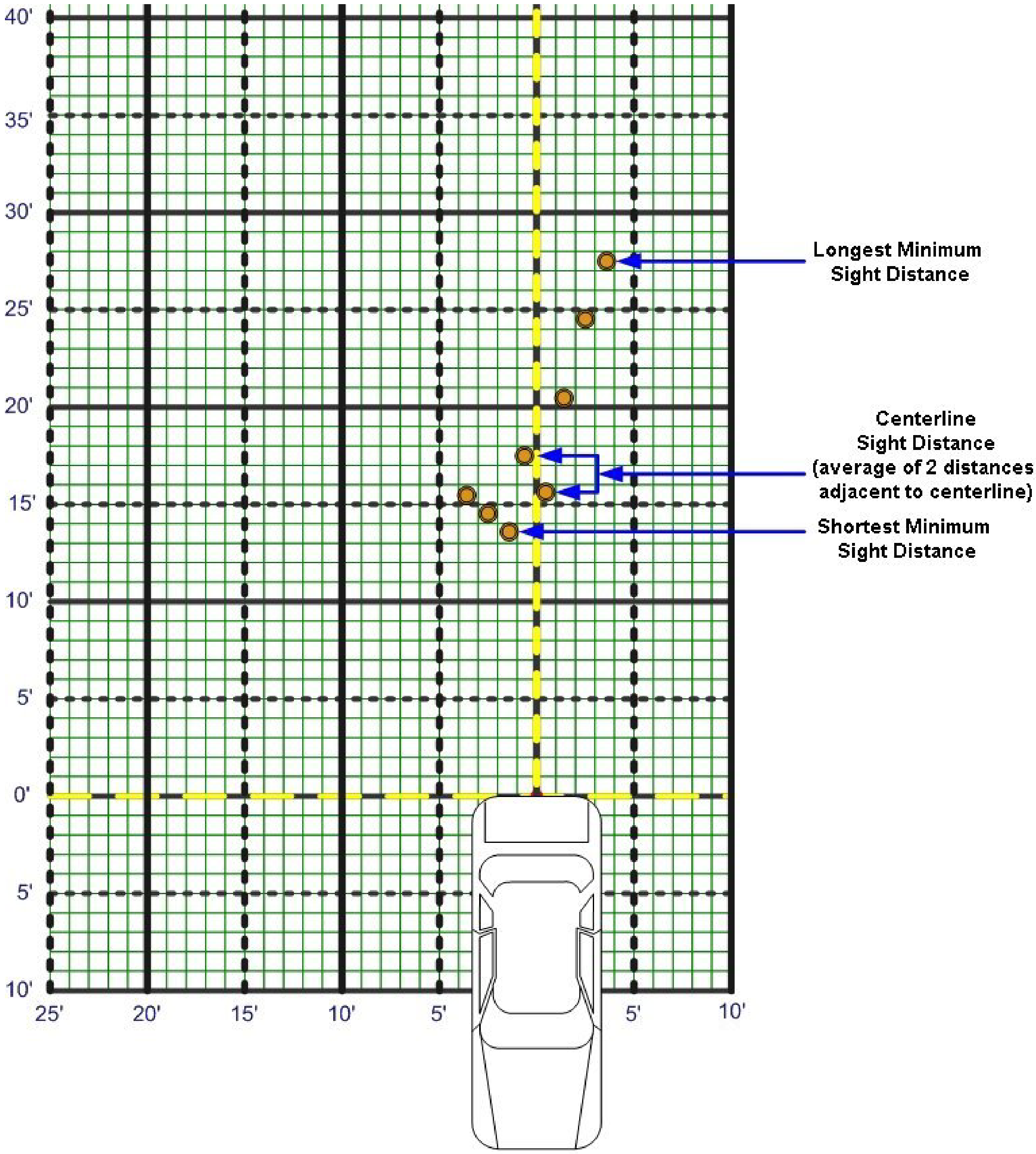

Figure 6. Illustration of 8 Sight Distance Data Points Measured and Definition of Sight Distance Terms

Rear visibility data presented in Table 4 include trials in which direct glances and mirror glances were recorded separately. Values for the centerline sight distance were interpolated from two measured values directly adjacent to the centerline (i.e., the reflector atop the cone was 6 inches from the vehicle's centerline) on either side. Table 4 also contains the shortest and longest minimum observed sight distances for each vehicle for a 50th percentile male driver.

Table 4. Summary of Direct Glance and Mirror Sight Distance for a 50th Percentile Male Driver Viewing a 29.4-Inch-Tall Traffic Cone

				Distance at which 29.4 Inch Tall Target Located Behind the Vehicle was Visible with Direct Glances			Distance at which 29.4 Inch Tall Target Located Behind the Vehicle was Visible with Mirrors		
Type	**Year**	**Make**	**Model**	Centerline	Shortest Minimum	Longest Minimum	Centerline	Shortest Minimum	Longest Minimum
Compact Car	2007	Toyota	Yaris (sedan)	13.5	12.5	17.5	21.0	8.5	21.5
Compact Car	2007	Toyota	Corolla S	14*	13.5	30.5	29.0	12.5	29.5
Compact Car	2006	BMW	330i	20.0	14.5	23.5	22.0	6.5	22.5
Compact Car	2007	Chevrolet	Cobalt	23.0	17.5	25.5	10.5	10.5	35.5
Compact Car	2007	Honda	Civic	25.0	22.5	28.5	28.0	12.5	28.5
Mid-size Car	2007	Nissan	Altima	17.0	16.5	22.5	26.0	13.5	28.5
Mid-size Car	2007	Pontiac	Grand Prix	18.0	16.5	18.5	20.5	20.5	21.5
Mid-size Car	2007	Toyota	Camry	21.0	20.5	25.5	33.5	19.5	33.5
Mid-size Car	2006	Ford	Taurus	21.5	17.5	25.5	24.0	19.5	24.5
Mid-size Car	2007	Honda	Accord	22.5	13.5	25.5	19.5	11.5	20.5
Mid-size Car	2006	Volkswagen	Passat	27.5	17.5	27.5	25.5	12.5	26.5
Mid-size Car	2005	Chevrolet	Malibu Maxx	29.0	17.5	30.5	34.0	7.5	34.5
Mid-size Car	2005	Cadillac	STS	29.5	26.5	32.5	27.0	16.5	27.5
Large Car	2005	Chrysler	300C	19.5	13.5	22.5	38.0	13.5	40.5
Large Car	2007	Ford	Five Hundred	20.0	13.5	20.5	19.0	10.5	19.5
Large Car	2007	Chevrolet	Impala	25.5	22.5	38.5	63.5	18.5	63.5
Compact SUV	2005	Subaru	Forrester	11.5	9.5	18.5	13.5	5.5	13.5
Compact SUV	2005	Honda	CRV	15.5	15.5	22.5	26.5	8.5	29.5
Compact SUV	2008	Ford	Escape	17.0	15.5	63.5	24.5	9.5	34.5
Compact SUV	2005	Infiniti	FX35	31.5	18.5	33.5	23.5	13.5	24.5
Mid-size SUV	2005	Ford	Explorer	15.5	14.5	20.5	21.5	11.5	21.5
Mid-size SUV	2007	Nissan	Xterra	28.5	25.5	30.5	28.5	19.5	29.5
Mid-size SUV	2007	Toyota	FJ Cruiser	34.5	19.5	63.5	48.0	19.5	63.5
Mid-size SUV	2007	Honda	Element	37.5	24.5	38.5	21.0	10.5	21.5
Mid-size SUV	2007	Jeep	Commander	>90**	>90**	>90**	37.5	12.5	42.5
Large SUV	2007	Chevrolet	Tahoe	24.5	24.5	47.5	33.0	10.5	38.5
Large SUV	2007	Ford	Expedition	25.5	23.5	28.5	28.0	21.5	29.5
Large SUV	2003	Hummer	H2	27.0	18.5	40.5	50.5	3.5	64.5
Large SUV	2008	Cadillac	Escalade	31.5	29.5	>90**	32.0	16.5	32.5
Large SUV	2006	Dodge	Durango	37.5	28.5	37.5	34.0	24.5	34.5
Small Pickup	2007	Ford	Ranger	11.5	11.5	12.5	14.5	12.5	14.5
Small Pickup	2006	Toyota	Tacoma	13.5	13.5	14.5	28.5	13.5	18.5
Small Pickup	2007	Nissan	Frontier	26.0	25.5	29.5	24.5	18.5	24.5
Large Pickup	2007	Dodge	Ram 1500	30.5	30.5	30.5	31.5	30.5	31.5
Large Pickup	2007	Toyota	Tundra	33.5	32.5	34.5	33.5	27.5	33.5
Large Pickup	2005	Chevrolet	Silverado 2500HD	35.5	34.5	37.5	39.0	30.5	39.5
Large Pickup	2006	Ford	F-150	38.0	36.5	39.5	35.5	31.5	36.5
Minivan	2007	Ford	Freestar	15.0	14.5	16.5	18.5	15.5	19.5
Minivan	2006	Mercury	Monterey	15.5	15.5	15.5	19.0	13.5	19.5
Minivan	2007	Kia	Sedona	21.0	20.5	37.5	22.0	19.5	23.5
Minivan	2006	Toyota	Sienna LE	22.5	22.5	25.5	30.0	15.5	30.5
Minivan	2007	Honda	Odyssey	25.5	23.5	34.5	28.5	13.5	28.5
Minivan	2005	Chevrolet	Uplander	31.5	31.5	53.5	29.5	21.5	30.5
Full-size Van	2004	GMC	Savana	43.5	42.5	44.5	67.0	18.5	73.5

*Note: There was a blindspot area from 18 ft to 28 ft behind the vehicle along the centerline.

** The visual target was not detectable directly behind the car within the 90 ft range assessed

Table 5 contains the same type of data for a 5th percentile female driver. Table 4 shows that longest minimum sight distance values for the 50^{th} percentile male driver were less than 50 feet for all but two of the 47 vehicles measured. For the 5^{th} percentile female driver, 38 of 44 vehicles had longest minimum sight distance values of less than 50 feet. This suggests that future measurement efforts could use a measurement grid with a longitudinal dimension of 50 feet, rather than 90 feet, and still obtain essentially as much information.

Table 5. Summary of Direct Glance and Mirror Sight Distance Data for a 5th Percentile Female Driver Viewing a 29.4-Inch-Tall Traffic Cone

				Distance at which 29.4 Inch Tall Target Located Behind the Vehicle was Visible with Direct Glances			Distance at which 29.4 Inch Tall Target Located Behind the Vehicle was Visible with Mirrors		
Type	**Year**	**Make**	**Model**	Centerline	Shortest Minimum	Longest Minimum	Centerline	Shortest Minimum	Longest Minimum
Compact Car	2007	Toyota	Yaris (sedan)	12.5	12.5	15.5	20	4.5	21.5
Compact Car	2006	BMW	330i	14.5	13.5	14.5	18.5	5.5	20.5
Compact Car	2007	Honda	Civic	19	18.5	23.5	26.5	7.5	26.5
Compact Car	2007	Toyota	Corolla S	20	19.5	24.5	17.5*	4.5	28.5
Compact Car	2007	Chevrolet	Cobalt	32	30.5	37.5	33	6.5	33.5
Mid-size Car	2007	Pontiac	Grand Prix	15	14.5	15.5	21	8.5	21.5
Mid-size Car	2007	Honda	Accord	16.5	16.5	20.5	19.5	10.5	20.5
Mid-size Car	2007	Nissan	Altima	16.5	14.5	16.5	24	8.5	25.5
Mid-size Car	2007	Toyota	Camry	19	16.5	24.5	32.5	8.5	32.5
Mid-size Car	2006	Ford	Taurus	19.5	18.5	24.5	23.5	14.5	23.5
Mid-size Car	2006	Volkswagen	Passat	29.5	29.5	32.5	24.5	7.5	24.5
Mid-size Car	2005	Cadillac	STS	31.5	31.5	32.5	26.5	11.5	26.5
Mid-size Car	2005	Chevrolet	Malibu Maxx	37.5	33.5	38.5	38.5	14.5	39.5
Large Car	2005	Chrysler	300C	21	20.5	31.5	39	11.5	42.5
Large Car	2007	Chevrolet	Impala	22.5	21.5	25.5	37.5	20.5	37.5
Large Car	2007	Ford	Five Hundred	26	23.5	27.5	18.5	8.5	18.5
Compact SUV	2005	Subaru	Forrester	12	9.5	17.5	11.5	6.5	12.5
Compact SUV	2005	Honda	CRV	19.5	18.5	30.5	27.5	19.5	30.5
Compact SUV	2008	Ford	Escape	22.5	22.5	58.5	33	16.5	39.5
Compact SUV	2005	Infiniti	FX35	30.5	21.5	34.5	20.25	11.5	21.5
Mid-size SUV	2005	Ford	Explorer	15.5	15.5	22.5	22.5	17.5	22.5
Mid-size SUV	2007	Nissan	Xterra	23.5	21.5	23.5	26	18.5	27.5
Mid-size SUV	2007	Honda	Element	29.5	29.5	41.5	23	10.5	23.5
Mid-size SUV	2007	Toyota	FJ Cruiser	67	21.5	90	43	12.5	53.5
Mid-size SUV	2007	Jeep	Commander	90	90	90	36.75	9.5	37.5
Large SUV	2007	Ford	Expedition	31	28.5	33.5	27.5	16.5	28.5
Large SUV	2008	Cadillac	Escalade	35.5	35.5	>90	33	13.5	34.5
Large SUV	2007	Chevrolet	Tahoe	36.5	36.5	43.5	40	25.5	43.5
Large SUV	2006	Dodge	Durango	39	30.5	39.5	31.5	22.5	33.5
Large SUV	2003	Hummer	H2	44.5	22.5	63.5	60.75	15.5	65.5
Small Pickup	2007	Ford	Ranger	12.5	12.5	12.5	14.5	11.5	18.5
Small Pickup	2006	Toyota	Tacoma	13.5	13.5	15.5	16.5	13.5	17.5
Small Pickup	2007	Nissan	Frontier	25.5	24.5	26.5	24.5	16.5	24.5
Large Pickup	2007	Dodge	Ram 1500	31.5	30.5	31.5	32	31.5	32.5
Large Pickup	2007	Toyota	Tundra	34.5	30.5	34.5	32.5	17.5	32.5
Large Pickup	2005	Chevrolet	Silverado 2500HD	37.5	37.5	37.5	39	30.5	39.5
Large Pickup	2006	Ford	F-150	60.5	60.5	60.5	38.5	17.5	36.5
Minivan	2006	Mercury	Monterey	15	12.5	15.5	17.5	11.5	17.5
Minivan	2007	Ford	Freestar	16.5	16.5	20.5	20	16.5	20.5
Minivan	2007	Honda	Odyssey	23	22.5	30.5	30	18.5	30.5
Minivan	2007	Kia	Sedona	26	25.5	29.5	21	15.5	24.5
Minivan	2006	Toyota	Sienna LE	34	32.5	35.5	28.5	19.5	28.5
Minivan	2005	Chevrolet	Uplander	46.5	45.5	60.5	28	15.5	28.5
Full-size Van	2004	GMC	Savana	43.5	43.5	43.5	≥73***	15.5	>90**

*Note: There was a blindspot area from 20 ft to 28 ft behind the vehicle along the centerline.

** The visual target was not detectable directly behind the car within the 90 ft range assessed

***One value adjacent to the centerline was greater than 90 ft, therefore this value could not be specifically calculated.

Centerline, shortest minimum, and longest minimum direct glance sight distances were also separately averaged for each vehicle type and size category. Figures 6 and 7 present values representing the average distance by vehicle type at which the 29.4-inch-tall object was directly visible to the two drivers. Since the visual target was not visible within the 90-foot longitudinal test limit in some cases for three SUVs measured, an average value that considered all the measured SUVs of that size could not be directly calculated. Therefore, one calculation was made that excluded vehicles that had a sight distance value of greater than 90 ft. A second calculation substituted a value of 90 feet (closest point to the bumper at which the target was shown to be invisible) to allow for an approximate calculation to be made that included these vehicles. These indirect calculations appear for the 50th percentile male driver in the mid-size SUV category (see Figure 7) and for the 5th percentile female driver in the large SUV category (see Figure 8).

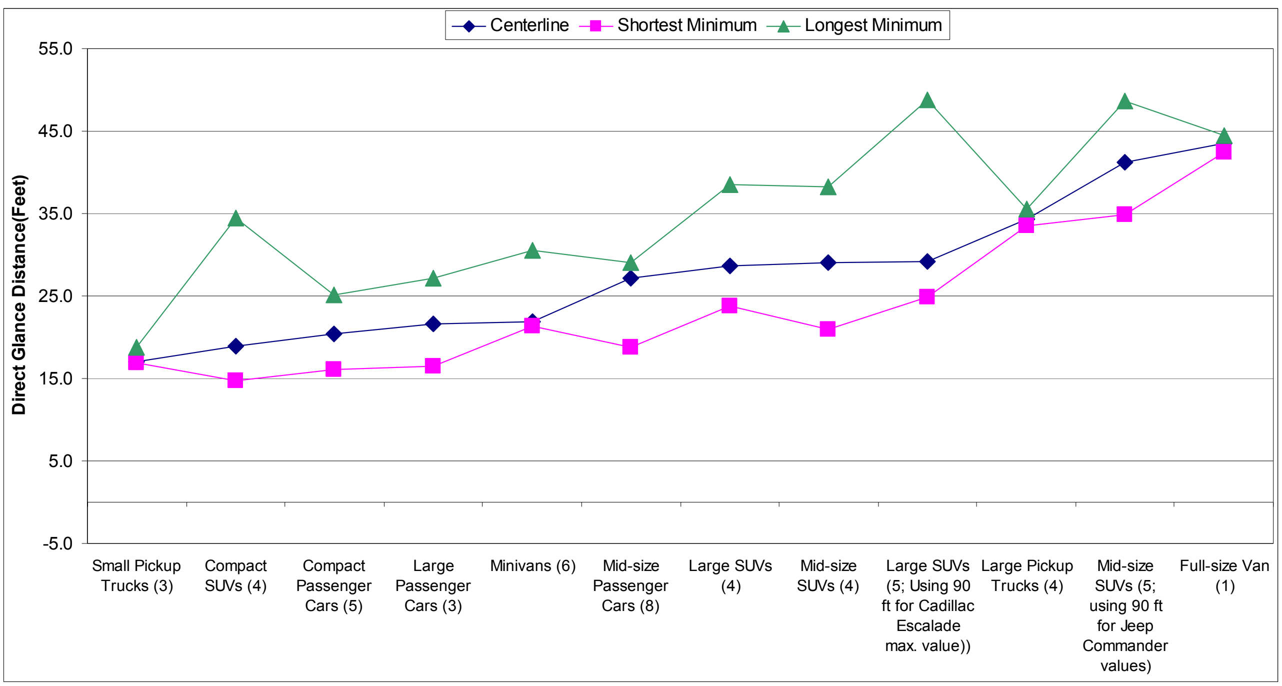

Figure 7. Direct Glance Rear Sight Distance Averages by Vehicle Type for a 50th Percentile Male Driver Viewing a 29.4-Inch-Tall Traffic Cone

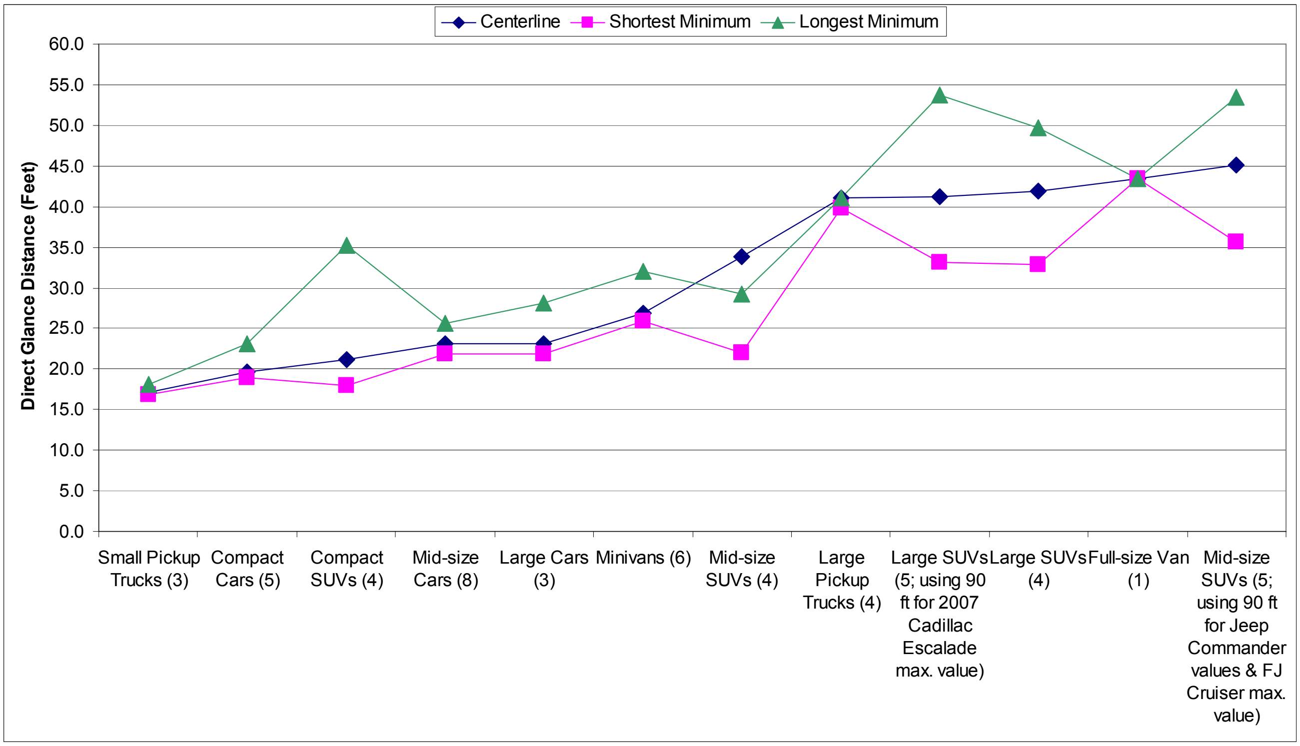

Figure 8. Direct Glance Rear Sight Distance by Vehicle Type for a 5th Percentile Female Driver Viewing a 29.4-Inch-Tall Traffic Cone

Figures 6 and 7 show that large and mid-size SUVs, large pickup trucks, and the full-size van were associated with the longest average direct glance sight distances. Small pickup trucks, compact passenger cars, and compact SUVs tended to have the shortest average direct glance sight distances in both cases. Average direct glance sight distances for mid-size and large passenger cars and minivans appeared in the middle of these two groups for both drivers. The range between shortest and longest minimum direct glance distance averages was largest for all categories of SUVs for both driver heights.

3.3 Average Direct Glance Rear Sight Distance

Average direct glance rear sight distance was calculated to assess whether this value, which described sight distance across the entire rear of the vehicle, would be a more descriptive metric for evaluating rear visibility. Each vehicle’s average rear direct glance sight distance was taken over 8 longitudinal sight distance values measured within 4 feet of the vehicle centerline on both sides. Sight distance values used represented the closest point to the rear bumper at which the visual target could be seen by the driver (some vehicles had “blind spots” that were beyond this point due to rear spoilers, etc.). Average rear sight distance for all 44 vehicles and both driver heights are presented in Table 6.

Table 6. Average Direct Glance Rear Sight Distance by Vehicle

Type	Year	Make	Model	50th Percentile Male Driver	5th Percentile Female Driver
Compact Car	2007	Toyota	Yaris (sedan)	14.3	13.5
Compact Car	2006	BMW	330i	18.1	14.3
Compact Car	2007	Chevrolet	Cobalt	22.5	20.3
Compact Car	2007	Toyota	Corolla S	22.6	22.3
Compact Car	2007	Honda	Civic	25.1	32.8
Mid-size Car	2007	Pontiac	Grand Prix	17.9	15.0
Mid-size Car	2007	Nissan	Altima	18.4	18.0
Mid-size Car	2007	Honda	Accord	20.0	16.3
Mid-size Car	2007	Toyota	Camry	21.8	19.5
Mid-size Car	2006	Ford	Taurus	22.0	20.9
Mid-size Car	2006	Volkswagen	Passat	25.0	29.9
Mid-size Car	2005	Chevrolet	Malibu Maxx	27.3	36.3
Mid-size Car	2005	Cadillac	STS	29.8	31.6
Large Car	2007	Chevrolet	Impala	19.5	23.8
Large Car	2007	Ford	Five Hundred	18.0	26.3
Large Car	2005	Chrysler	300C	29.9	25.5
Compact SUV	2005	Subaru	Forrester	13.0	13.0
Compact SUV	2005	Honda	CRV	17.3	22.6
Compact SUV	2005	Infiniti	FX35	27.8	30.4
Compact SUV	2008	Ford	Escape	29.4	34.3
Mid-Size SUV	2005	Ford	Explorer	16.1	17.9
Mid-Size SUV	2007	Nissan	Xterra	28.4	22.9
Mid-Size SUV	2007	Honda	Element	34.8	31.4
Mid-Size SUV	2007	Toyota	FJ Cruiser	37.6	>60.1*
Mid-Size SUV	2007	Jeep	Commander	>90*	>90*
Large SUV	2007	Ford	Expedition	25.9	30.9
Large SUV	2003	Hummer	H2	28.3	42.3
Large SUV	2007	Chevrolet	Tahoe	30.6	37.9
Large SUV	2006	Dodge	Durango	32.3	34.9
Large SUV	2008	Cadillac	Escalade	>48.5*	>48.4*
Small Pickup	2007	Ford	Ranger	11.6	12.5
Small Pickup	2006	Toyota	Tacoma	13.6	14.0
Small Pickup	2007	Nissan	Frontier	26.9	25.4
Large Pickup	2007	Dodge	Ram 1500	30.5	31.4
Large Pickup	2007	Toyota	Tundra	33.6	33.5
Large Pickup	2005	Chevrolet	Silverado 2500HD	35.3	37.5
Large Pickup	2006	Ford	F-150	37.9	60.5
Minivan	2007	Ford	Freestar	15.4	17.4
Minivan	2006	Mercury	Monterey	15.5	14.6
Minivan	2007	Kia	Sedona	25.4	27.3
Minivan	2006	Toyota	Sienna LE	23.0	33.8
Minivan	2007	Honda	Odyssey	28.1	26.8
Minivan	2005	Chevrolet	Uplander	36.3	49.5
Full-size Van	2004	GMC	Savana	43.6	43.5

* Note: These values included at least one data point that was beyond the 90 ft measurement grid. For those data points, a value of 90 ft was substituted in the average calculation.

Contrary to what might be expected, average direct glance rear sight distance values were found to be shorter for the 5th percentile female driver for 15 of the 44 vehicles. This finding may be affected by the seating position of the small female, which, if more forward may place the drivers' eyes in closer proximity to the center rearview mirror, thereby affording a view of a larger area. This finding may also be due to more liberal body torso movement (i.e., leaning) by the 5th percentile female driver during testing, and may also have been affected by power seat height adjustment in vehicles with that feature.

Figure 9 shows the distribution of average direct glance rear sight distance values for a 50th percentile male for the 44 vehicles measured. The mean value was 27.0 ft (SD=12.83).

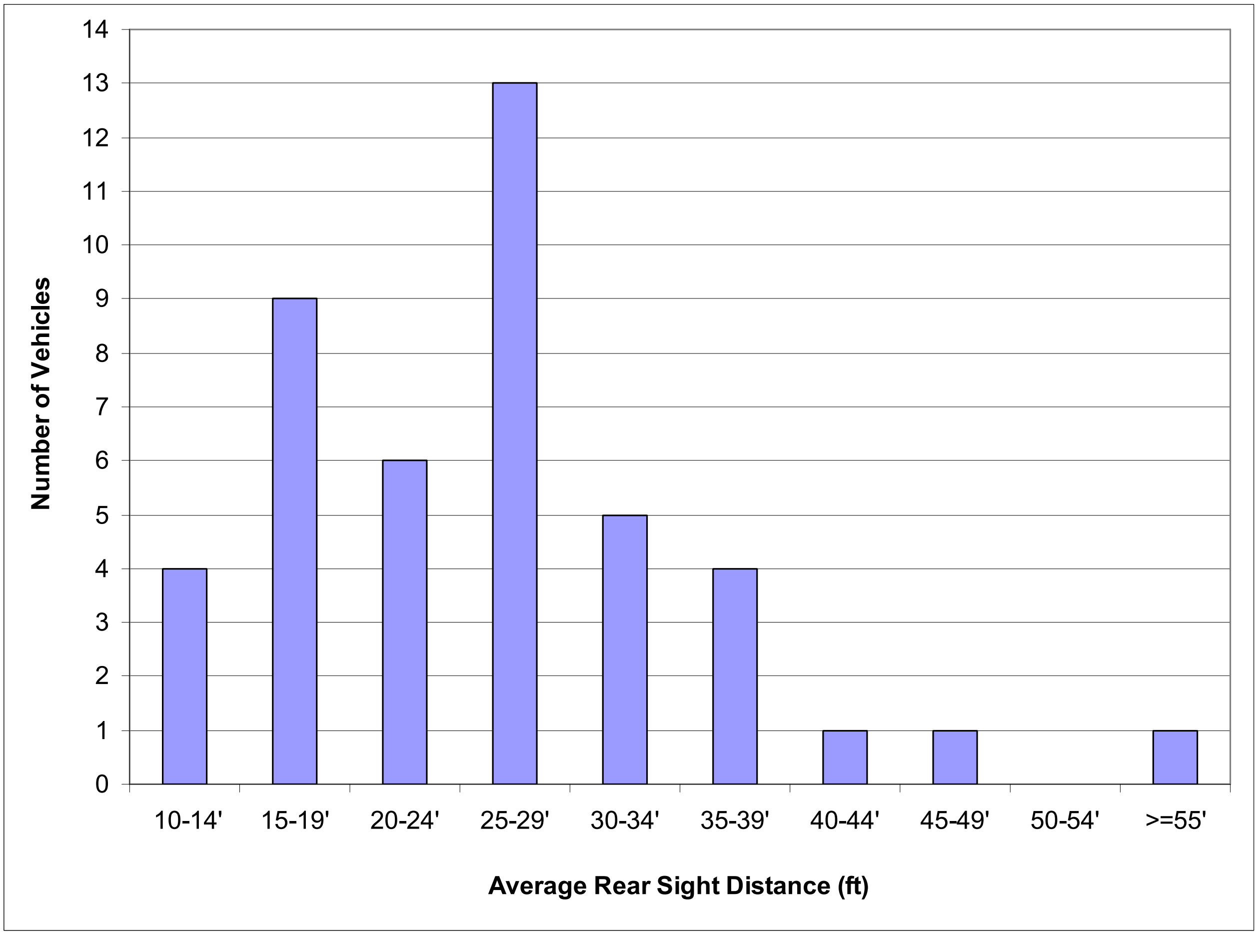

Figure 9. Distribution of Average Direct Glance Rear Sight Distance Values for the 50th Percentile Male Driver

Average direct glance sight distance was calculated for each of the 9 vehicle type and size groups by taking an average over the individual vehicles' averages in each group. Figure 10 illustrates average sight distance values for the 50th percentile male driver by vehicle type. "Error bars" shown for each vehicle type in the chart indicate the shortest and longest direct glance average sight distance for each vehicle type. The trend in sight distance magnitude evident in this figure resembles that seen in both of the two prior figures, namely that SUVs, large pickup trucks, and full-size vans have the longest average sight distances.

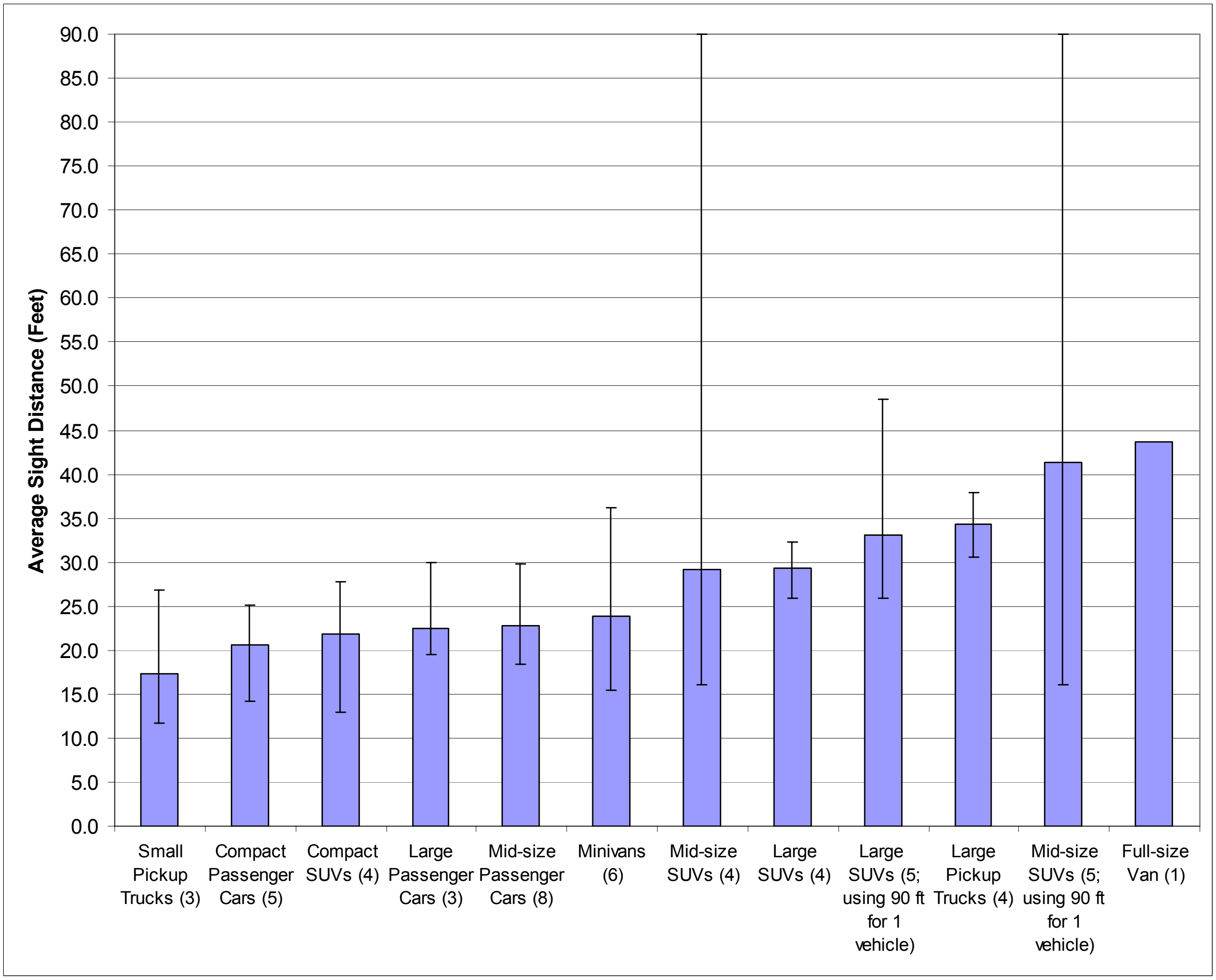

Figure 10. Average Direct Glance Sight Distance by Vehicle Type for the 50th Percentile Male Driver

Note: Error bars indicate the shortest and longest direct glance average sight distance for each vehicle type.

3.4 Blind Zone Areas

To permit the comparison of rear visibility characteristics across different vehicles, several rear blind zone area calculations were made. The 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). The authors felt that since all passenger vehicles have side mirrors and center rearview mirrors that are essentially the same, the key source of variability in the rear visibility afforded a driver would be the structure of the vehicle's body and interior components (e.g., rear head restraints). Therefore, these data highlight the direct rear visibility of vehicles resulting from their structural characteristics.

Multiple calculations of blind zone magnitude were computed. The first calculation of blind zone magnitude summarizes blind spot data points over a 90 by 70 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 60 foot area. The third calculation summarizes blind spot data over a 50 by 20 foot area, representing an area approximately three vehicles wide. The last two calculations summarize blind spot data points for a 50-foot longitudinal range at 8-foot and 6-foot widths.

Table 7 summarizes blind zone area calculations for vehicles evaluated in this study. The 2007 Jeep Commander has the largest blind spot area according to each of the area calculations. The two vehicles with the next largest blind zone areas for both the 90 by 70 foot area blind spot calculation and the 50 by 60 foot calculation are the 2007 Cadillac Escalade, and the 2007 Toyota FJ Cruiser.

Table 7. Vehicle Direct View Blind Zone Areas for Five FOV Measurement Field Sizes and a 50th Percentile Male Driver

Type	Year	Make	Model	90' long. x 70' lat.	50' long. x 60' lat.	50' long. x 20' lat.	50' long. x 8' lat.	50' long. x 6' lat.
Compact Car	2006	BMW	330i	271	271	221	141	112
Compact Car	2007	Chevrolet	Cobalt (coupe)	453	453	341	177	135
Compact Car	2007	Honda	Civic	400	400	361	197	147
Compact Car	2007	Toyota	Corolla	398	398	344	209	161
Compact Car	2007	Toyota	Yaris (sedan)	194	194	184	111	82
Mid-size Car	2005	Cadillac	STS	592	565	436	234	175
Mid-size Car	2005	Chevrolet	Malibu Maxx	437	437	370	214	170
Mid-size Car	2006	Ford	Taurus	361	361	340	180	136
Mid-size Car	2007	Honda	Accord	297	297	266	164	130
Mid-size Car	2007	Nissan	Altima	280	280	241	143	103
Mid-size Car	2007	Pontiac	Grand Prix	339	339	271	139	105
Mid-size Car	2007	Toyota	Camry	326	326	303	170	125
Mid-size Car	2006	Volkswagen	Passat	422	422	356	196	153
Large Car	2005	Chrysler	300C	428	428	312	152	117
Large Car	2007	Chevrolet	Impala	651	651	492	235	174
Large Car	2007	Ford	Five Hundred	268	268	253	140	108
Compact SUV	2005	Honda	CRV	330	330	304	134	95
Compact SUV	2005	Infiniti	FX35	423	423	391	218	179
Compact SUV	2005	Subaru	Forrester	193	193	188	100	75
Compact SUV	2008	Ford	Escape	1030	631	550	218	146
Mid-size SUV	2007	Jeep	Commander	3023	1409	829	400	300
Mid-size SUV	2007	Honda	Element	515	515	443	274	214
Mid-size SUV	2007	Toyota	FJ Cruiser	1992	1128	710	278	208
Mid-size SUV	2007	Nissan	Xterra	515	515	433	223	168
Mid-size SUV	2005	Ford	Explorer	391	391	263	125	95
Large SUV	2003	Hummer	H2	1045	766	595	222	163
Large SUV	2008	Cadillac	Escalade	2403	1376	688	300	221
Large SUV	2006	Dodge	Durango	740	740	532	246	190
Large SUV	2007	Chevrolet	Tahoe	1796	1165	633	241	161
Large SUV	2007	Ford	Expedition	1215	948	465	203	152
Small Pickup	2006	Toyota	Tacoma	185	185	185	105	78
Small Pickup	2007	Ford	Ranger	122	122	122	89	66
Small Pickup	2007	Nissan	Frontier	459	459	413	211	157
Large Pickup	2005	Chevrolet	Silverado 2500HD	705	705	580	294	210
Large Pickup	2006	Ford	F-150	982	982	728	299	224
Large Pickup	2007	Dodge	Ram 1500	581	581	481	240	180
Large Pickup	2007	Toyota	Tundra	709	709	529	265	200
Minivan	2005	Chevrolet	Uplander	892	718	548	283	202
Minivan	2006	Mercury	Monterey	282	282	252	120	90
Minivan	2006	Toyota	Sienna LE	589	547	361	180	133
Minivan	2007	Ford	Freestar	366	366	281	119	89
Minivan	2007	Honda	Odyssey	1393	843	579	221	159
Minivan	2007	Kia	Sedona	1160	776	518	199	138
Full-size Van	2004	GMC	Savana	873	869	700	353	265

Figure 11 graphically illustrates blind zone area data by vehicle type. Figures 12 through 14 separately show these data by vehicle type for cars, SUVs, and pickup trucks and vans, respectively. These figures illustrate the range in rear visibility within a vehicle type. The 90 foot by 70 foot blind zone area calculation is not presented in Figures 10 through 13 so that the graphs would be less compressed and therefore easier to read.

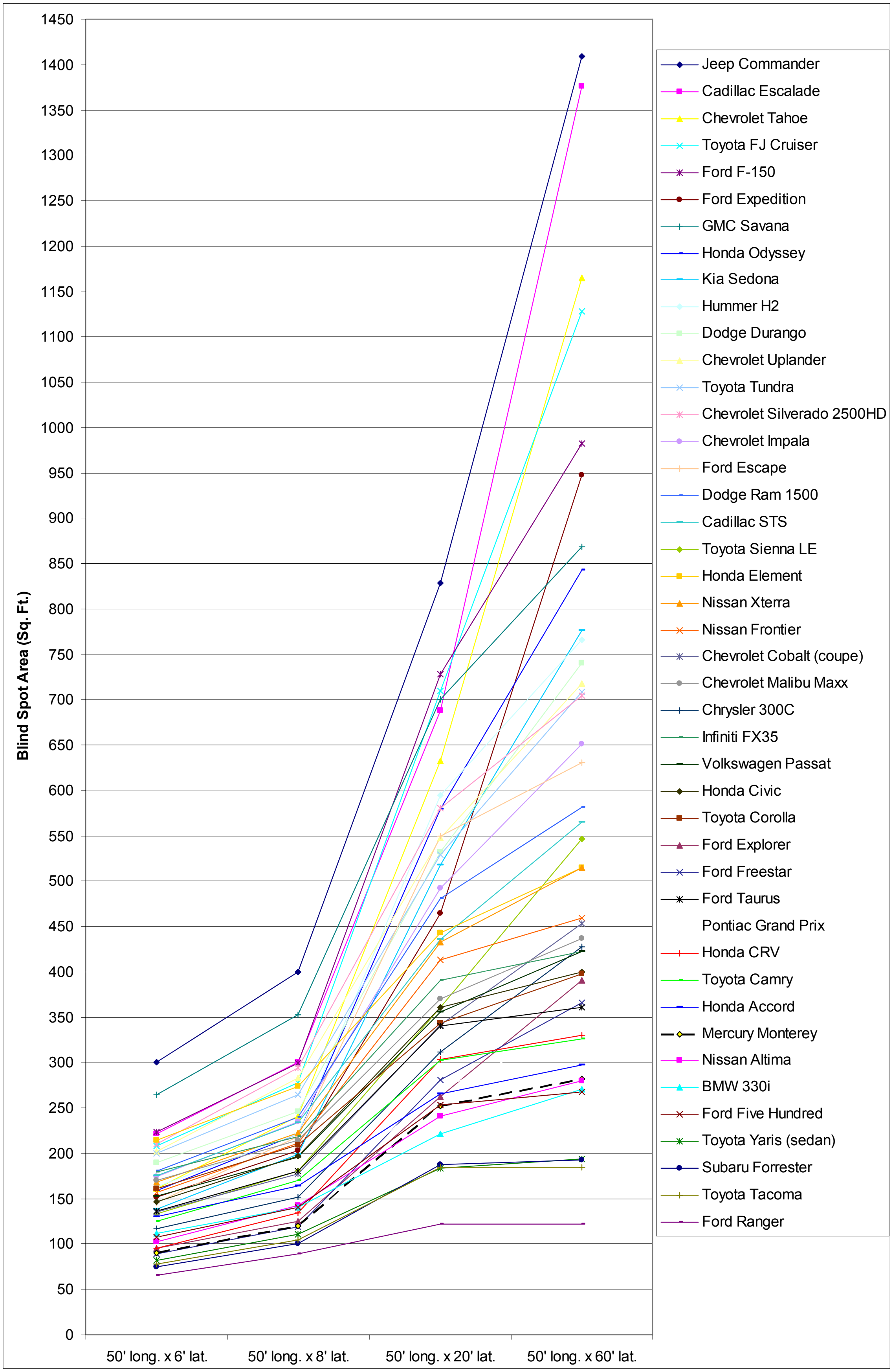

Figure 11. Blind Zone Area: All 44 Vehicles

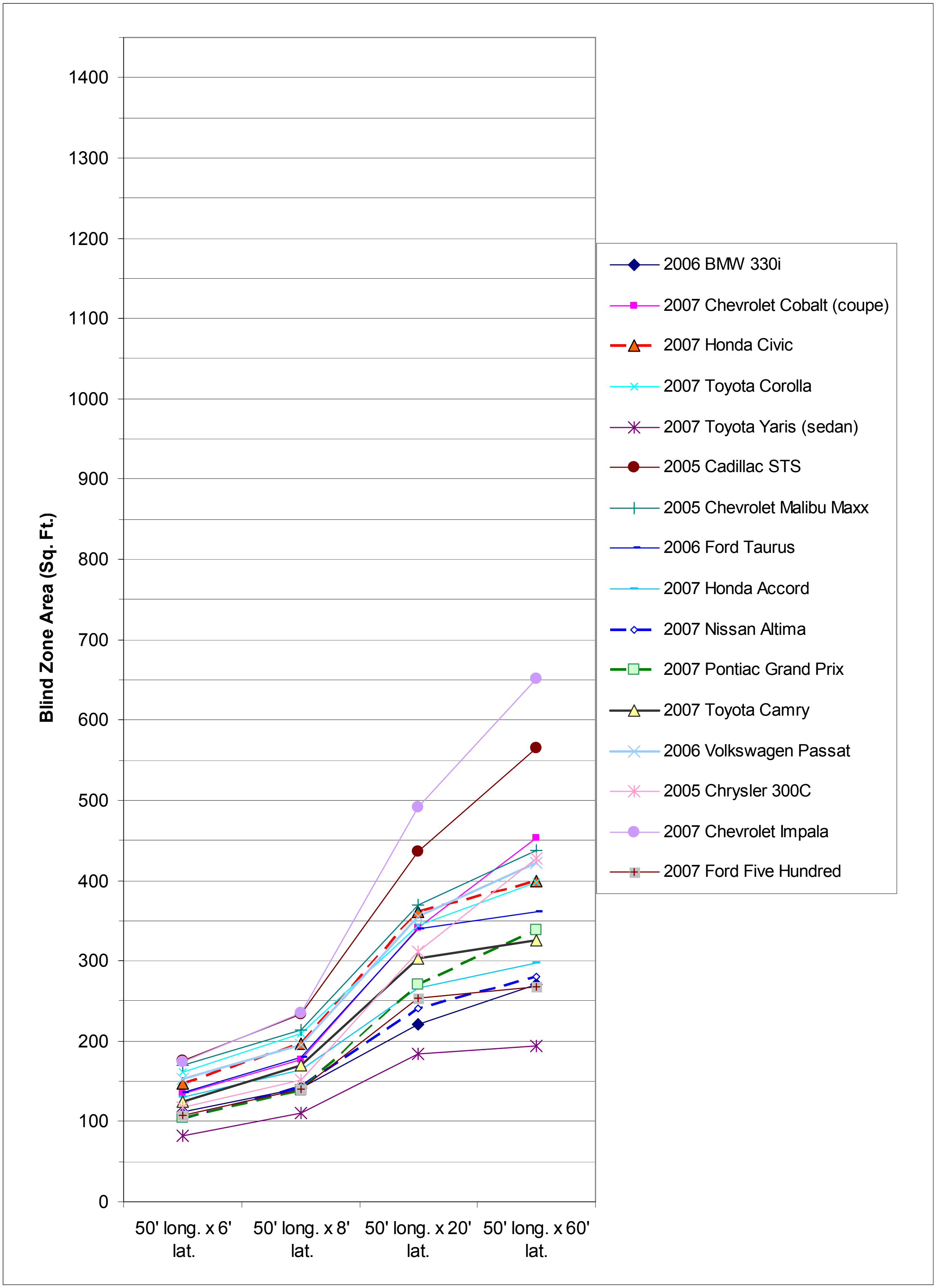

Figure 12. Blind Zone Area: Cars

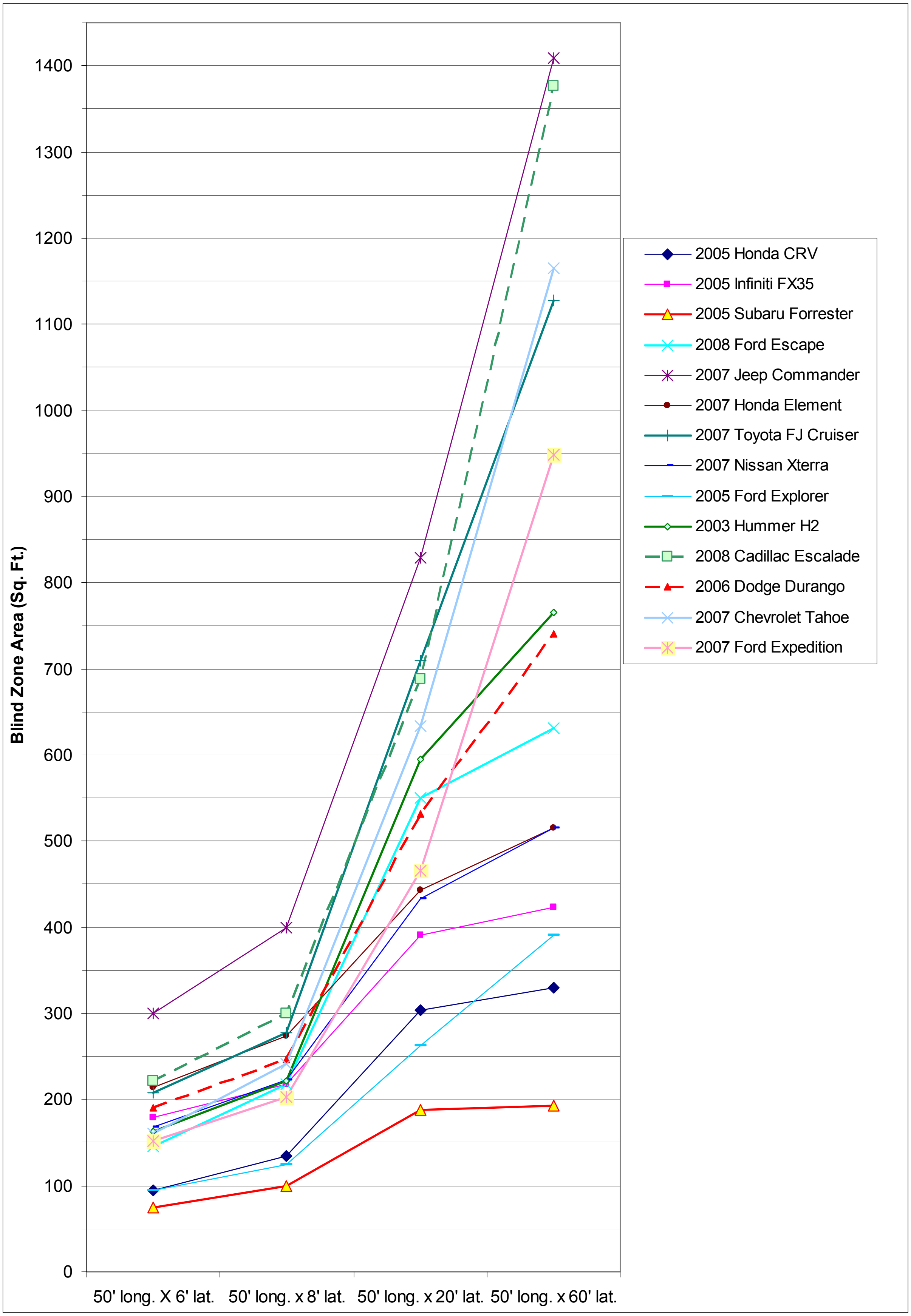

Figure 13. Blind Zone Area: SUVs

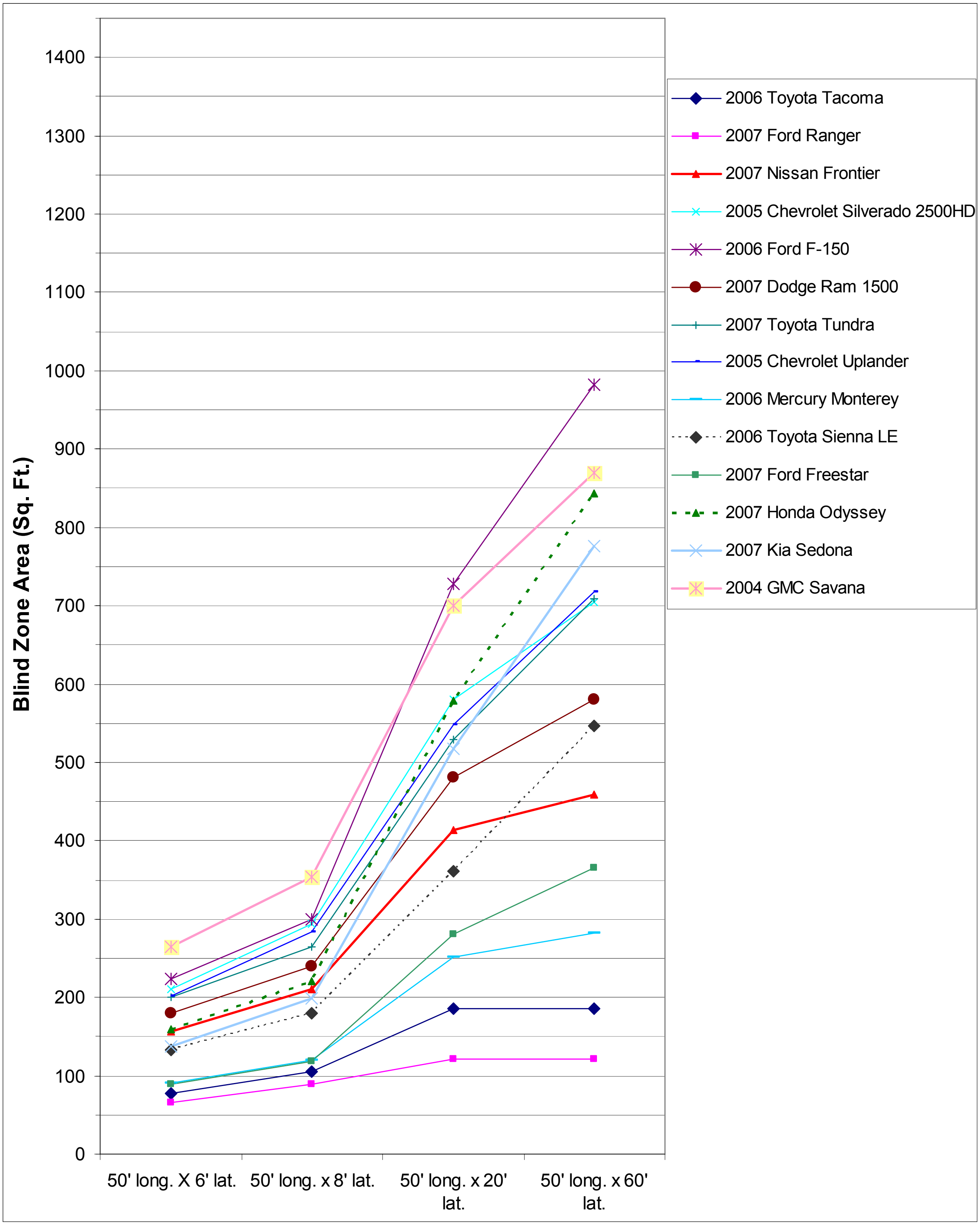

Figure 14. Blind Zone Area: Pickup Trucks and Vans

Figure 15 shows the distribution of rear blind zone area values for a 50th percentile male for the 44 vehicles measured. The 50 by 20 foot and 50 by 24 foot areas provide the greatest spread of vehicles across the area values. As a result, these areas may provide the best basis for a stratified scheme for differentiation of rear visibility quality, as will be discussed later in Section 4.

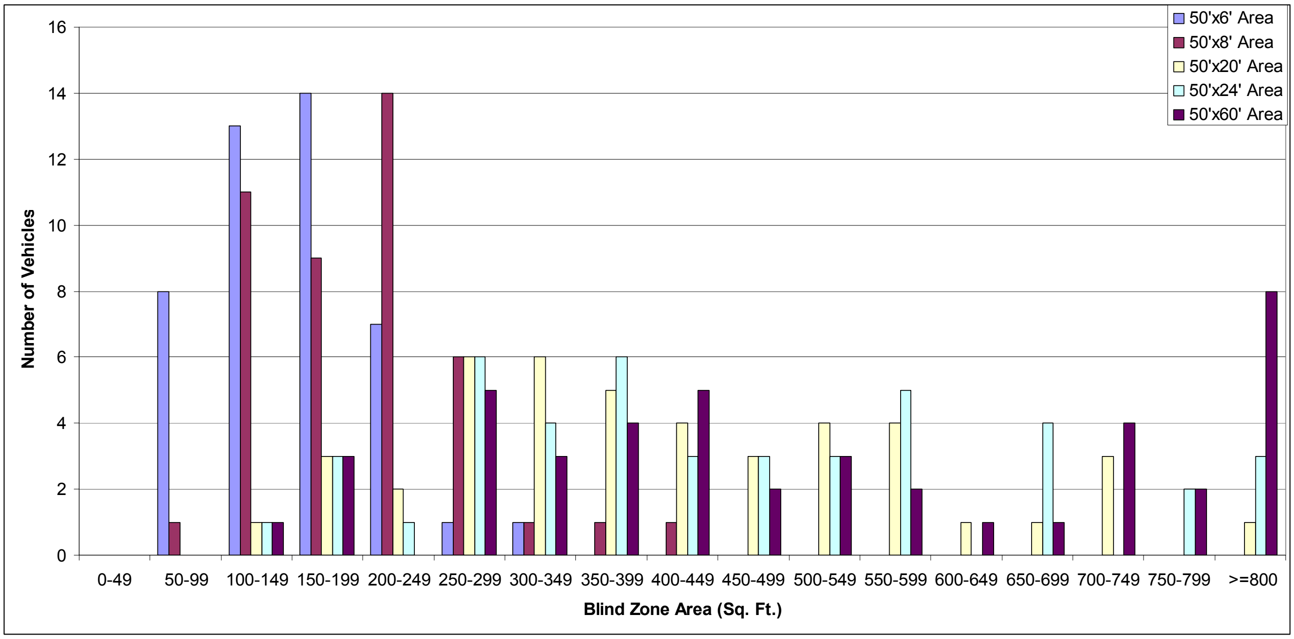

Figure 15. Distribution of Blind Zone Area Data for Multiple Area Calculations

Figure 16 summarizes the direct view blind zone area data over each of the vehicle type and size groups for four of the FOV measurement field sizes for the 50th percentile male driver. Small pickup trucks had the smallest blind zone areas for all four metrics calculated. Compact and mid-sized passenger cars had the second and third smallest blind zone areas, respectively, for all four metrics. Large passenger cars and compact SUVs held the fourth and fifth positions, depending on the metric.

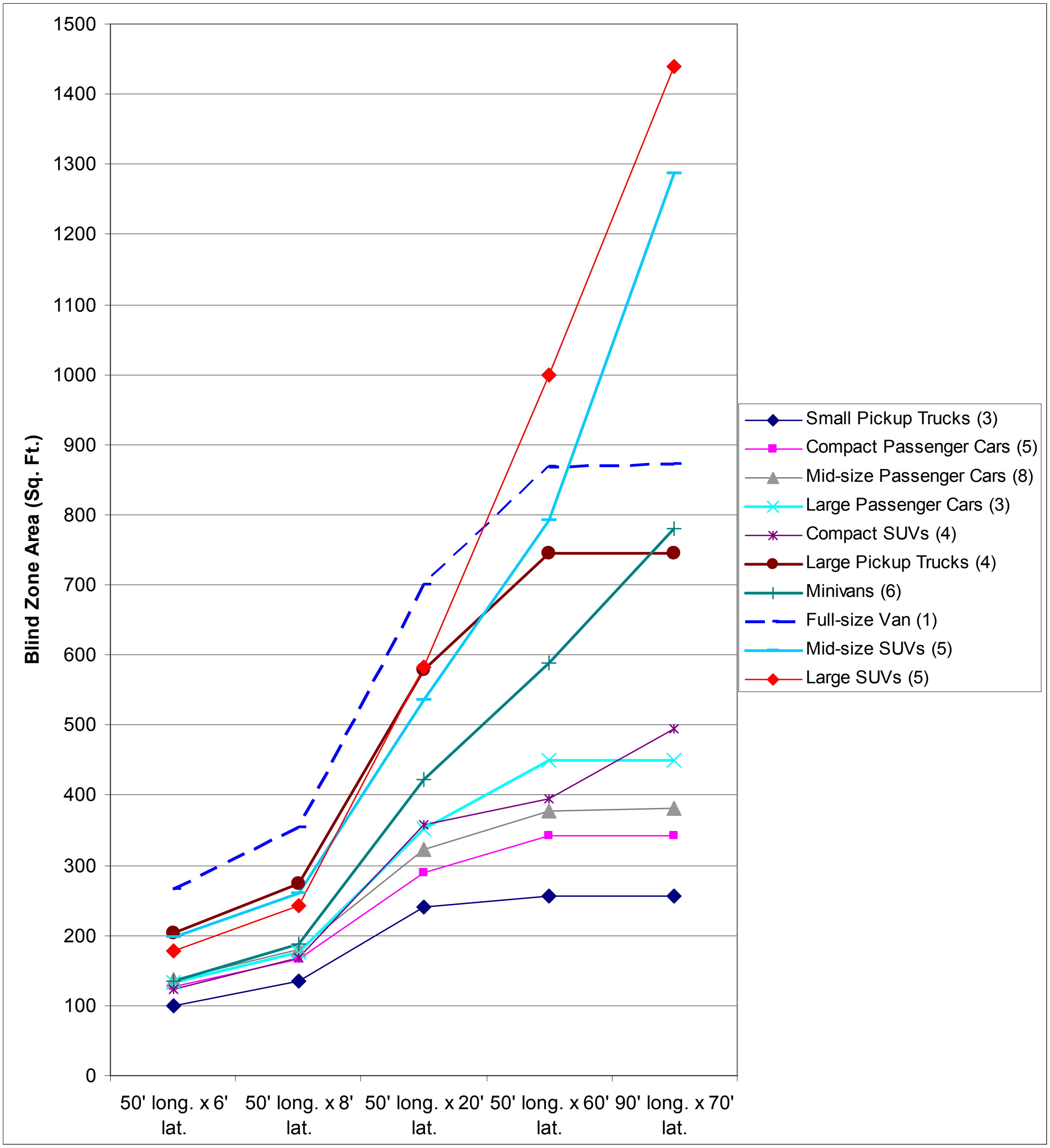

Figure 16. Direct View Blind Zone Areas for a 50th Percentile Male Driver, By Vehicle Type

Tables 8 and 9 list the vehicles with the six largest blind zone areas for five blind zone area calculations for the 50th percentile male and the 5th percentile female drivers, respectively. The vehicles with the largest blind zone areas for each of the metrics were the 2007 Jeep Commander for the 50th percentile male driver and the Ford F-150 for the 5th percentile female driver. The Cadillac Escalade, Chevrolet Tahoe, Ford F-150, and Toyota FJ Cruiser each appeared in the top 6 values for most of the metrics listed.

Table 8. Six Largest Direct-View Blind Zone Areas for Multiple FOV Measurement Field Sizes and a 50th Percentile Male Driver

Blind Spot Area Rank	50' long x 6' wide	50' long x 8' wide	50' long x 20' wide	50' long x 60' wide	90' long x 70' wide
1	2007 Jeep Commander (300 sq. ft.)	2007 Jeep Commander (400 sq. ft.)	2007 Jeep Commander (829 sq. ft.)	2007 Jeep Commander (1409 sq. ft.)	2007 Jeep Commander (3023 sq. ft.)
2	2004 GMC Savanna (265 sq. ft.)	2004 GMC Savanna (353 sq. ft.)	2006 Ford F-150 (728 sq. ft.)	2007 Cadillac Escalade (1376 sq. ft.)	2007 Cadillac Escalade (2403 sq. ft.)
3	2006 Ford F-150 (224 sq. ft.)	2007 Cadillac Escalade (300 sq. ft.)	2007 Toyota FJ Cruiser (710 sq. ft.)	2007 Chevrolet Tahoe (1165 sq. ft.)	2007 Toyota FJ Cruiser (1992 sq. ft.)
4	2007 Cadillac Escalade (221 sq. ft.)	2006 Ford F-150 (299 sq. ft.)	2004 GMC Savanna (700 sq. ft.)	2007 Toyota FJ Cruiser (1128 sq. ft.)	2007 Chevrolet Tahoe (1796 sq. ft.)
5	2007 Honda Element (214 sq. ft.)	2005 Chevrolet Silverado 2500HD (294 sq. ft.)	2007 Cadillac Escalade (688 sq. ft.)	2006 Ford F-150 (982 sq. ft.)	2007 Honda Odyssey (1393 sq. ft.)
6	2005 Chevrolet Silverado 2500HD (210 sq. ft.)	2005 Chevrolet Uplander (283 sq. ft.)	2007 Chevrolet Tahoe (633 sq. ft.)	2007 Ford Expedition (948 sq. ft.)	2007 Ford Expedition (1215 sq. ft.)

Table 9. Six Largest Direct-View Blind Zone Areas for Multiple FOV Measurement Field Sizes and a 5th Percentile Female Driver

Blind Spot Area Rank	50' long x 6' wide	50' long x 8' wide	50' long x 20' wide	50' long x 60' wide	90' long x 70' wide
1	2006 Ford F-150 (300 sq. ft.)	2006 Ford F-150 (400 sq. ft.)	2006 Ford F-150 (1000 sq. ft.)	2006 Ford F-150 (2298 sq. ft.)	2006 Ford F-150 (3910 sq. ft.)
2	2007 Jeep Commander (300 sq. ft.)	2007 Jeep Commander (400 sq. ft.)	2007 Jeep Commander (924 sq. ft.)	2007 Jeep Commander (1775 sq. ft.)	2007 Jeep Commander (3813 sq. ft.)
3	2005 Chevrolet Uplander (281 sq. ft.)	2005 Chevrolet Uplander (377 sq. ft.)	2005 Chevrolet Uplander (834 sq. ft.)	2007 Chevrolet Tahoe (1618 sq. ft.)	2007 Cadillac Escalade (2840 sq. ft.)
4	2004 GMC Savanna (258 sq. ft.)	2004 GMC Savanna (344 sq. ft.)	2007 Chevrolet Tahoe (807 sq. ft.)	2007 Cadillac Escalade (1518 sq. ft.)	2007 Chevrolet Tahoe (2629 sq. ft.)
5	2007 Toyota FJ Cruiser (249 sq. ft.)	2007 Cadillac Escalade (321 sq. ft.)	2004 GMC Savanna (795 sq. ft.)	2007 Toyota FJ Cruiser (1267 sq. ft.)	2007 Toyota FJ Cruiser (2349 sq. ft.)
6	2003 Hummer H2 (237 sq. ft.)	2007 Toyota FJ Cruiser (320 sq. ft.)	2007 Cadillac Escalade (756 sq. ft.)	2007 Ford Expedition (1250 sq. ft.)	2007 Ford Expedition (1912 sq. ft.)

Tables 10 and 11 list the vehicles with the six smallest blind zone areas for five blind zone area calculations for the 50th percentile male and the 5th percentile female drivers, respectively.

Table 10. Six Smallest Direct-View Blind Zone Areas for Multiple FOV Measurement Field Sizes and a 50th Percentile Male Driver

Blind Spot Area Rank	50' long x 6' wide	50' long x 8' wide	50' long x 20' wide	50' long x 60' wide	90' long x 70' wide
1	Ford Ranger (66 sq. ft.)	Ford Ranger (89 sq. ft.)	Ford Ranger (122 sq. ft.)	Ford Ranger (122 sq. ft.)	Ford Ranger (122 sq. ft.)
2	Subaru Forrester (75 sq. ft.)	Subaru Forrester (100 sq. ft.)	Toyota Yaris (184 sq. ft.)	Toyota Tacoma (185 sq. ft.)	Toyota Tacoma (185 sq. ft.)
3	Toyota Tacoma (78 sq. ft.)	Toyota Tacoma (105 sq. ft.)	Toyota Tacoma (185 sq. ft.)	Subaru Forrester (193 sq. ft.)	Subaru Forrester (193 sq. ft.)
4	Toyota Yaris (82 sq. ft.)	Toyota Yaris (111 sq. ft.)	Subaru Forrester (188 sq. ft.)	Toyota Yaris (194 sq. ft.)	Toyota Yaris (194 sq. ft.)
5	Ford Freestar (89 sq. ft.)	Ford Freestar (119 sq. ft.)	BMW 330i (221 sq. ft.)	Ford Five Hundred (268 sq. ft.)	Ford Five Hundred (268 sq. ft.)
6	Mercury Monterey (90 sq. ft.)	Mercury Monterey (120 sq. ft.)	Nissan Altima (241 sq. Ft.)	BMW 330i (271 sq. ft.)	BMW 330i (271 sq. ft.)

Table 11. Six Smallest Direct-View Blind Zone Areas for Multiple FOV Measurement Field Sizes and a 5th Percentile Female Driver

Blind Spot Area Rank	50' long x 6' wide	50' long x 8' wide	50' long x 20' wide	50' long x 60' wide	90' long x 70' wide
1	Subaru Forrester (72 sq. ft.)	Ford Ranger (96 sq. ft.)	Toyota Yaris (179 sq. ft.)	Toyota Tacoma (190 sq. ft.)	Toyota Tacoma (190 sq. ft.)
2	Ford Ranger (72 sq. ft.)	Subaru Forrester (100 sq. ft.)	Toyota Tacoma (190 sq. ft.)	Toyota Yaris (203 sq. ft.)	Toyota Yaris (203 sq. ft.)
3	Toyota Yaris (78 sq. ft.)	Toyota Yaris (104 sq. ft.)	BMW 330i (195 sq. ft.)	Mercury Monterey (243 sq. ft.)	Mercury Monterey (243 sq. ft.)
4	Toyota Tacoma (80 sq. ft.)	Toyota Tacoma (108 sq. ft.)	Ford Ranger (198 sq. ft.)	BMW 330i (243 sq. ft.)	BMW 330i (243 sq. ft.)
5	BMW 330i (83 sq. ft.)	BMW 330i (110 sq. ft.)	Mercury Monterey (220 sq. ft.)	Ford Ranger (303 sq. ft.)	Pontiac Grand Prix (326 sq. ft.)
6	Mercury Monterey (86 sq. ft.)	Mercury Monterey (113 sq. ft.)	Honda Accord (236 sq. ft.)	Pontiac Grand Prix (326 sq. ft.)	Nissan Altima (328 sq. Ft.)

4.0 RATING REAR VISIBILITY

This section discusses a method developed by IAG, which uses the concept of actual versus possible visible area to describe the rear visibility of vehicles is described. Comments on the rating system are discussed.

4.1 Insurance Australia Group Visibility Assessment Criteria

The Insurance Australia Group (IAG) developed “Visibility Assessment Criteria” [4, 12] 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.

The IAG scheme considers the actual visible area within a 1.8-meter-wide (5.9 feet) by 15-meter-long (49.2 feet) 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 12. 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 12. IAG Preliminary Star Rating Criteria for Measured Area, A

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

4.2 Comments on the IAG Visibility Assessment Criteria

4.2.1 Visual Target Height

The 600-mm-tall (23.62 inch) visual target used in the IAG rating system was approximately 5 inches shorter than NHTSA’s 29.4-inch-tall visual target. NHTSA’s visual target height was roughly equivalent to the average height of a standing 1-year-old child. NHTSA’s testing required the driver to indicate when they could see the entire 3-inch-diameter reflector atop the cone. Seeing the top 3 inches of the object simulates the amount of an object that might need to be visible in order for the driver to correctly identify it as a child. As a result, the net difference in visual target heights can be considered approximately 2.5 inches.

4.2.2 Appropriateness of Rear Visibility Lateral Range Considered

Preliminary results of a NHTSA Special Crash Investigation (SCI) that was initiated in 2006 and focused on backover cases show that pedestrians were approaching from the right or left of the vehicle approximately twice as often as those who were stationary behind the vehicle. If a majority of victims in backover crashes approach the area behind the vehicle from the side, the examination of a vehicle's rear characteristics over a field wider than that of the width of the vehicle may provide visibility assessment results that are more relevant to safety.

What is the importance of the area not directly behind the vehicle's initial position compared to the importance of the area that is directly behind the initial position? Clearly, stationary pedestrians can only be struck by the vehicle if they are either directly behind the vehicle's initial position or adjacent to and in the path of a vehicle that is turning while backing. However, NHTSA's SCI backover cases recorded to date show that approximately two-thirds of the pedestrians struck during backing were not initially in a location where they would have been struck by the vehicle if they had remained stationary. These data suggests that moving pedestrians may be a substantial portion of the backing crash problem. However, where the driver needs to be able to see a moving pedestrian so as not to strike them is not known.

IAG bases its rating on an area 1.8 meters (5.9 ft) wide centered directly behind the vehicle. For the 44 vehicles for which the rear field of view was measured in this study, the average vehicle width was 6.16 feet with a maximum width of 6.77 feet and a minimum width of 5.54 feet. Therefore, the IAG system only considers the area directly behind the vehicle. However, as stated above, NHTSA's SCI cases to date show that approximately two-thirds of pedestrians struck while backing were moving and not initially directly behind the vehicle's initial position. So, there is considerable interest in determining the danger area for pedestrians during backing in addition to the area directly behind the vehicle's initial position.

4.2.3 Appropriateness of Rear Visibility Longitudinal Range Considered

Another aspect of rear visibility measurement that would affect a rating system's relationship to safety is the longitudinal distance from the bumper that the rating system considers. 1. How far back from the rear bumper of the vehicle does the region of interest for pedestrian safety extend? Intuitively, it is clear that pedestrians who are just behind the vehicle bumper (e.g., a fraction of a foot) have a very high probability of being hit if the vehicle should backup. Equally clearly, pedestrians who are far behind the vehicle (e.g., 1000 or more feet) have little chance of being struck by the backing vehicle. From these two extreme cases, it is clear that a pedestrian's chance of being struck by a backing vehicle decreases when the pedestrian is further back from the rear bumper at the vehicle's pre-backing location (referred to as the vehicle's initial position). What is not known is how rapidly this probability decreases as the pedestrian is placed further and further back.

IAG considers that the region of interest extends back 15.0 meters (approximately 50 feet) from the vehicle's initial position. This intuitively seems reasonable. However, it would be good to check this number using naturalistic backing data recently collected by NHTSA during the On-Road Study of Drivers' Use of Rearview Video Systems (ORSDURVS) [13].

4.2.4 Probability of a Backover Crash as a Function of Vehicular and Pedestrian Related Factors

Monte Carlo simulation of a backing vehicle and walking pedestrian could be used to calculate a probability-based importance weighting for each square in a grid of 1-foot squares around the rear of a vehicle. The probability-based importance weightings for each grid square would be based on the number of pedestrian-vehicle backing collisions (i.e., backover crashes) predicted by the Monte Carlo simulation for trials in which the pedestrian was initially (i.e., at the time that the vehicle began to back up) in the center of one square of the grid of 1-foot squares around the rear of a vehicle. The importance weightings could then combined with the measured rear fields of view to compute a rear visibility metric for each vehicle.

To develop such a simulation, two very important assumptions about the behavior of the driver and the pedestrian would need to be made. First, the driver of the vehicle would be assumed to be completely unaware of the presence of the pedestrian, i.e., they never looked to see if there was a pedestrian present. Therefore, the motion of the vehicle would be totally independent of the position of the pedestrian. Second, the pedestrian would be assumed to be completely unaware of the presence of the vehicle. Therefore, the motion of the pedestrian would be totally independent of the position of the vehicle. Note that it would be entirely possible for the pedestrian to walk or run into the vehicle. This would be counted as a backover crash if the impact was with the rear of the vehicle. If the impact was with either side or the front of the vehicle, the crash would not counted as a backing crash. Note that this approach does not consider backover crashes in which a vehicle's front wheel strikes a pedestrian while the vehicle is turning.

Four descriptors for the vehicle would need to be defined:

1. The width of the vehicle,
2. The distance that the vehicle backed up during each backing trial,
3. The average backing speed of the vehicle during each backing trial, and
4. The path of the vehicle.

An average vehicle width could be calculated from the U.S. fleet.

The distance that the vehicle backed up during each backing trial was determined by a random draw from a three-parameter Weibull probability distribution. The Weibull distribution used for distance backed was based on 6,185 naturalistic backing events by 37 subjects that were collected during the ORSDURVS study [13].

This simulation assumes that the vehicle backs up at a constant speed. While real vehicles have a time-varying speed profile during backing, to simplify the simulation, a constant backing speed could be chosen.

Four descriptors for the pedestrian would need to be defined:

1. The pedestrian height, in the horizontal plane,
2. The initial X and Y position of the pedestrian,
3. The average speed at which the pedestrian was moving, and
4. The direction in which the pedestrian was moving.

5.0 DISCUSSION

Rear visibility is affected by vehicle design and individual differences between drivers. This research effort sought to describe the rear visibility of a range of current vehicles to demonstrate how rear visibility and blind zone size can differ depending on vehicle type and characteristics, as well as driver height. This section notes differences between the present study's results and those of related efforts and also discusses the utility of rear visibility information. Also discussed is the impact of the driver on rear visibility and backing crash avoidance.

5.1 Comparing Rear Visibility Data to Those of Related Studies

Consumer Reports results that showed pickup trucks to have the longest "blind spots," followed by minivans and SUVs. The average rear blind spot length (at the vehicle's centerline) for vehicles tested by Consumer Reports was 14 feet for a 68-inch-tall driver. Paine, et al. (2003) reported an average blind spot length of 23 feet for the vehicles they measured. However, the corresponding metric in the current study, direct glance sight distance, which considered 8 distance values across the rear of the vehicle, showed an average value of 27 feet (SD=12.8) for a 50th percentile male (69.1 inches tall) driver. This NHTSA study also found that full-size vans, mid-size SUVs, and large pickup trucks have the longest "blind spots." Measurements detailed in this report also show the largest blind zones were found to be associated with full-size vans, large SUVs, large pickup trucks, and mid-size SUVs. Differences in reported blind spot lengths across the three studies may be due to the measurement method used (i.e., one central value versus eight distributed values) or the mix of particular vehicles measured.

5.2 Rear Visibility Consumer Information

The news media, through the reporting of backover crash incidents, has raised the public's awareness of this safety problem. Rear visibility metrics, such as the IAG rating system described here, may be useful in providing consumer information regarding the quality of rear visibility a particular vehicle affords a driver. This type of information if provided to consumers may help draw their attention to the issue of visibility and help them make an informed purchase decision. Thus, providing safety-related vehicle visibility information would provide a helpful public service to parents of small children and other drivers who encounter pedestrians during their daily driving.

5.3 Rear Visibility and the Driver

A number of driver-related factors impact the rear field of view a driver is afforded in a particular vehicle. Driver dimensions (i.e., seated eye height), range of torso and neck rotation, peripheral vision, and presence of eye glasses affect a driver's ability to see objects behind the vehicle. Individual differences in 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) also may affect what they can see. Individual driver preferences regarding seat adjustment and mirror positioning may also affect rear visibility.

Individual differences such as those listed above may have affected these results. Based on a review of test data with the two research staff members who served as the drivers, it is believed that the shorter driver 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 (Tables 5 and 6) and average sight distance show better results for some vehicles for the shorter driver. Future rear visibility measurement efforts will investigate ways to make the measurements more objective, such as through the use of a surrogate, mechanical driver.

Driver expectation also appears to have an impact on driver behavior during backing maneuvers, affecting things such as glance behavior and drivers' responses to rear parking system warnings. Drivers choose where they look while driving and how thoroughly they visually scan the area around the vehicle before backing. A separate NHTSA study that examined driver behavior during backing maneuvers may provide additional insight into drivers' glance behavior during backing and help identify opportunities to encourage "good" backing behavior. A vehicle with great rear visibility still requires the driver to exhibit proper active visual scanning behavior in order to successfully locate relevant obstacles and avoid colliding with them while backing.

6.0 SUMMARY AND CONCLUSIONS

This report describes measurement of the rear visibility characteristics of a set of 44 vehicles. The visibility of a visual target (29.4-inch-tall traffic cone with red 3-inch-diameter reflector atop it) was determined over a 6300-square-foot area stretching 35 feet to either side of the vehicle's centerline and 90 feet back from the vehicle's rear bumper, as well as on either side of the vehicle aft of the side mirrors. Rear visibility was measured for both a 50^{th} percentile male driver (69.1 inches tall) and a 5^{th} percentile female driver (59.8 inches tall). The areas over which the visual target was visually discernible using direct glances and indirect glances (i.e., using mirrors) was determined.

Since the vehicle's structural features, such as pillars and head restraints, may affect rear visibility, rear longitudinal sight distance was examined along the entire width of the vehicle. Eight distance values were measured perpendicularly out from the vehicle's rear bumper. The "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. The "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. To get the centerline sight distance, the two longitudinal distance values on immediately adjacent to the centerline were averaged. Finally, average rear longitudinal sight distance was a mean of the eight individual longitudinal sight distance values.

Average rear longitudinal sight distances to a 29.4-inch-tall traffic cone (i.e., approximately the height of a 1-year-old child) were shortest for small pickup trucks, compact SUVs, and compact passenger cars. Average rear sight longitudinal distances were longest for full-size vans (45 feet), mid-size (44 feet) and large SUVs (≥ 34 feet), and large pickup trucks (35 feet).

The longest minimum rear longitudinal sight distance was less than 50 feet for 42 of 44 vehicles measured. Based on this result, a longitudinal and lateral limit of 50 feet is recommended for future rear visibility measurement efforts.

To permit the comparison of rear visibility characteristics across different vehicles, several rear blind zone area calculations were made. The blind zone area calculations considered only those areas not visible by direct glances (i.e., areas visible using mirrors or rearview video systems were not considered in these calculations). The rationale for this was that since all passenger vehicles have side mirrors and center rearview mirrors that are essentially the same, the key source of variability in the rear visibility afforded a driver would be the structure of the vehicle's body and interior components (e.g., rear head restraints). Therefore, these data highlight the direct rear visibility of vehicles resulting primarily from their structural characteristics.

Direct view rear blind zone areas were found to be smallest for small pickup trucks, compact passenger cars, and mid-size passenger cars. Direct view rear blind zone areas were largest for full-size vans, large and mid-size SUVs, and large pickup trucks.

Average blind zone sizes by vehicle types ranged from 100 square feet (small pickup trucks) to 1440 square feet (large SUVs).

Besides providing information regarding the rear visibility characteristics and associated blind zone size for vehicles, these data may be used to relate rear FOV to the incidence of backover crashes for individual vehicle make models. Rear visibility measurement results, in the form of a consumer-friendly vehicle rating, could also be disseminated to assist vehicle buyers in understanding visibility aspects of vehicle design that may not be easily discerned during a test drive.

7.0 REFERENCES

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8.0 APPENDICES

8.1 Appendix A: Graphical Plots of FOV Data

This section contains graphical plots of data for the 44 measured vehicles. For each vehicle, plots are presented for a 5th percentile female driver and a 50th percentile male driver. Field of view graphical plots show vehicle perimeters to the nearest foot. To more clearly depict the data, only a 60-foot-wide by 50-foot-long portion of the data were plotted.

Each plot combines direct glance and mirror data. The data were combined by starting with the eye glance plots and adding mirror data to locations which could not be seen with direct glances. This was done using a logic formula that first evaluated whether a location was visible with direct glances. If a location was visible using direct glances, a glance symbol was placed in that location. If the location was not visible by direct glance, the program would check to see whether the location was visible using mirrors. If the location was visible with mirrors, a mirror symbol was placed in that location. If it was visible with neither glances nor mirrors, then the location was left blank. With this method of combing plots, some data points shown as visible using direct eye glances may also be visible using mirrors.

For vehicles equipped with a rearview camera system, the video system’s FOV was illustrated in a separate figure.

Figure 17. FOV Plot for a 2006 BMW 330i with 50th Percentile Male Driver

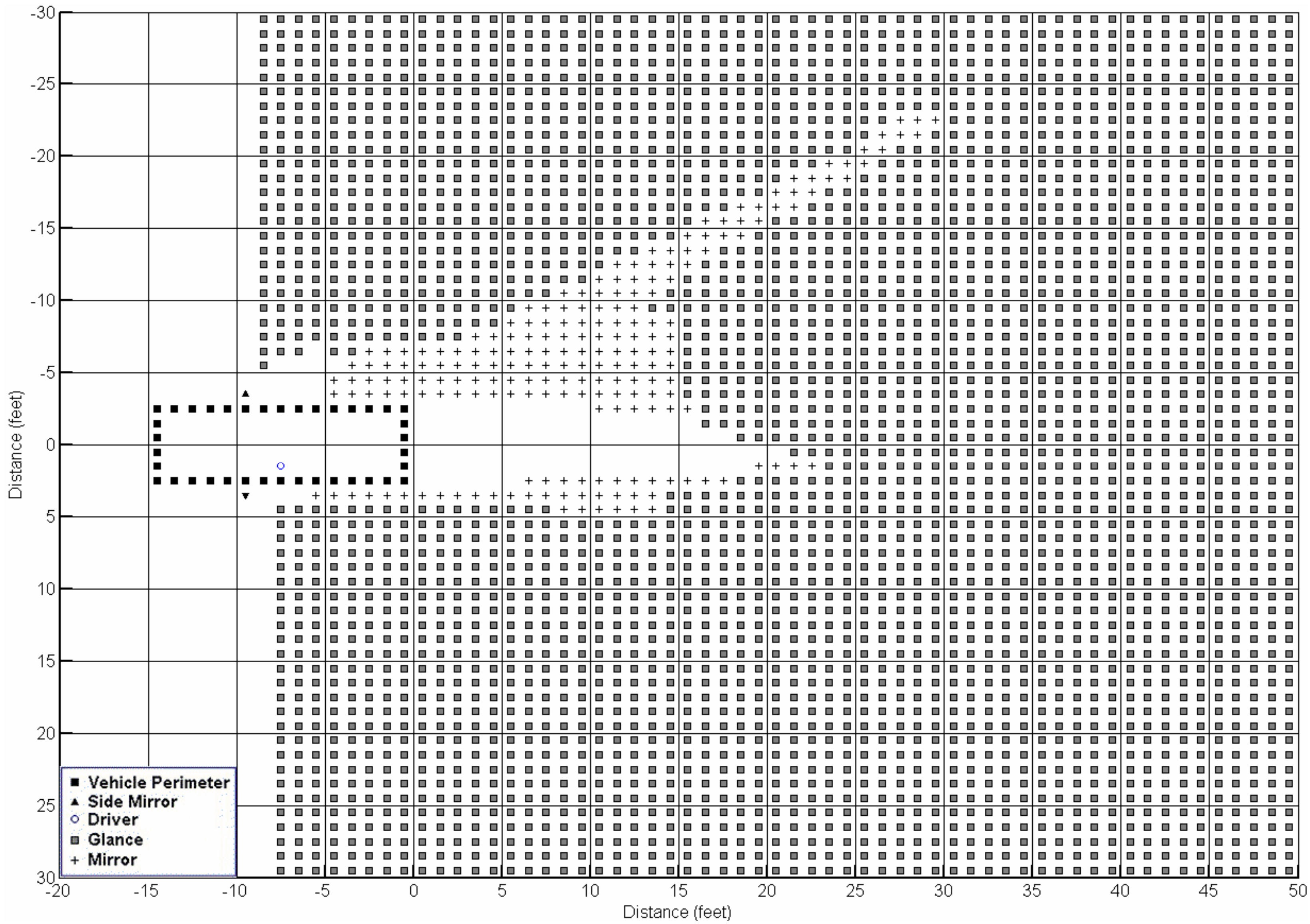


Figure 18. FOV Plot for a 2006 BMW 330i with 5th Percentile Female Driver

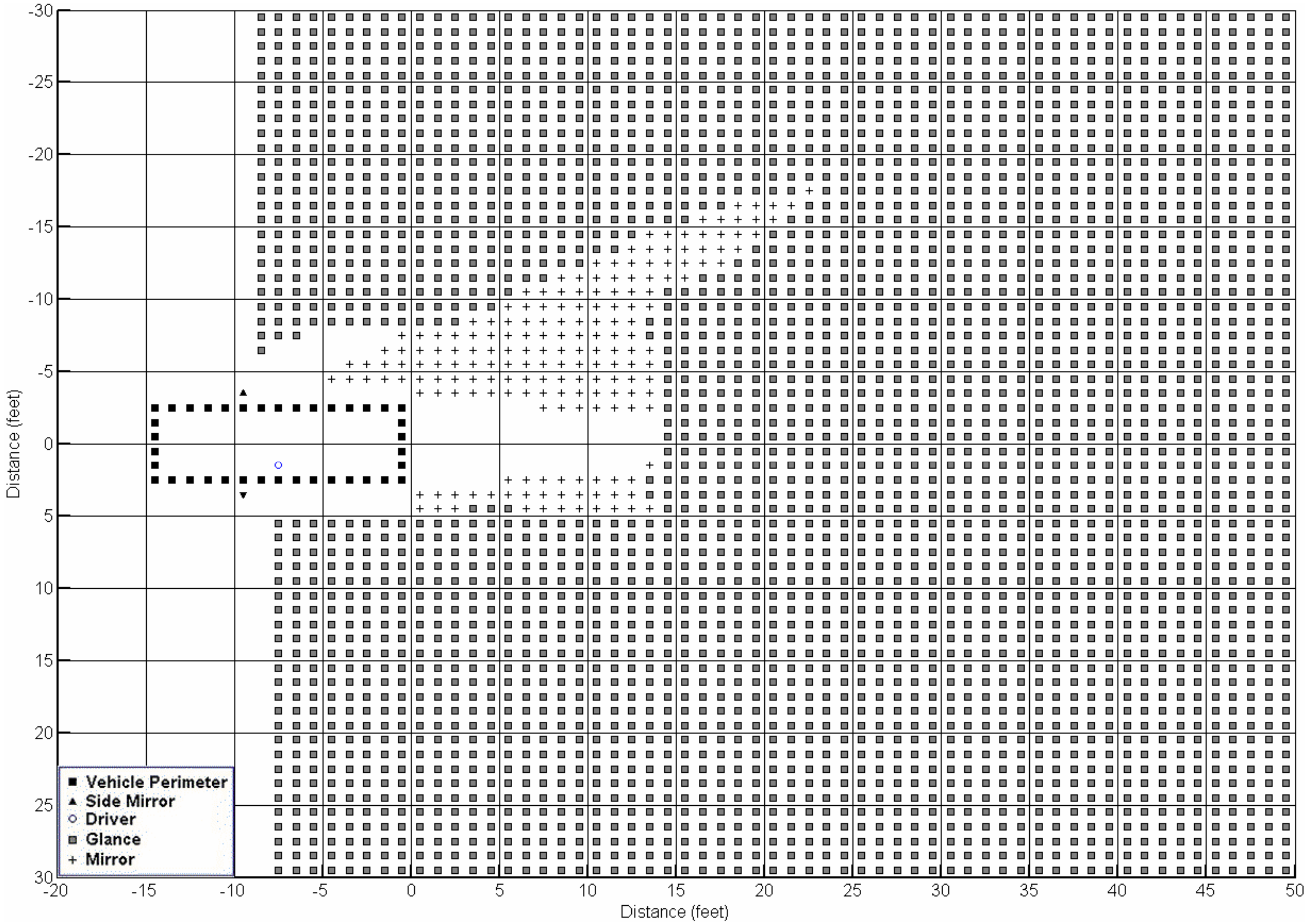


Figure 19. FOV Plot for 2005 Cadillac STS a with 50th Percentile Male Driver

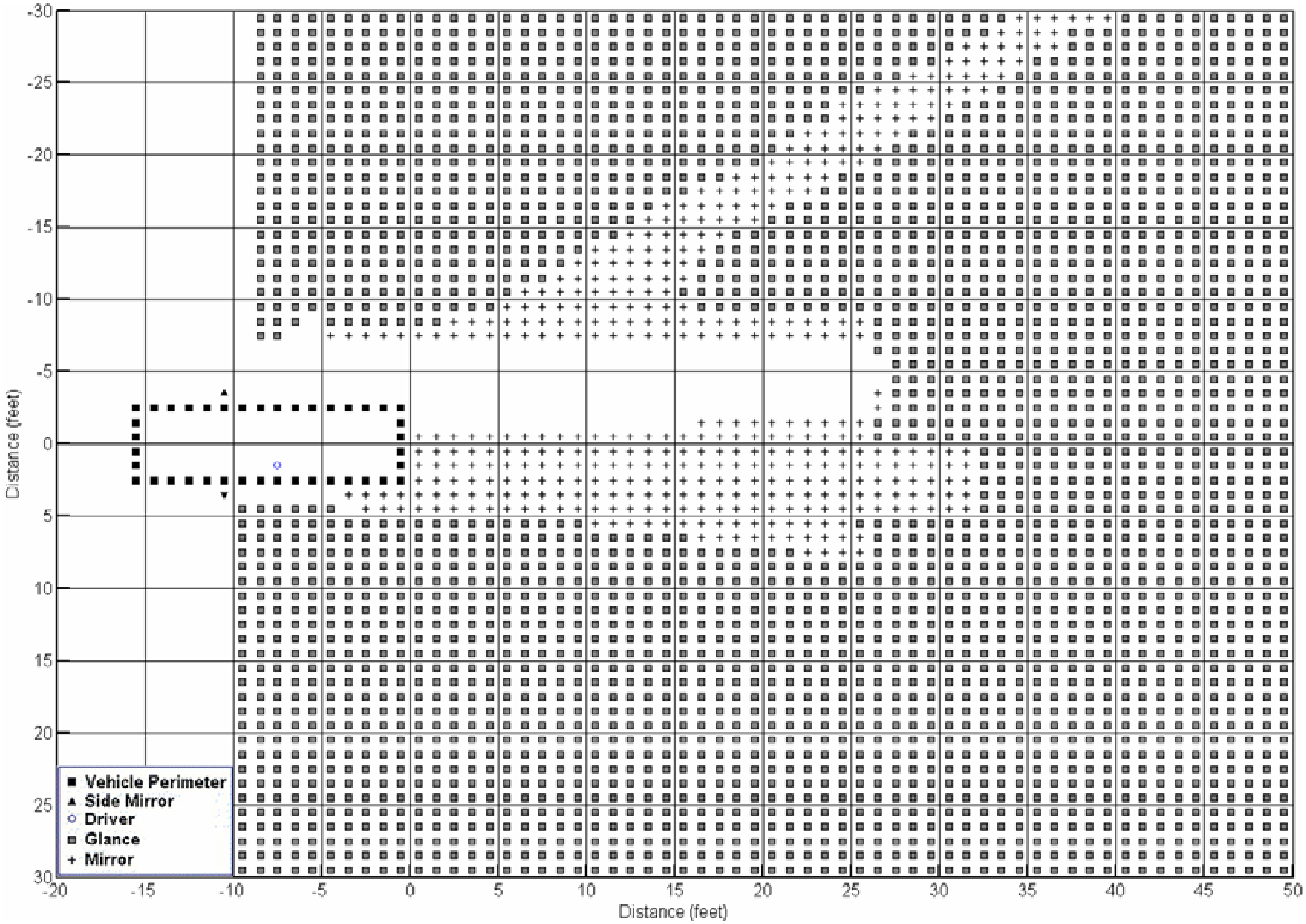


Figure 20. FOV Plot for a 2005 Cadillac STS with 5th Percentile Female Driver

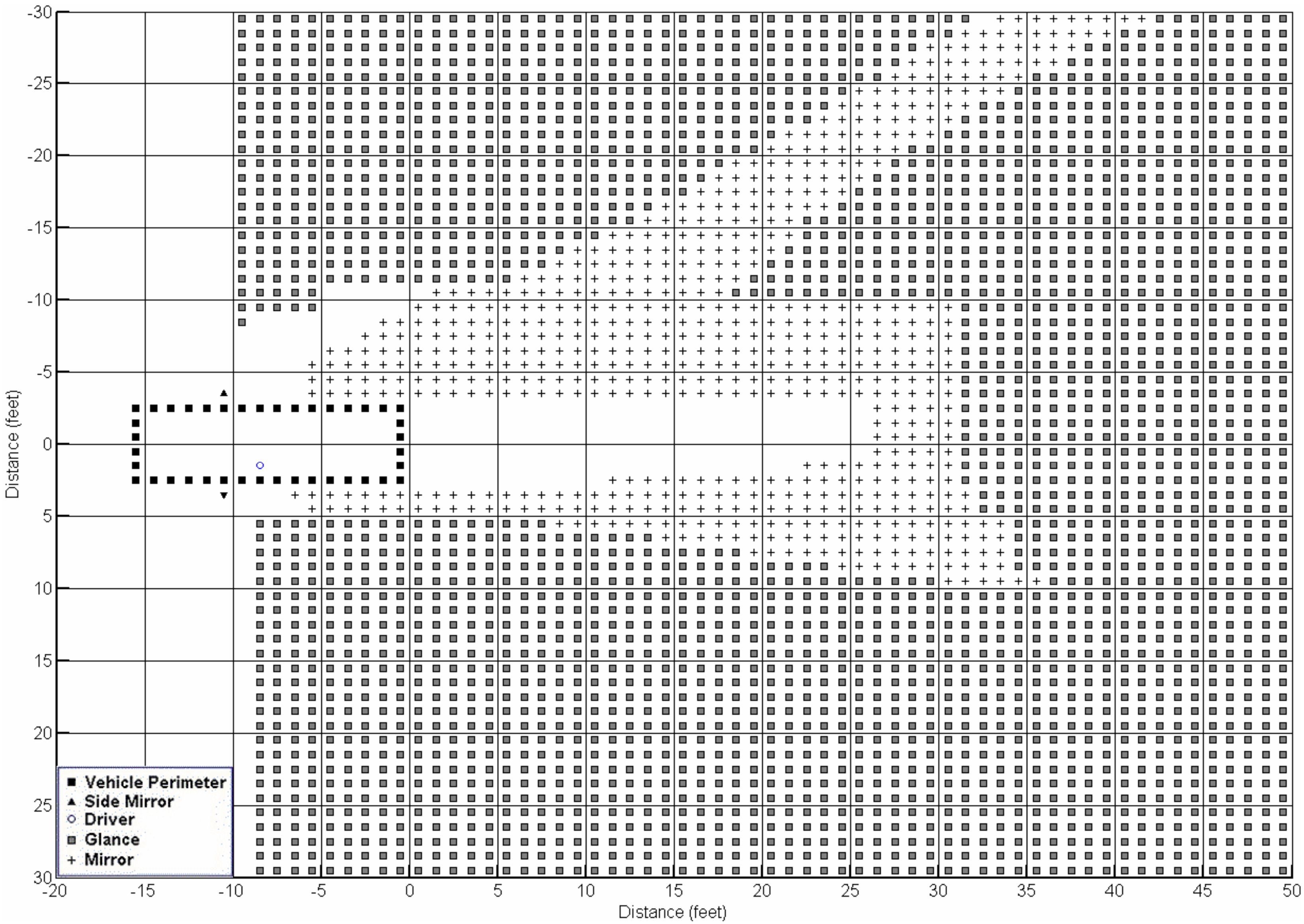


Figure 21. FOV Plot for a 2007 Chevrolet Cobalt Coupe with 50th Percentile Male Driver

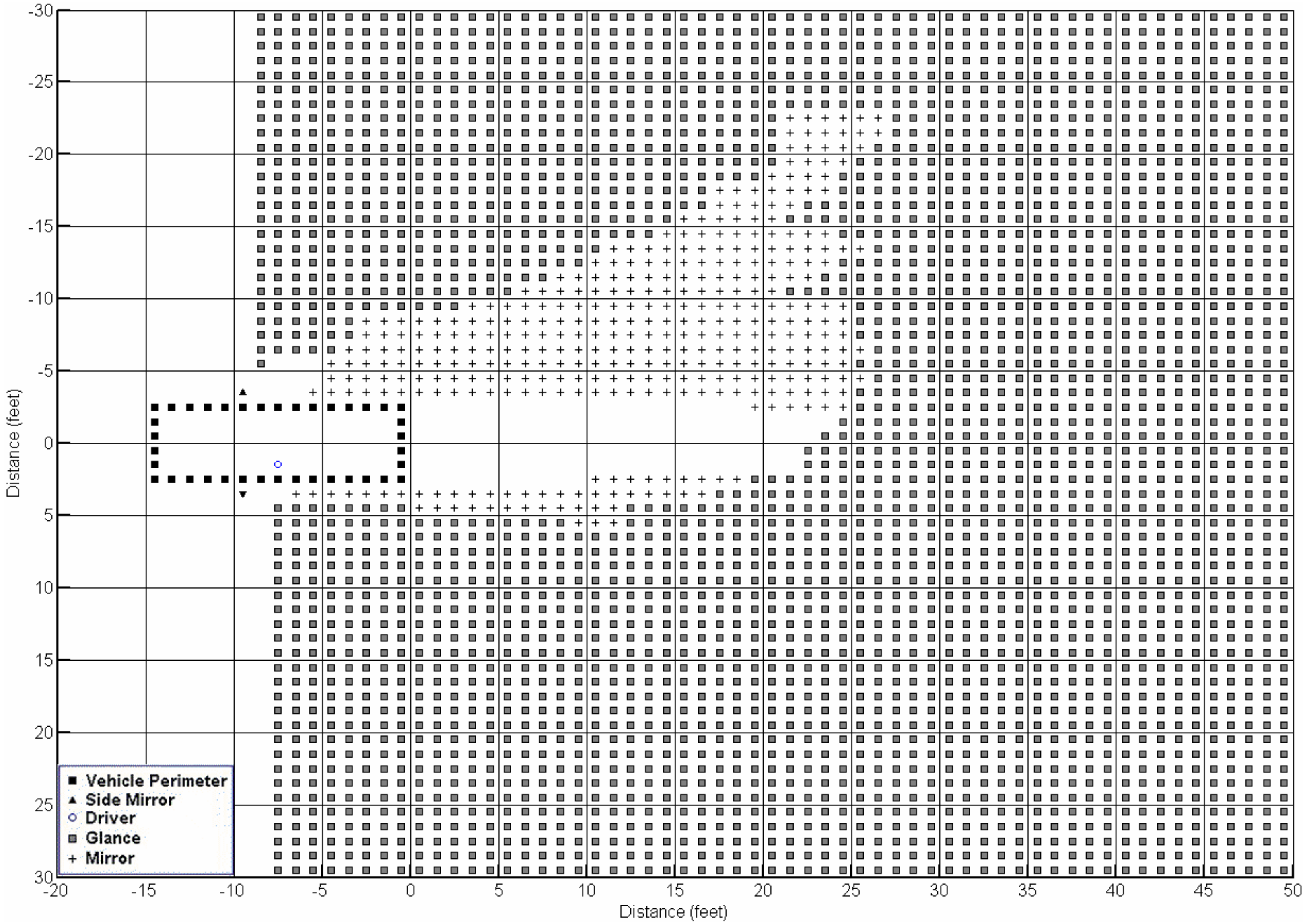


Figure 22. FOV Plot for a 2007 Chevrolet Cobalt Coupe with 5th Percentile Female Driver

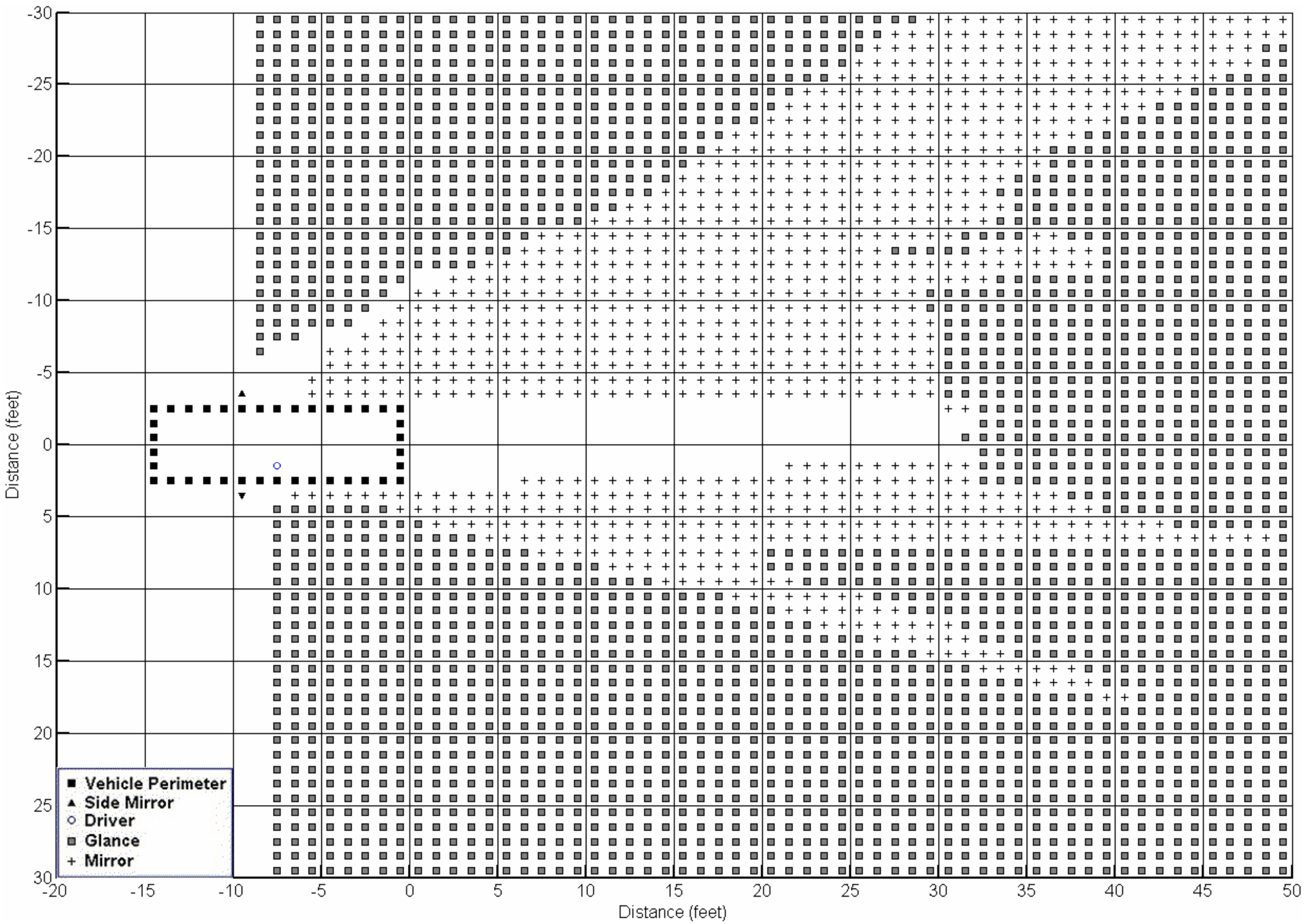


Figure 23. FOV Plot for a 2007 Chevrolet Impala with 50th Percentile Male Driver

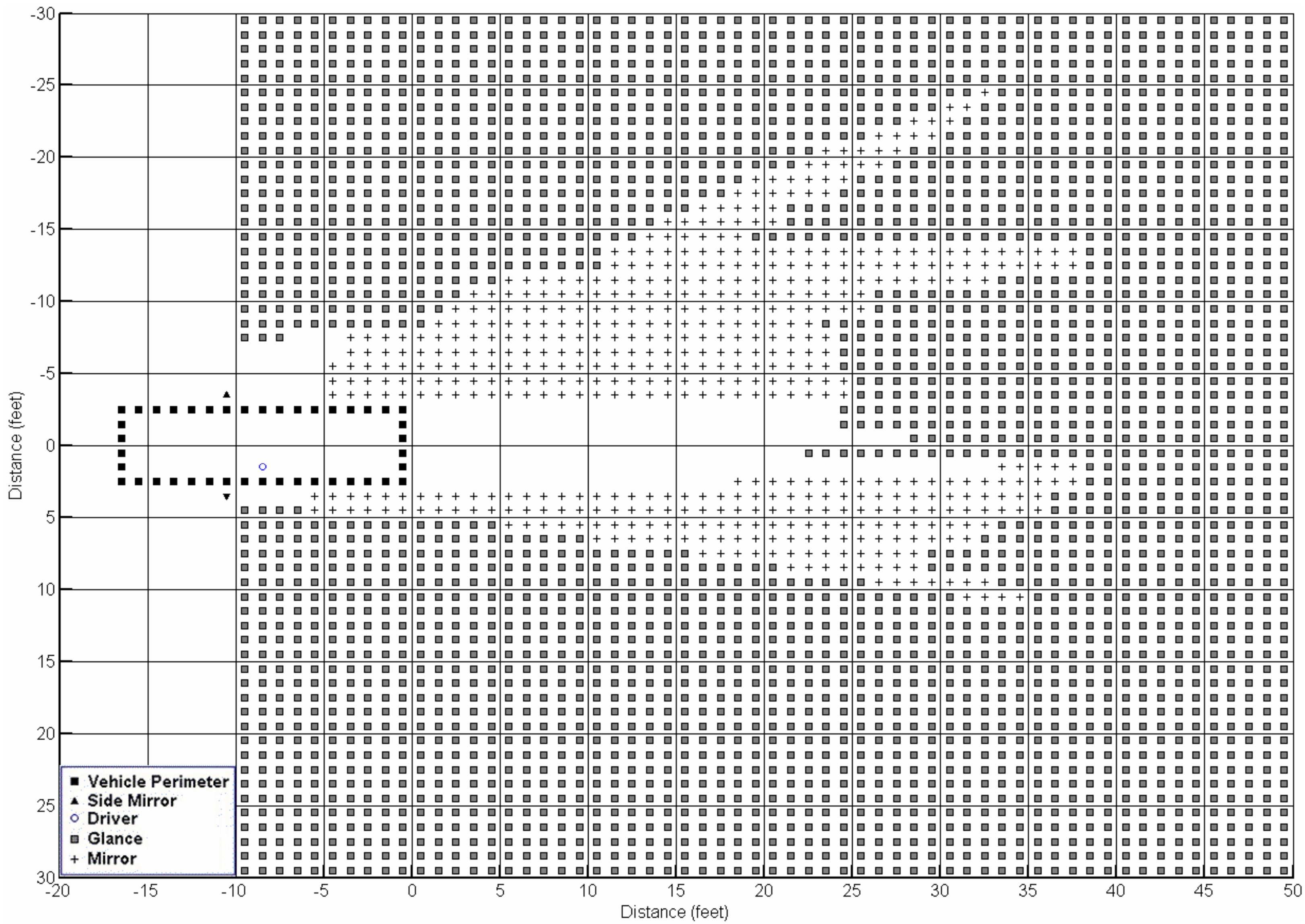


Figure 24. FOV Plot for a 2007 Chevrolet Impala with 5th Percentile Female Driver

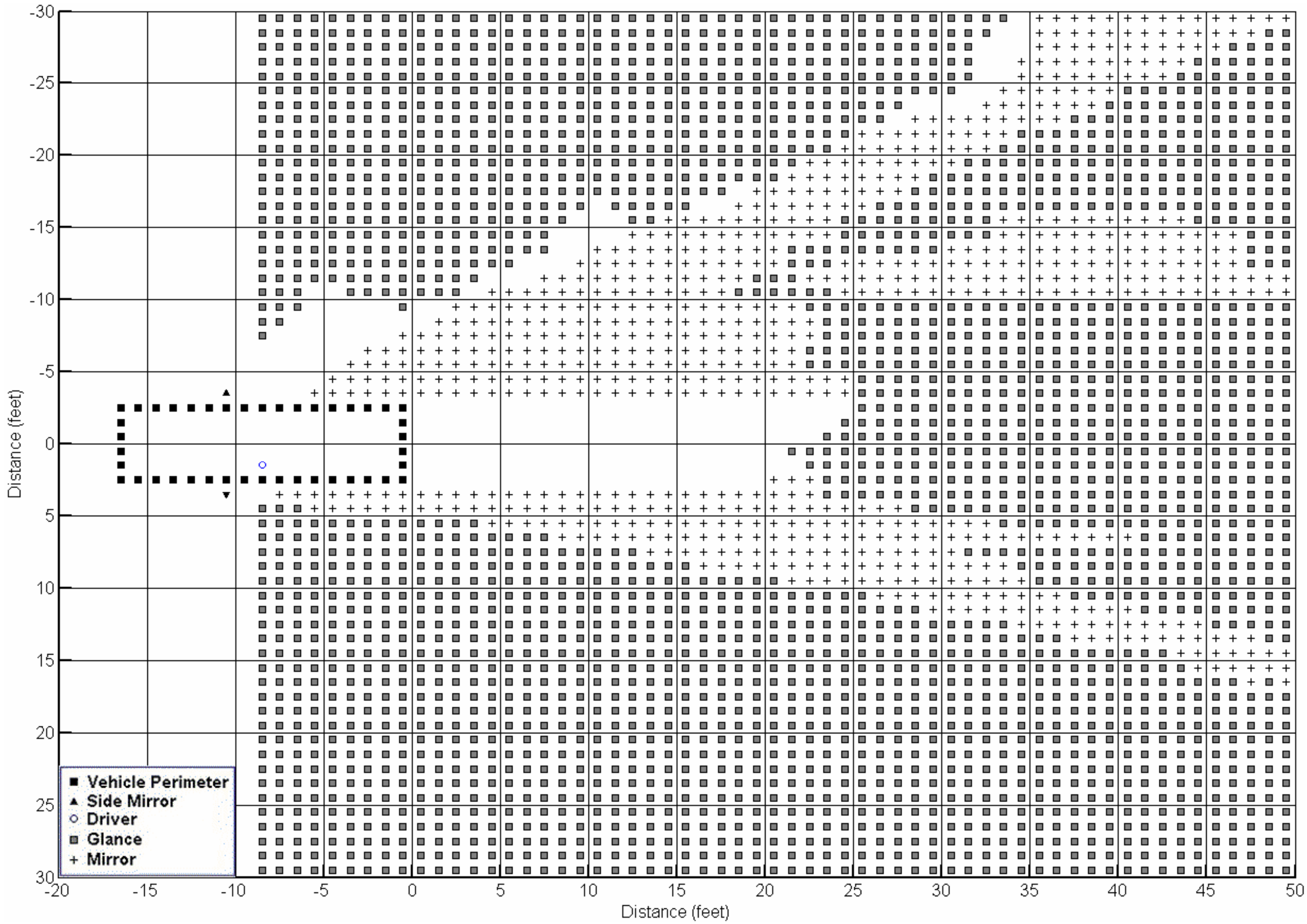


Figure 25. FOV Plot for a 2005 Chevrolet Malibu Maxx with 50th Percentile Male Driver (Same Body Style as 2007)

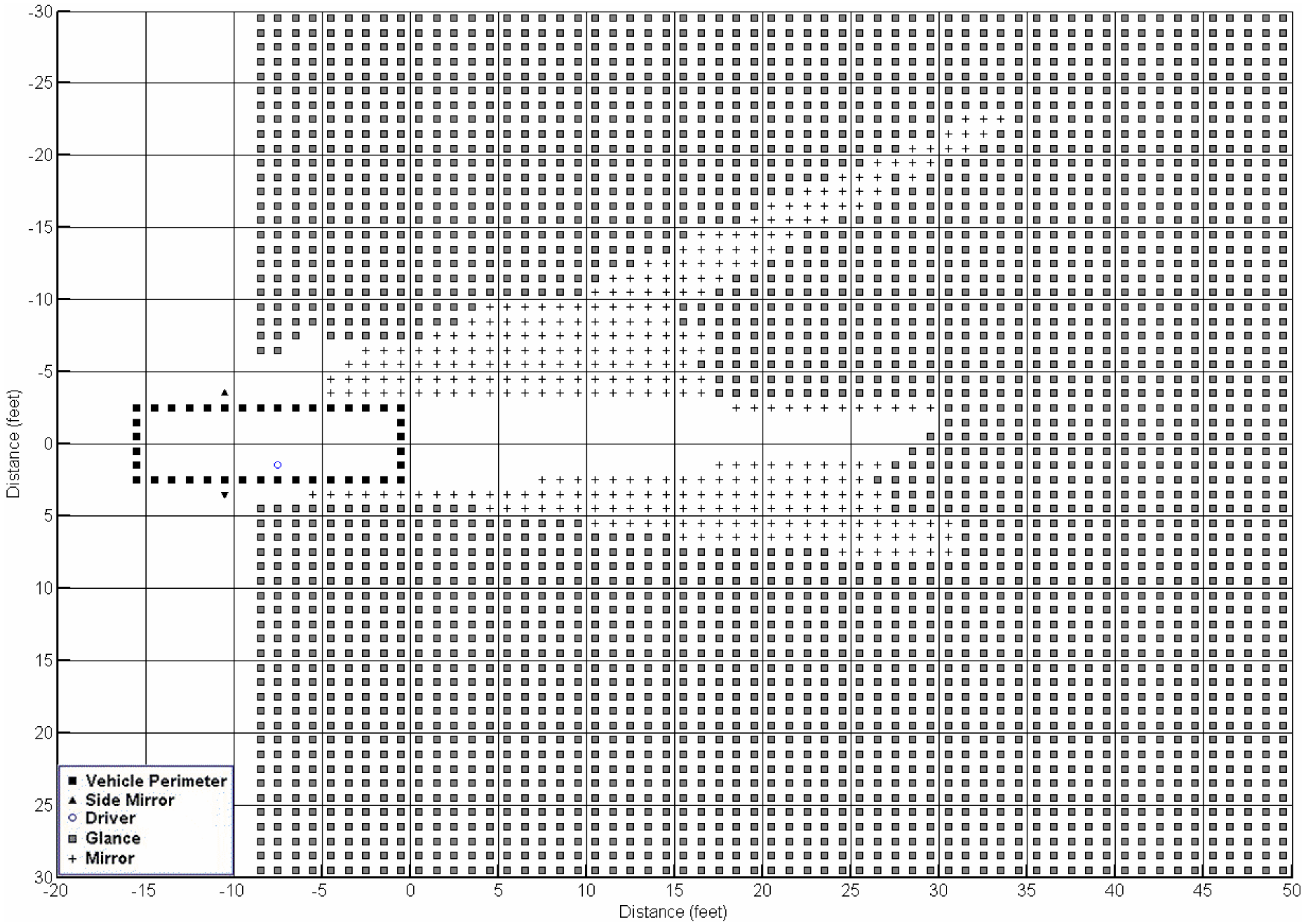


Figure 26. FOV Plot for a 2005 Chevrolet Malibu Maxx with 5th Percentile Female Driver (Same Body Style as 2007)

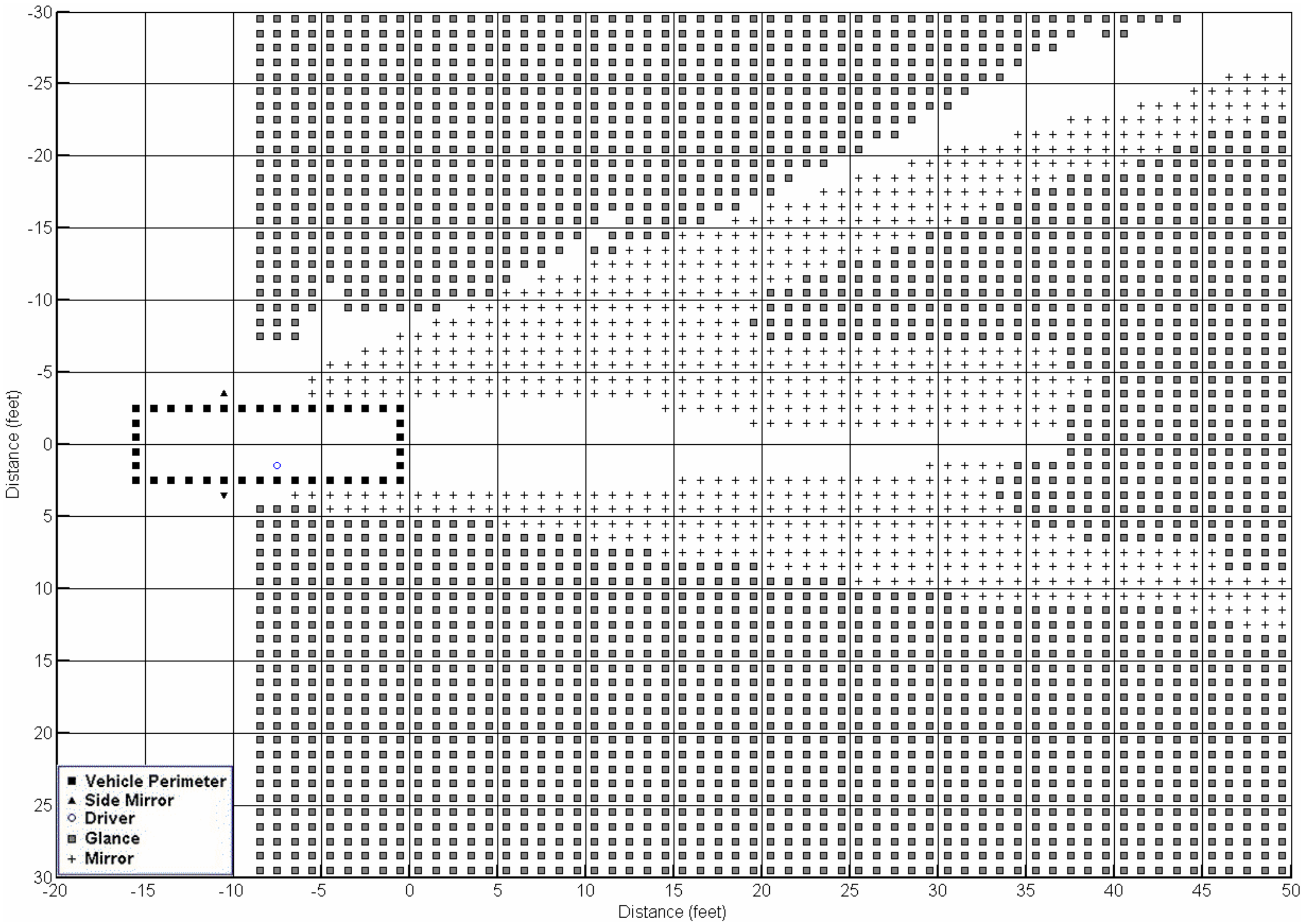


Figure 27. FOV Plot for a 2007 Chrysler 300C with 50th Percentile Male Driver

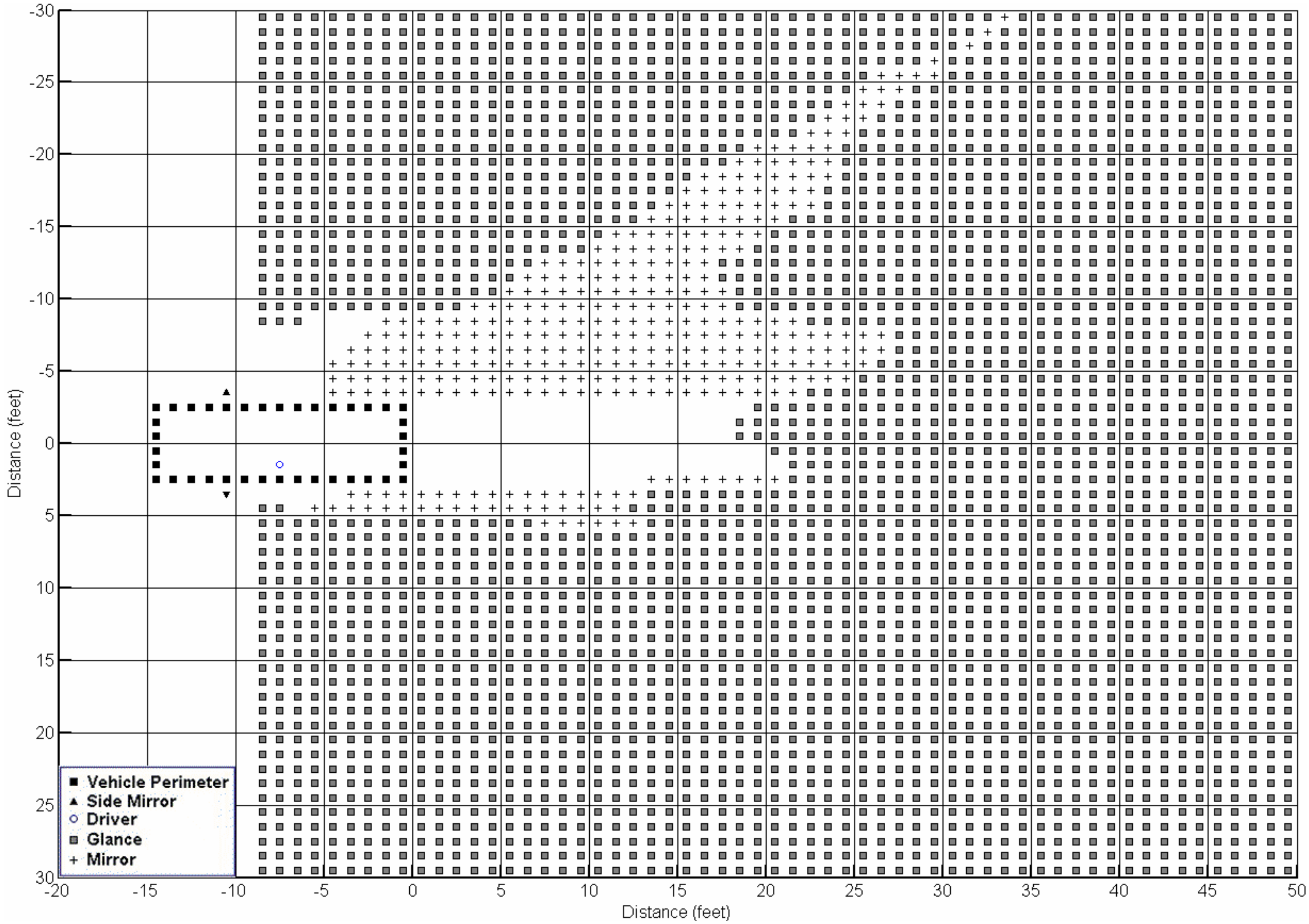


Figure 28. FOV Plot for a 2007 Chrysler 300C with 5th Percentile Female Driver

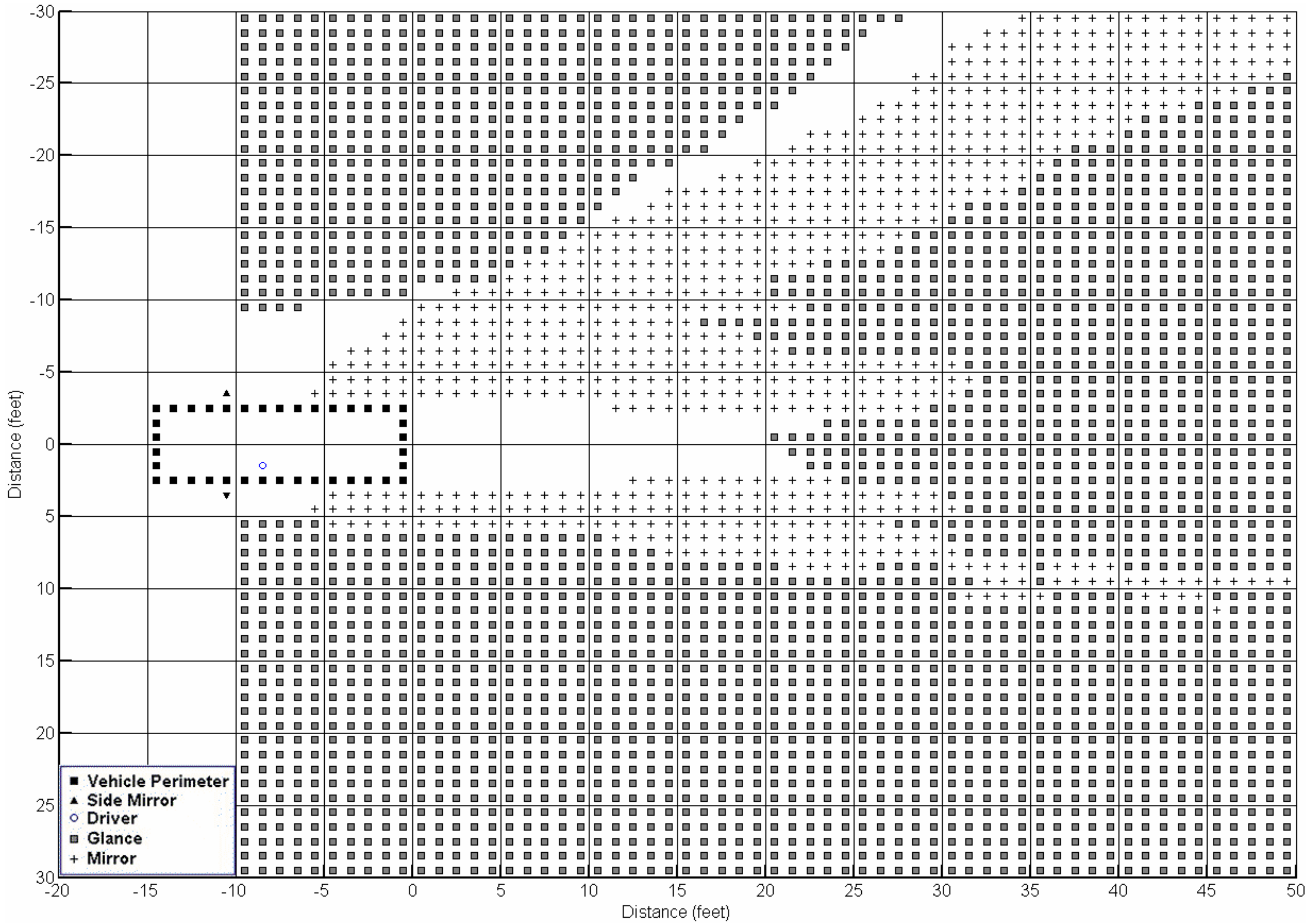


Figure 29. FOV Plot for a 2007 Ford Five Hundred with 50th Percentile Male Driver

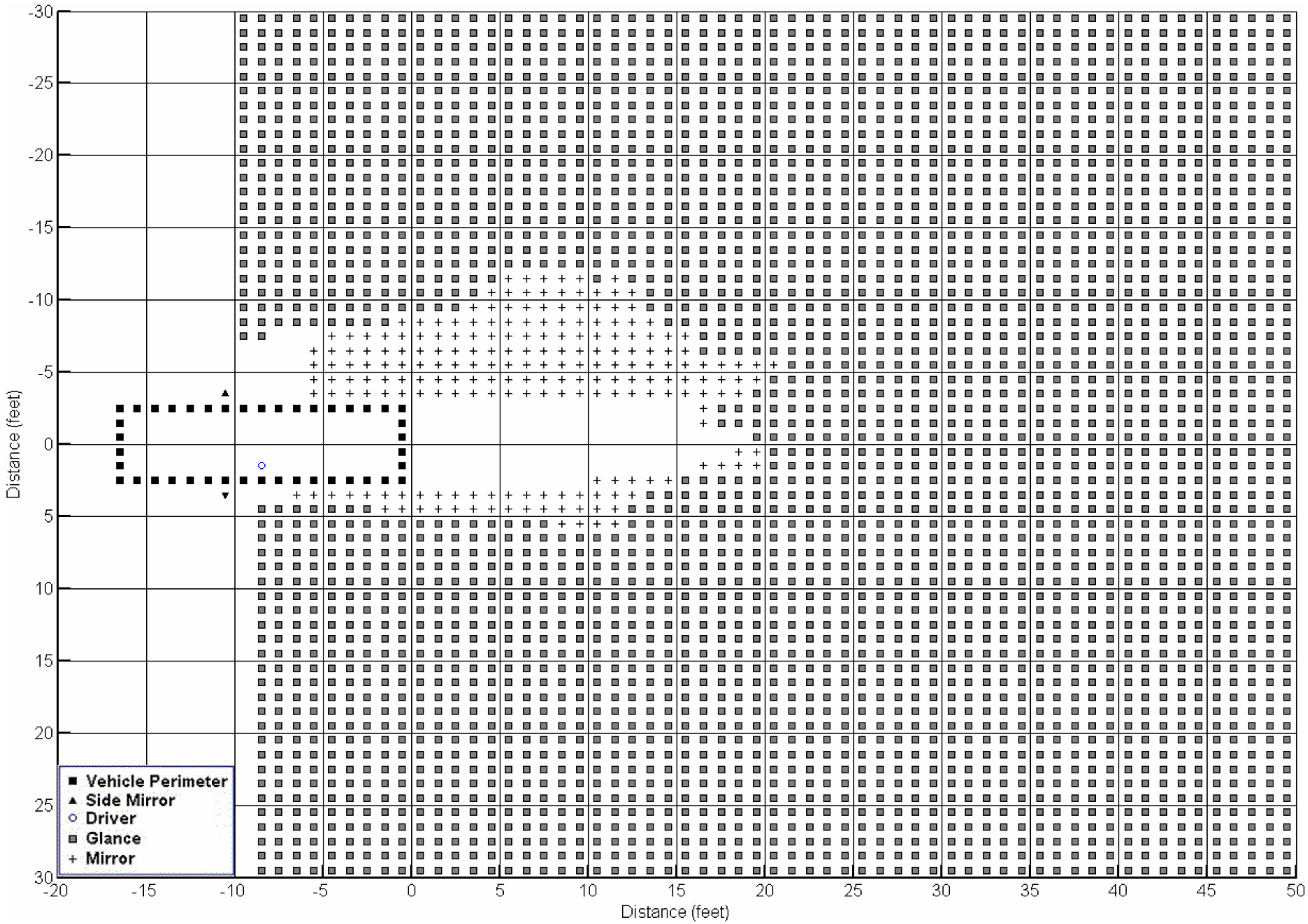


Figure 30. FOV Plot for a 2007 Ford Five Hundred with 5th Percentile Female Driver

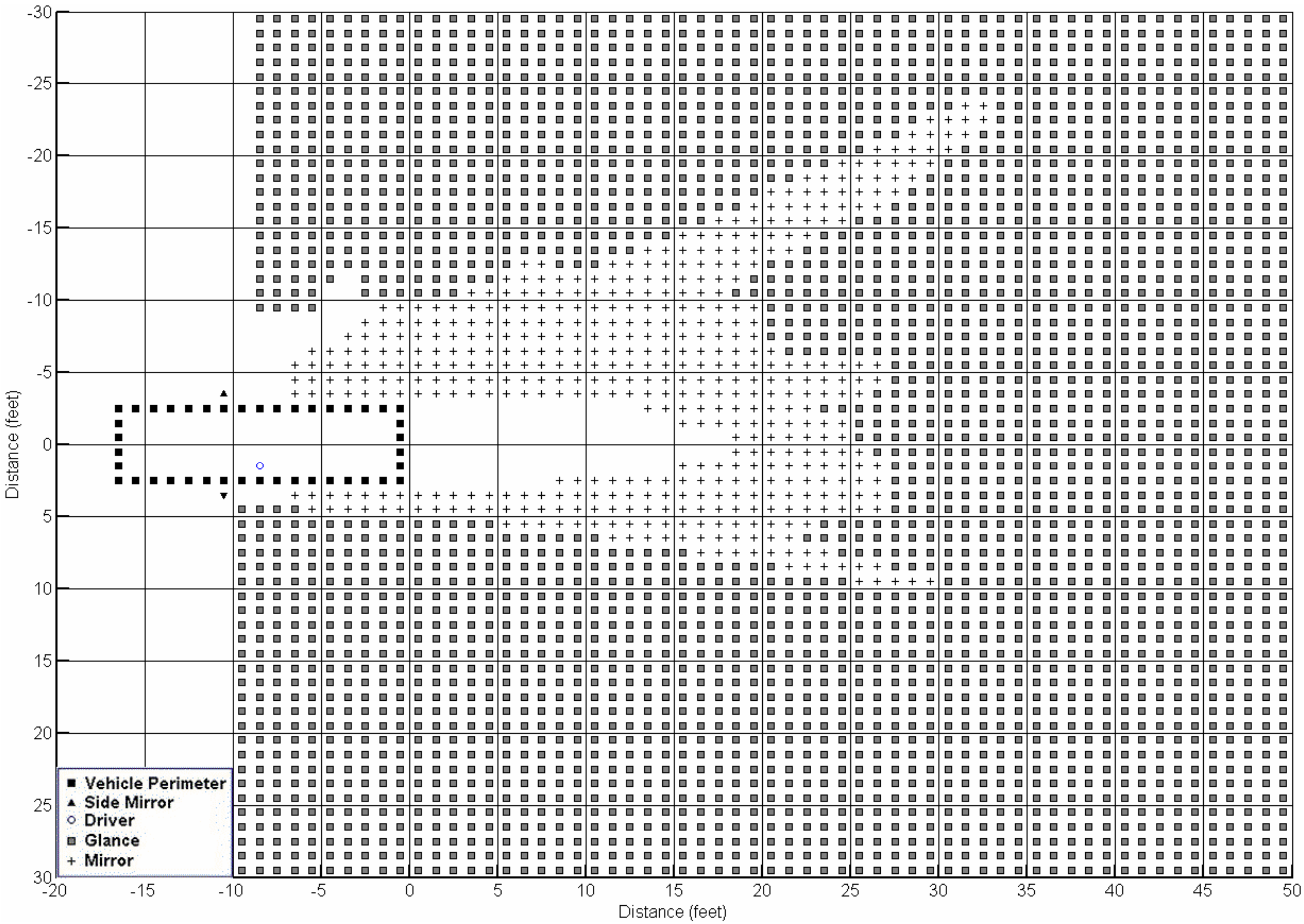


Figure 31. FOV Plot for a 2006 Ford Taurus with 50th Percentile Male Driver

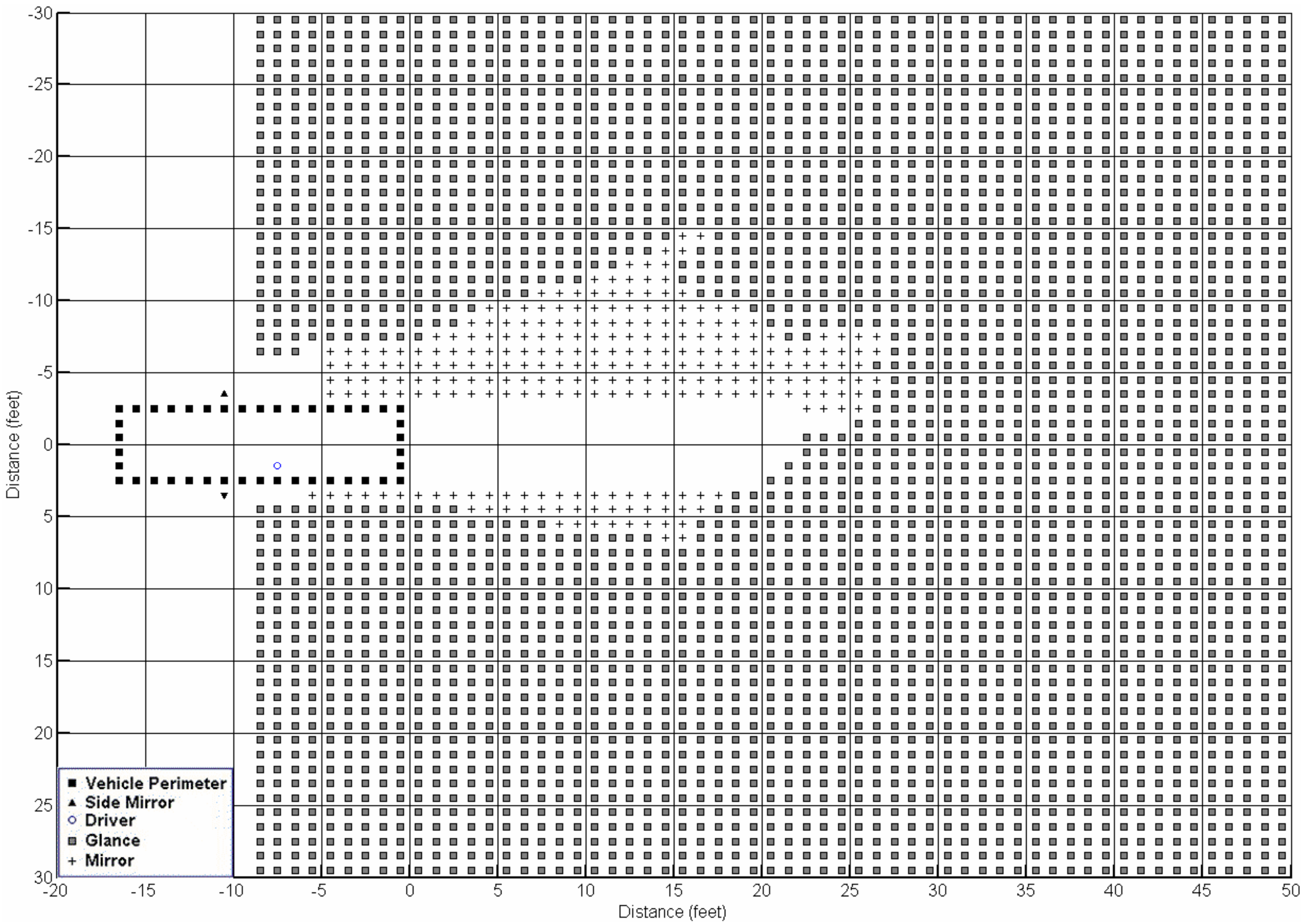


Figure 32. FOV Plot for a 2006 Ford Taurus with 5th Percentile Female Driver

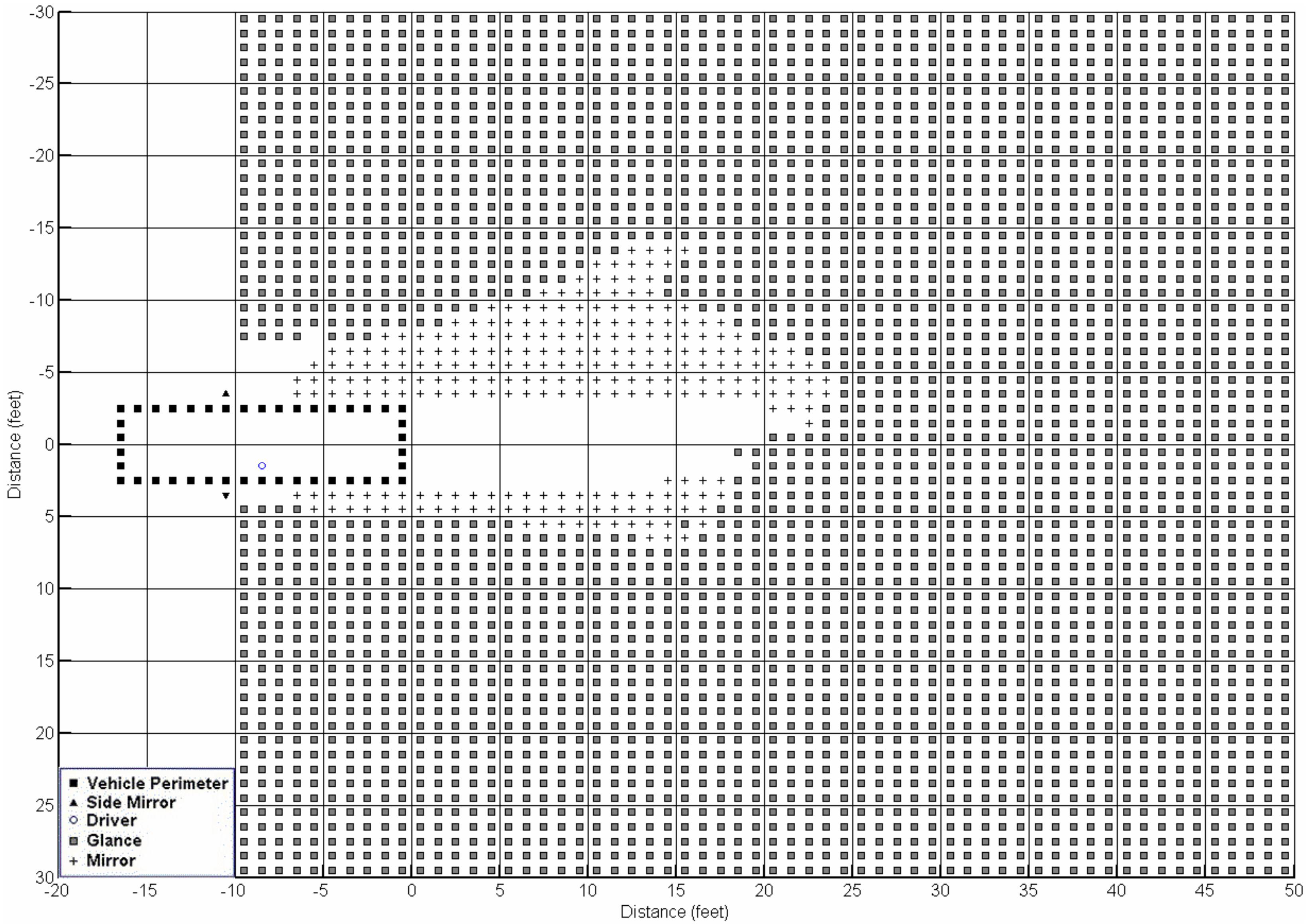


Figure 33. FOV Plot for a 2007 Honda Accord with 50th Percentile Male Driver

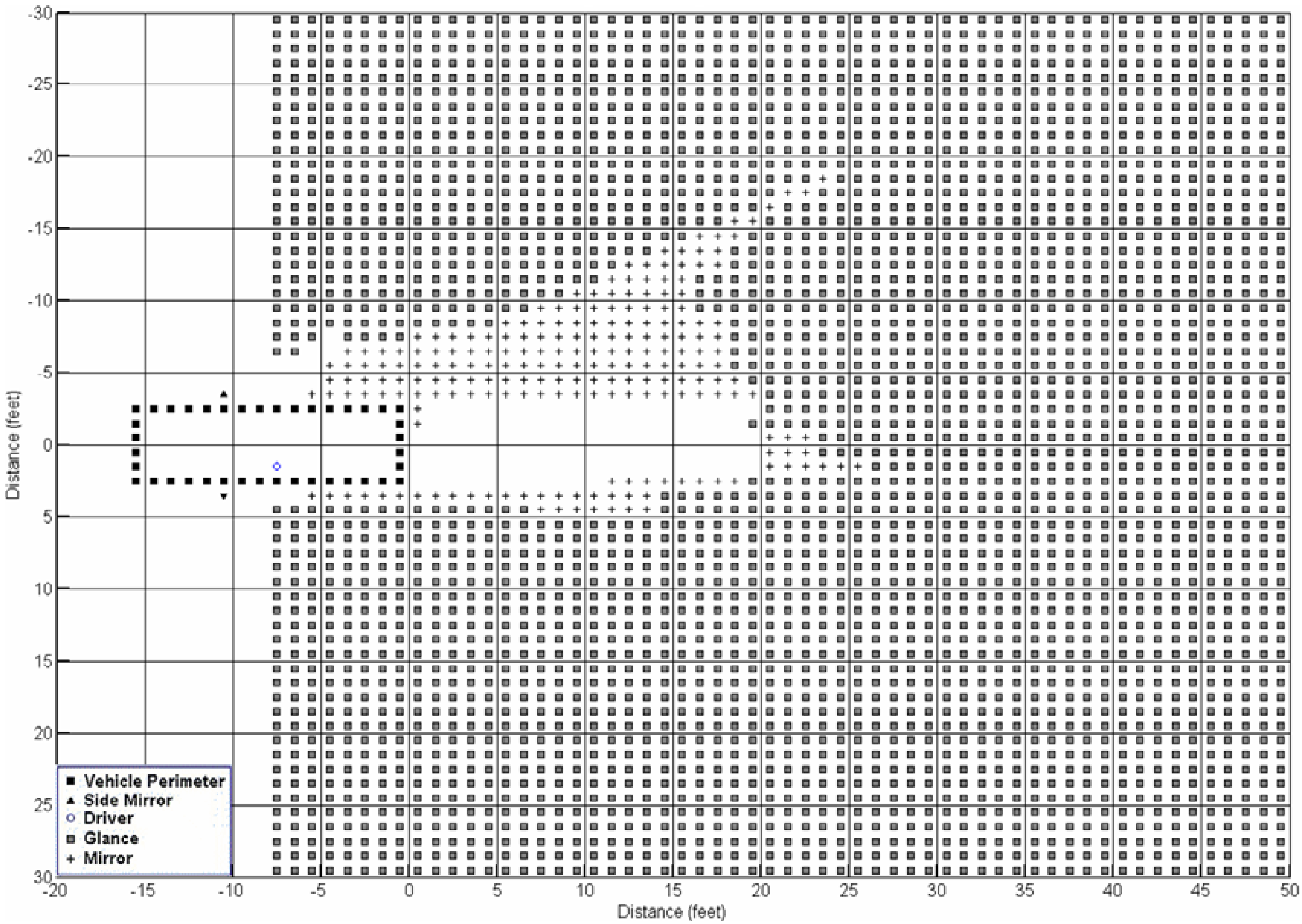


Figure 34. FOV Plot for a 2007 Honda Accord with 5th Percentile Female Driver

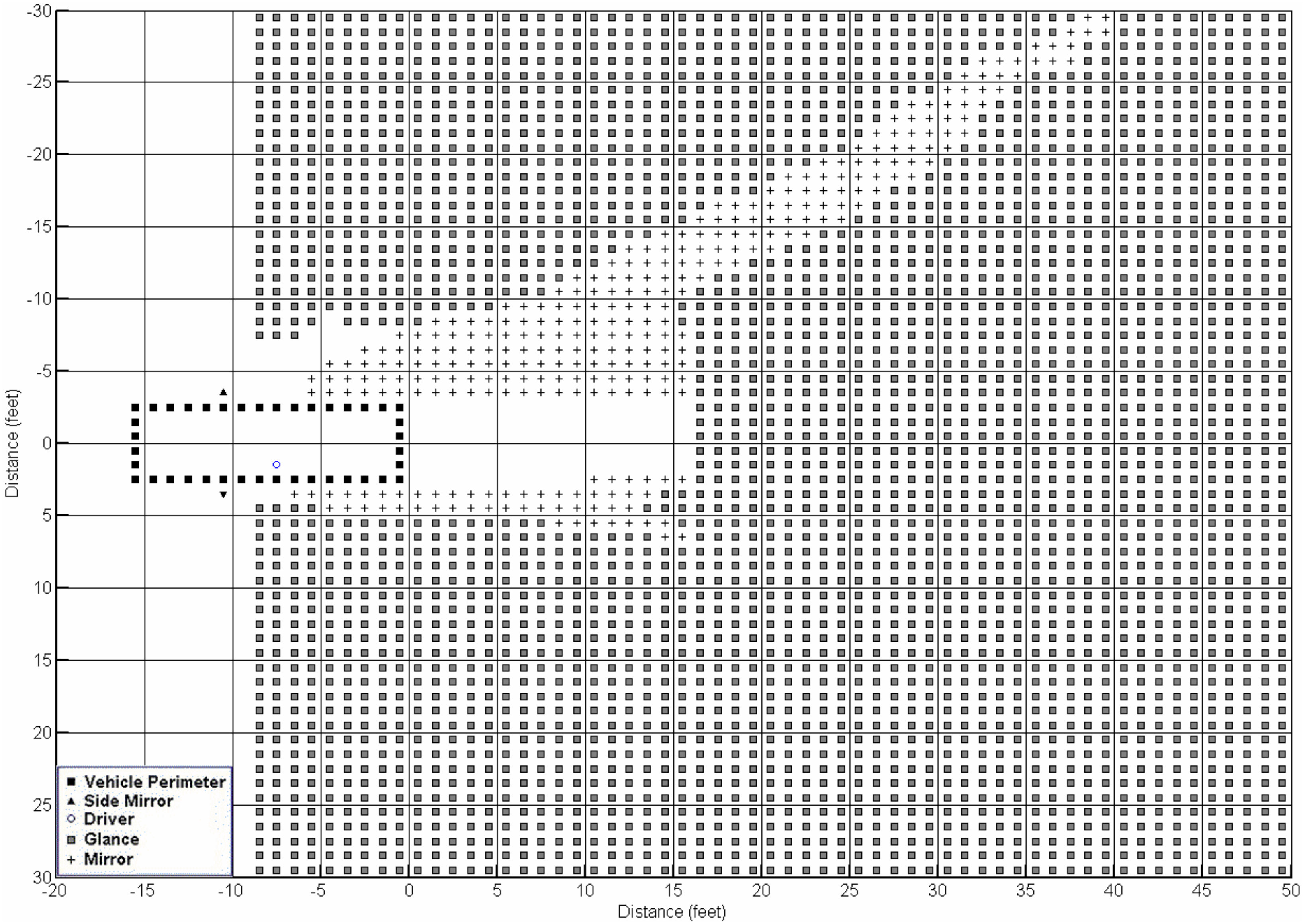


Figure 35. FOV Plot for a 2007 Honda Civic with 50th Percentile Male Driver

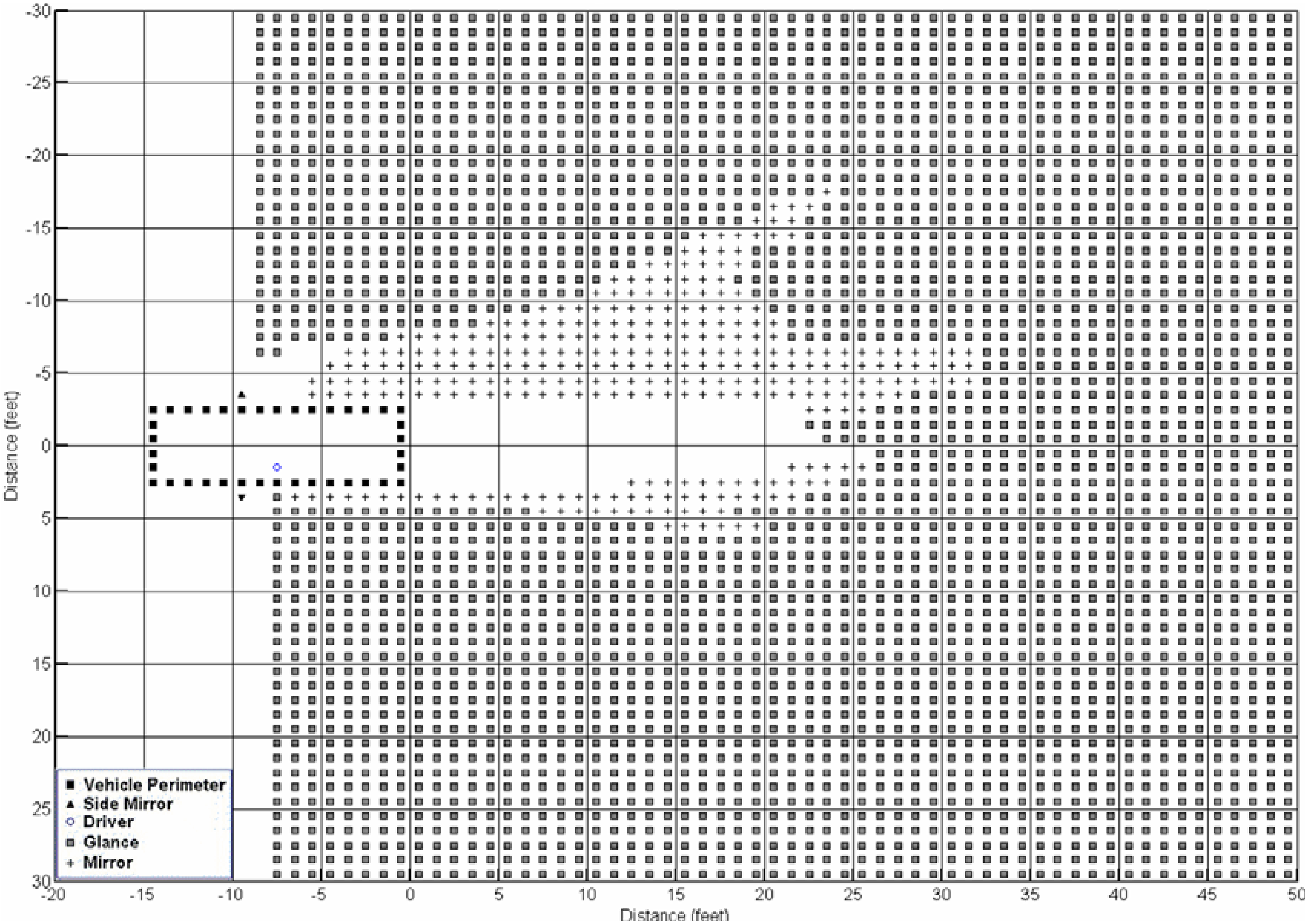


Figure 36. FOV Plot for a 2007 Honda Civic with 5th Percentile Female Driver

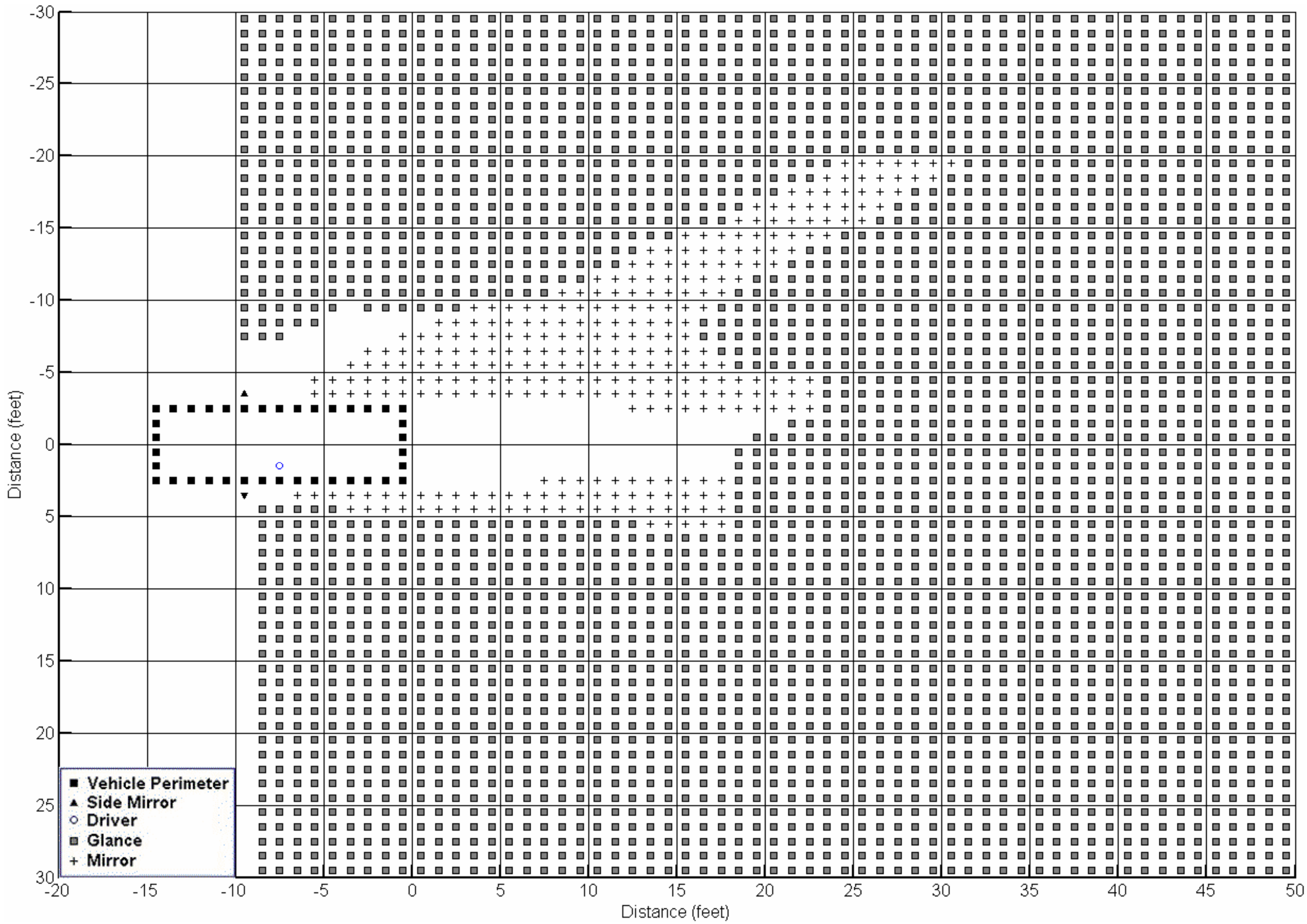


Figure 37. FOV Plot for a 2007 Nissan Altima with 50th Percentile Male Driver

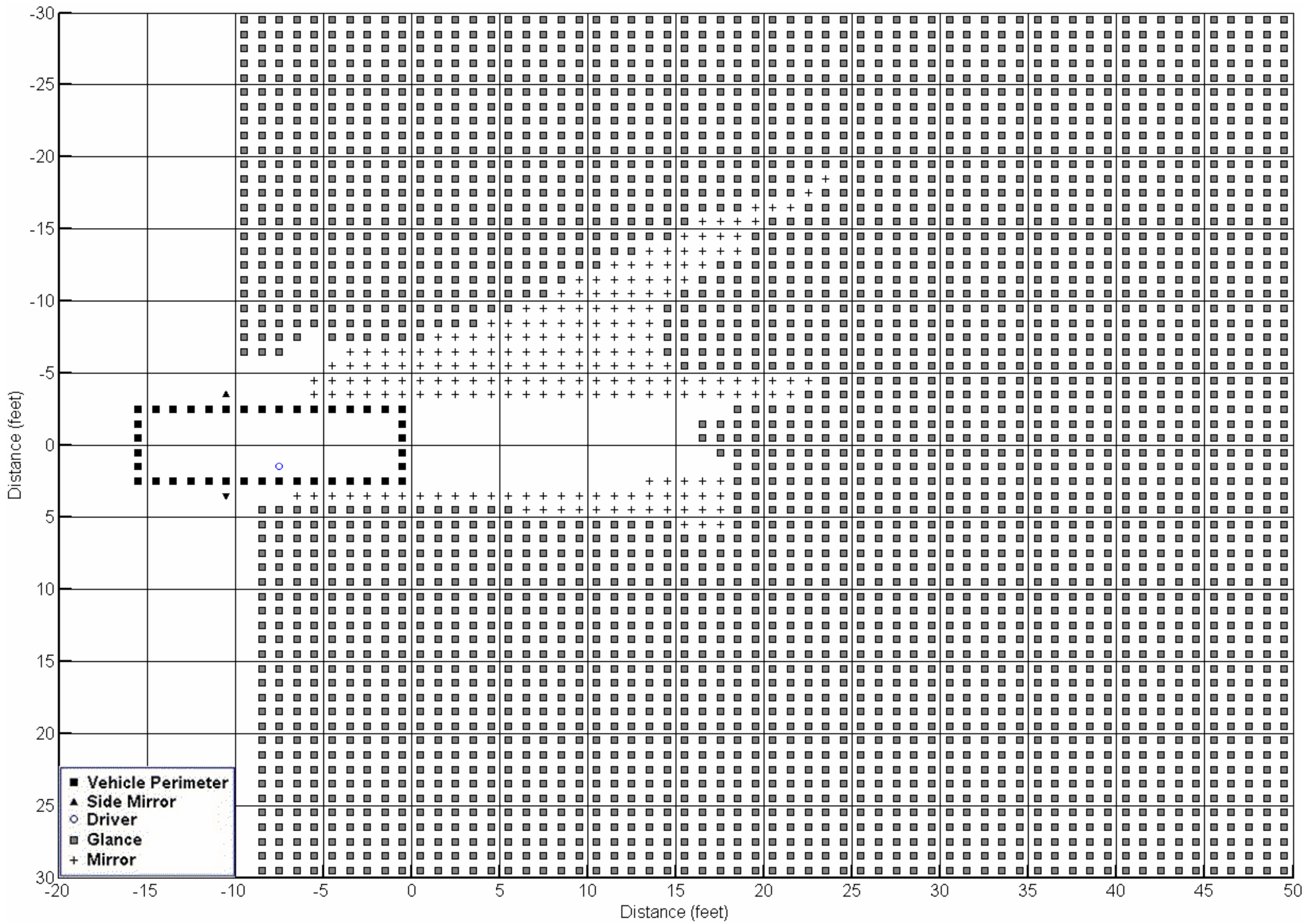


Figure 38. FOV Plot for a 2007 Nissan Altima with 5th Percentile Female Driver

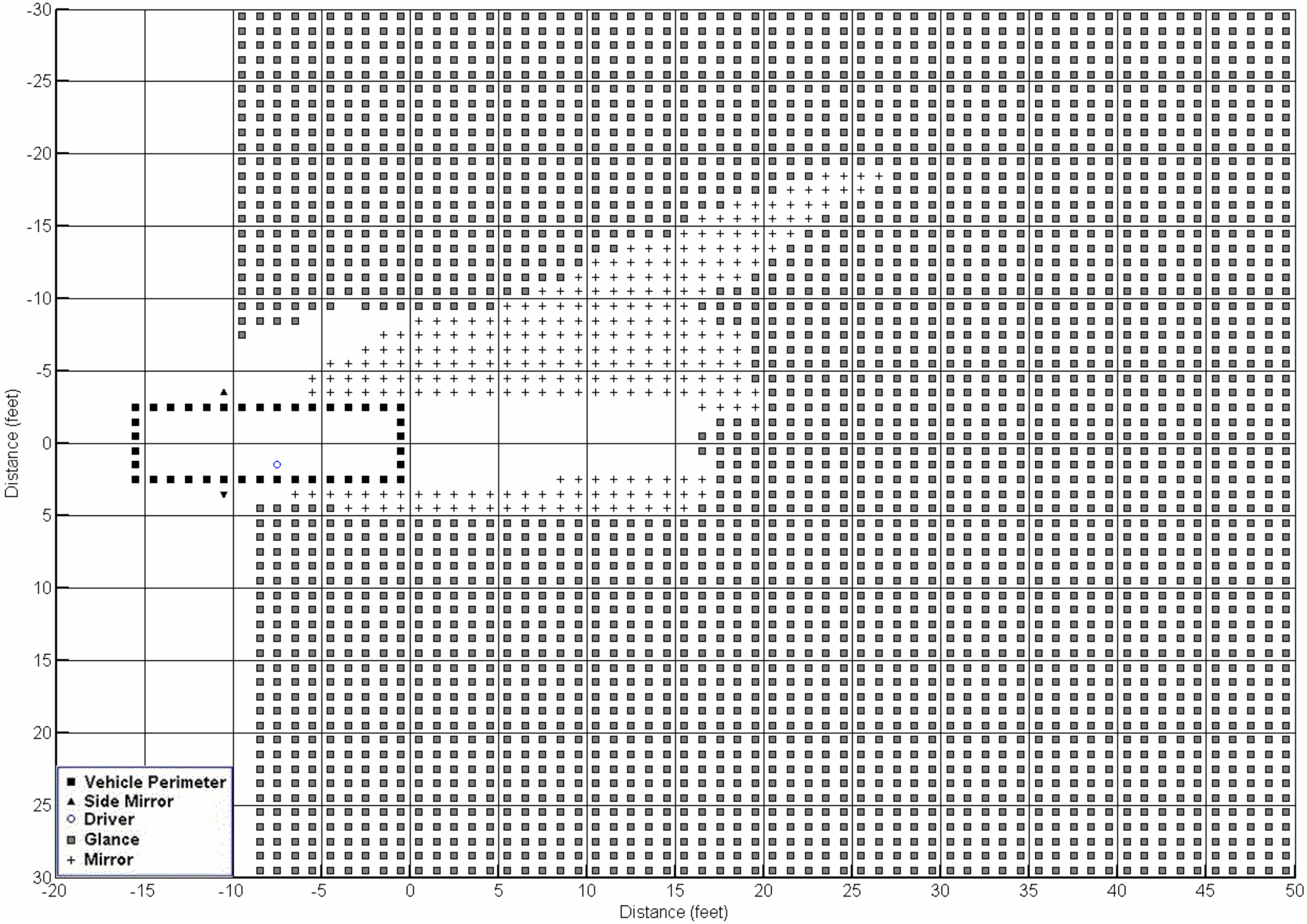


Figure 39. FOV Plot for a 2007 Pontiac Grand Prix with 50th Percentile Male Driver

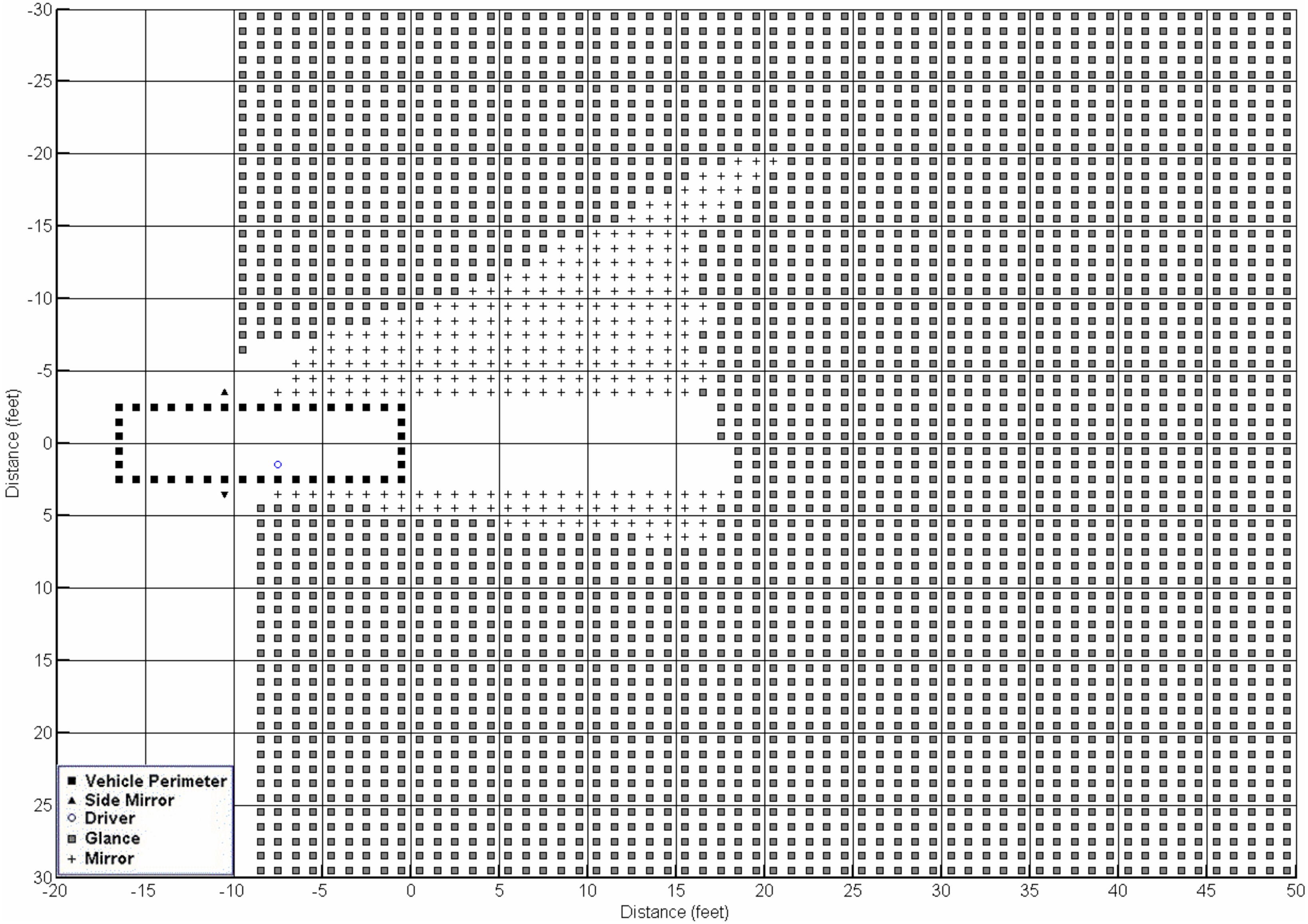


Figure 40. FOV Plot for a 2007 Pontiac Grand Prix with 5th Percentile Female Driver

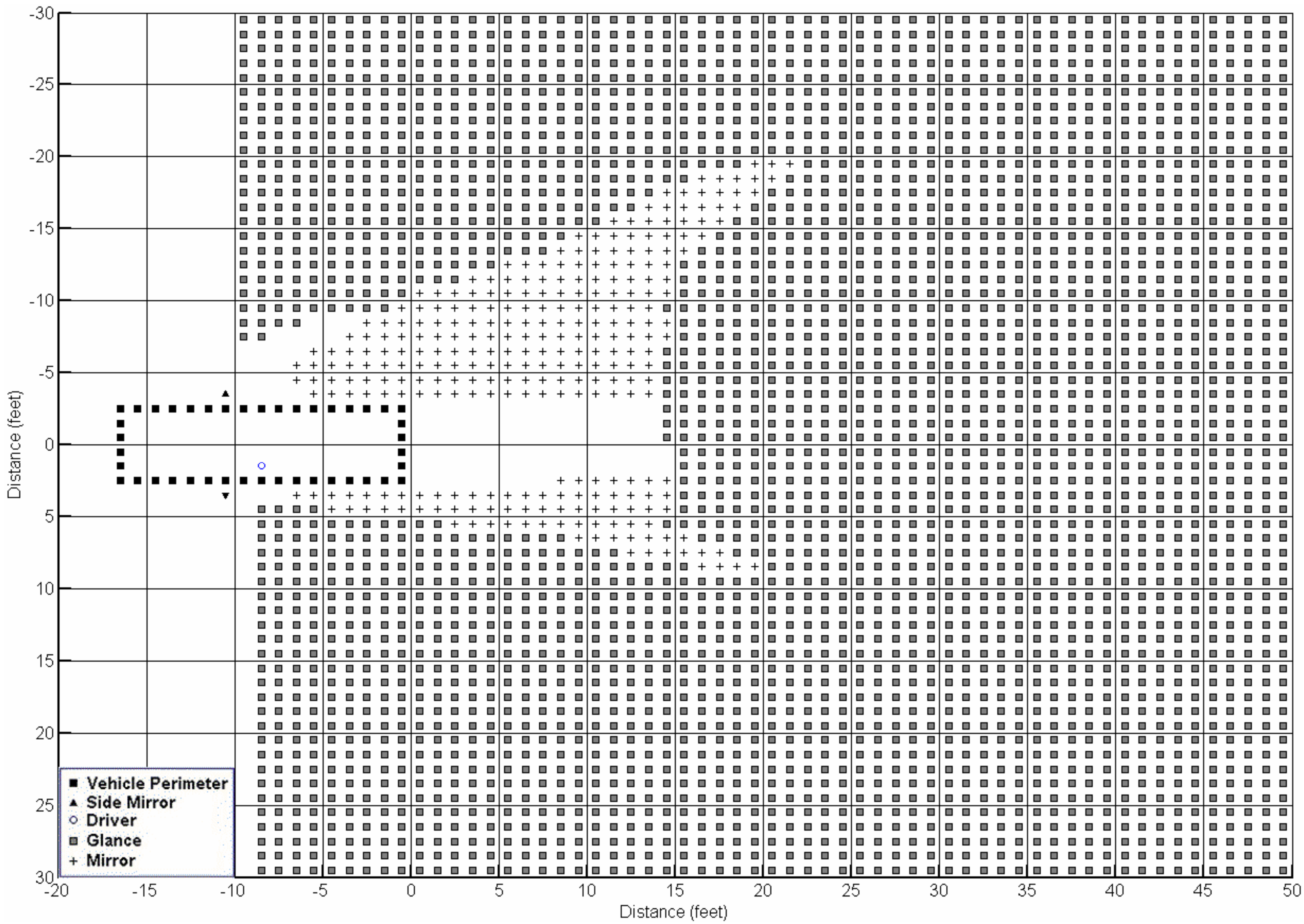


Figure 41. FOV Plot for a 2005 Subaru Forrester with 50th Percentile Male Driver

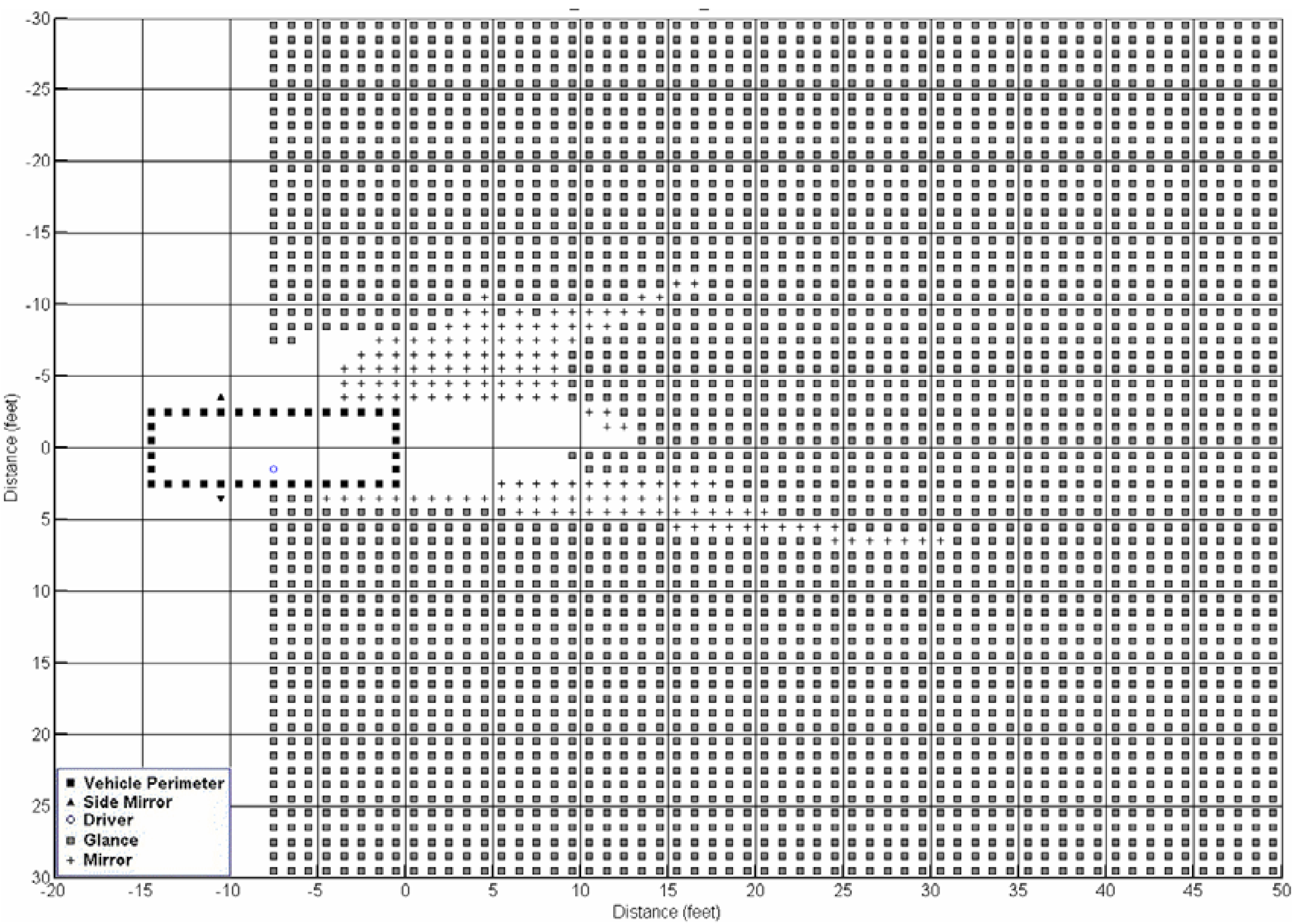


Figure 42. FOV Plot for a 2005 Subaru Forrester with 5th Percentile Female Driver

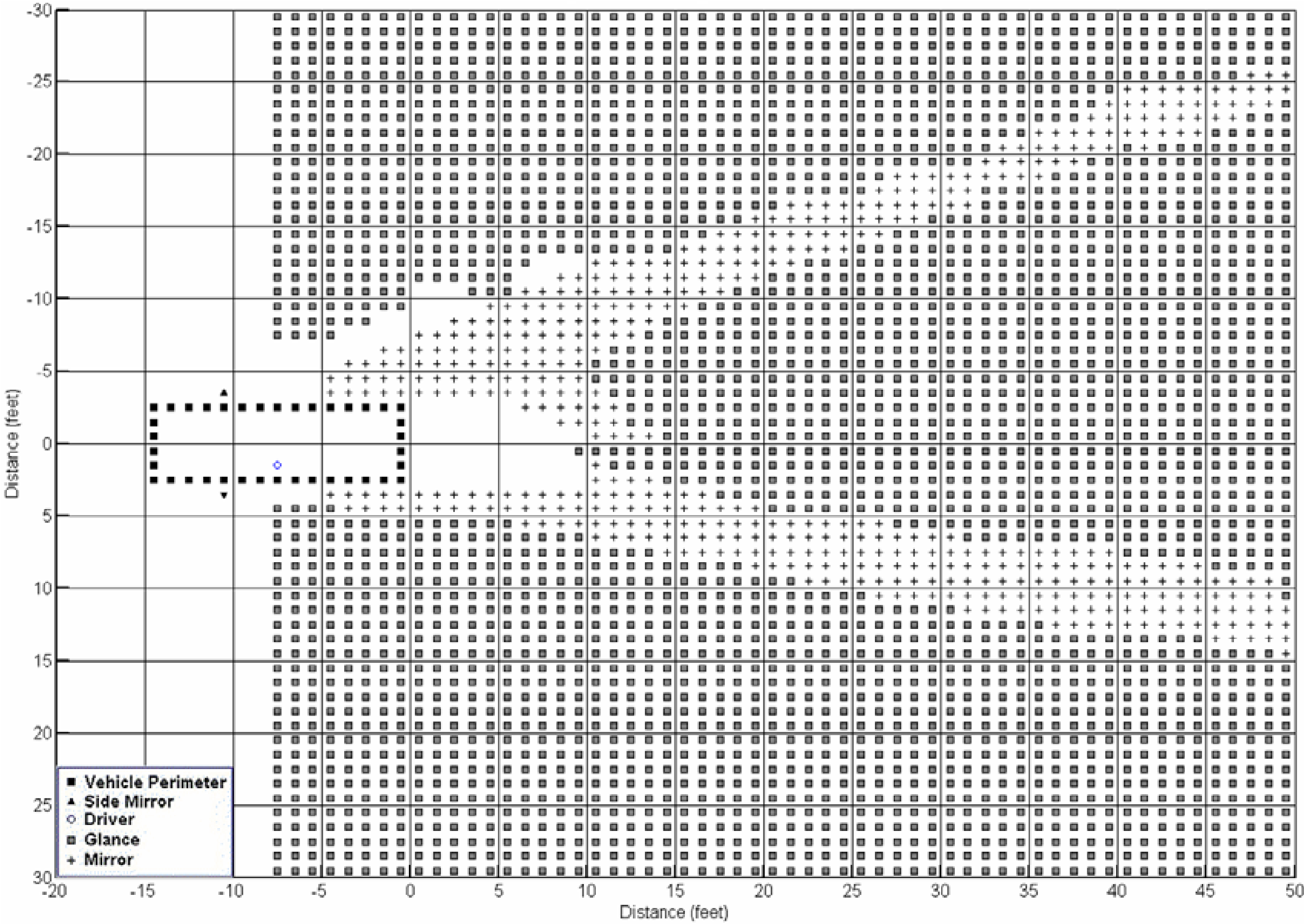


Figure 43. FOV Plot for a 2007 Toyota Camry with 50th Percentile Male Driver

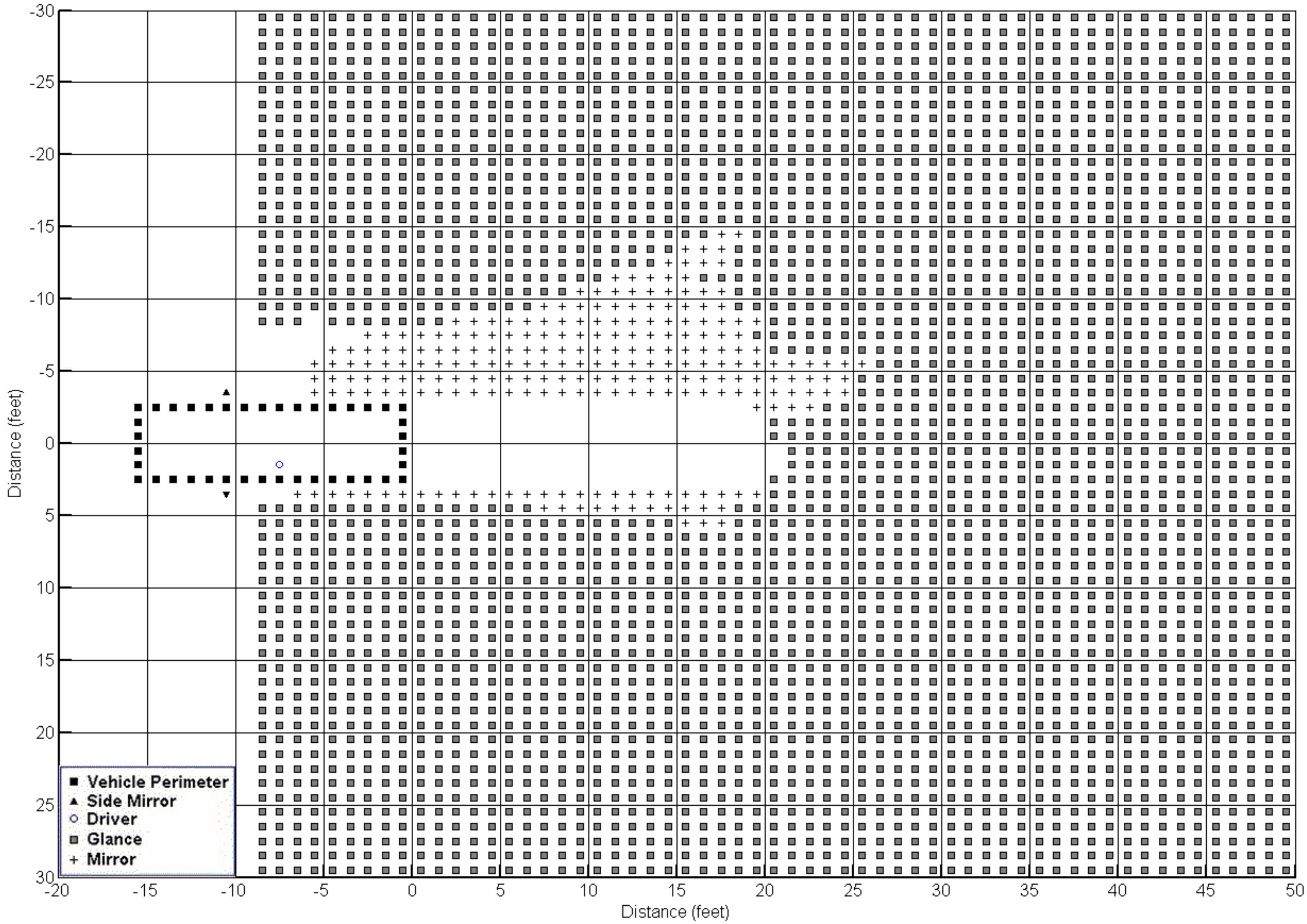


Figure 44. FOV Plot for a 2007 Toyota Camry with 5th Percentile Female Driver

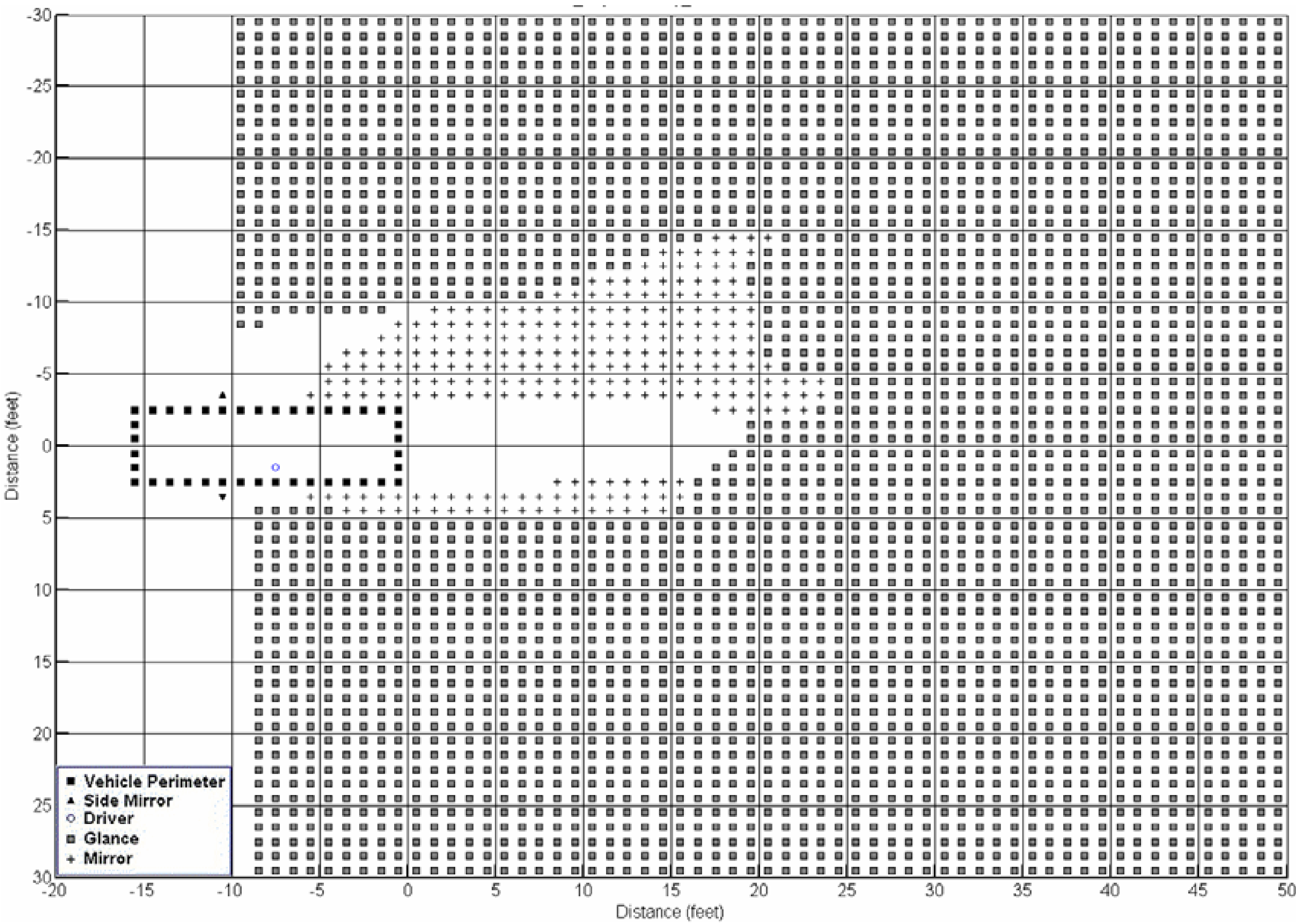


Figure 45. FOV Plot for a 2007 Toyota Corolla S with 50th Percentile Male Driver

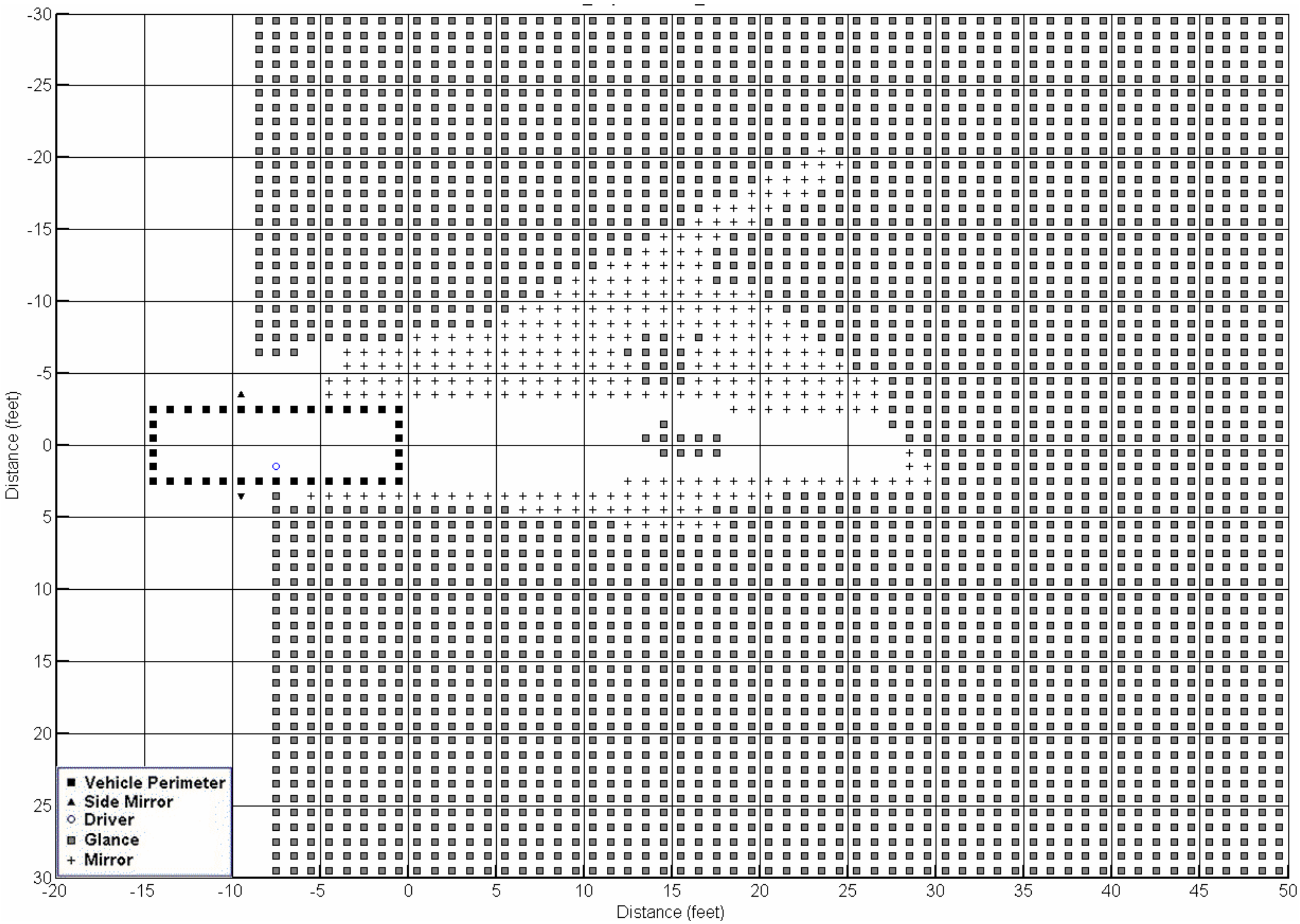


Figure 46. FOV Plot for a 2007 Toyota Corolla S with 5th Percentile Female Driver

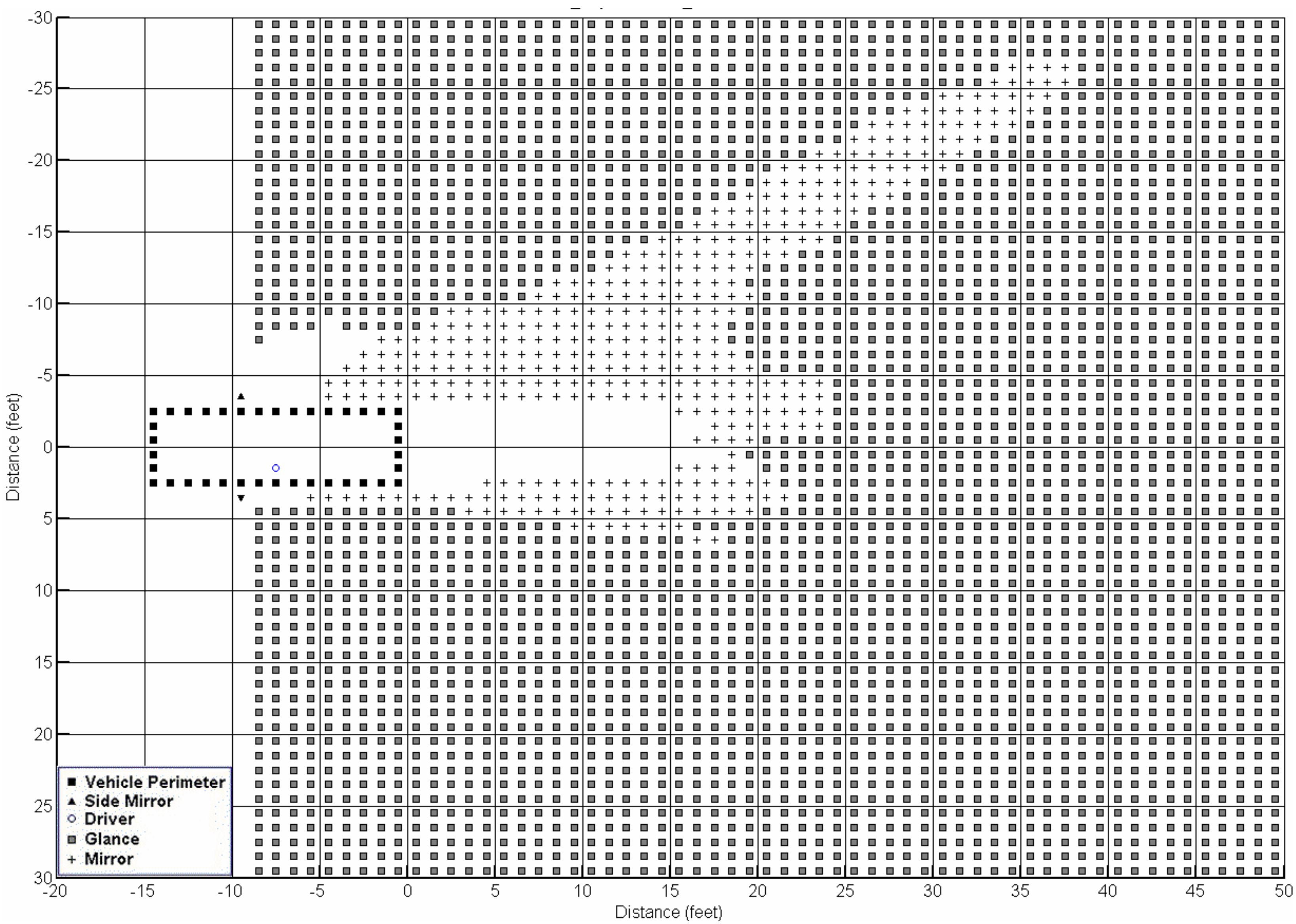


Figure 47. FOV Plot for a 2007 Toyota Yaris 4-door with 50th Percentile Male Driver

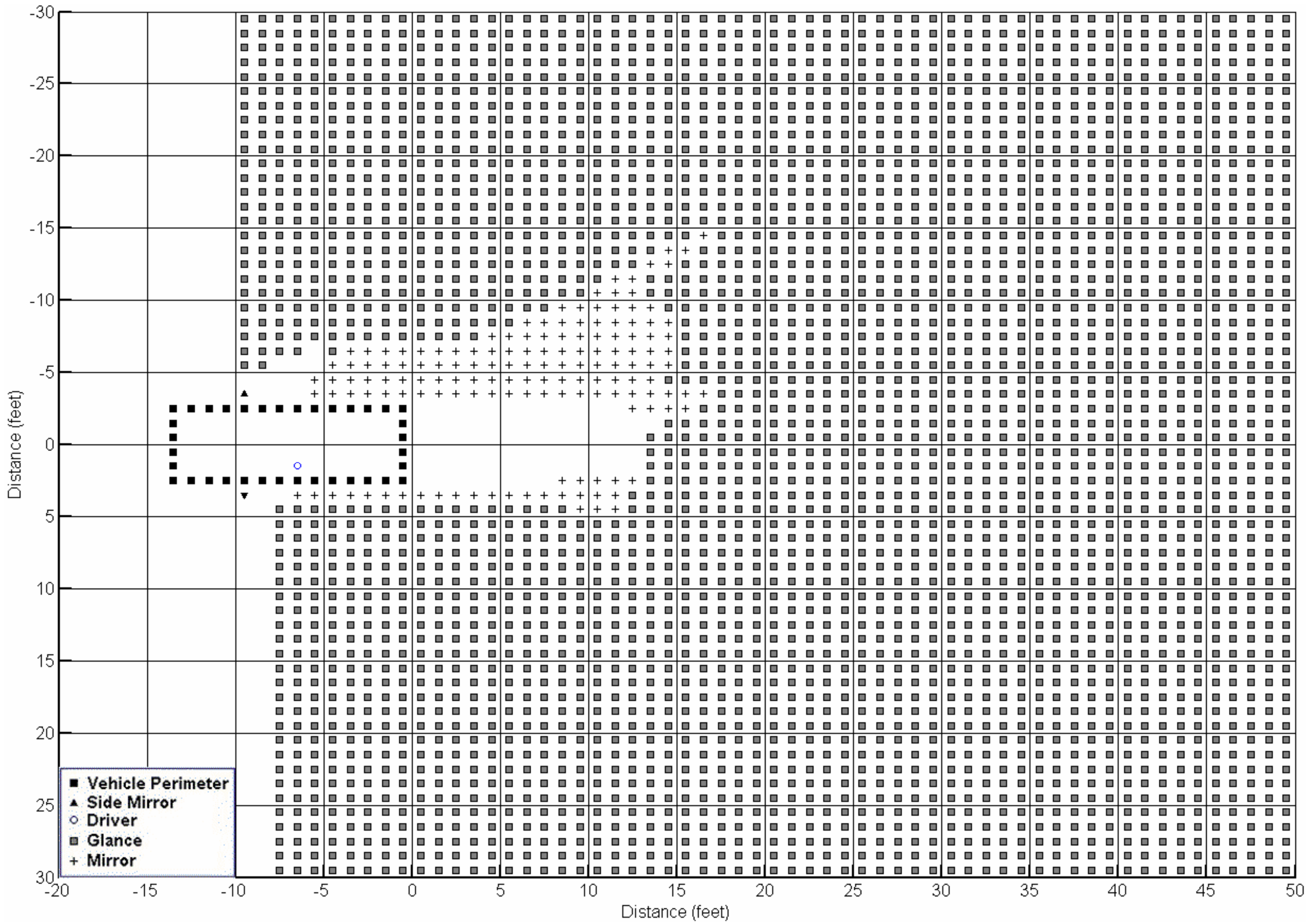


Figure 48. FOV Plot for a 2007 Toyota Yaris 4-door with 5th Percentile Female Driver

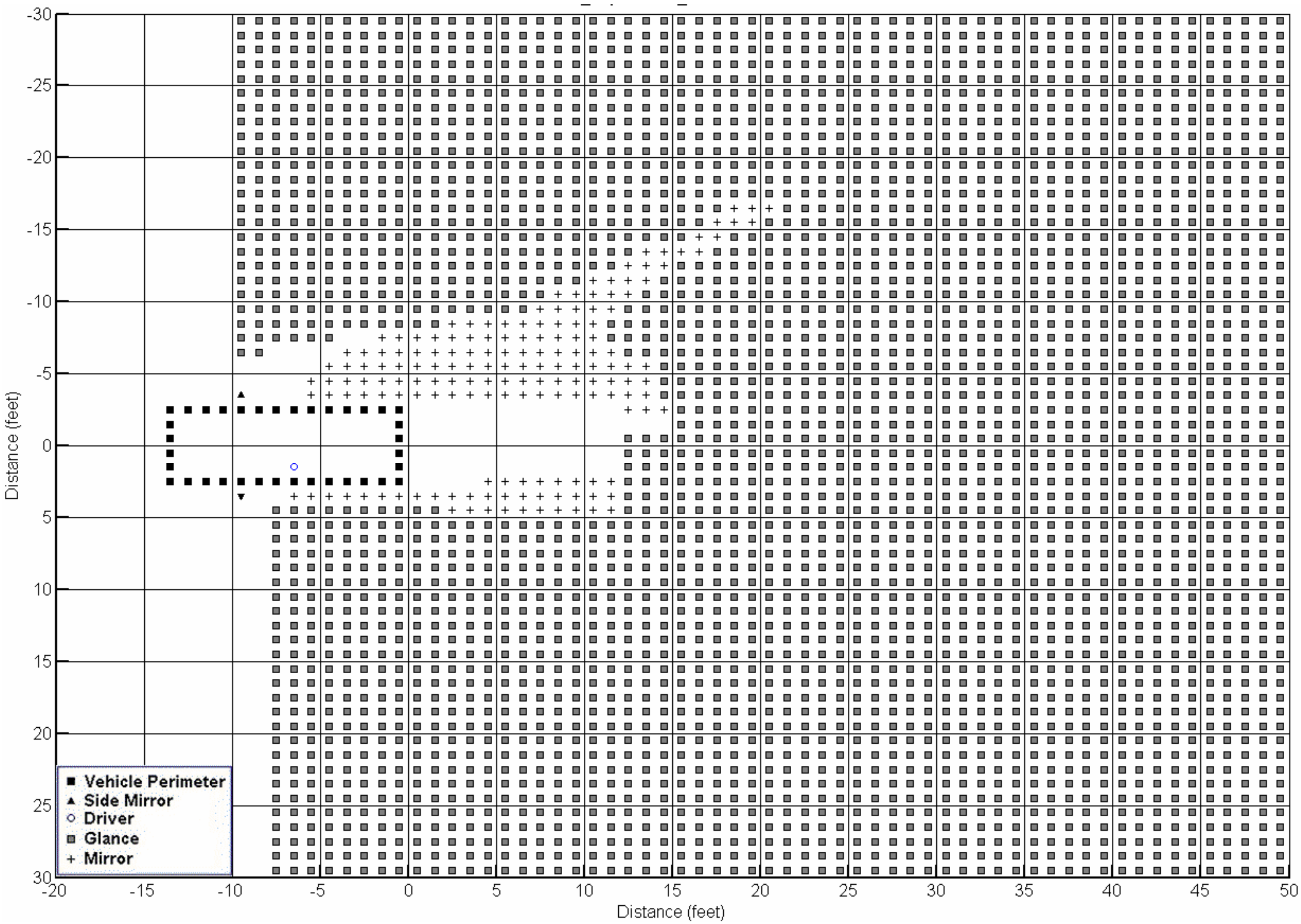


Figure 49. FOV Plot for a 2006 Volkswagen Passat 4-door with 50th Percentile Male Driver

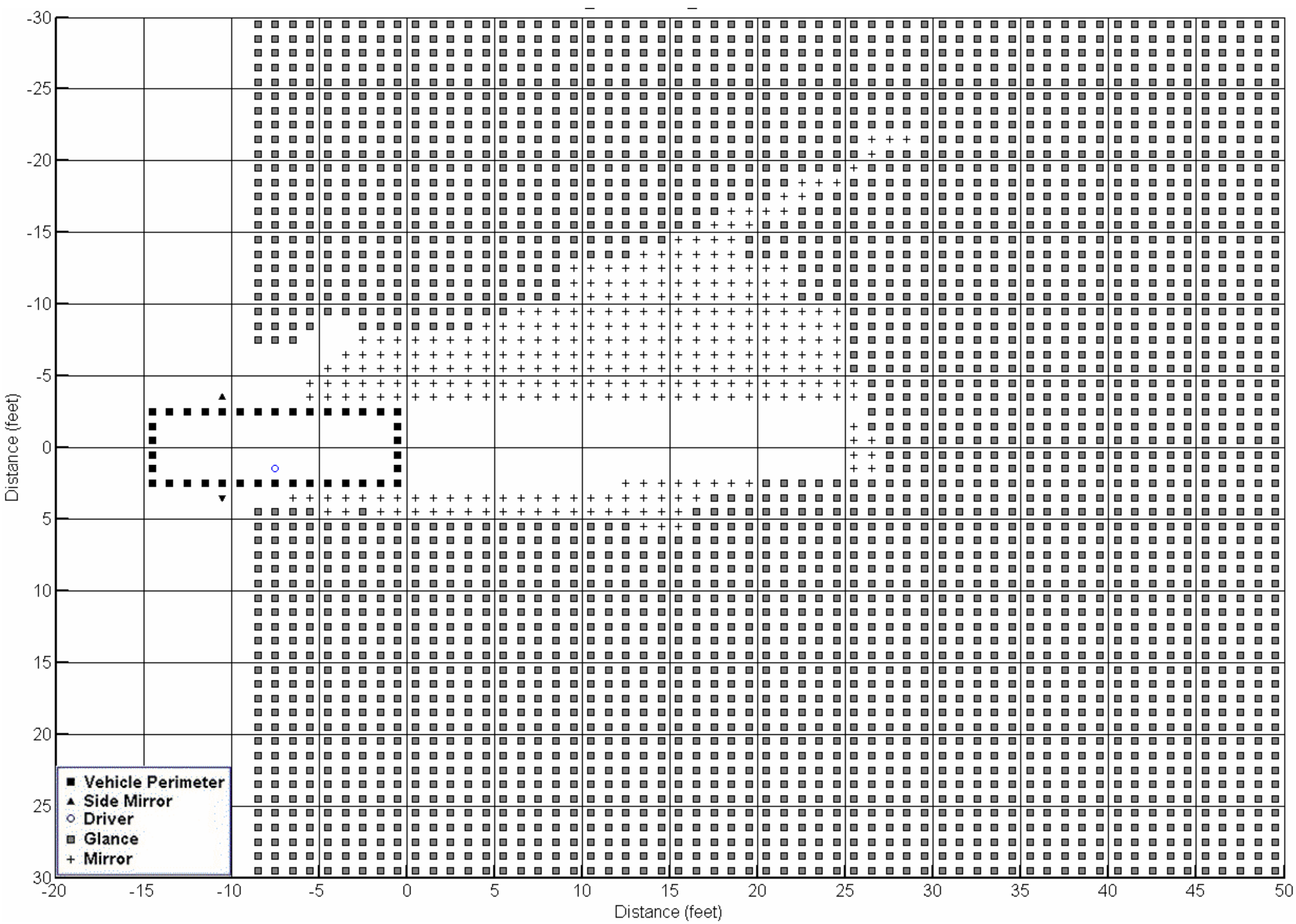


Figure 50. FOV Plot for a 2006 Volkswagen Passat 4-door with 5th Percentile Female Driver

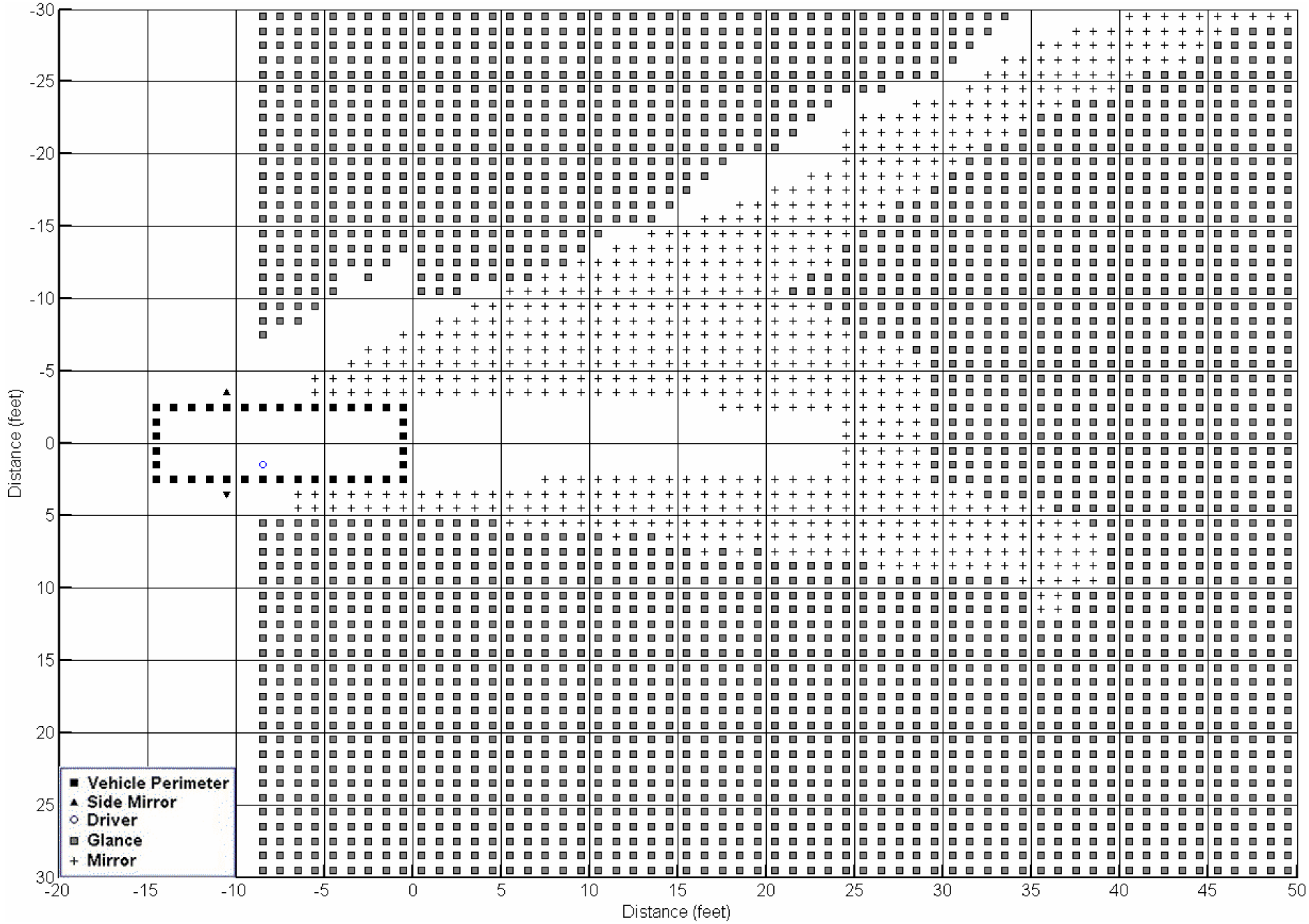


Figure 51. FOV Plot for a 2005 Chevrolet Silverado 2500HD with 50th Percentile Male Driver

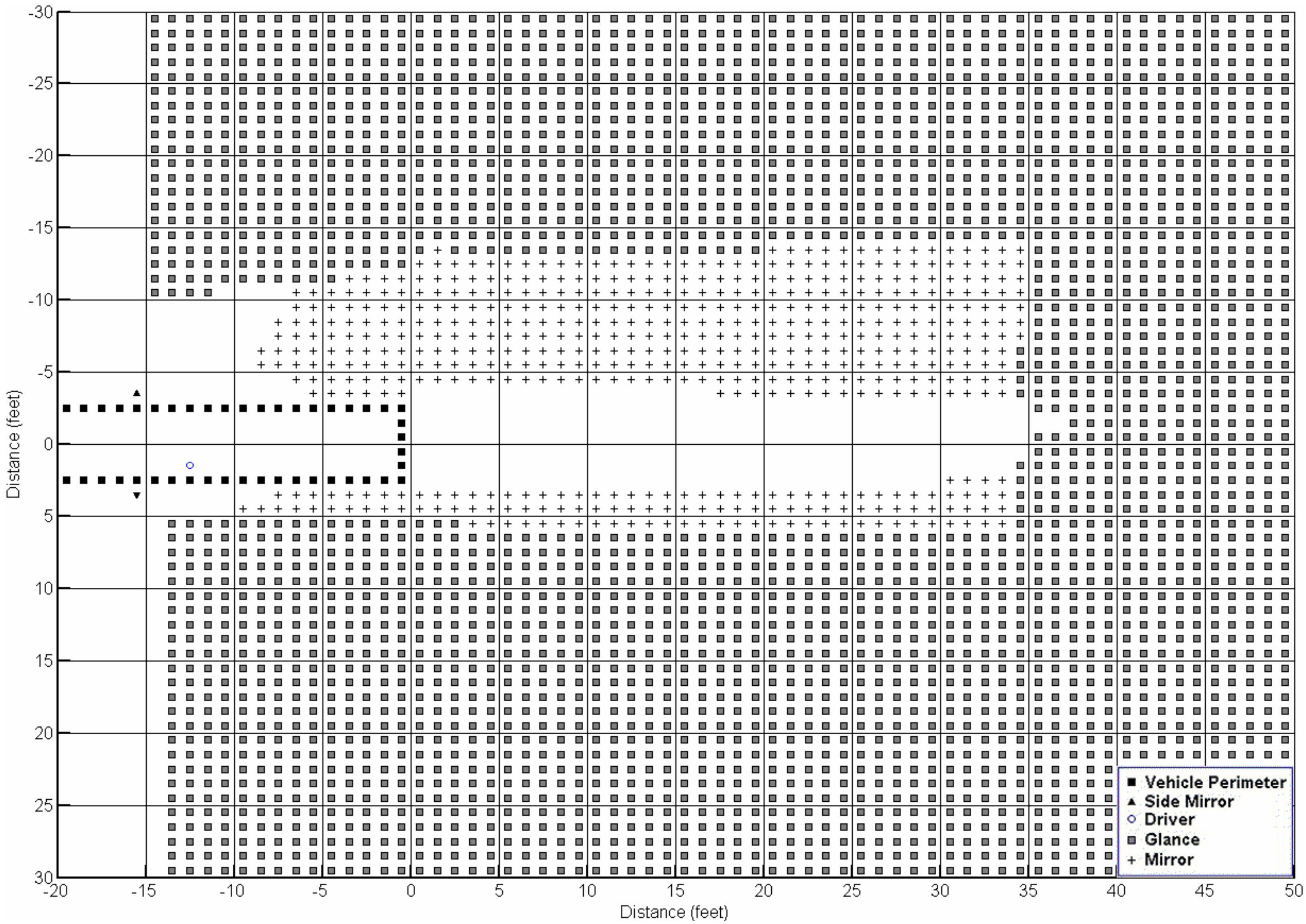


Figure 52. FOV Plot for a 2005 Chevrolet Silverado 2500HD with 5th Percentile Female Driver

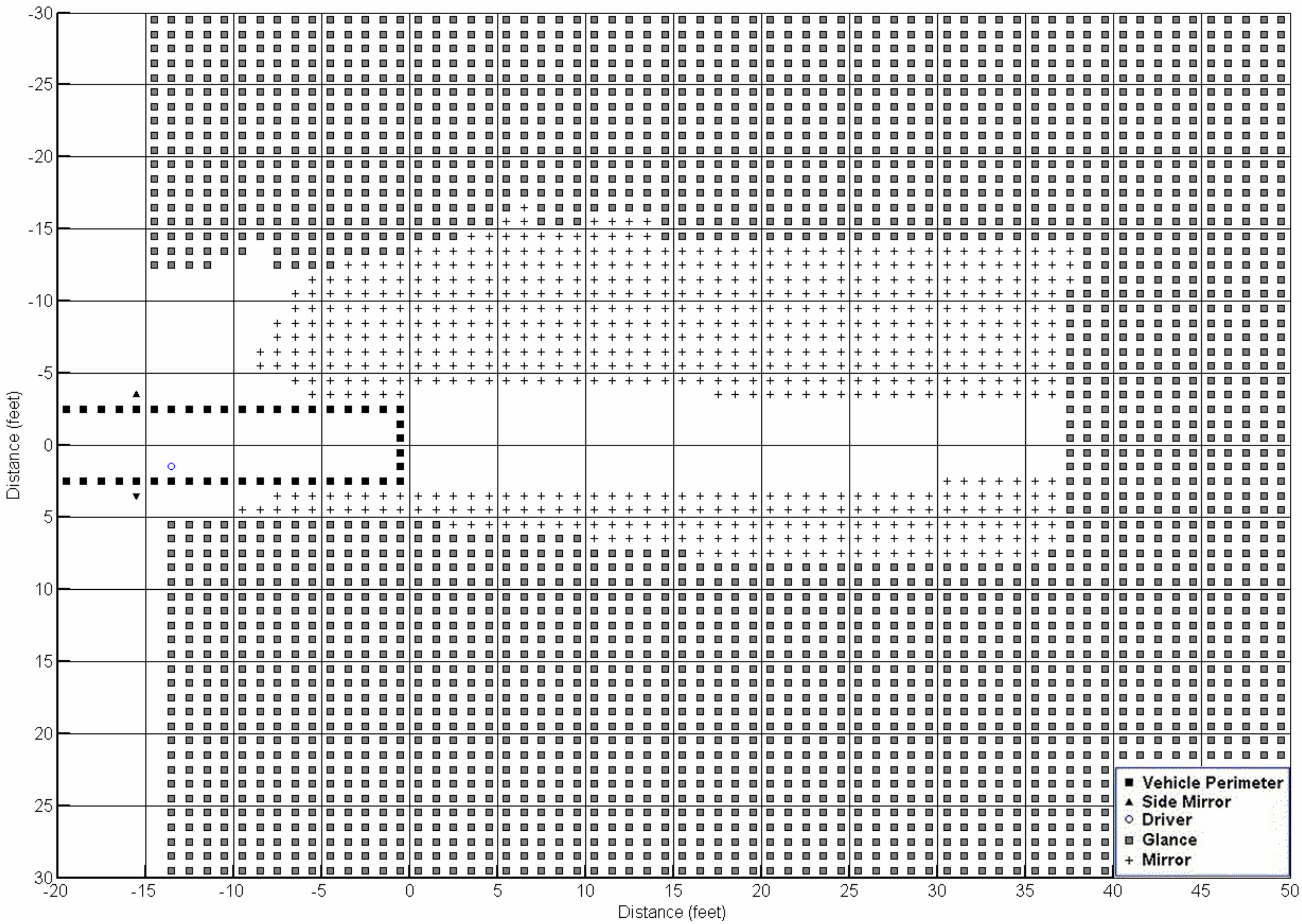


Figure 53. FOV Plot for a 2007 Dodge Ram 1500 with 50th Percentile Male Driver

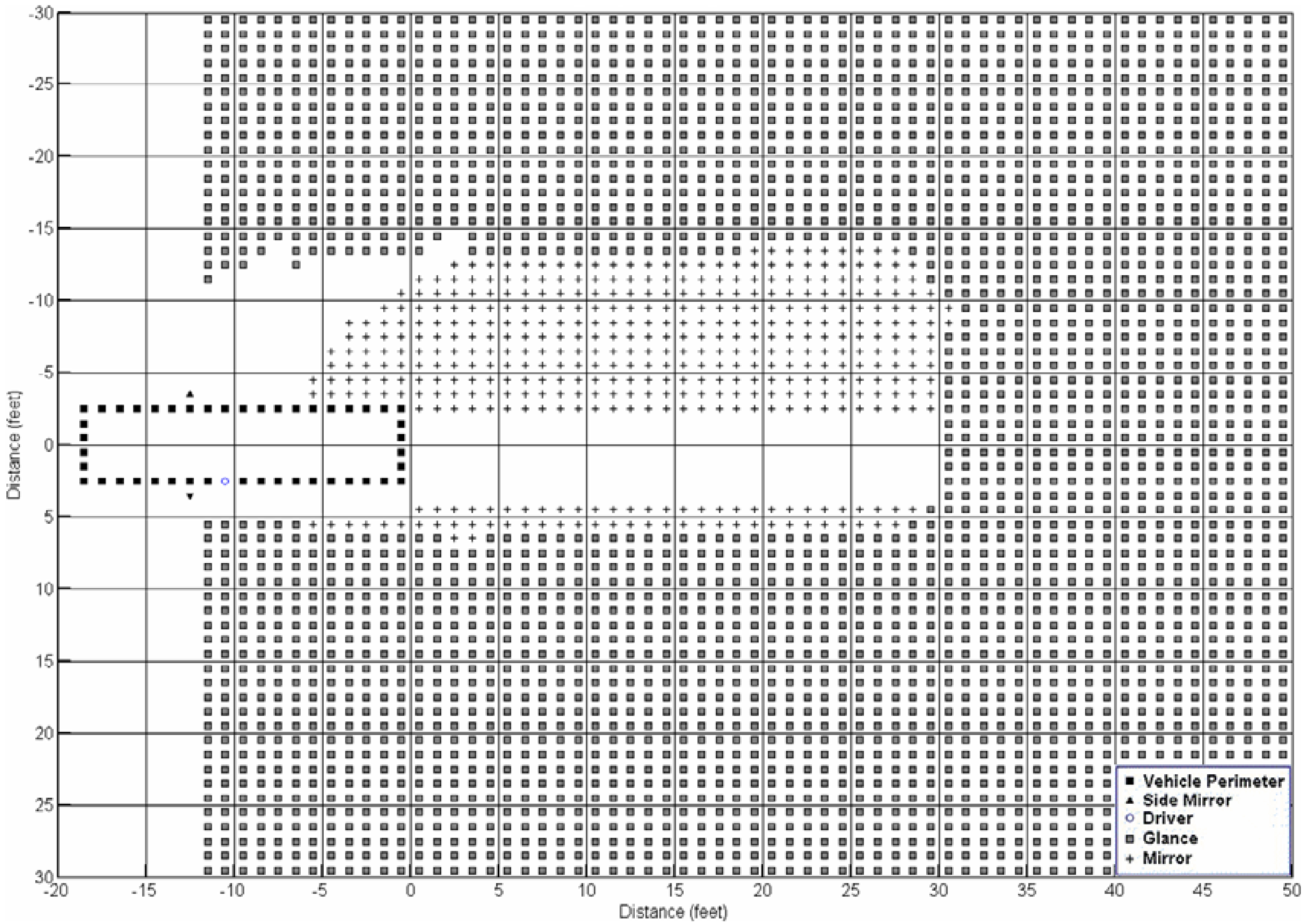


Figure 54. FOV Plot for a 2007 Dodge Ram 1500 with 5th Percentile Female Driver

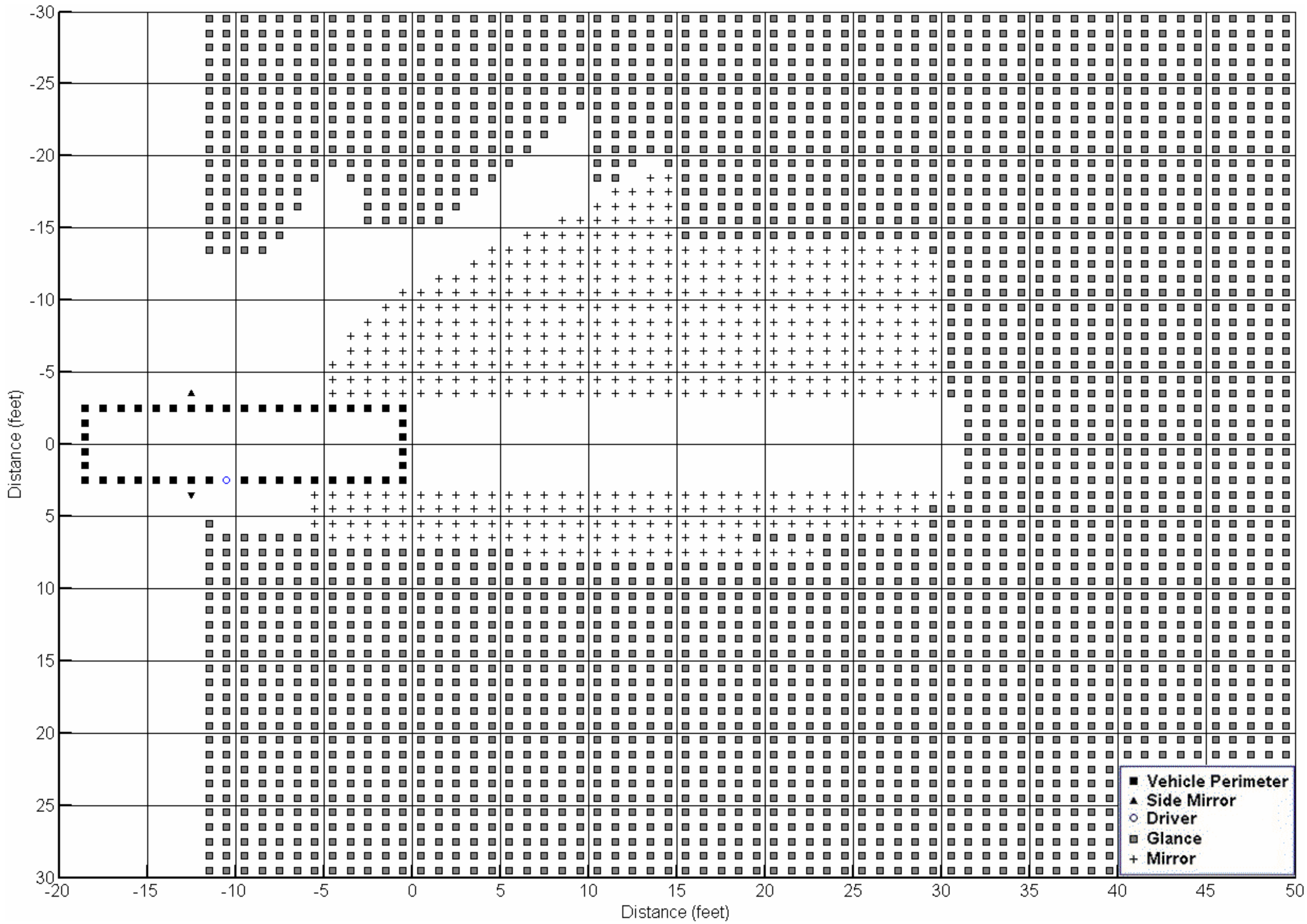


Figure 55. FOV Plot for a 2006 Ford F-150 with 50th Percentile Male Driver

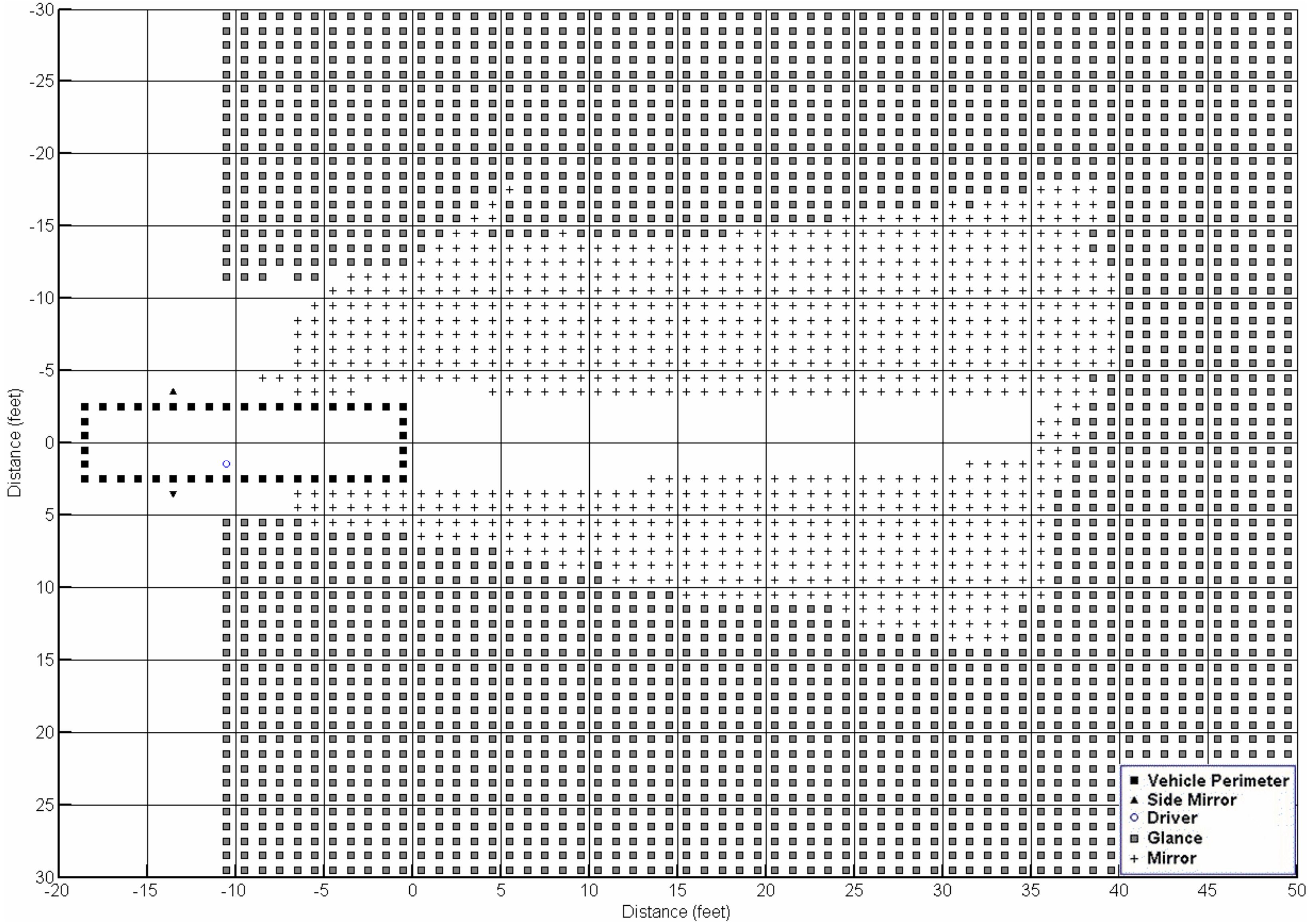


Figure 56. FOV Plot for a 2006 Ford F-150 with 5th Percentile Female Driver

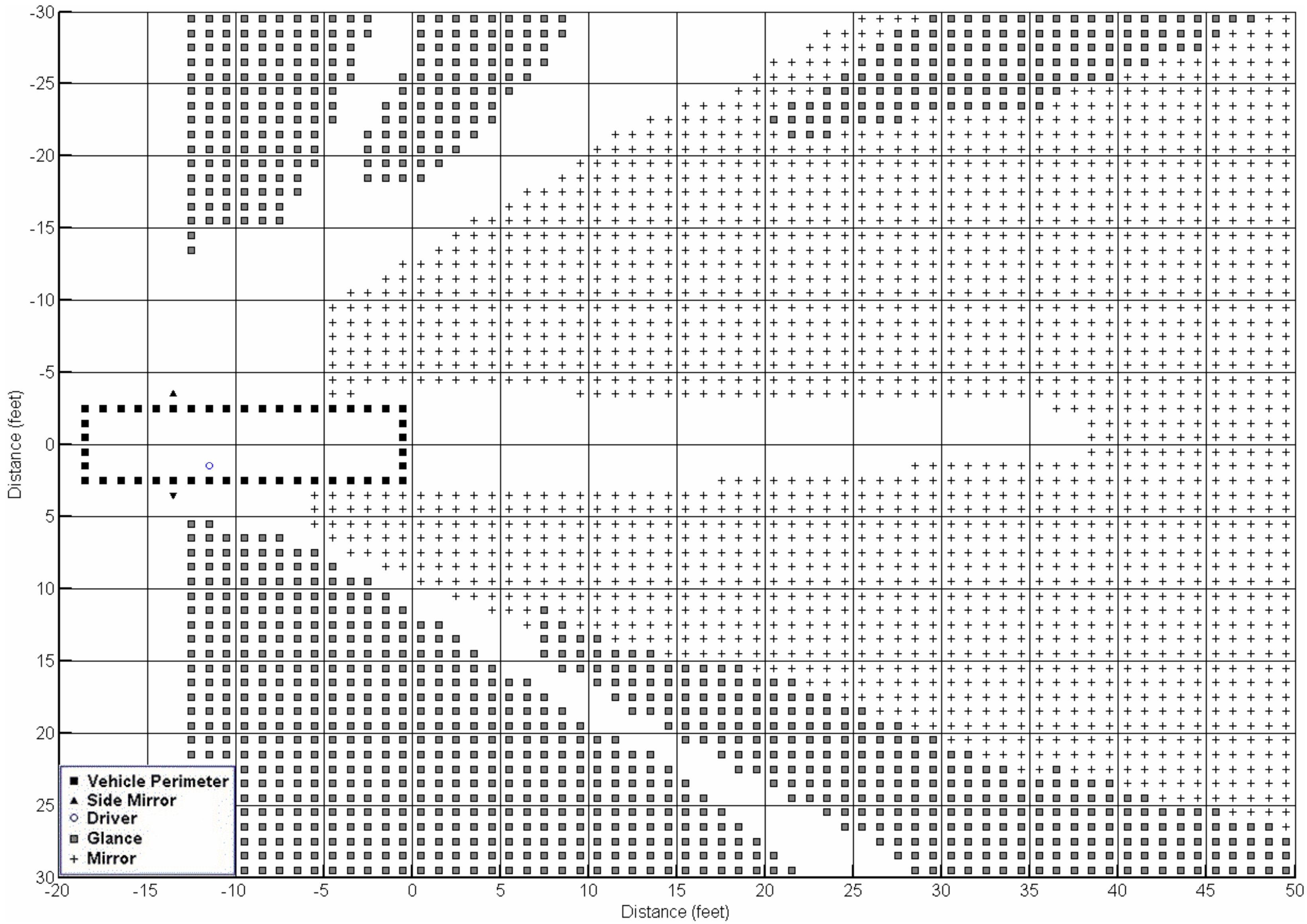


Figure 57. FOV Plot for a 2007 Ford Ranger with 50th Percentile Male Driver

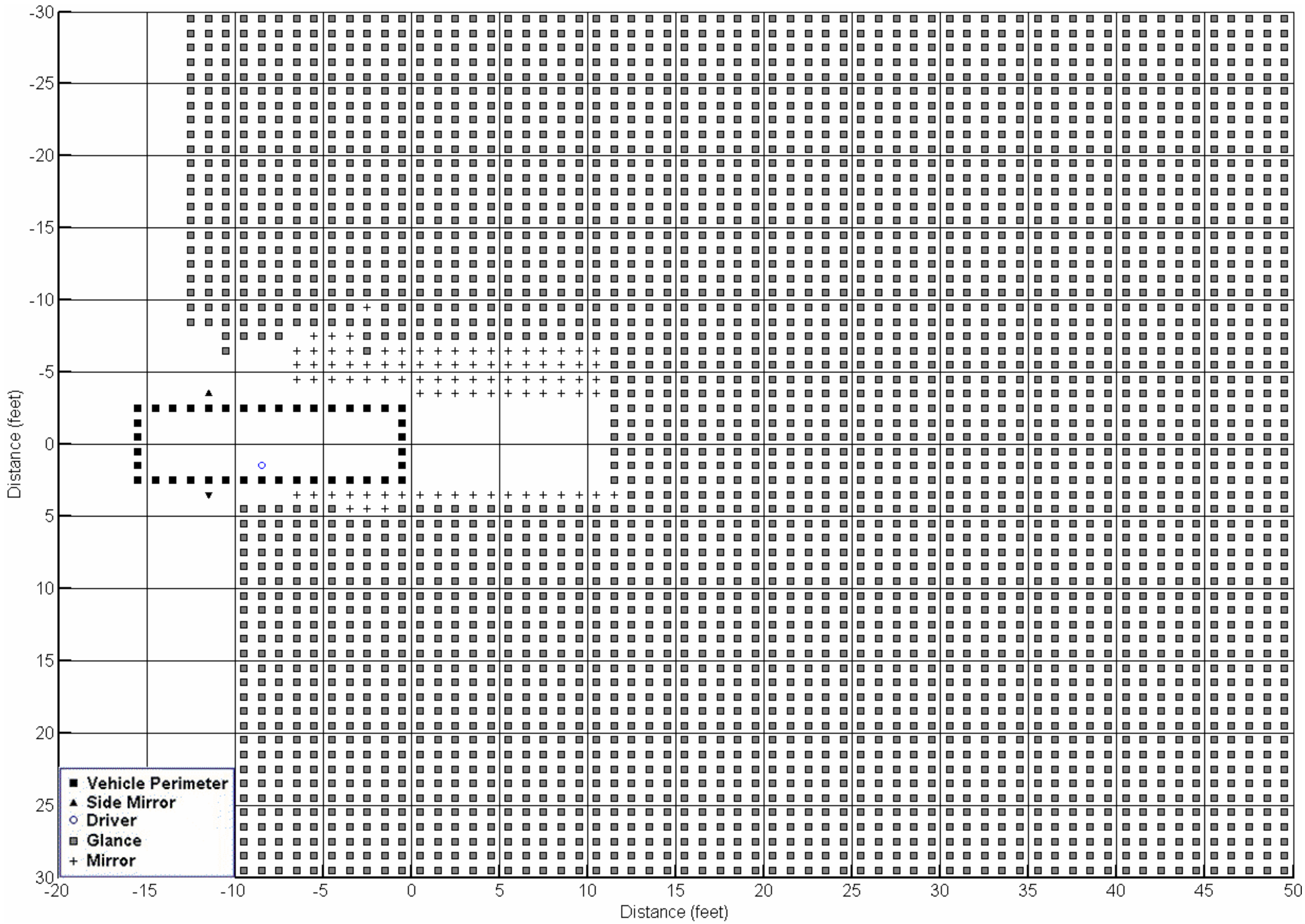


Figure 58. FOV Plot for a 2007 Ford Ranger with 5th Percentile Female Driver

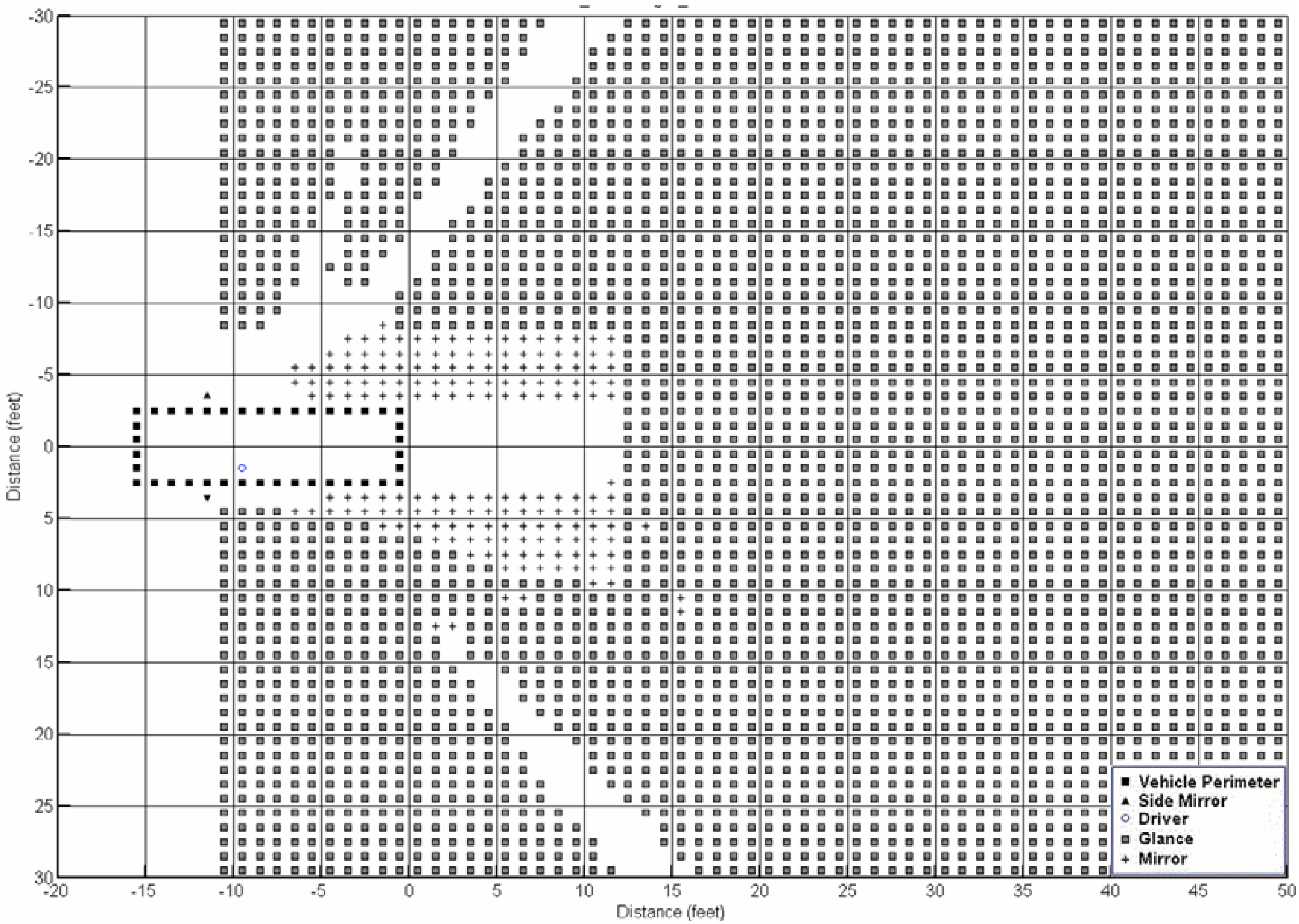


Figure 59. FOV Plot for a 2007 Nissan Frontier with 50th Percentile Male Driver

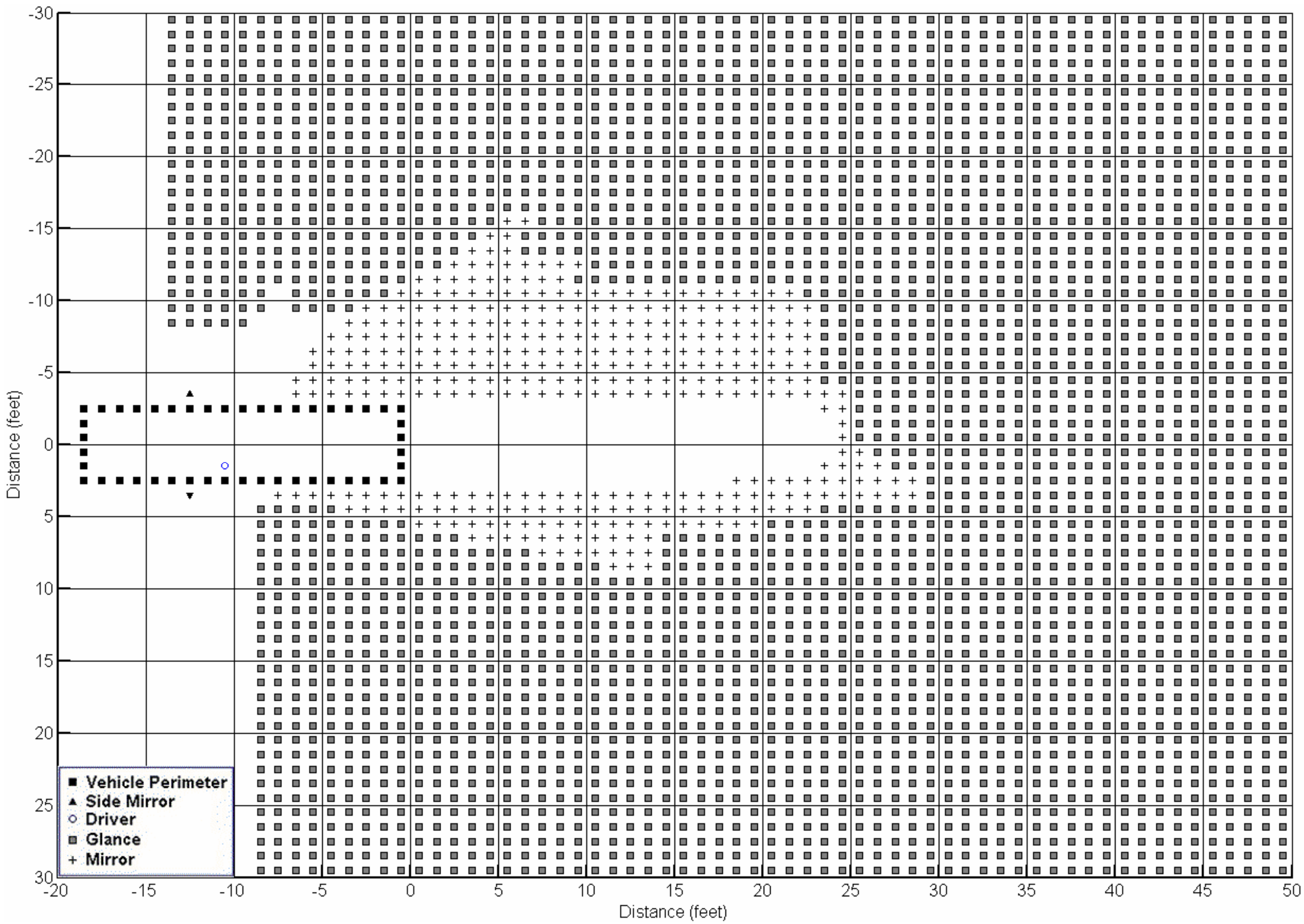


Figure 60. FOV Plot for a 2007 Nissan Frontier with 5th Percentile Female Driver

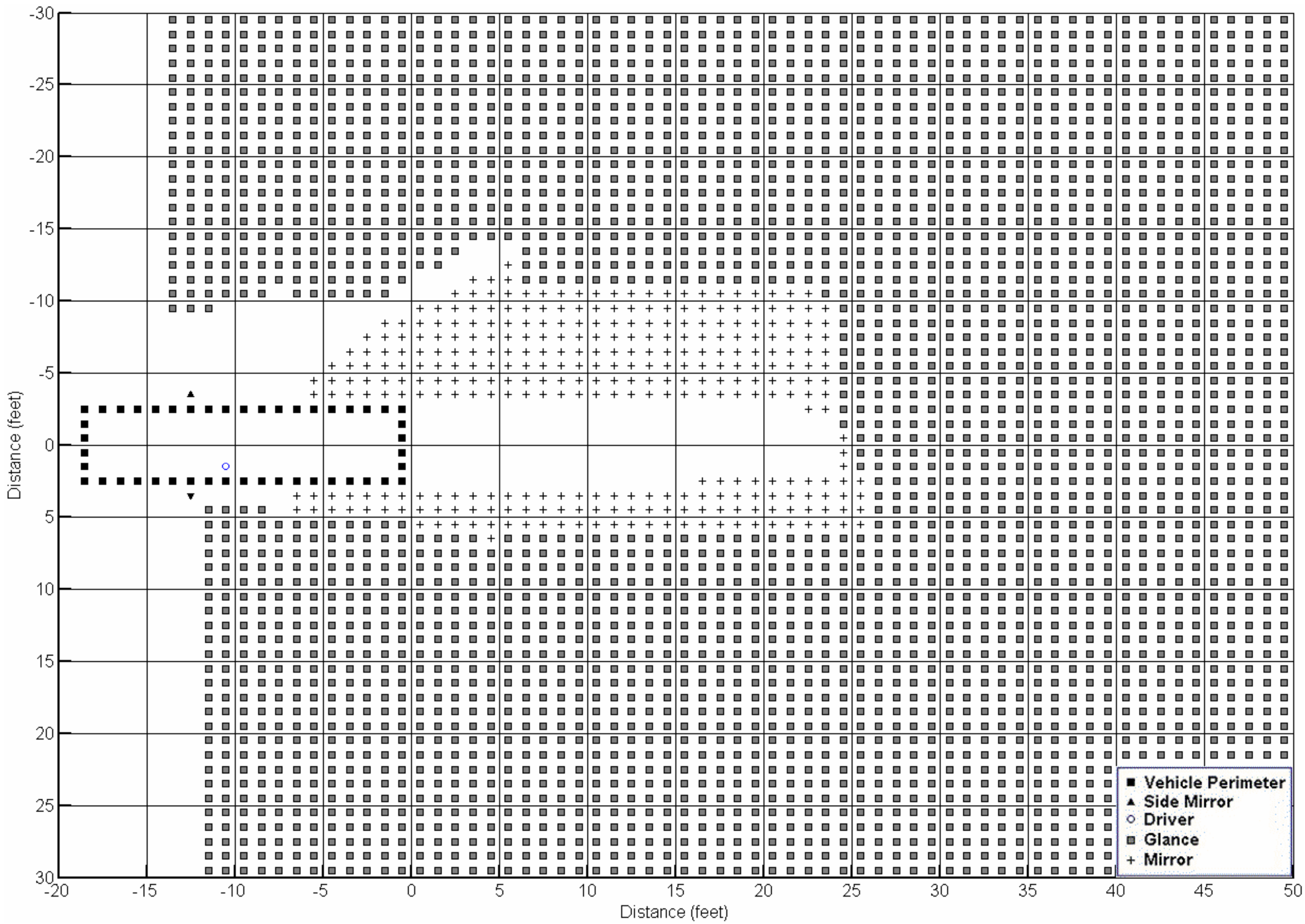


Figure 61. FOV Plot for a 2006 Toyota Tacoma with 50th Percentile Male Driver

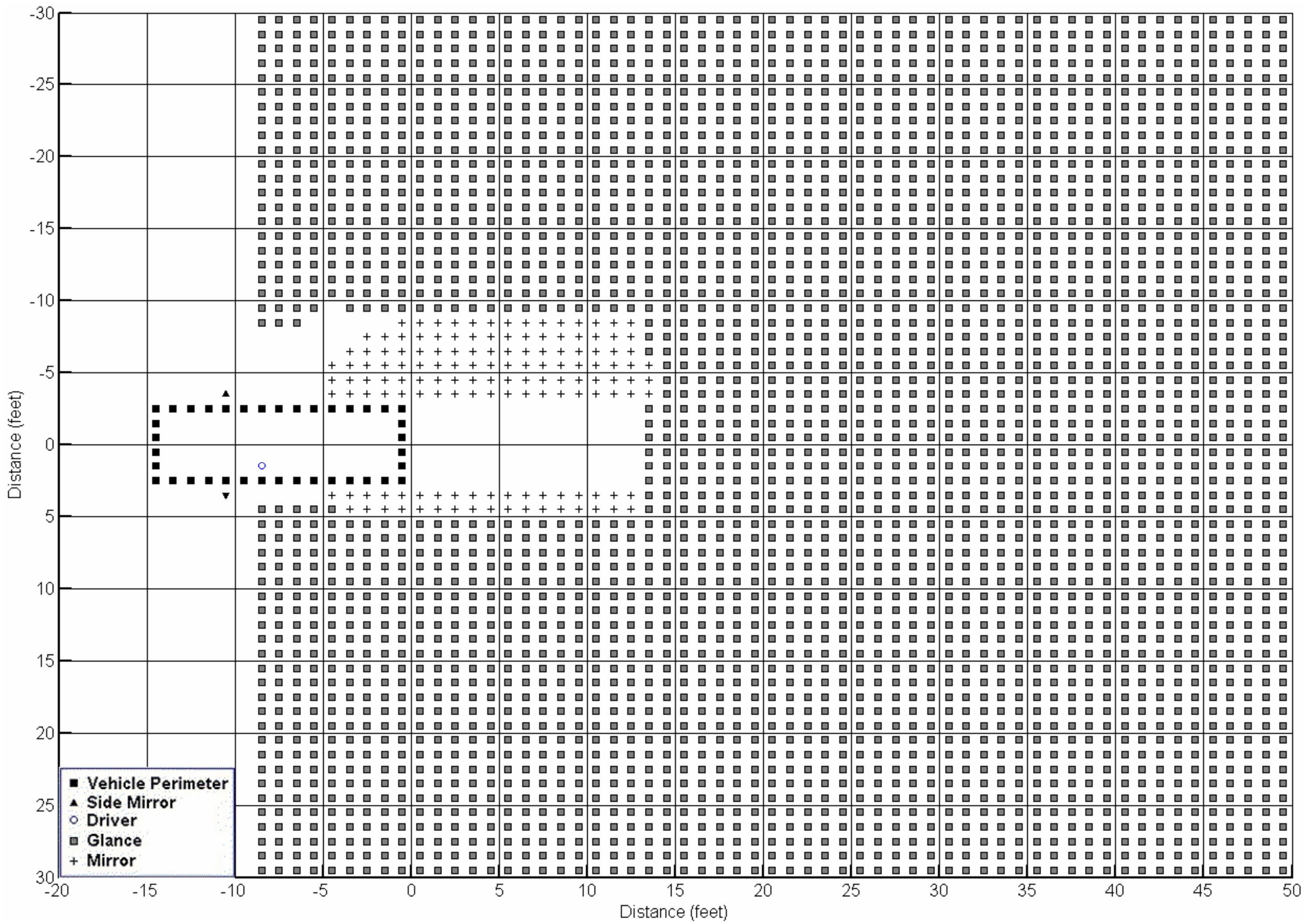


Figure 62. FOV Plot for a 2006 Toyota Tacoma with 5th Percentile Female Driver

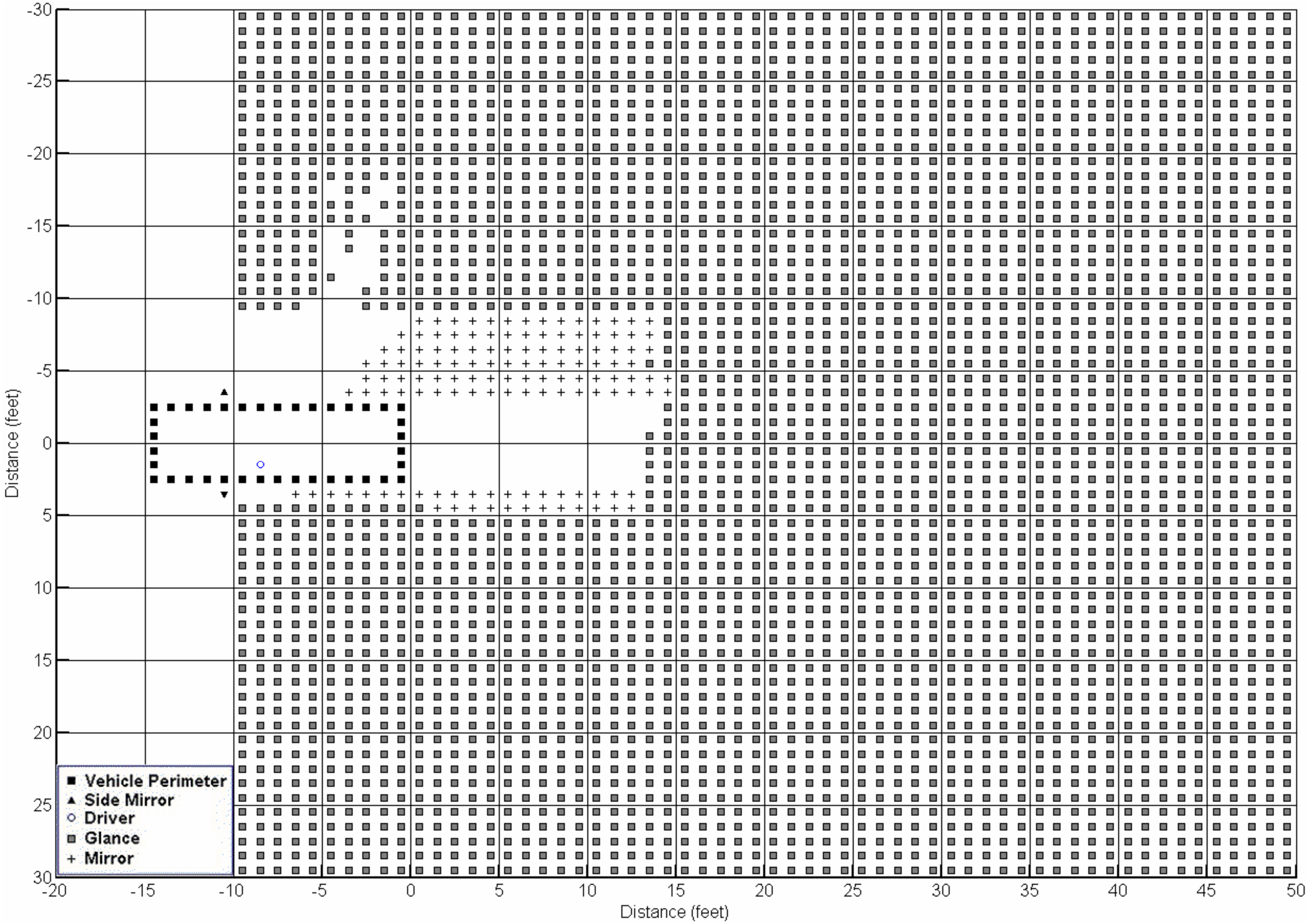


Figure 63. FOV Plot for a 2007 Toyota Tundra with 50th Percentile Male Driver

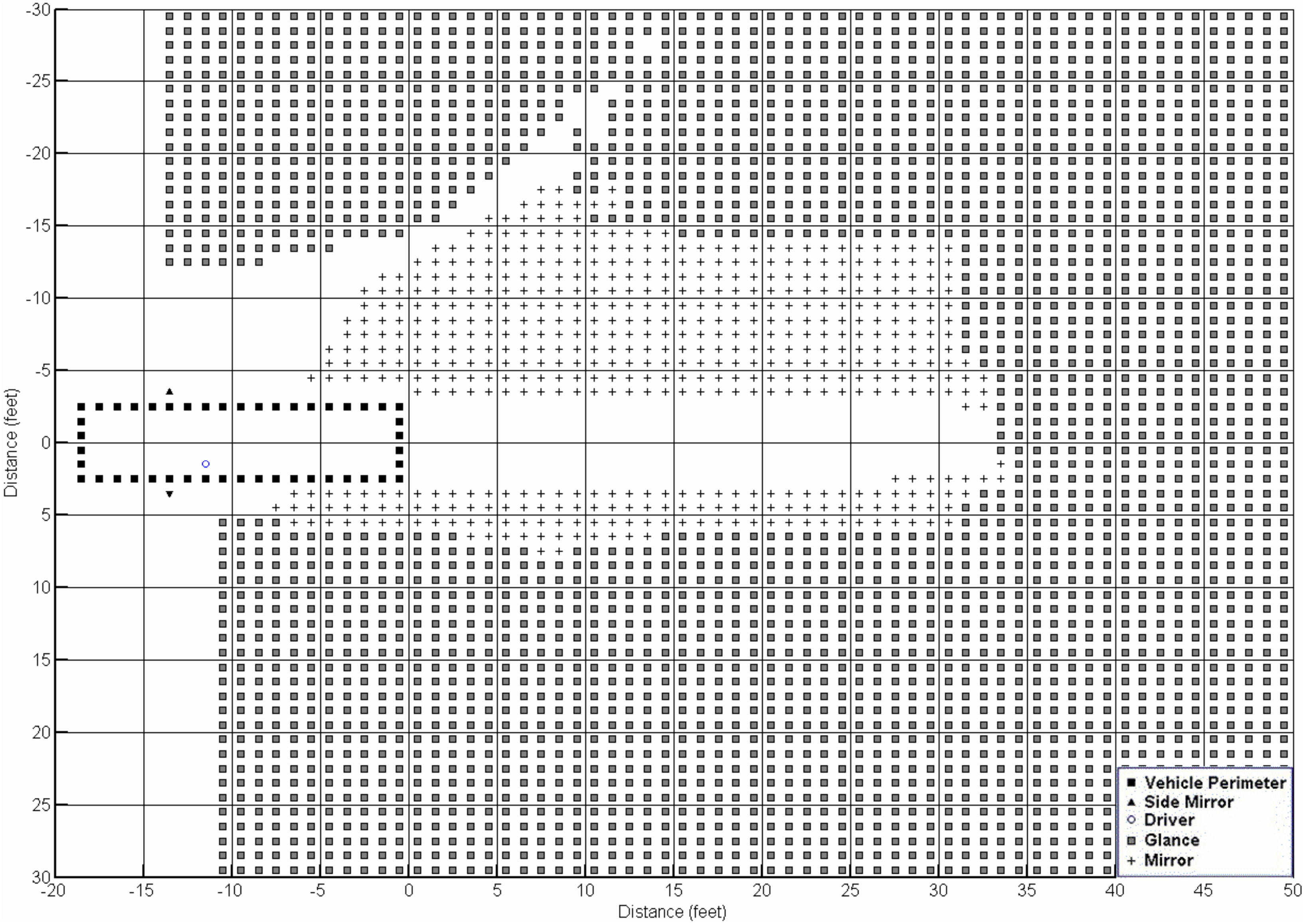


Figure 64. FOV Plot for a 2007 Toyota Tundra with 5th Percentile Female Driver

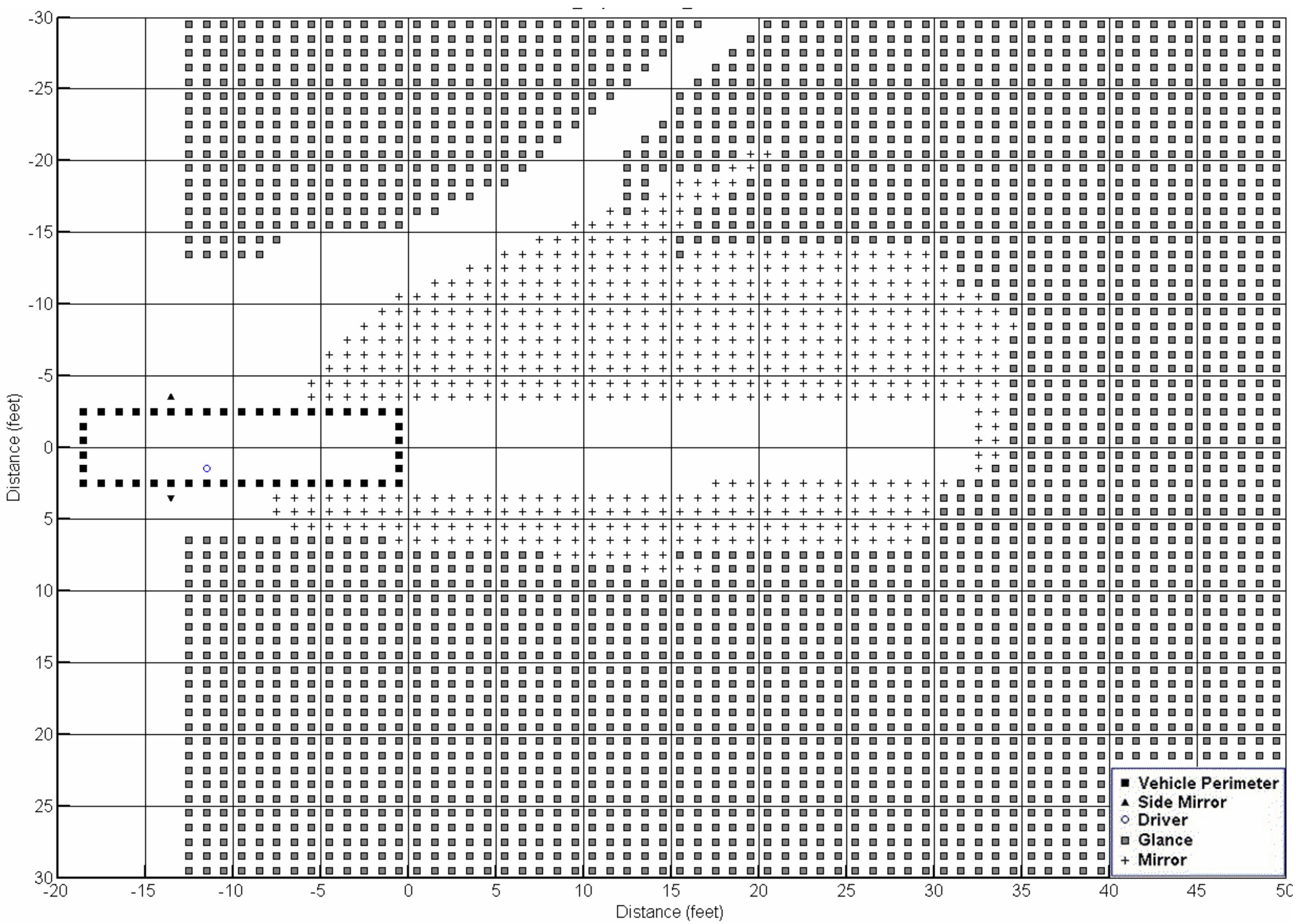


Figure 65. FOV Plot for a 2007 Cadillac Escalade with 50th Percentile Male Driver

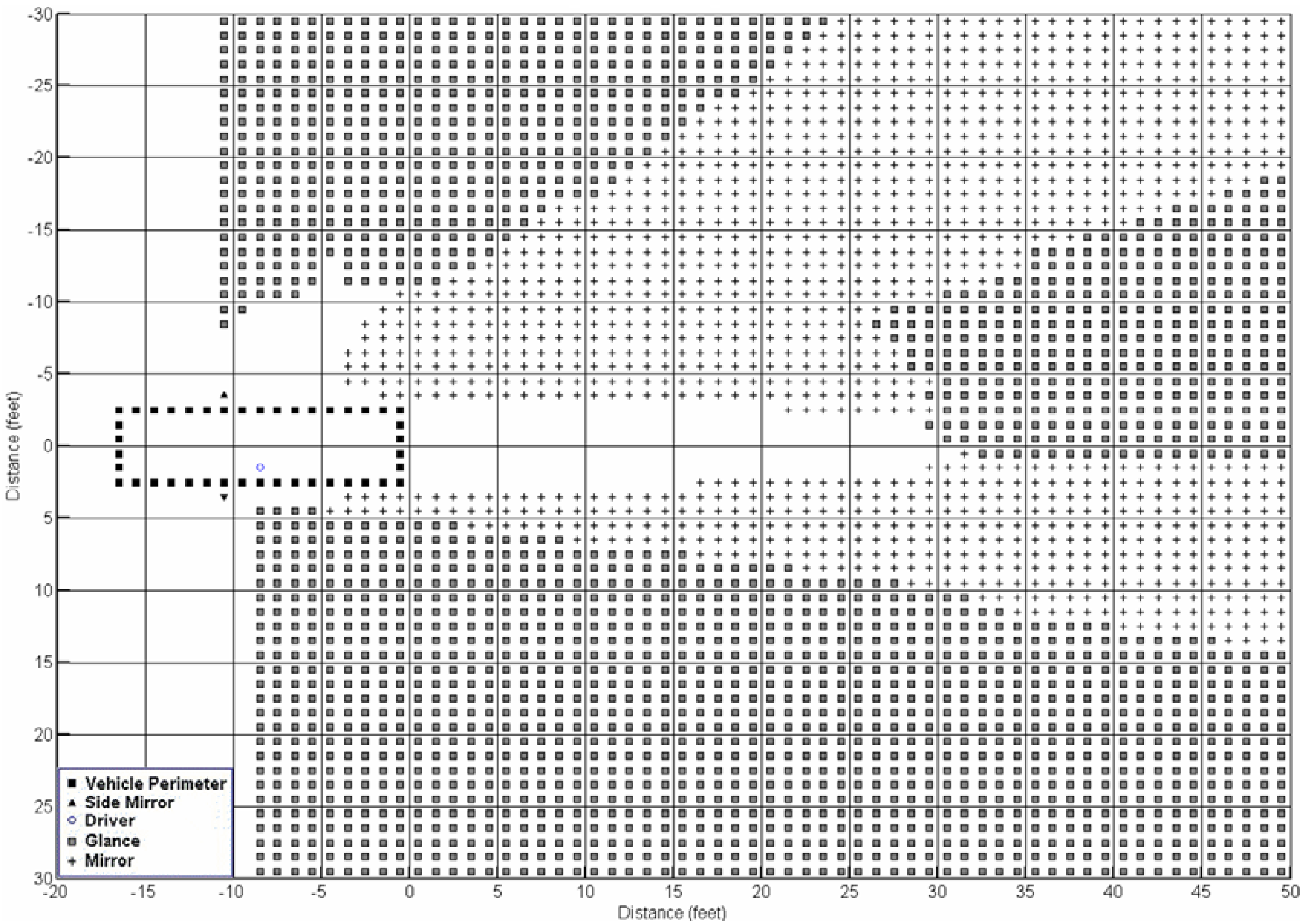


Figure 66. FOV Plot for a 2007 Cadillac Escalade with 5th Percentile Female Driver

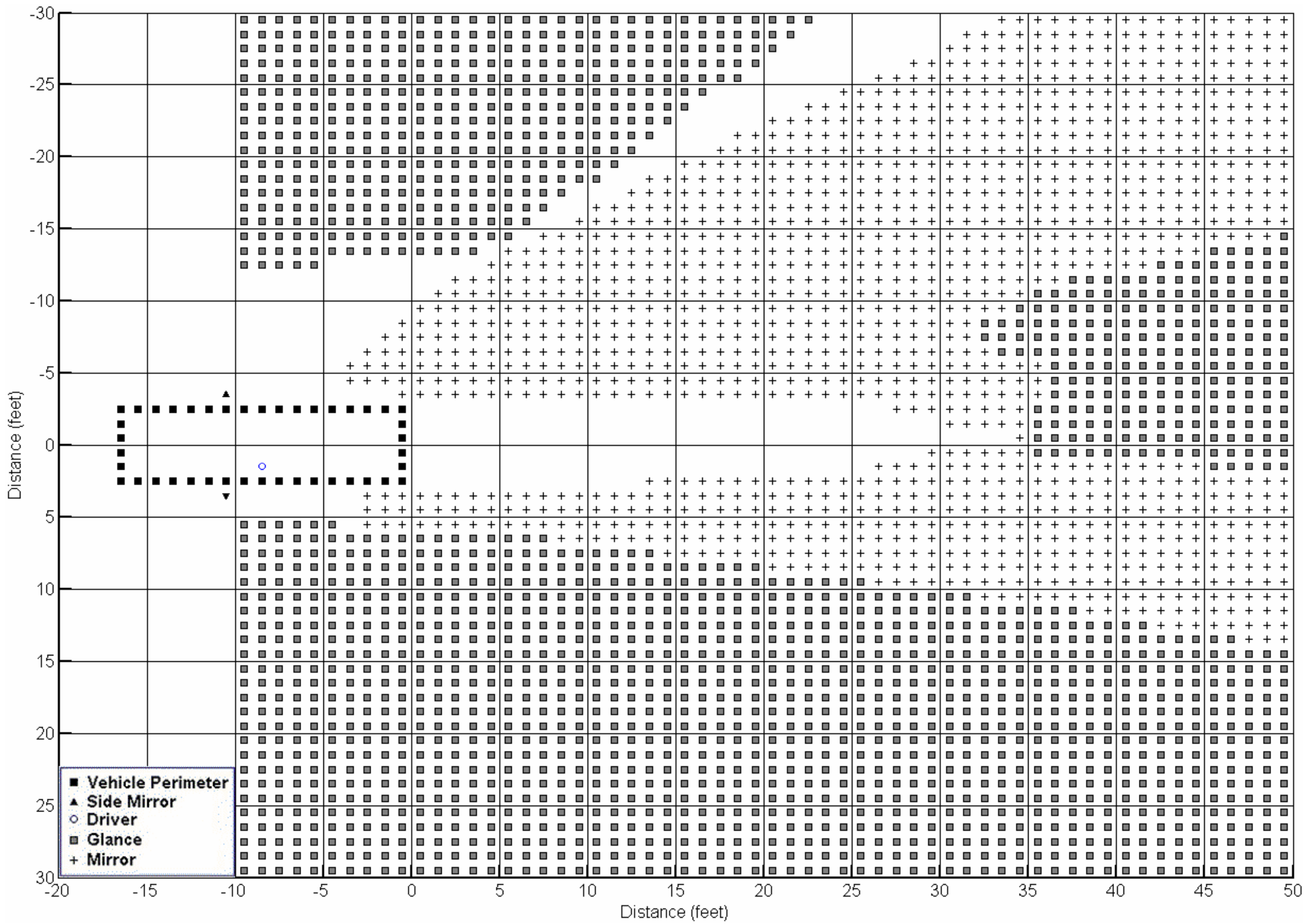


Figure 67. FOV Plot for a 2007 Cadillac Escalade Rearview Video System

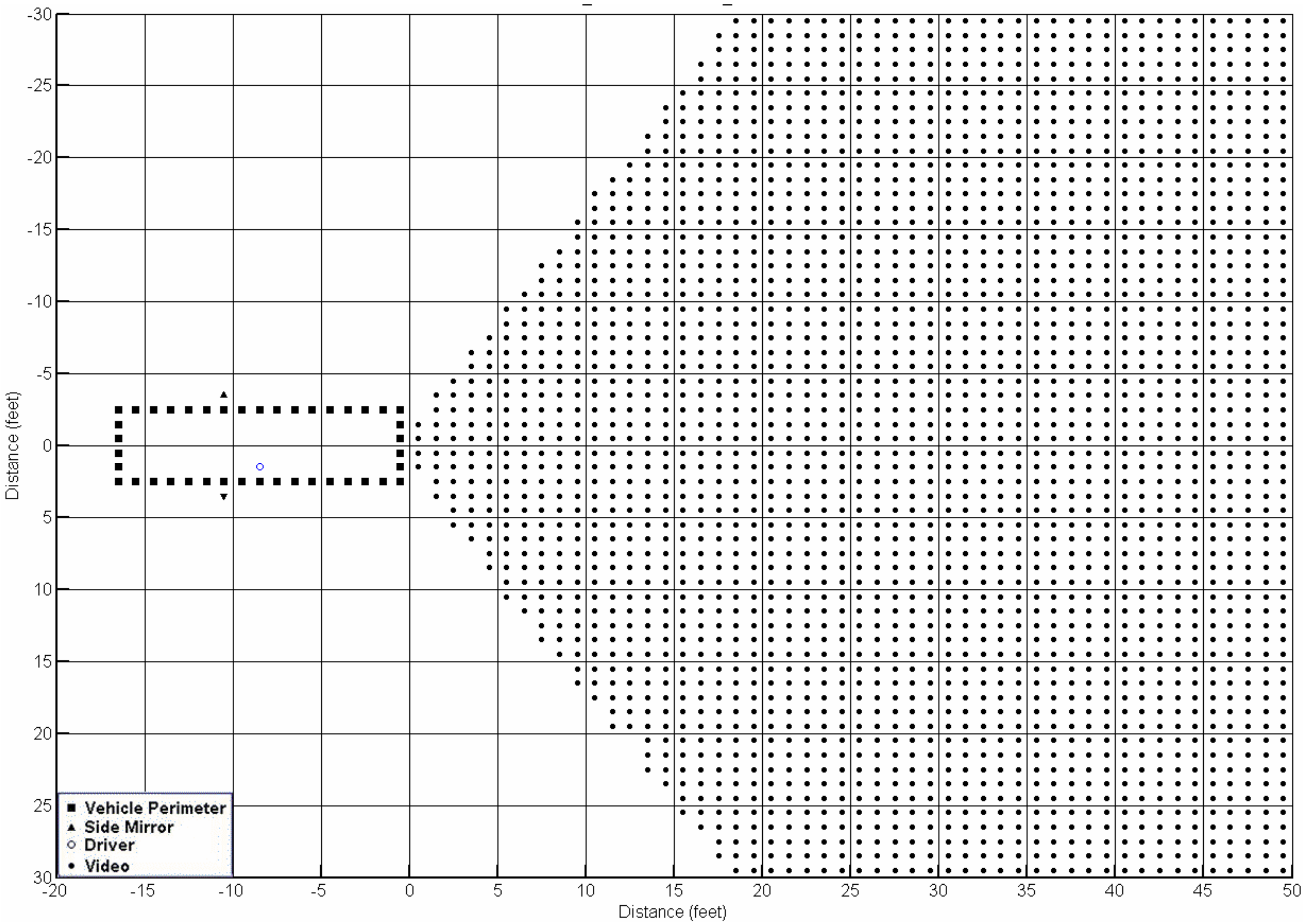


Figure 68. FOV Plot for a 2007 Chevrolet Tahoe with 50th Percentile Male Driver

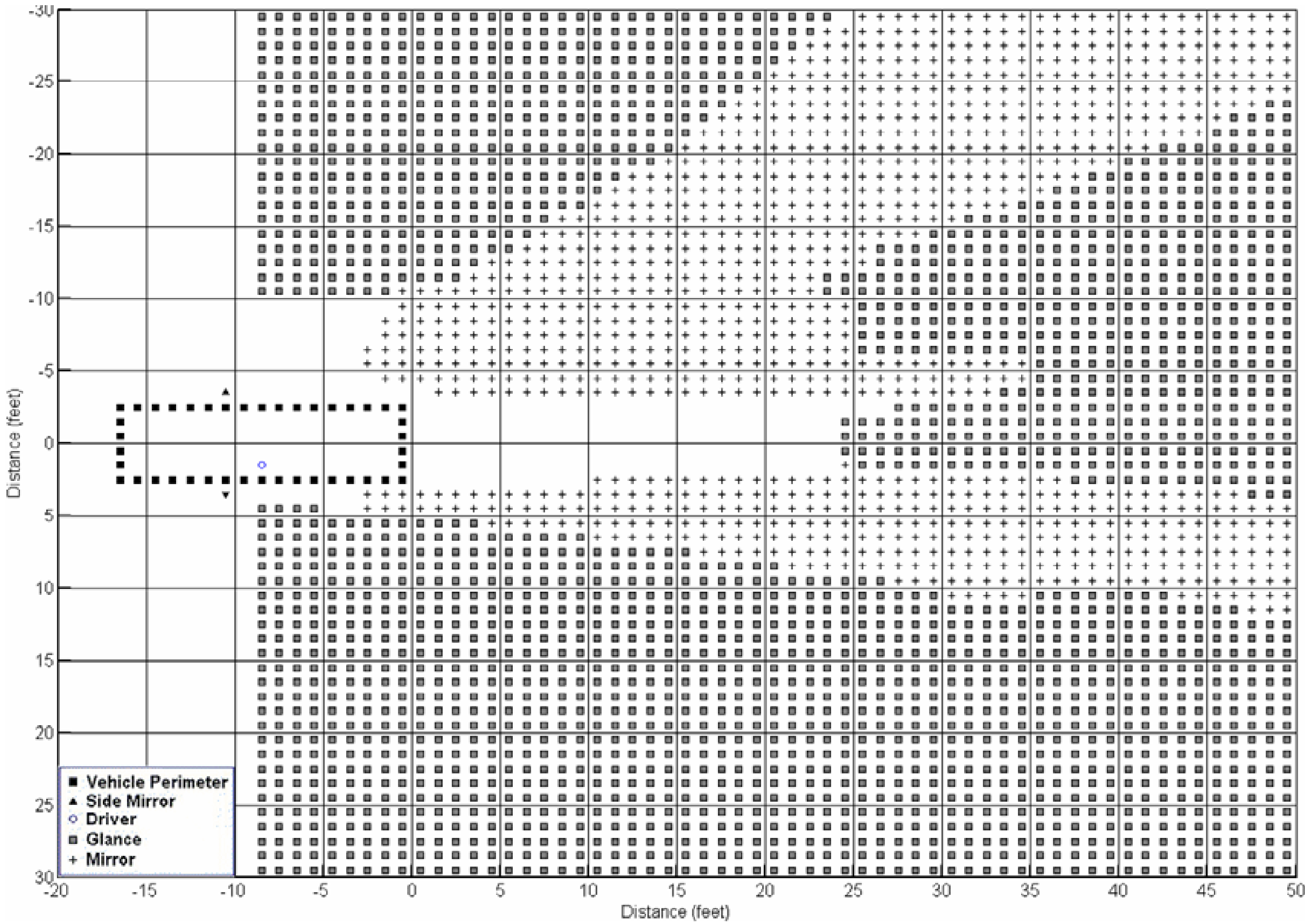


Figure 69. FOV Plot for a 2007 Chevrolet Tahoe with 5th Percentile Female Driver

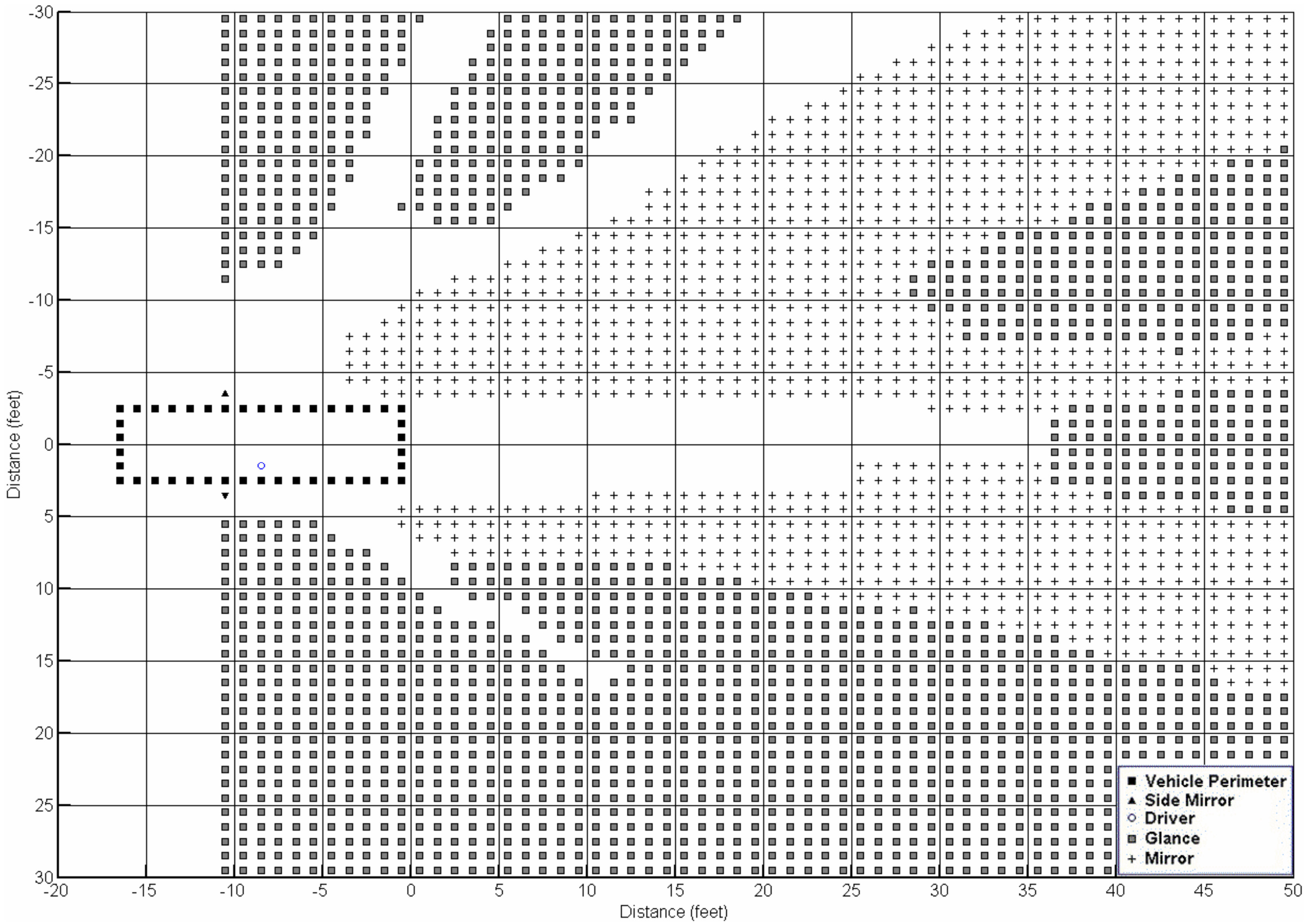


Figure 70. FOV Plot for a 2006 Dodge Durango with 50th Percentile Male Driver

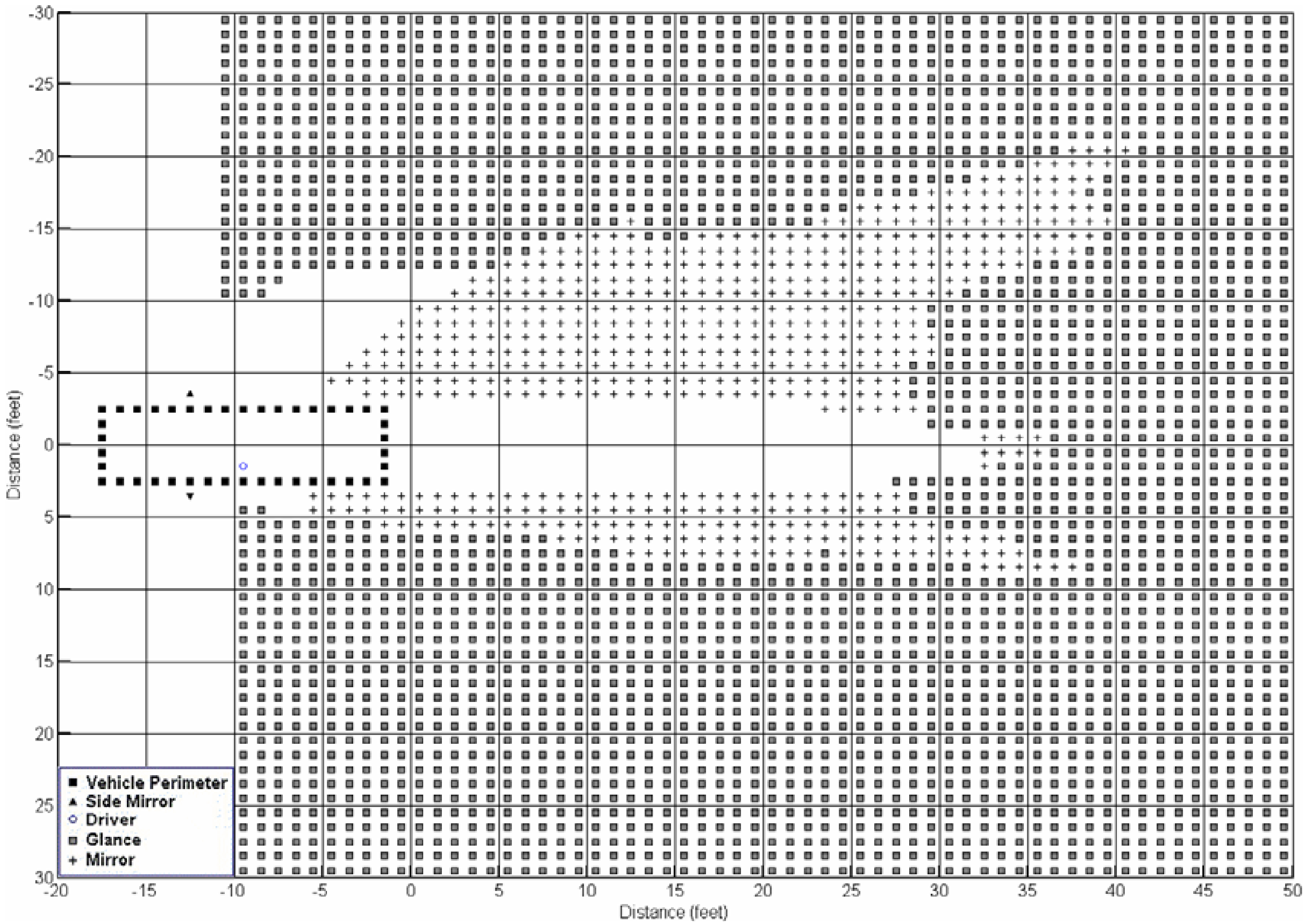


Figure 71. FOV Plot for a 2006 Dodge Durango with 5th Percentile Female Driver

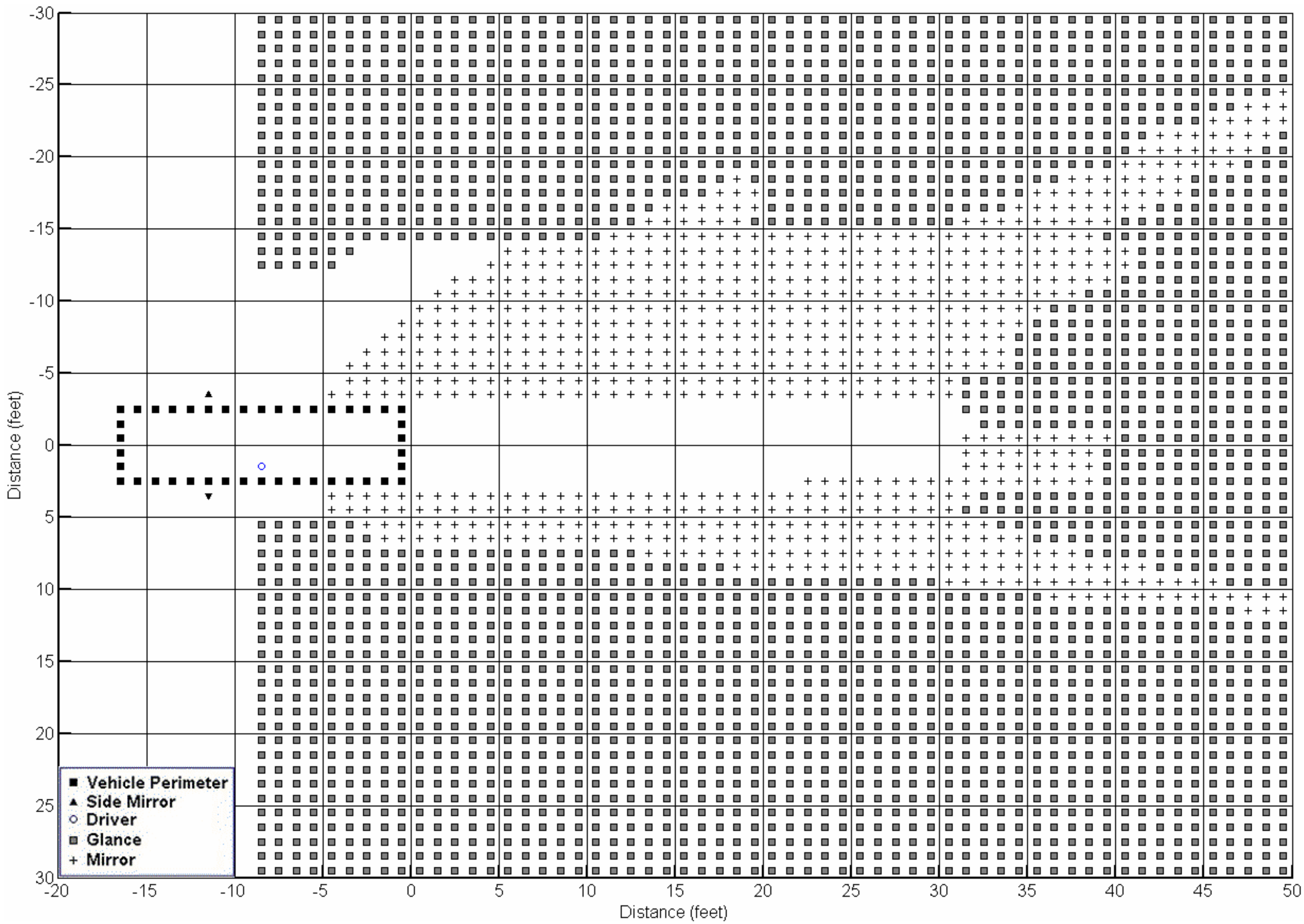


Figure 72. FOV Plot for a 2008 Ford Escape with 50th Percentile Male Driver

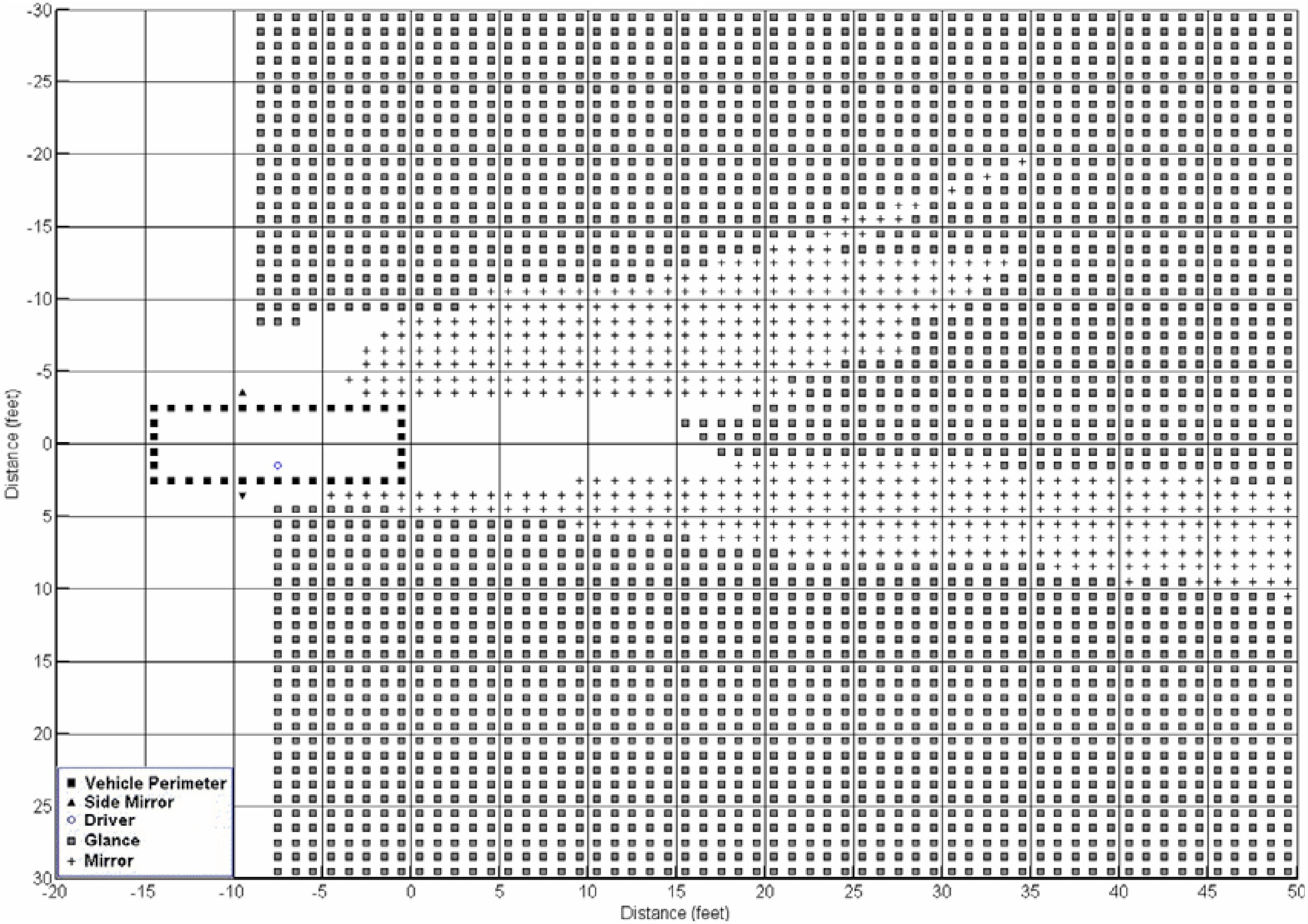


Figure 73. FOV Plot for a 2008 Ford Escape with 5th Percentile Female Driver

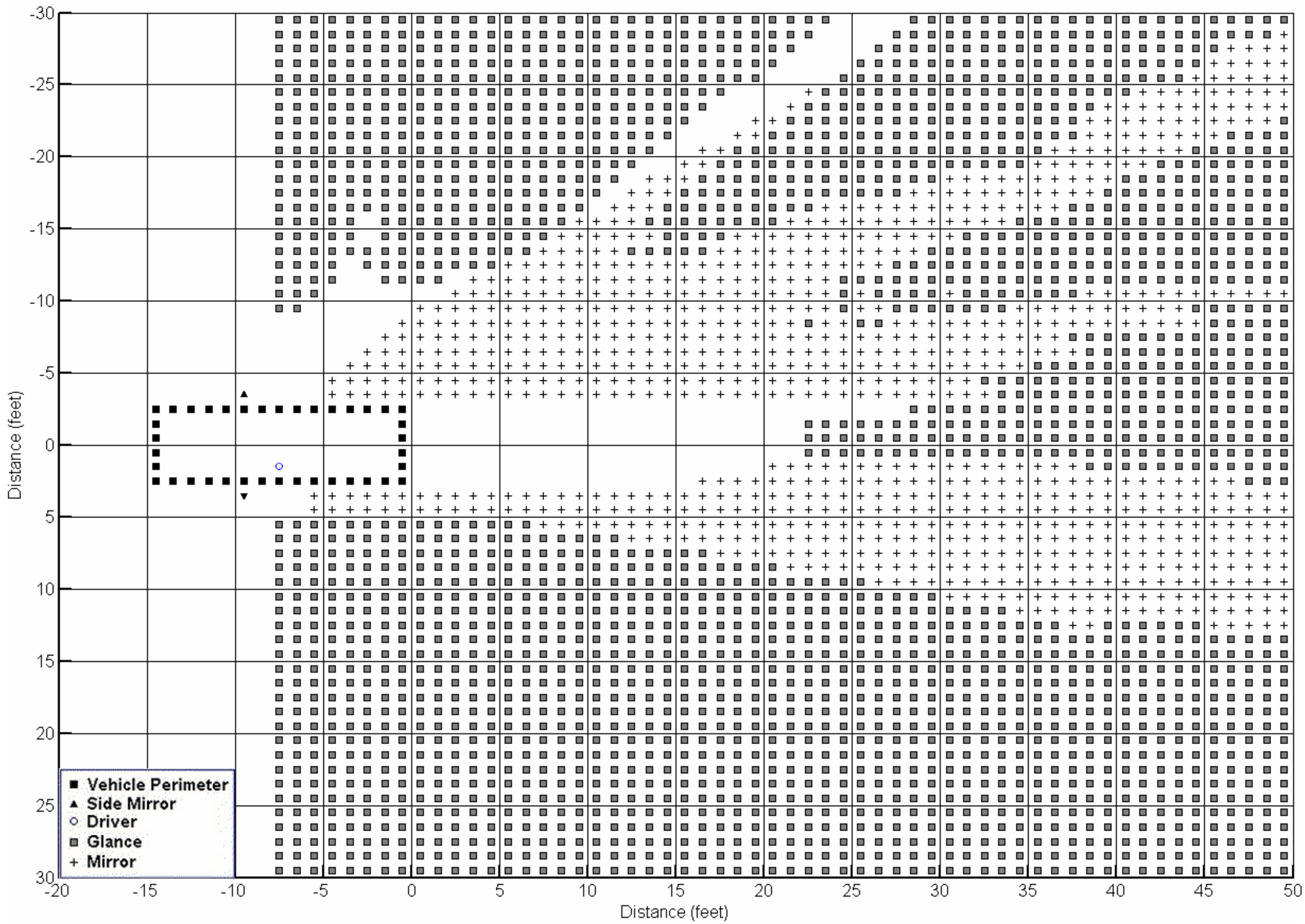


Figure 74. FOV Plot for a 2007 Ford Expedition with 50th Percentile Male Driver

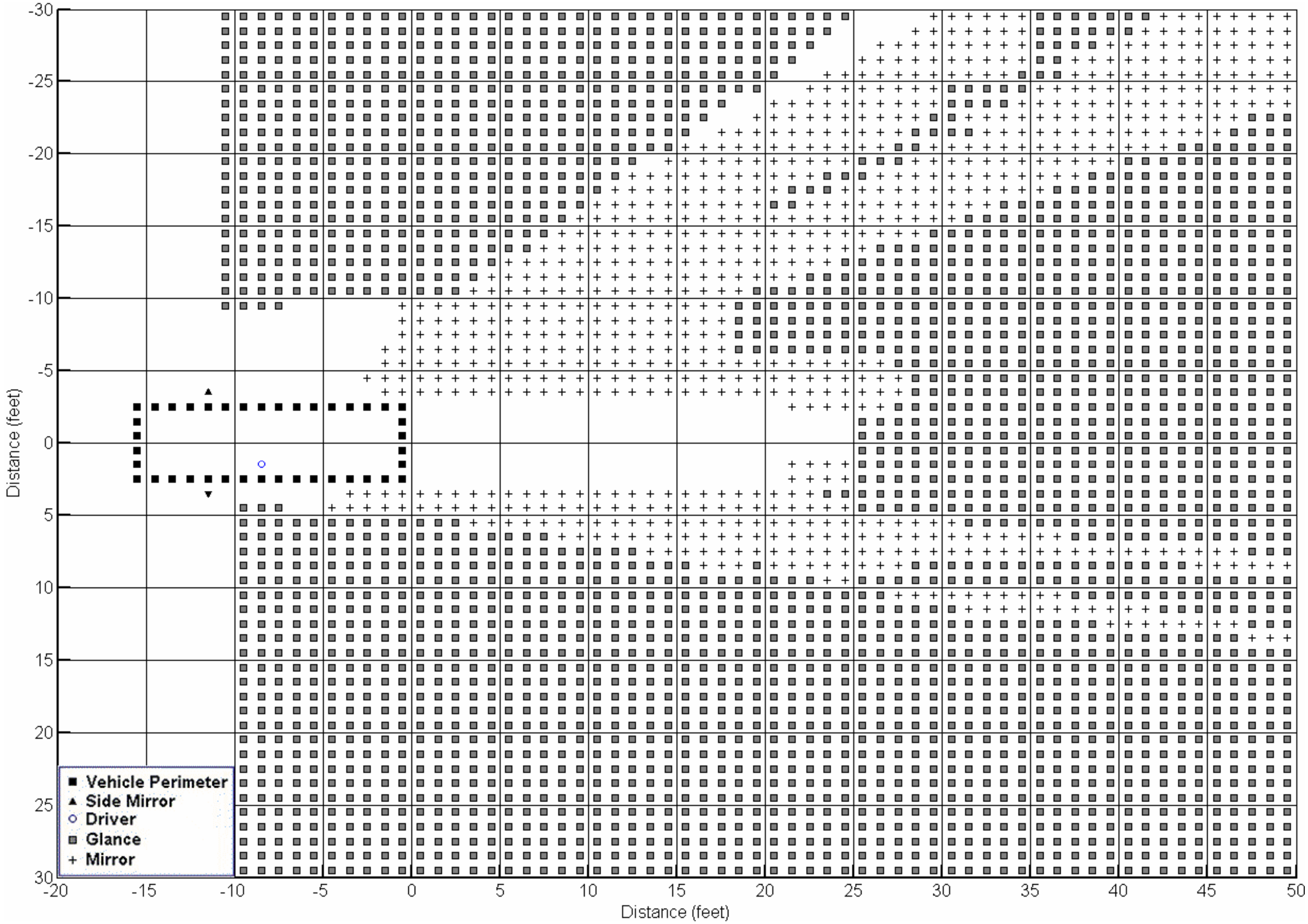


Figure 75. FOV Plot for a 2007 Ford Expedition with 5th Percentile Female Driver

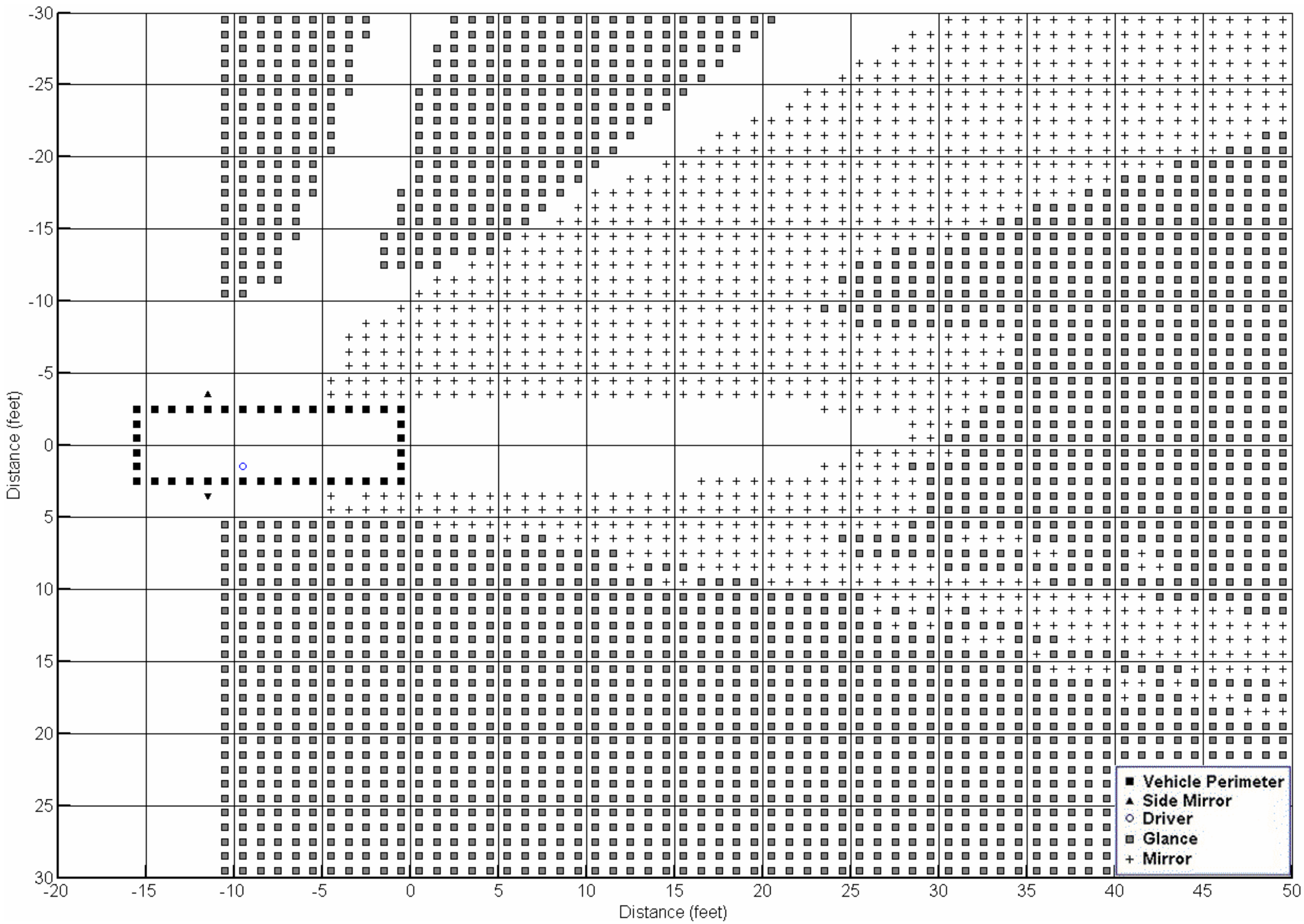


Figure 76. FOV Plot for a 2005 Ford Explorer with 50th Percentile Male Driver

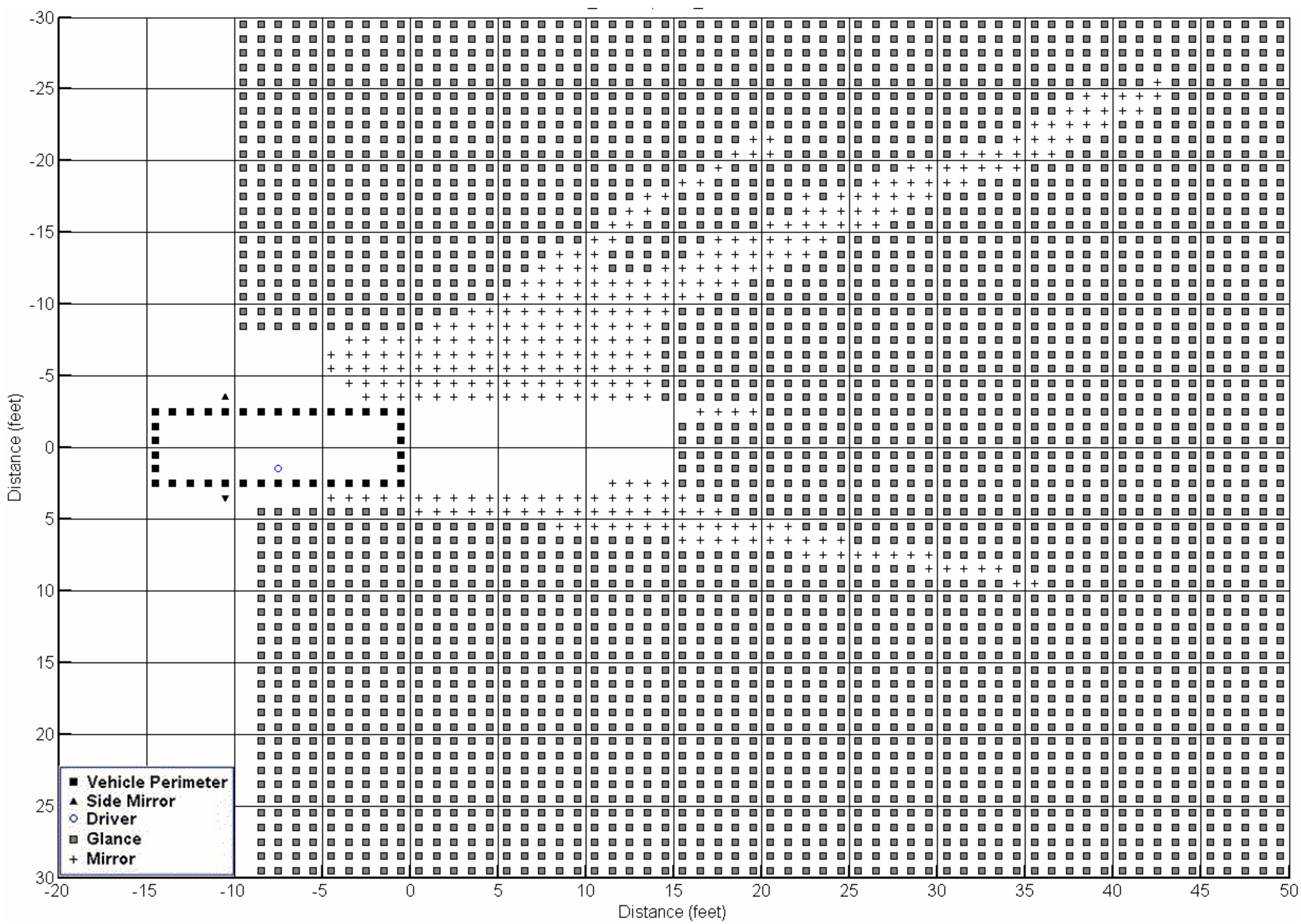


Figure 77. FOV Plot for a 2005 Ford Explorer with 5th Percentile Female Driver

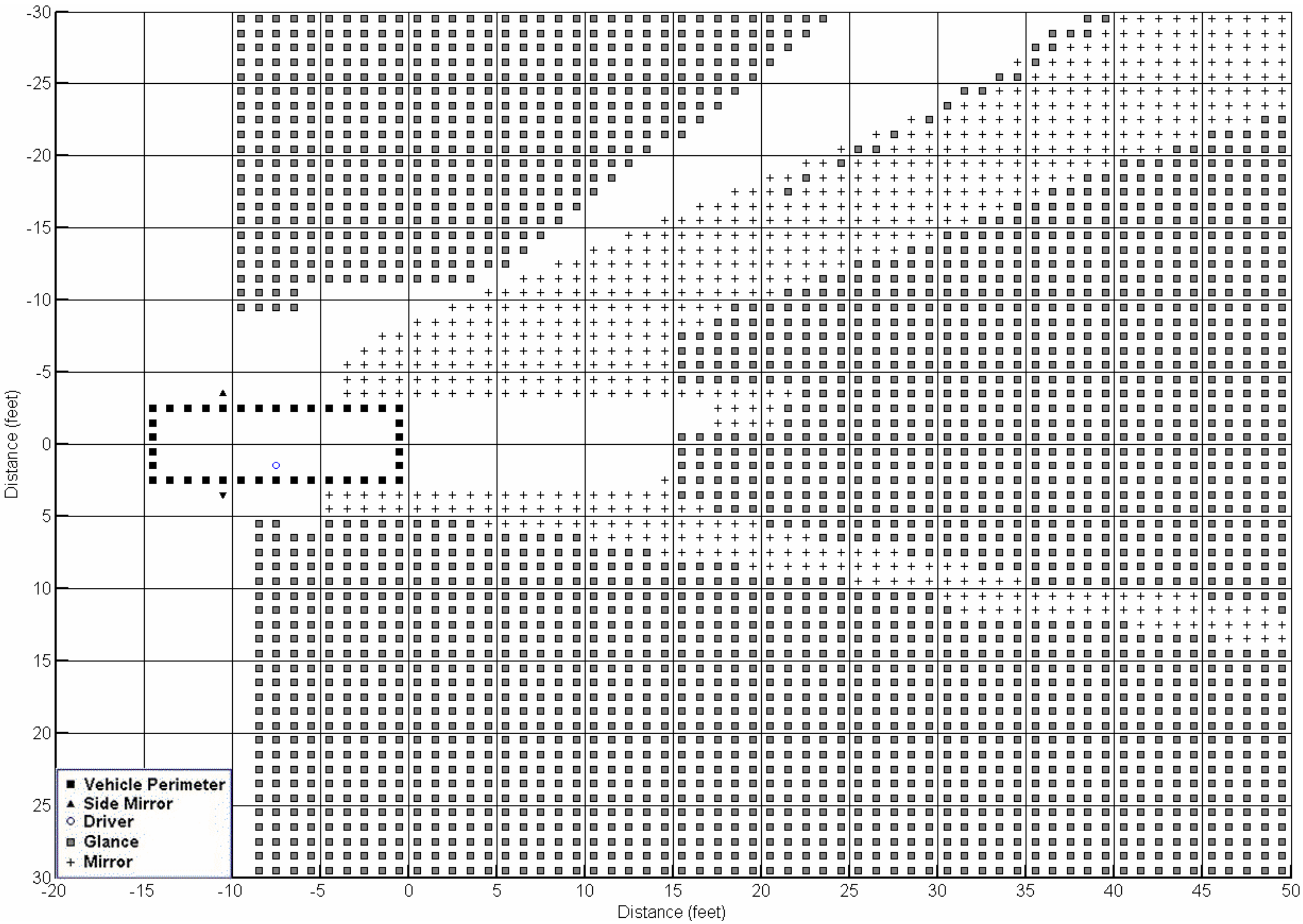


Figure 78. FOV Plot for a 2005 Honda CR-V with 50th Percentile Male Driver

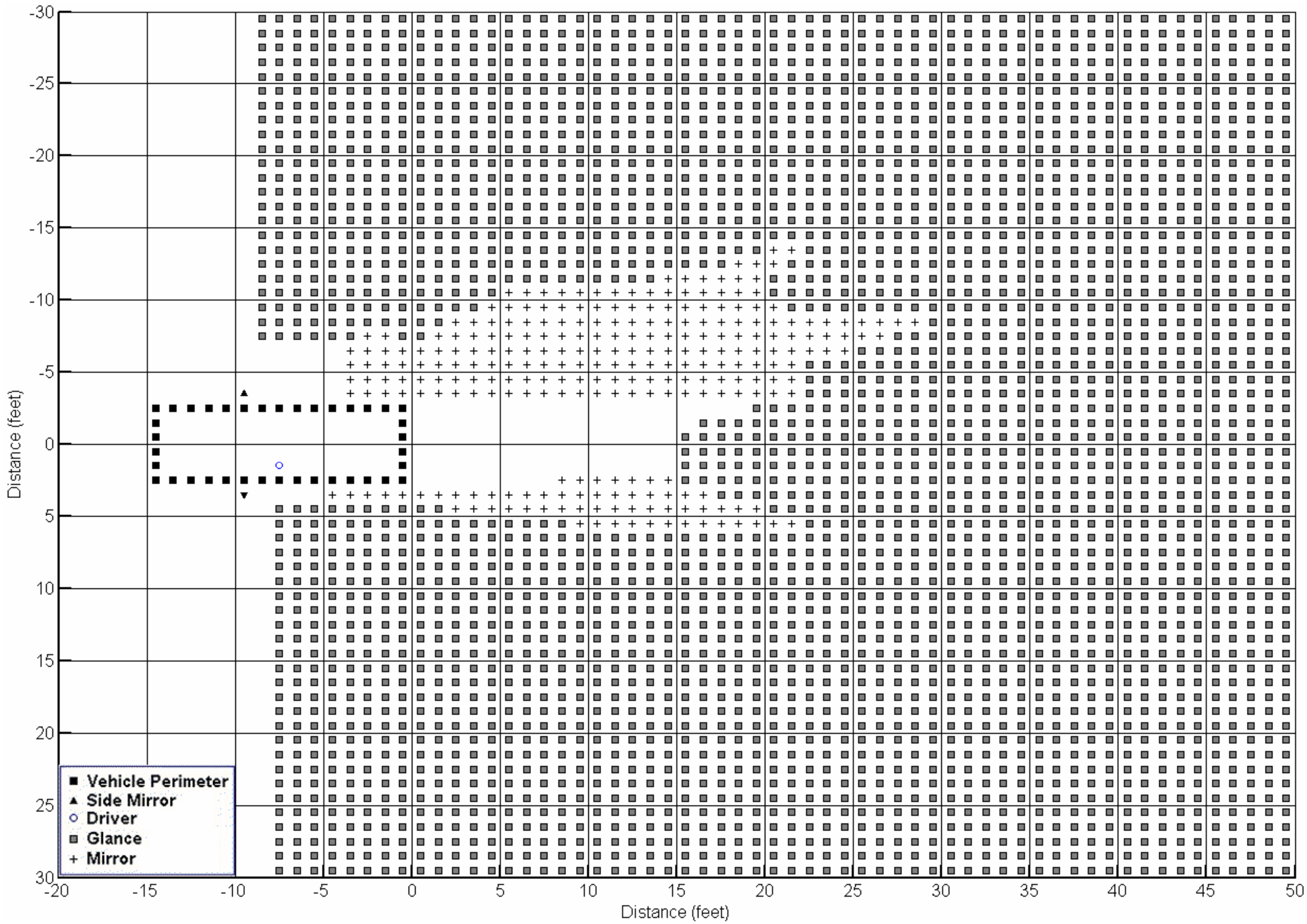


Figure 79. FOV Plot for a 2005 Honda CR-V with 5th Percentile Female Driver

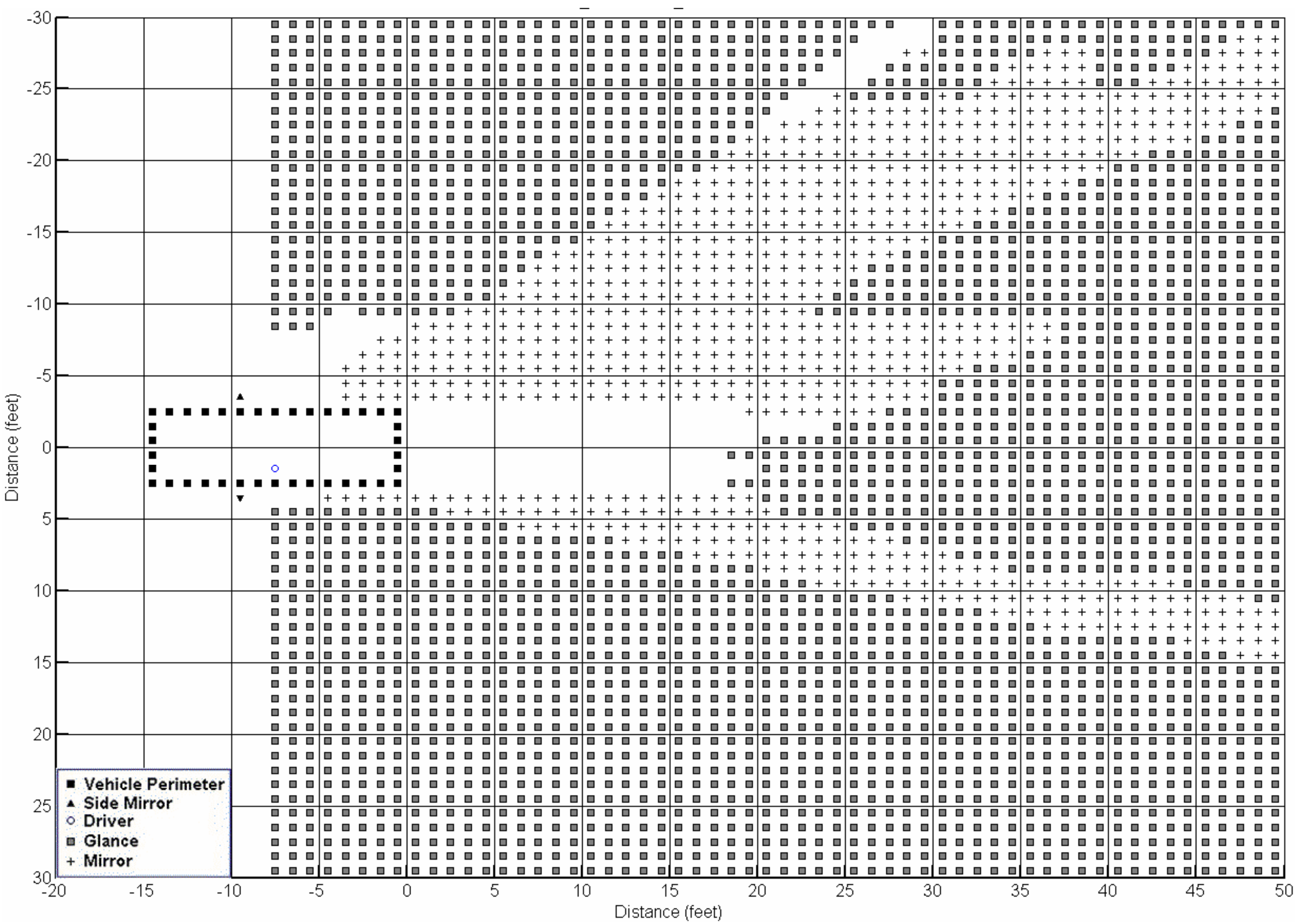


Figure 80. FOV Plot for a 2007 Honda Element with 50th Percentile Male Driver

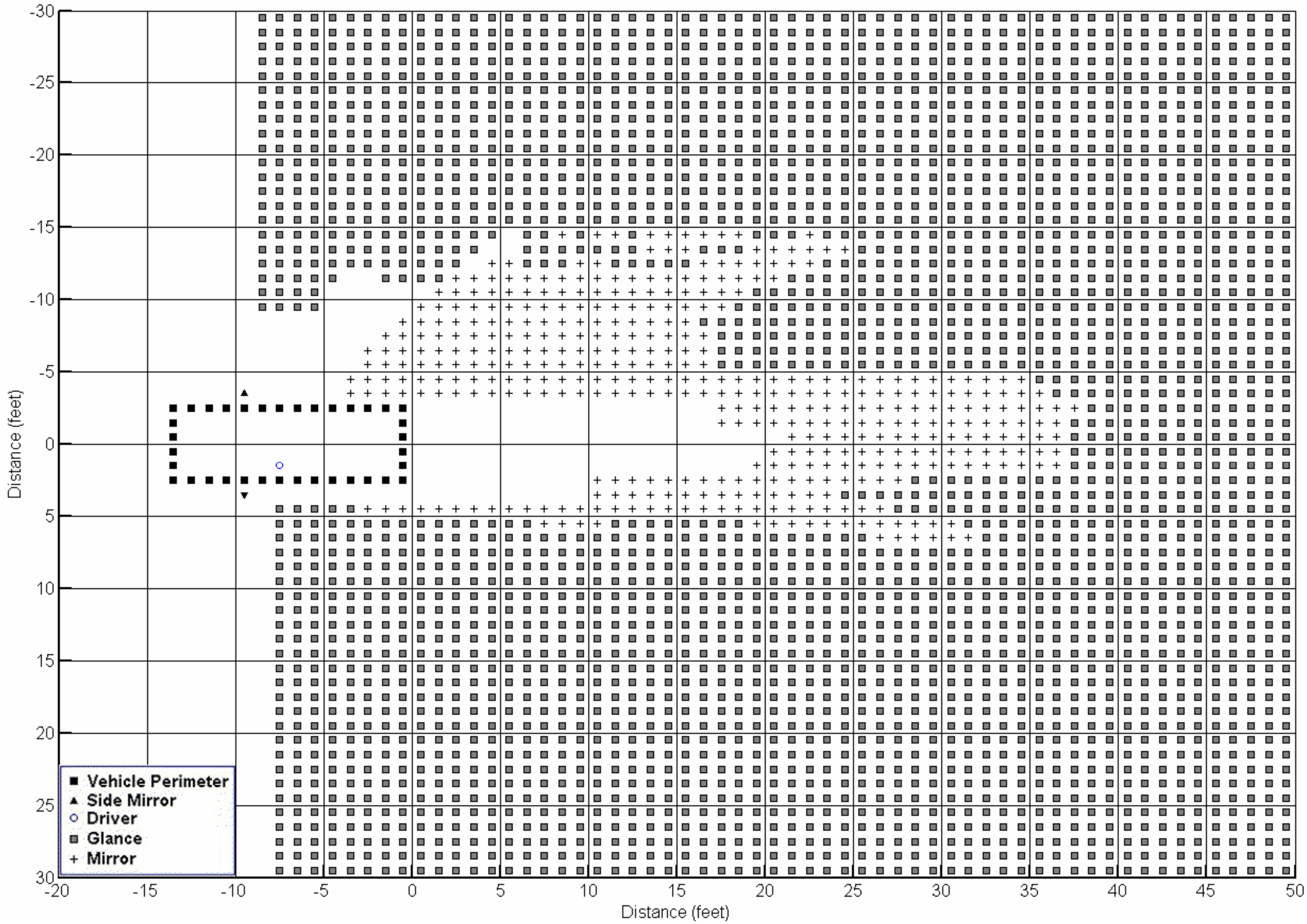


Figure 81. FOV Plot for a 2007 Honda Element with 5th Percentile Female Driver

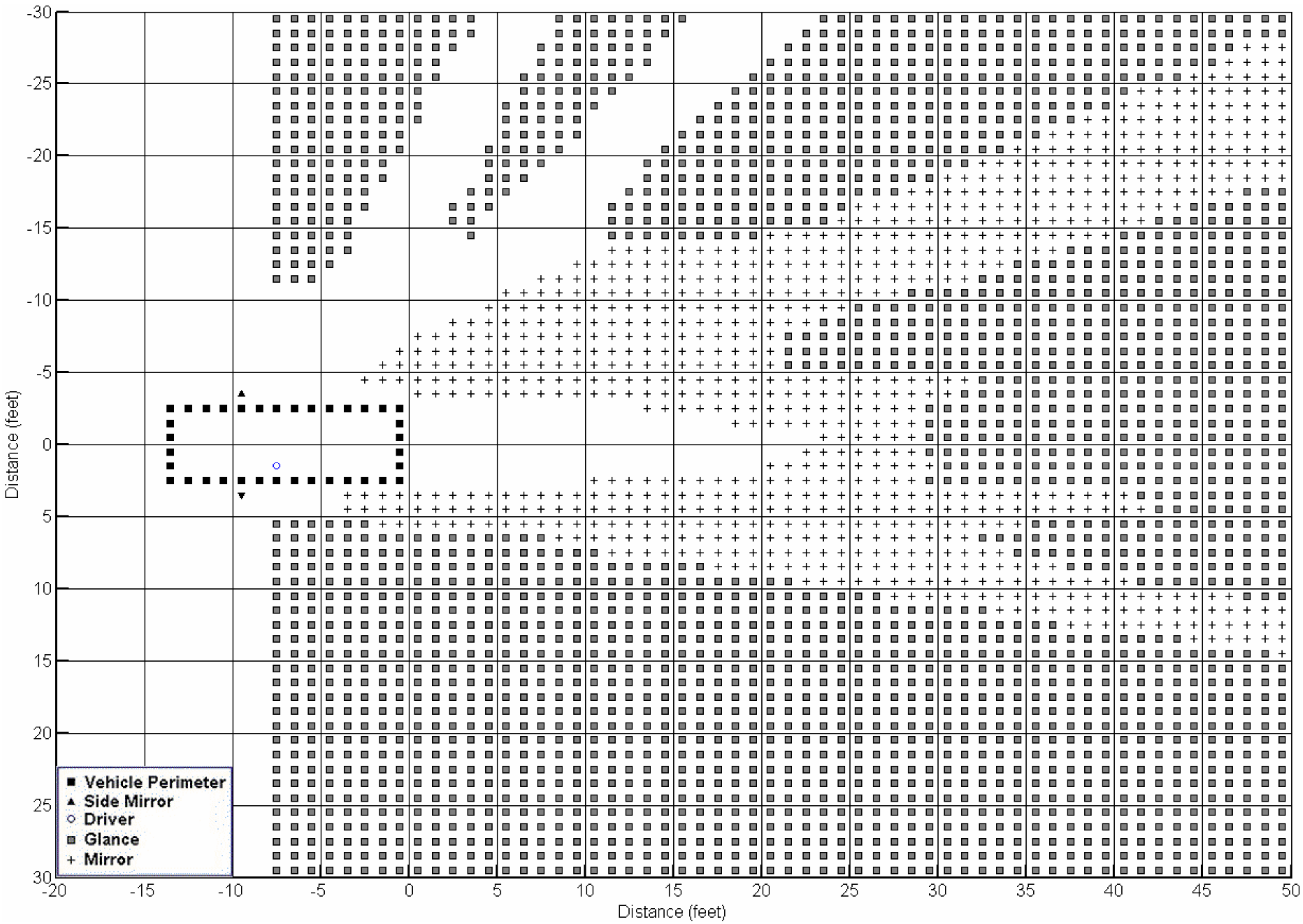


Figure 82. FOV Plot for a 2003 Hummer H2 with 50th Percentile Male Driver

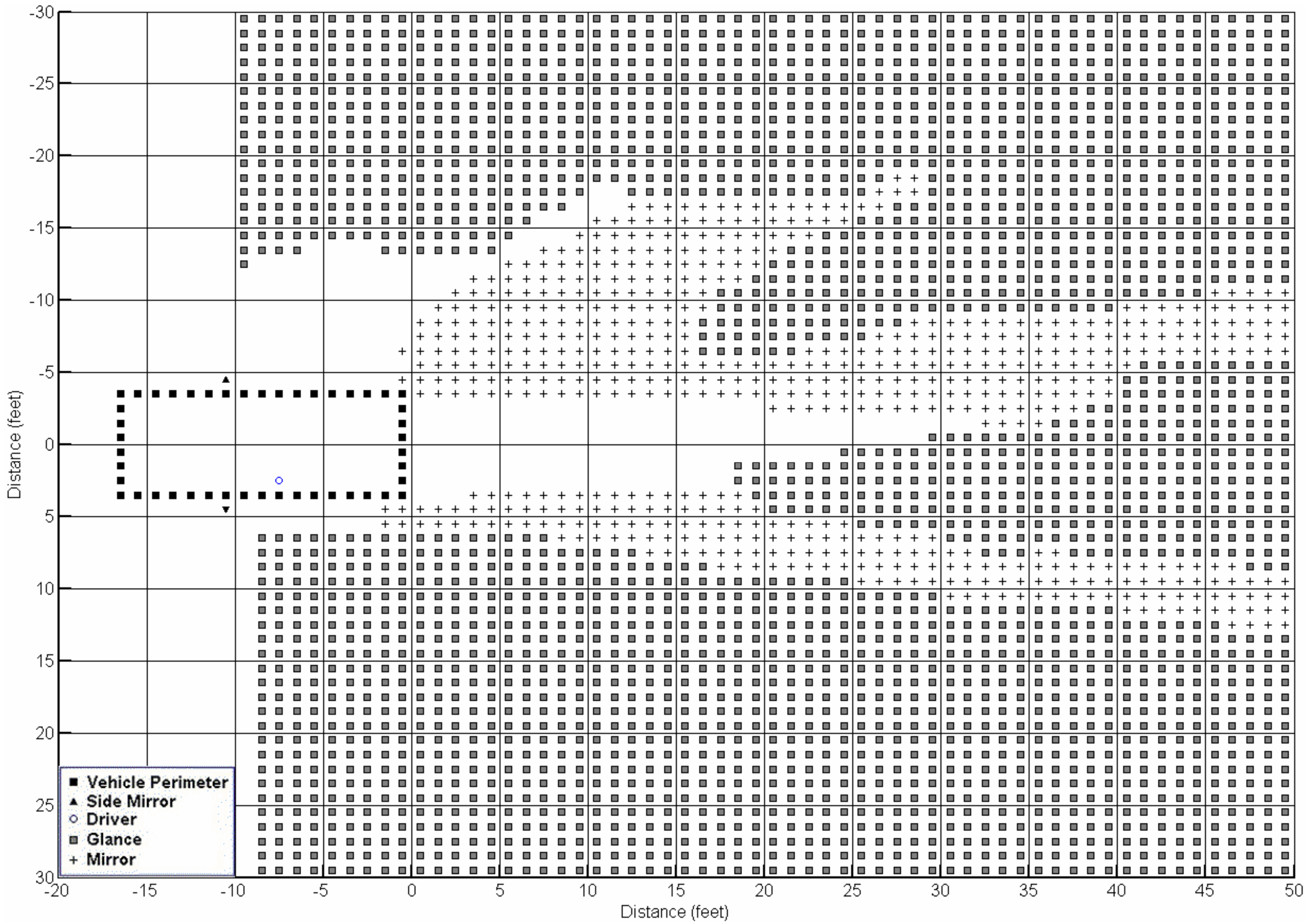


Figure 83. FOV Plot for a 2003 Hummer H2 with 5th Percentile Female Driver

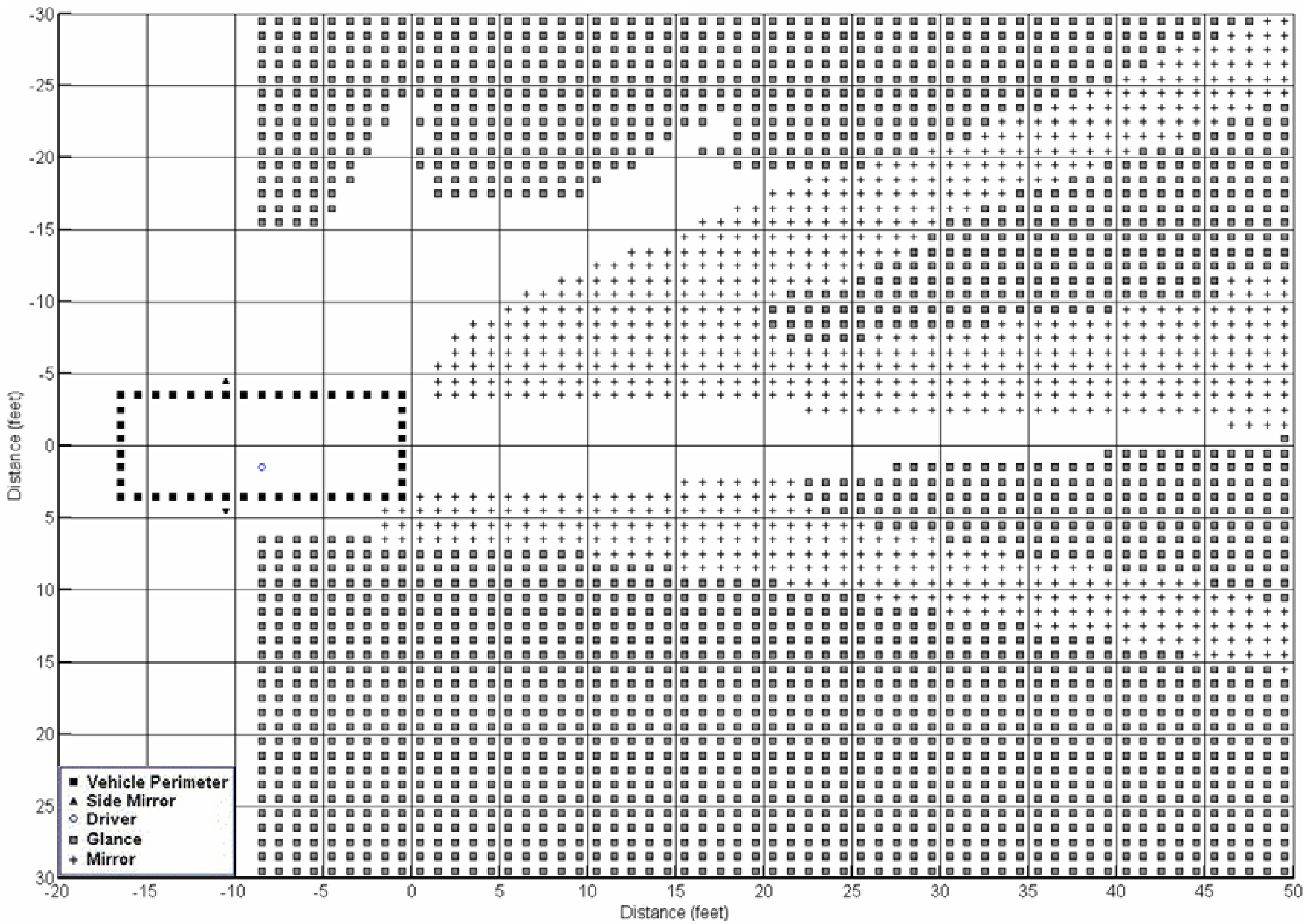


Figure 84. FOV Plot for a 2005 Infiniti FX35 with 50th Percentile Male Driver

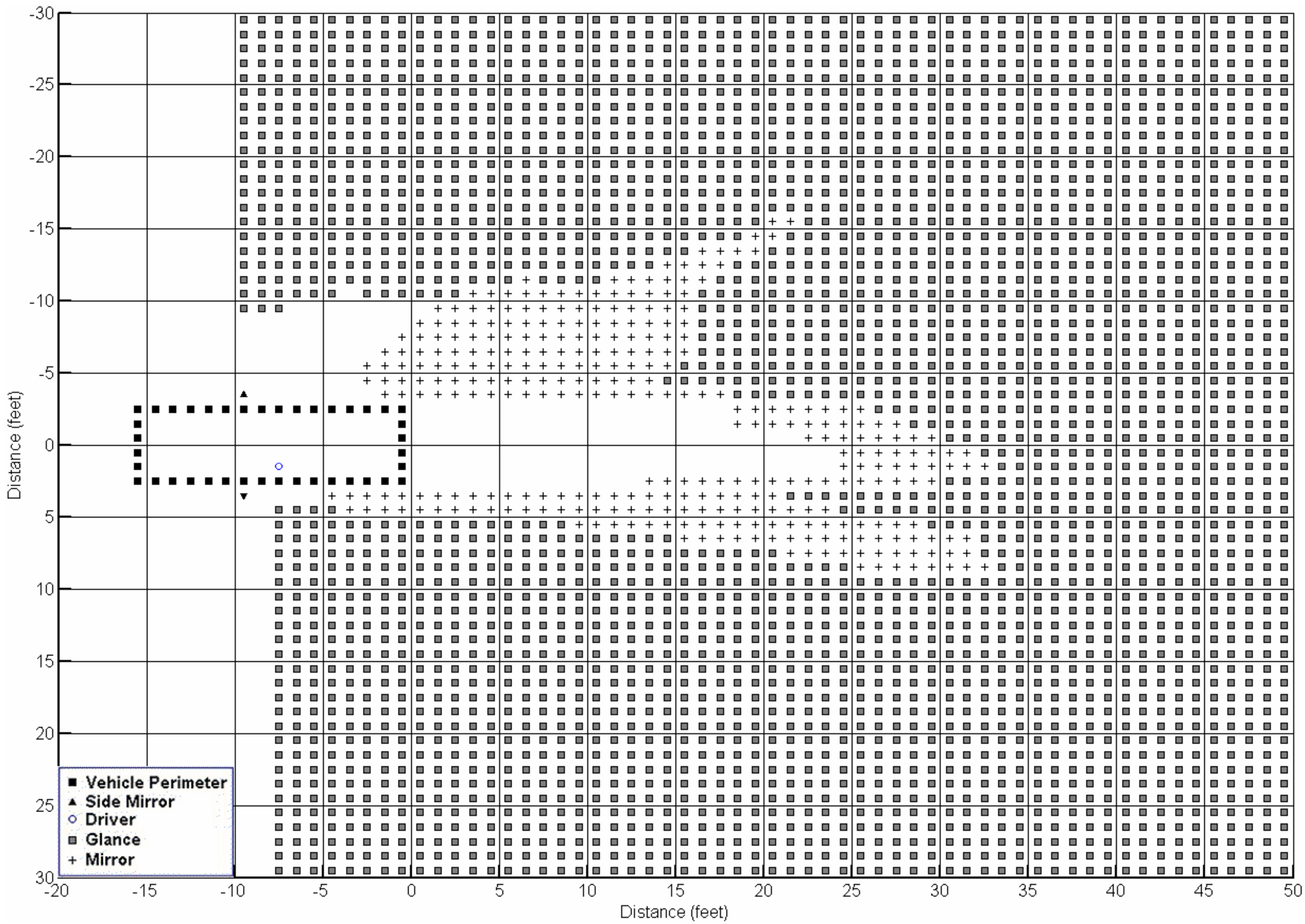


Figure 85. FOV Plot for a 2005 Infiniti FX35 with 5th Percentile Female Driver

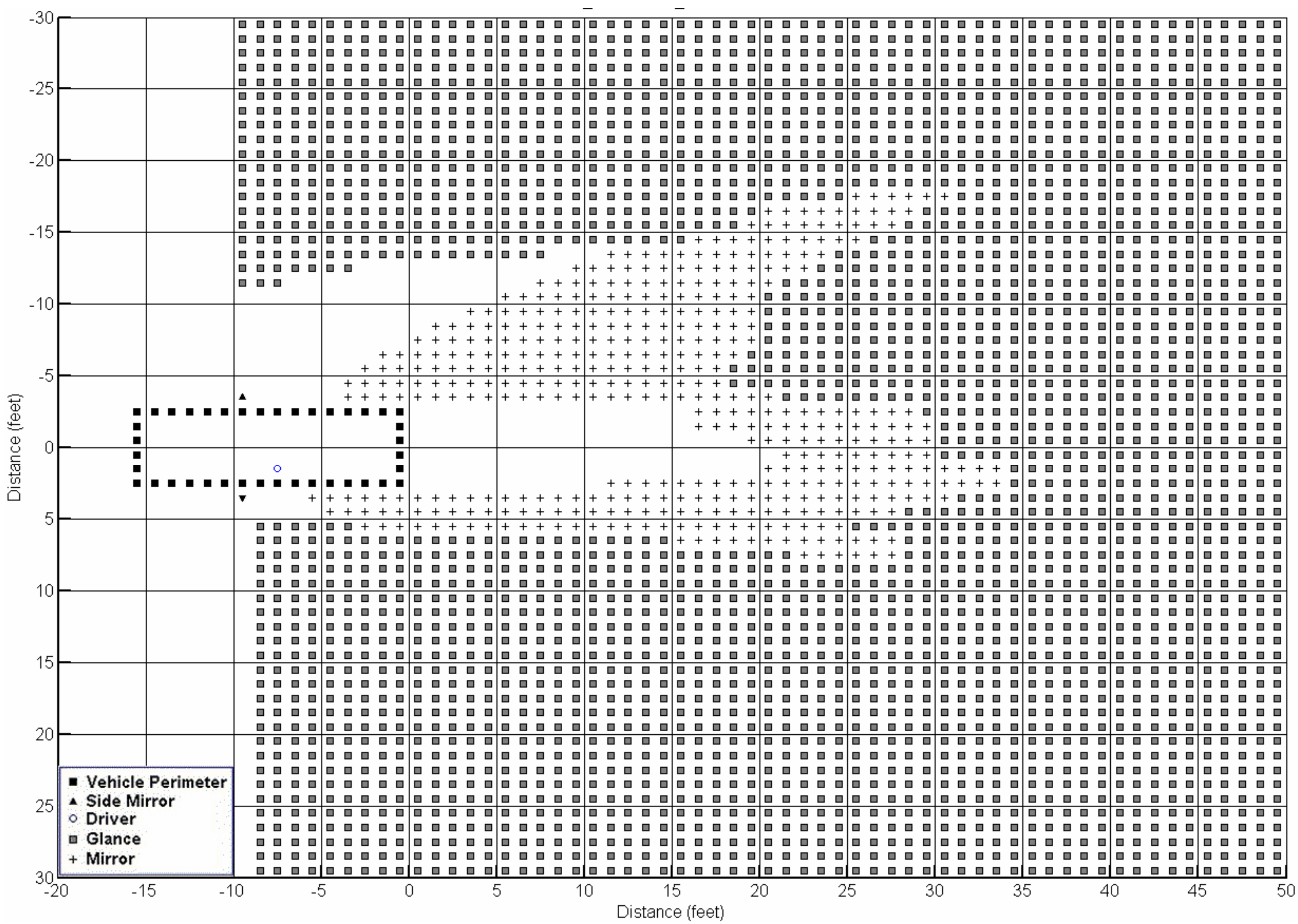


Figure 86. FOV Plot for a 2005 Infiniti FX35 Rearview Video System

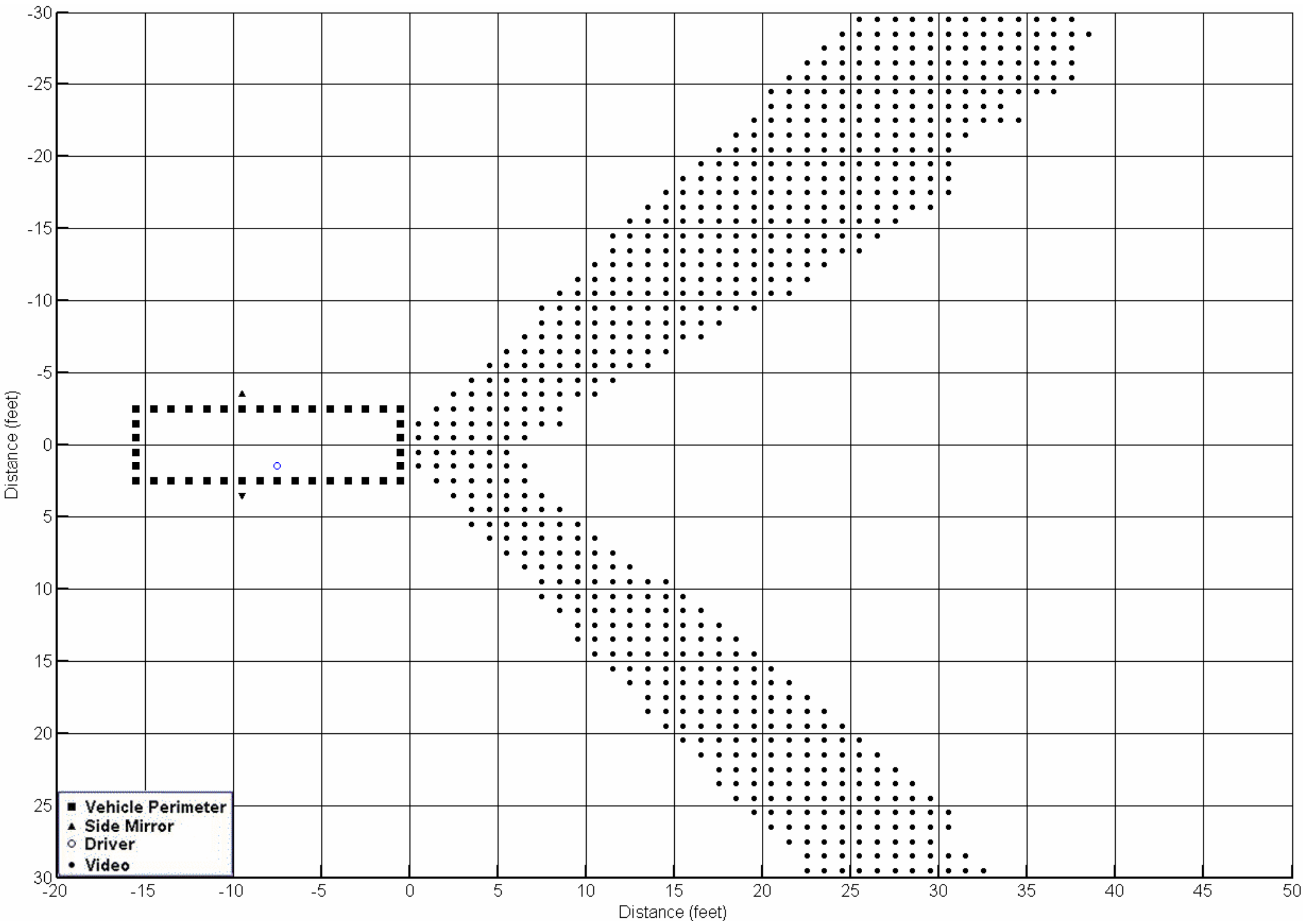


Figure 87. FOV Plot for a 2007 Jeep Commander with 50th Percentile Male Driver

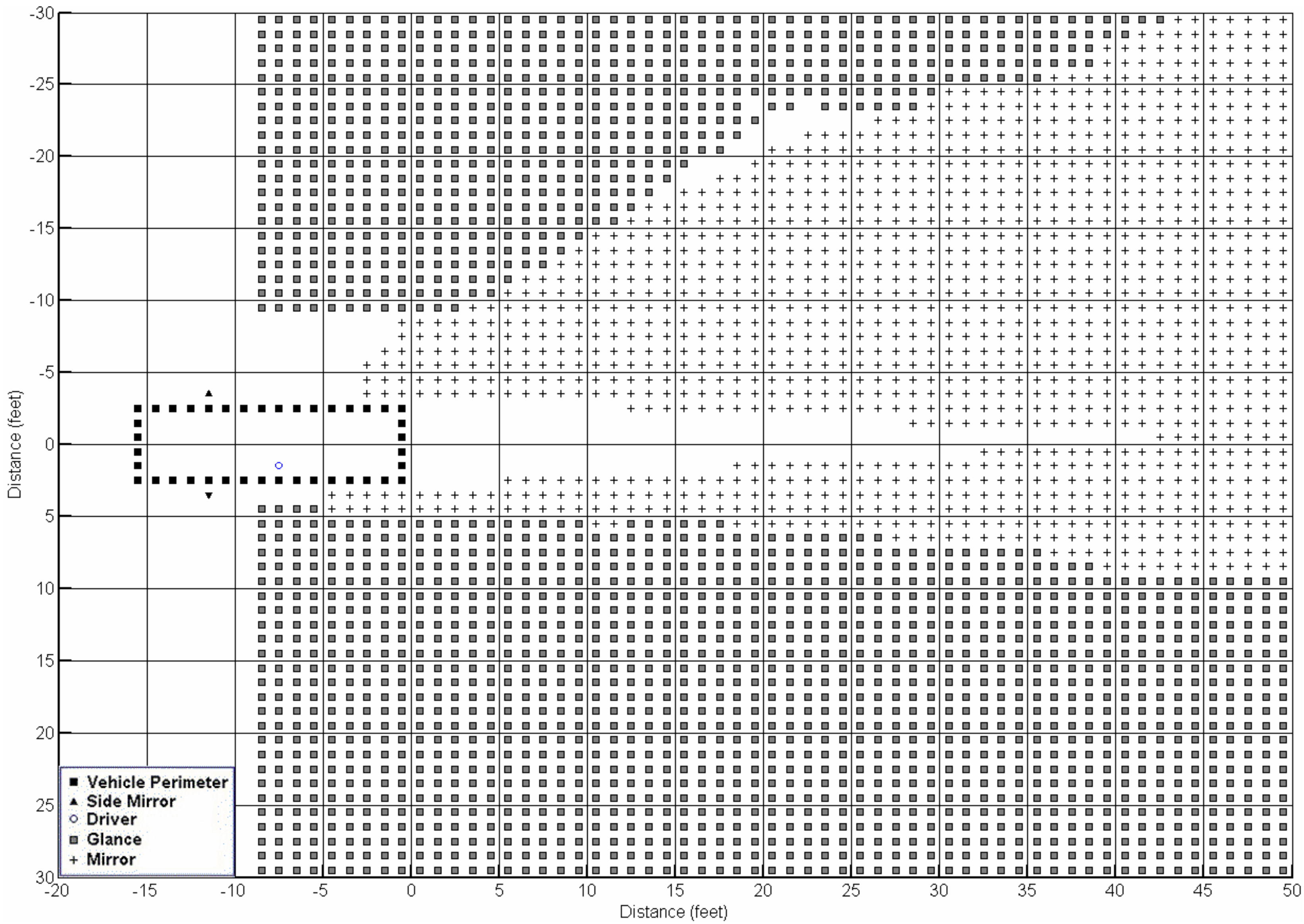


Figure 88. FOV Plot for a 2007 Jeep Commander with 5th Percentile Female Driver

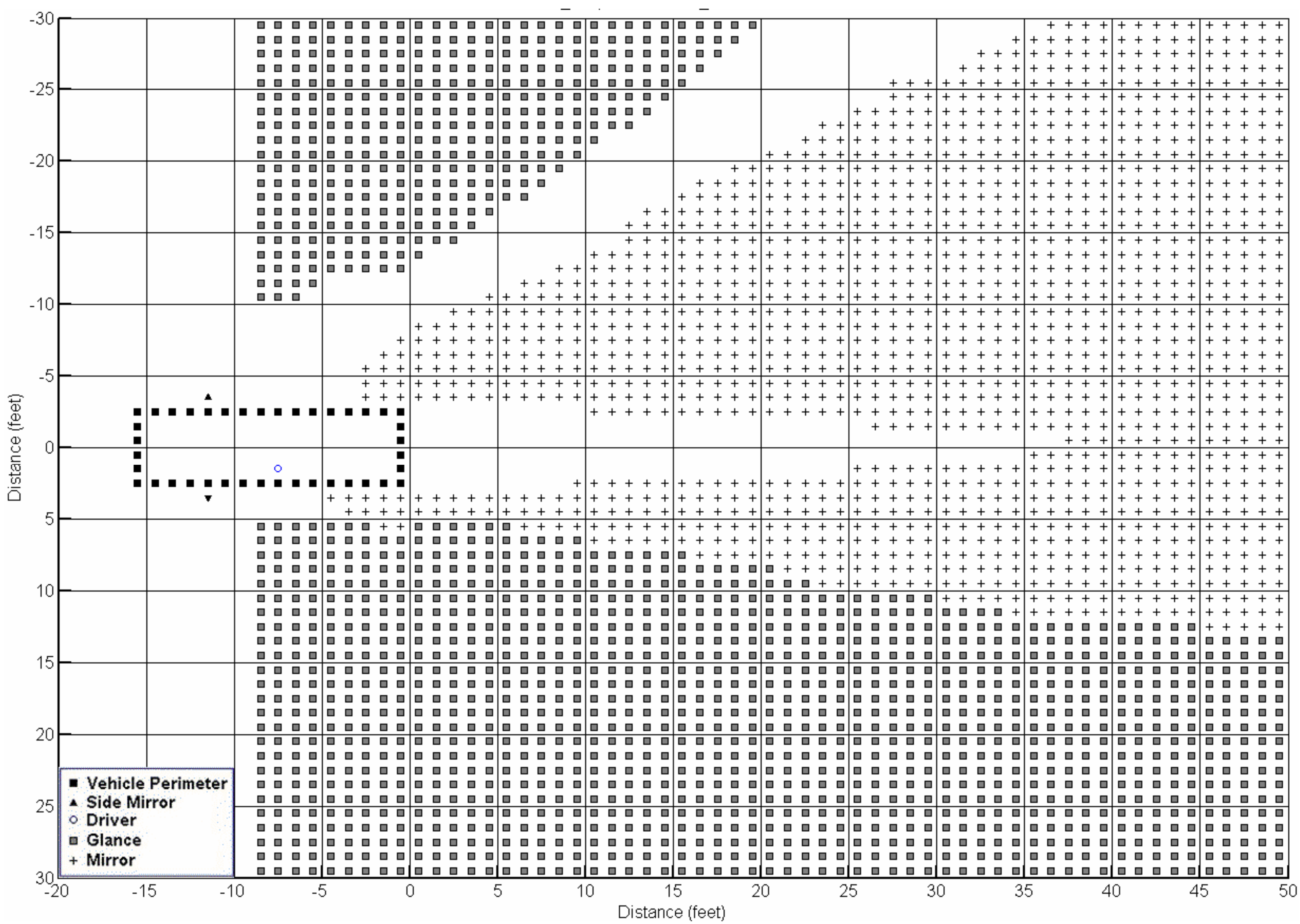


Figure 89. FOV Plot for a 2007 Nissan Xterra with 50th Percentile Male Driver

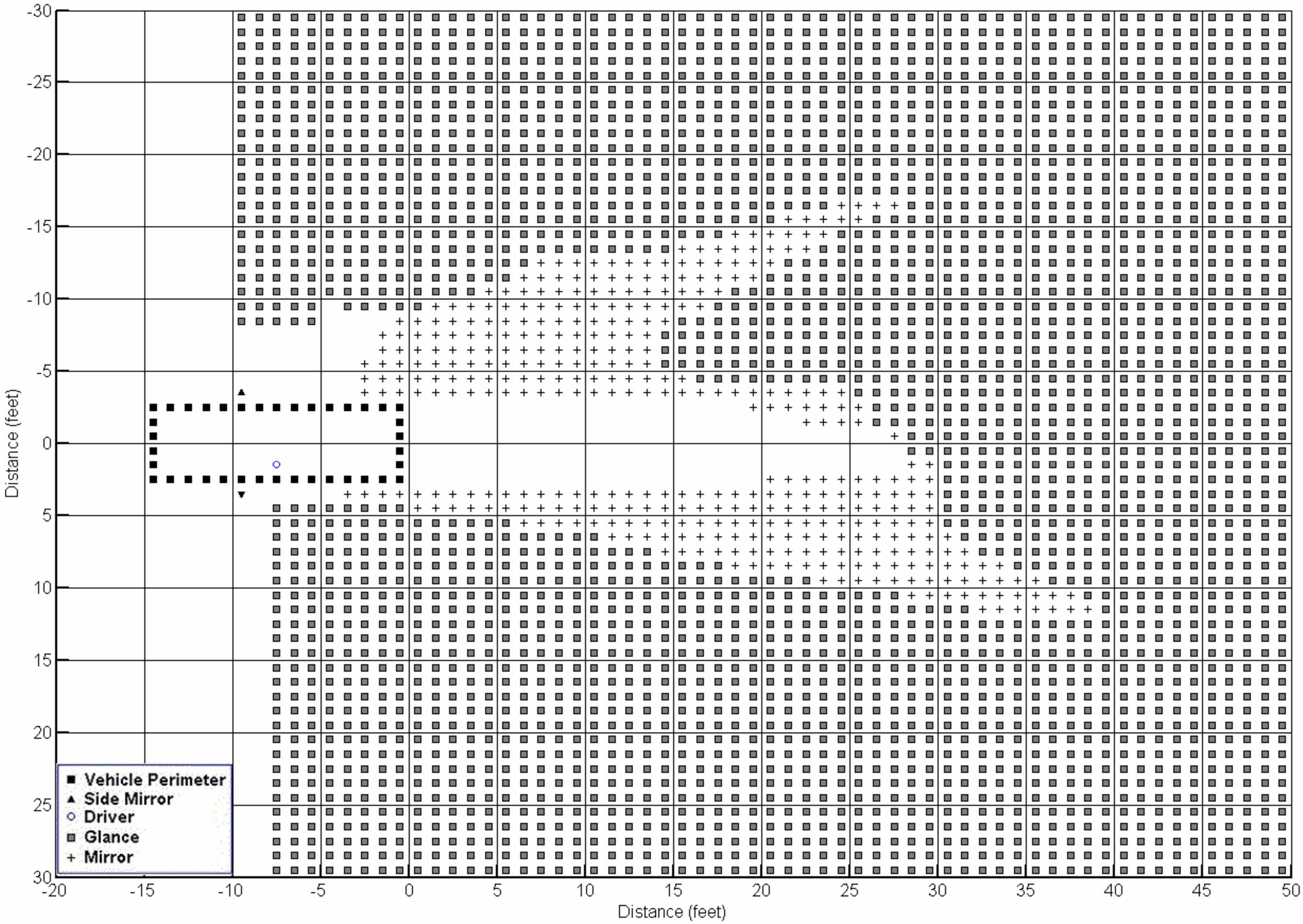


Figure 90.   FOV Plot for a 2007 Nissan Xterra with 5th Percentile Female Driver

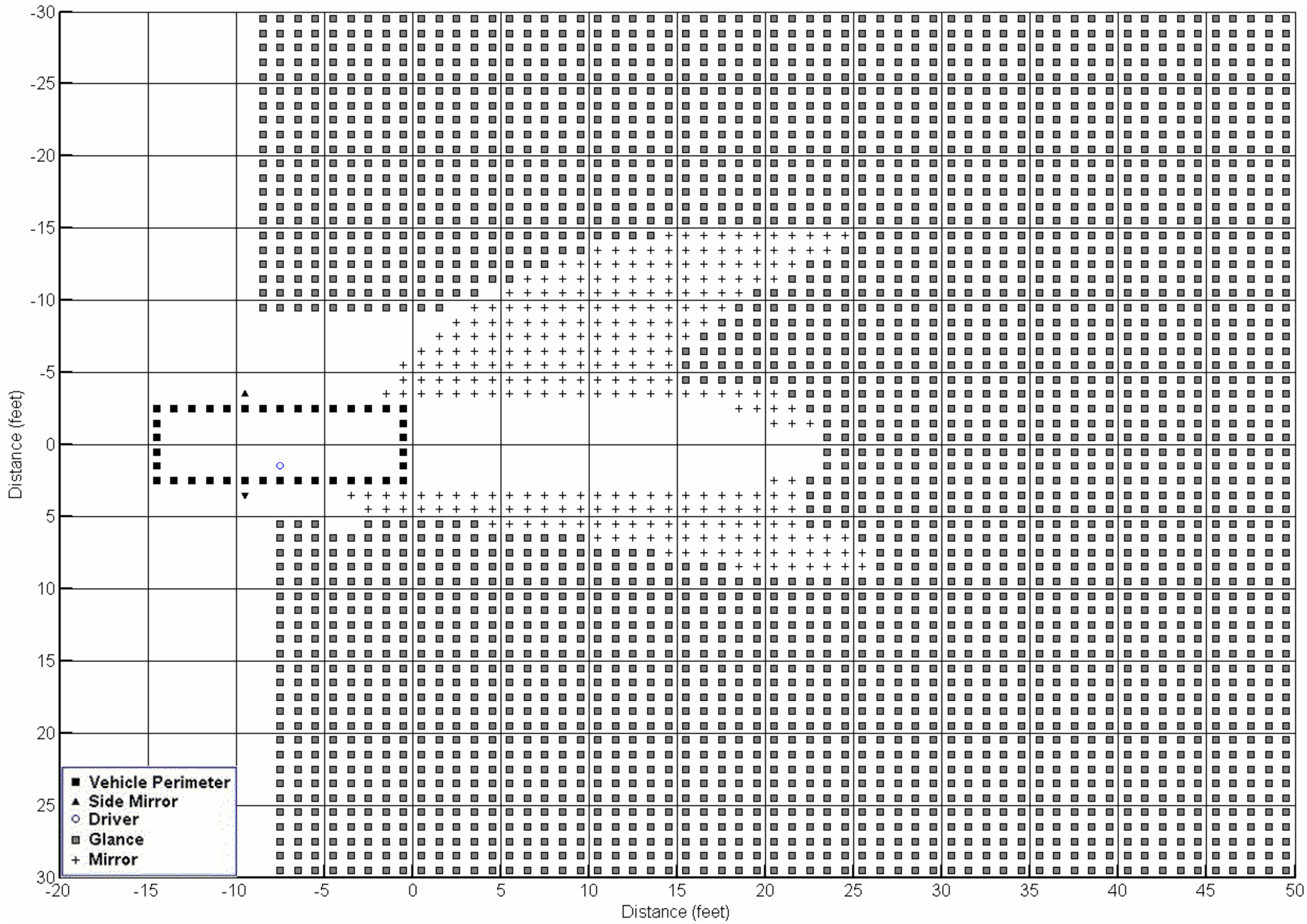


Figure 91. FOV Plot for a 2007 Toyota FJ Cruiser with 50th Percentile Male Driver

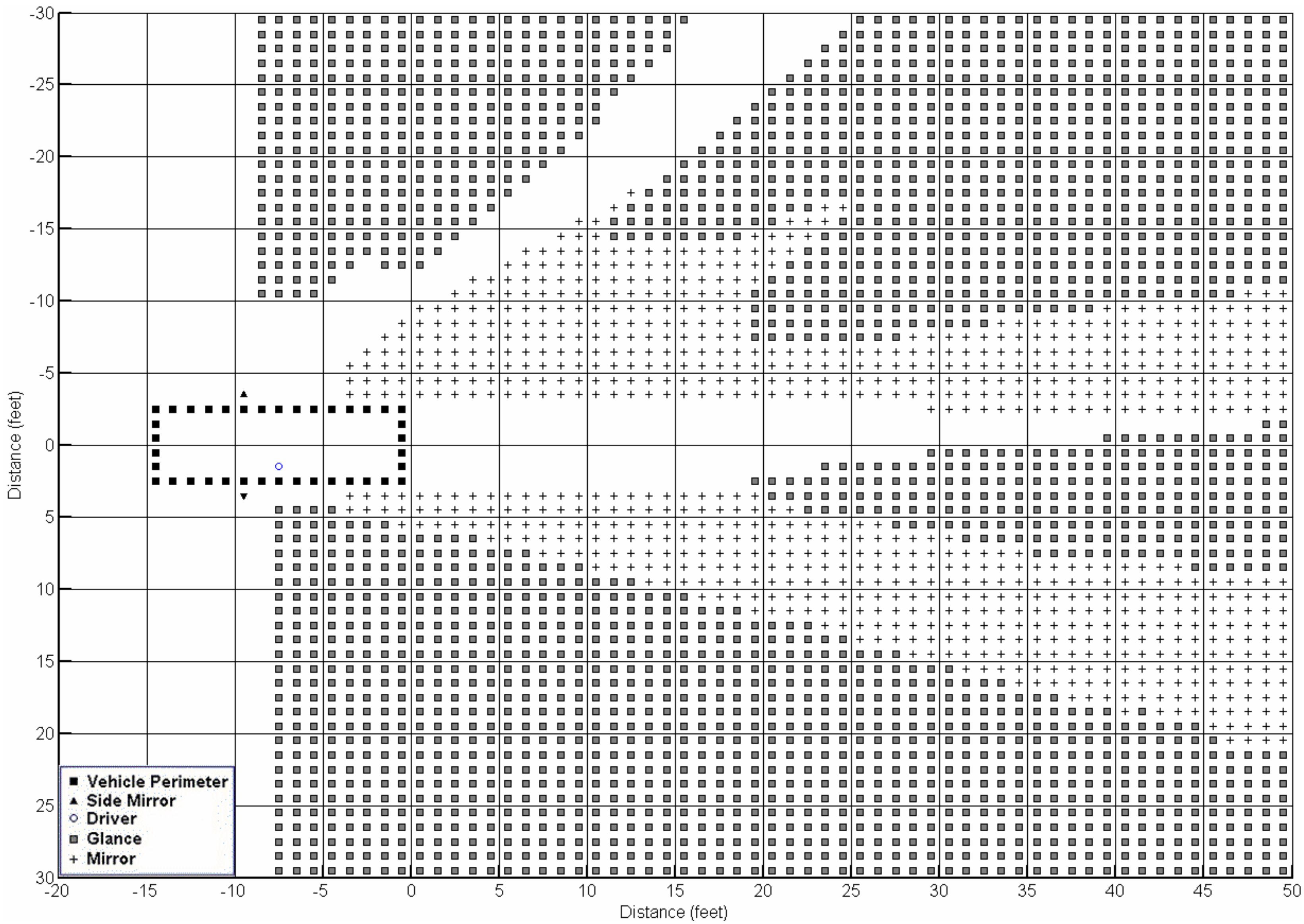


Figure 92. FOV Plot for a 2007 Toyota FJ Cruiser with 5th Percentile Female Driver

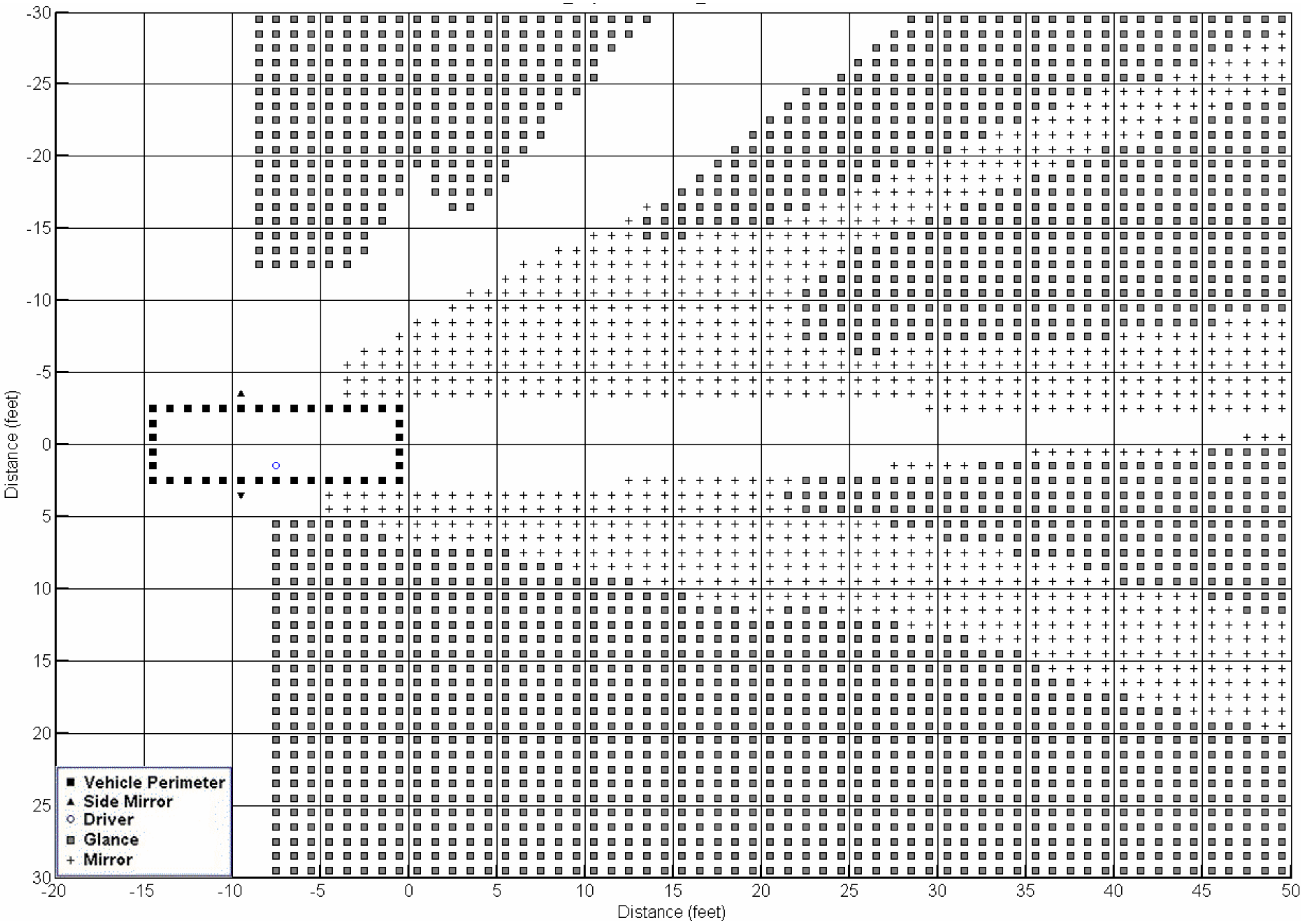


Figure 93. FOV Plot for a 2005 Chevrolet Uplander with 50th Percentile Male Driver

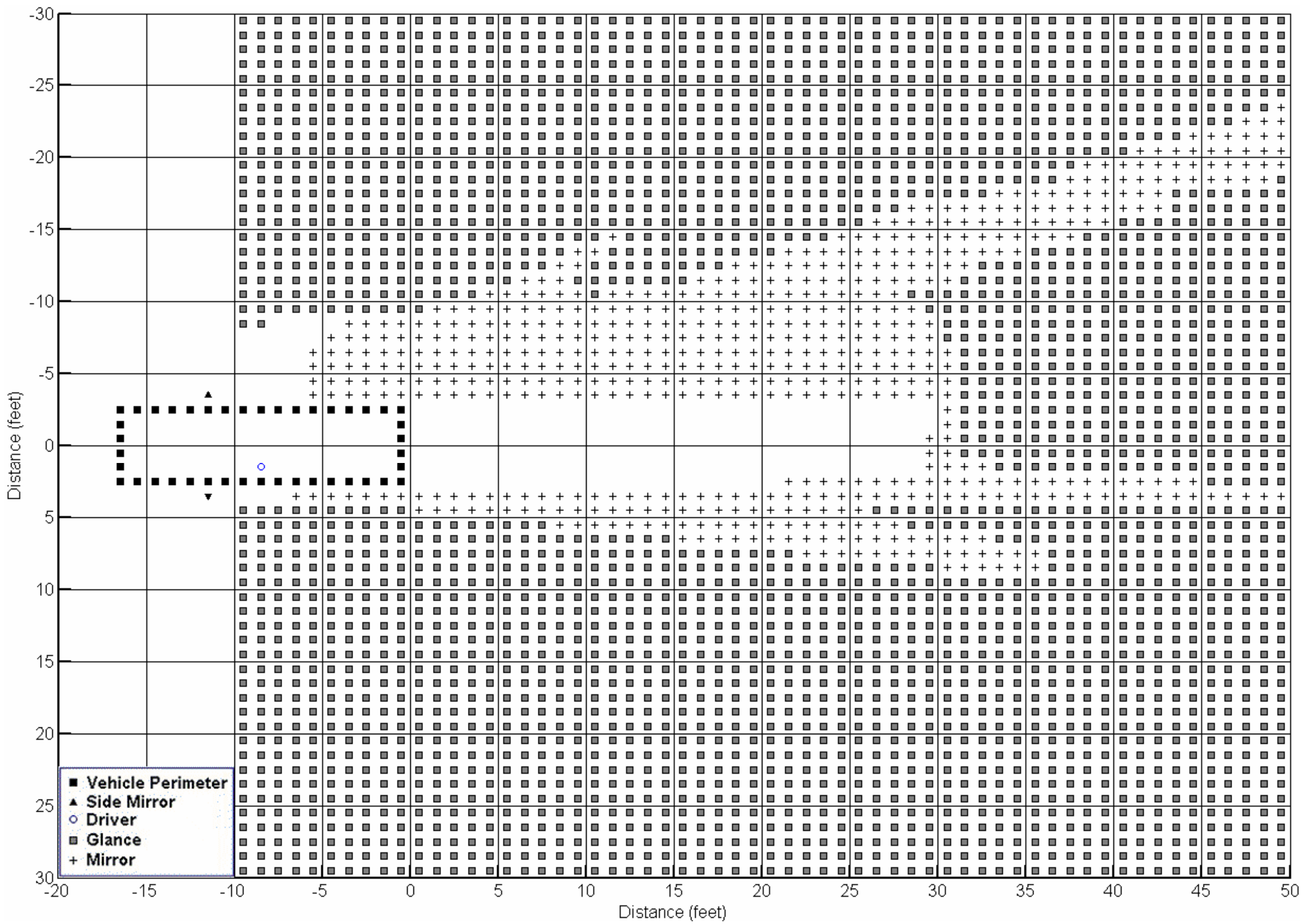


Figure 94. FOV Plot for a 2005 Chevrolet Uplander with 5th Percentile Female Driver

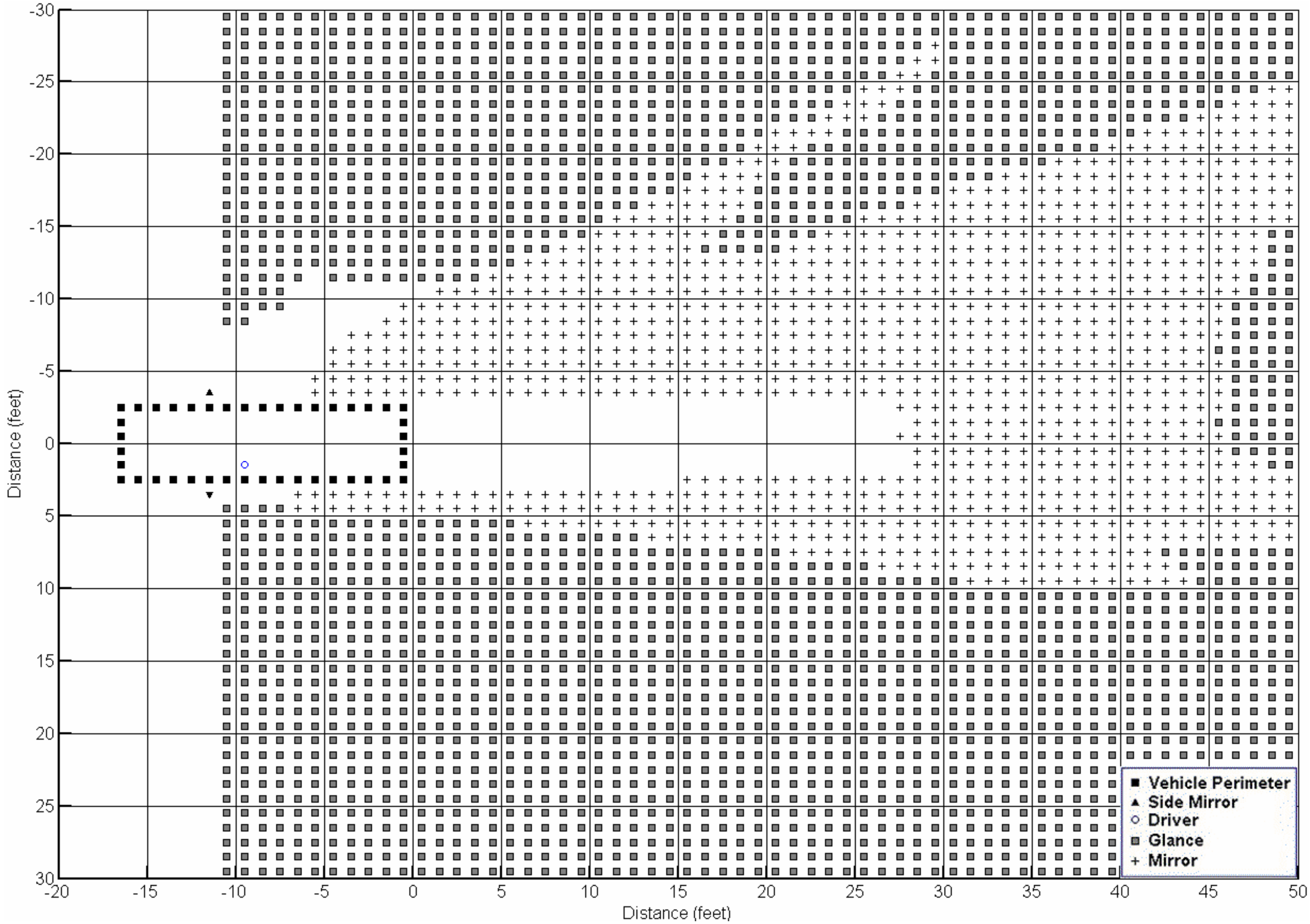


Figure 95. FOV Plot for a 2007 Ford Freestar with 50th Percentile Male Driver

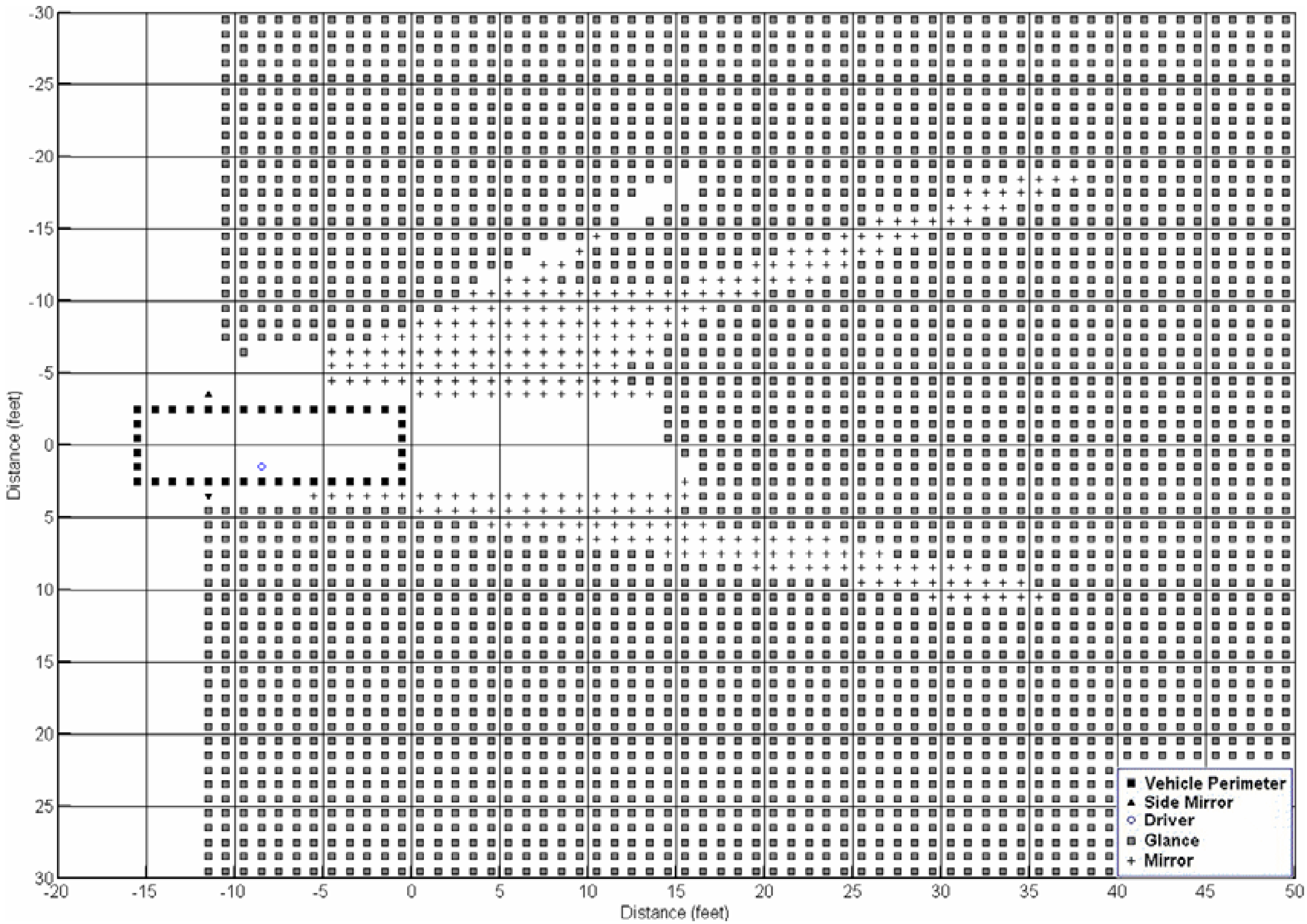


Figure 96. FOV Plot for a 2007 Ford Freestar with 5th Percentile Female Driver

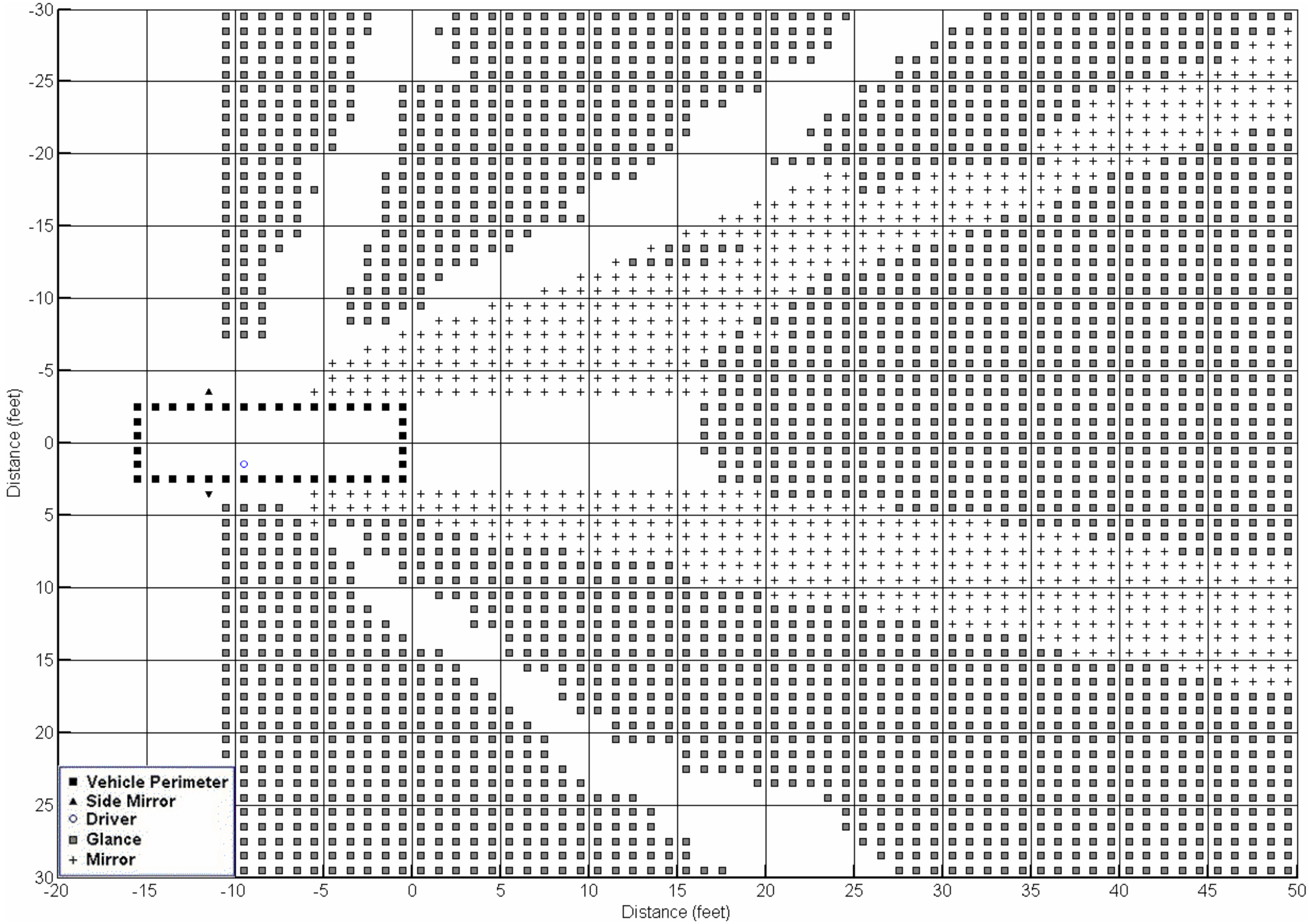


Figure 97. FOV Plot for a 2004 GMC Savanna with 50th Percentile Male Driver

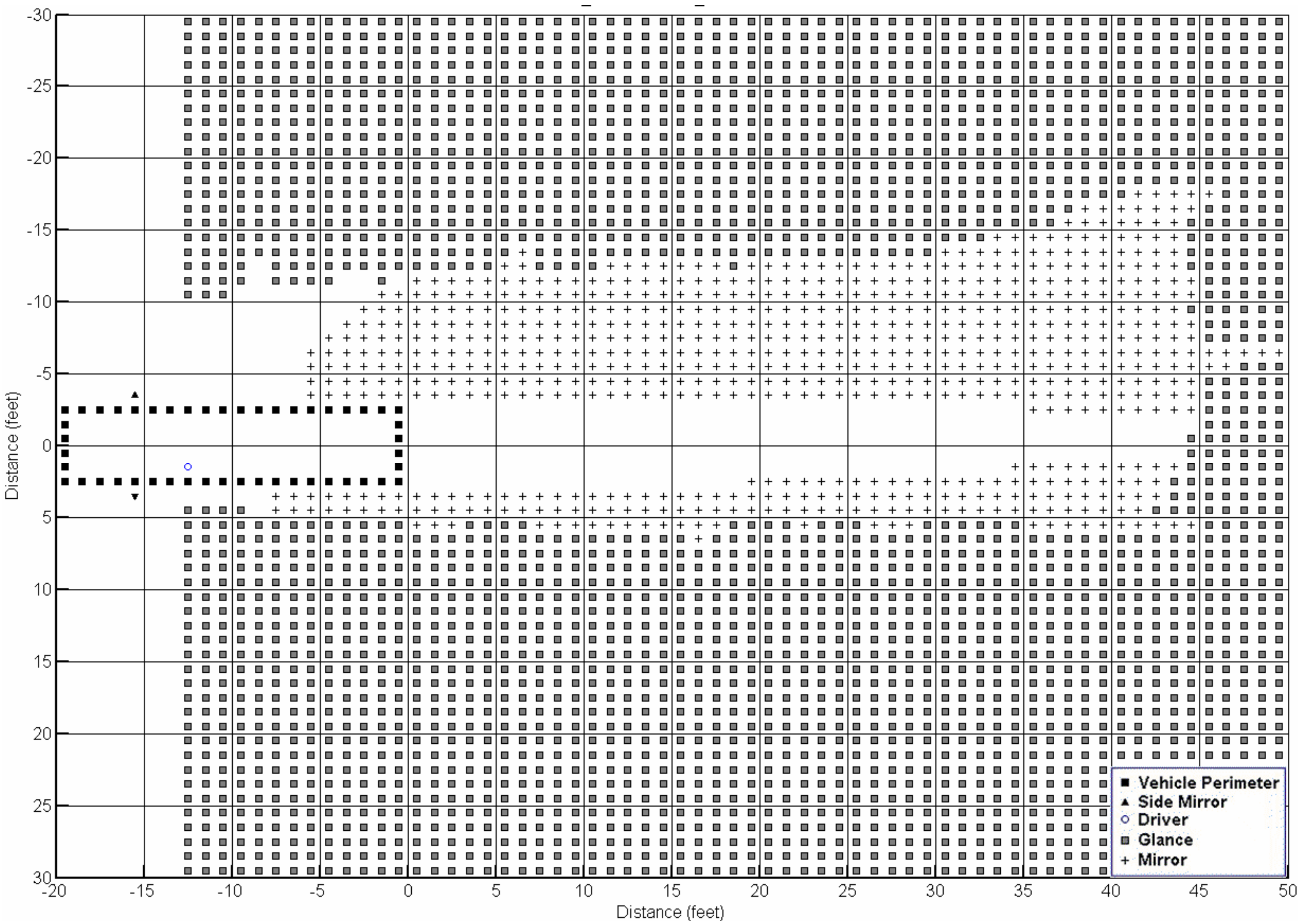


Figure 98. FOV Plot for a 2004 GMC Savanna with 5th Percentile Female Driver

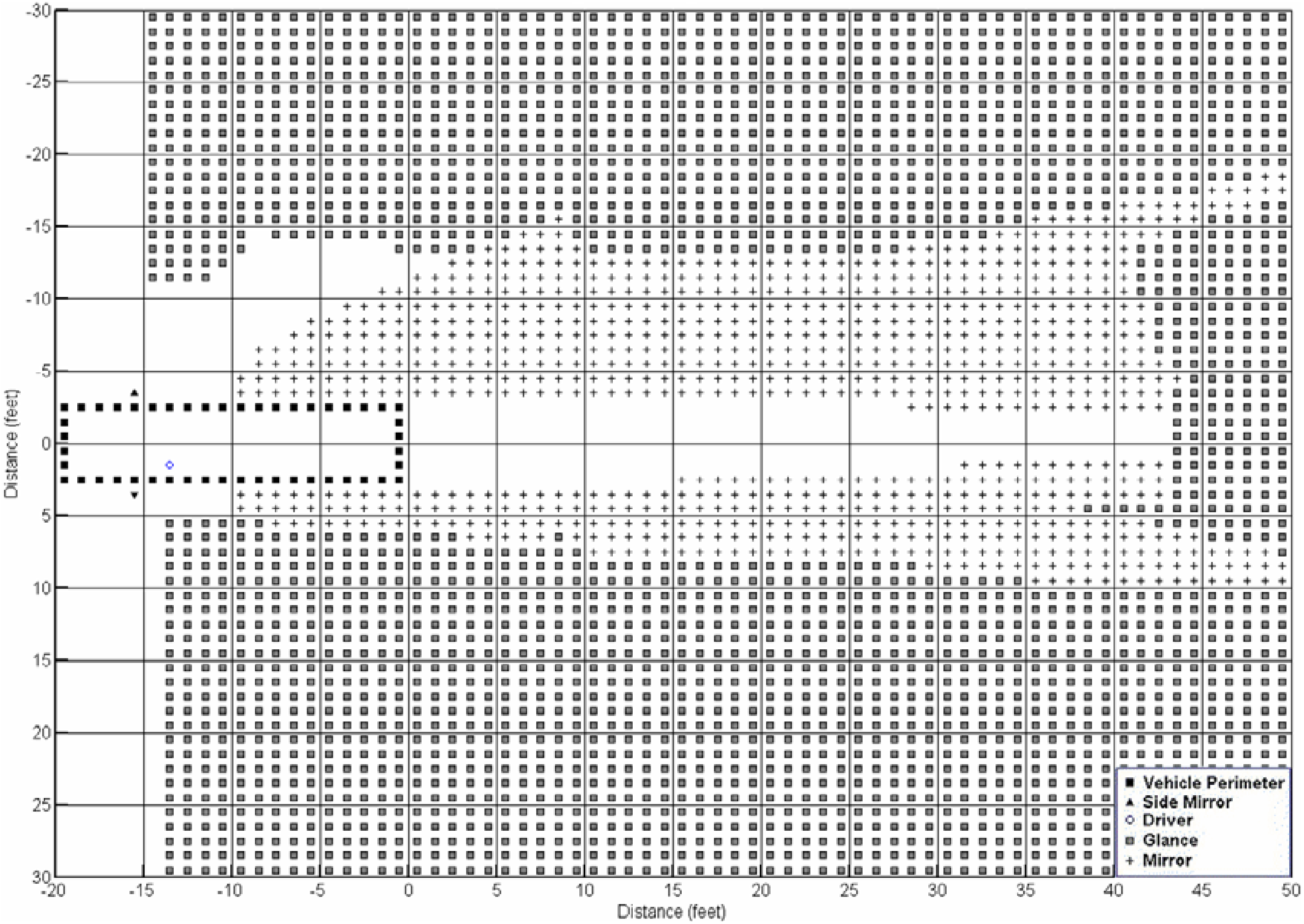


Figure 99. FOV Plot for a 2007 Honda Odyssey with 50th Percentile Male Driver

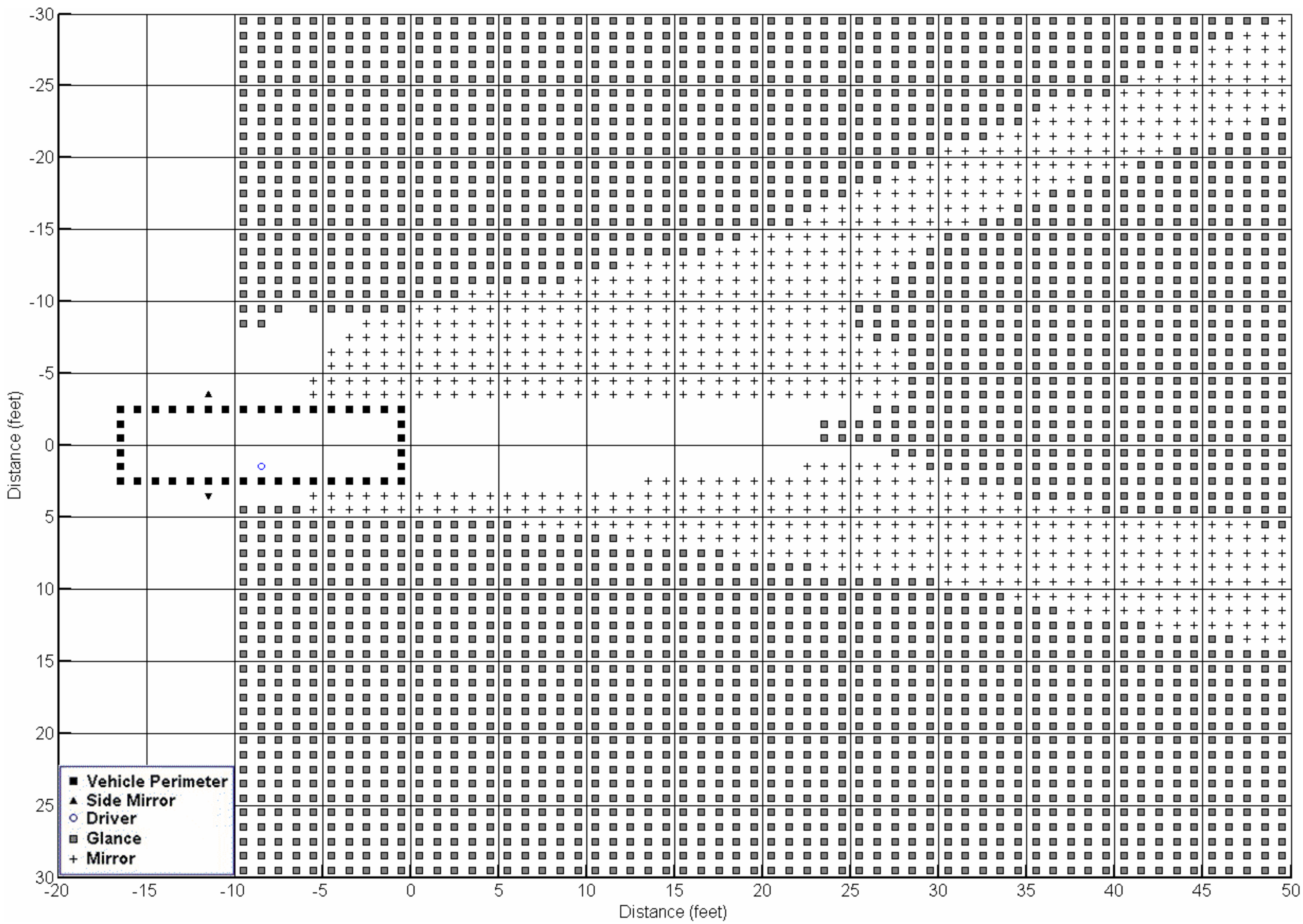


Figure 100. FOV Plot for a 2007 Honda Odyssey with 5th Percentile Female Driver

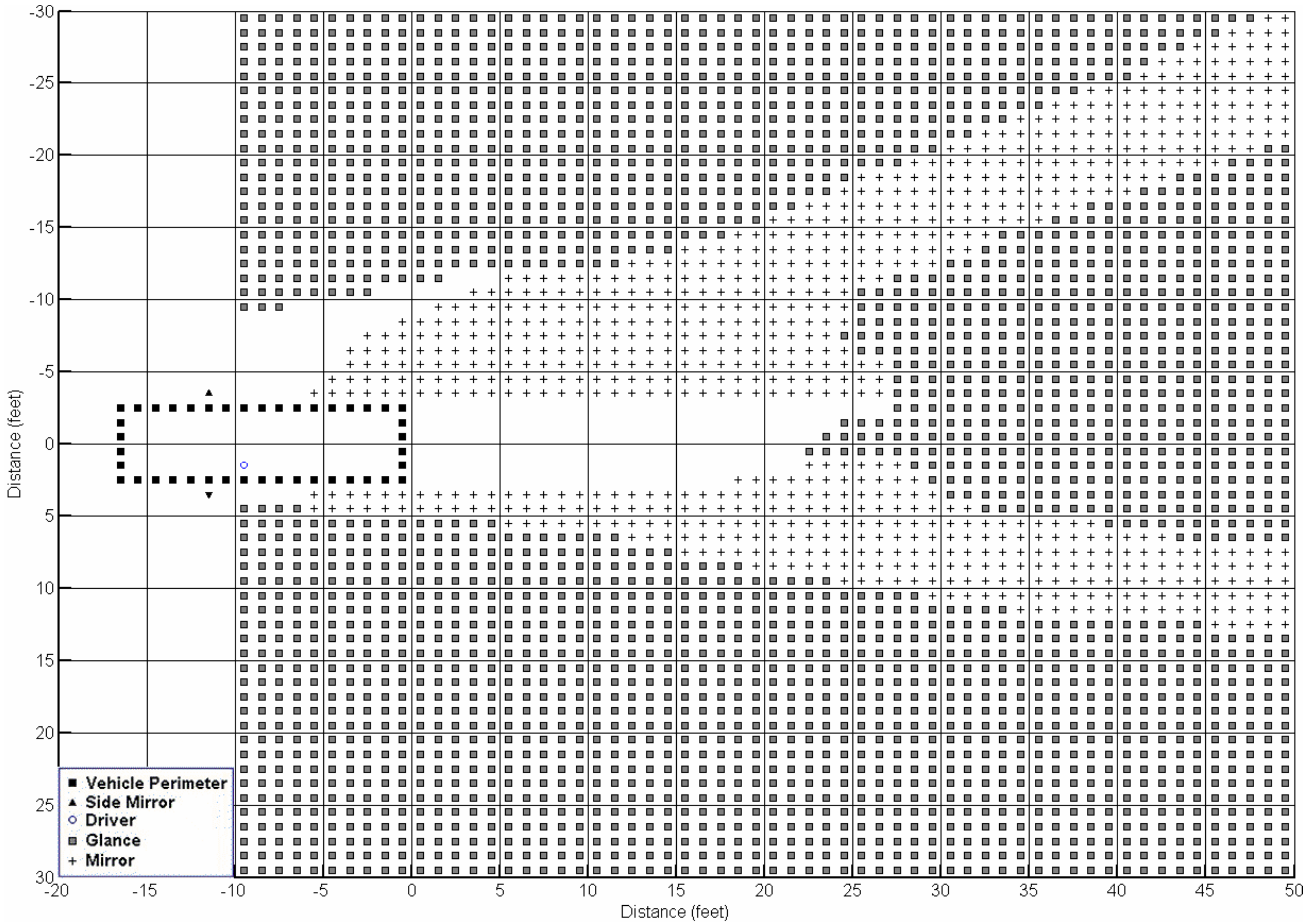


Figure 101. FOV Plot for a 2007 Honda Odyssey Rearview Video System

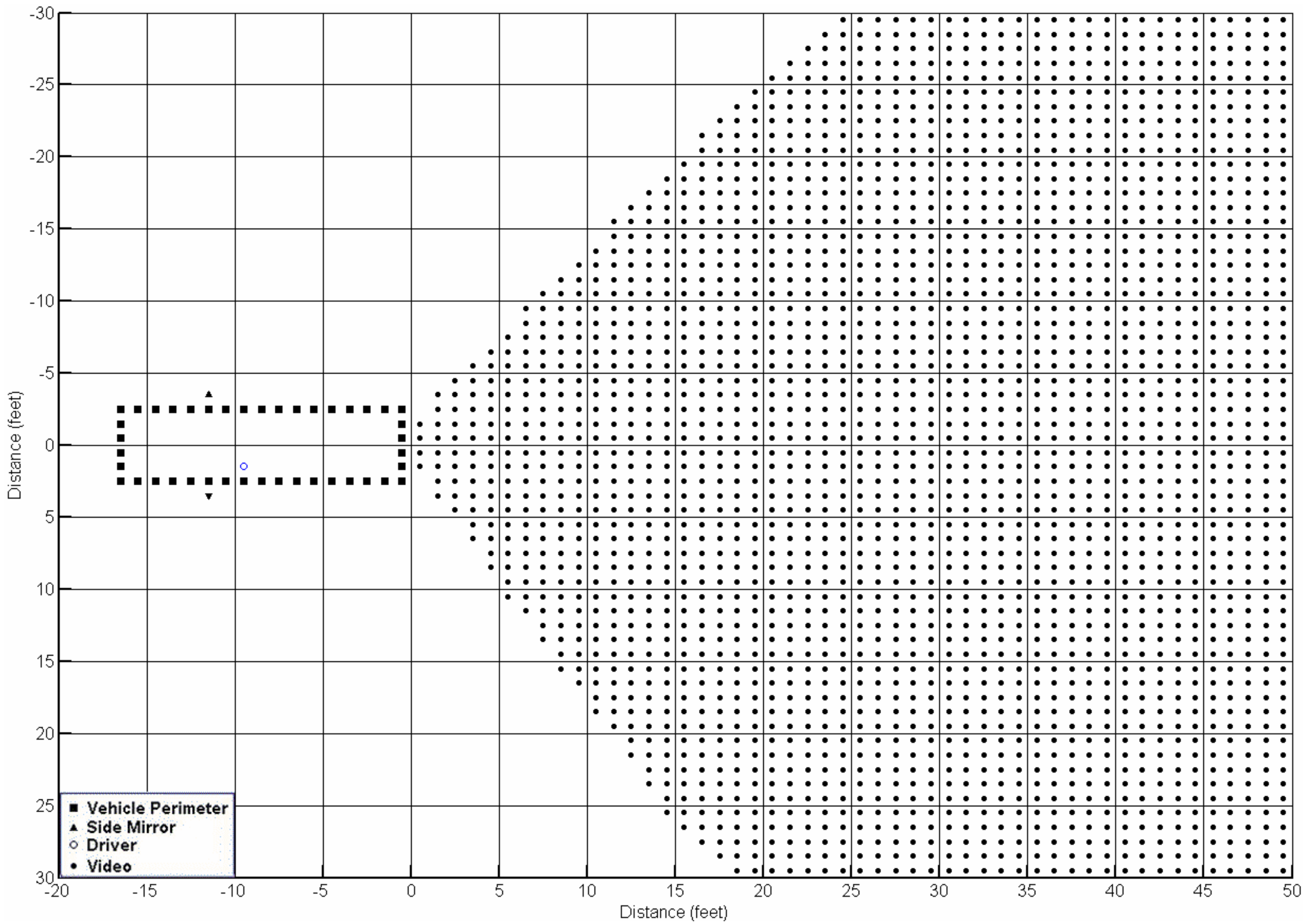


Figure 102. FOV Plot for a 2007 Kia Sedona with 50th Percentile Male Driver

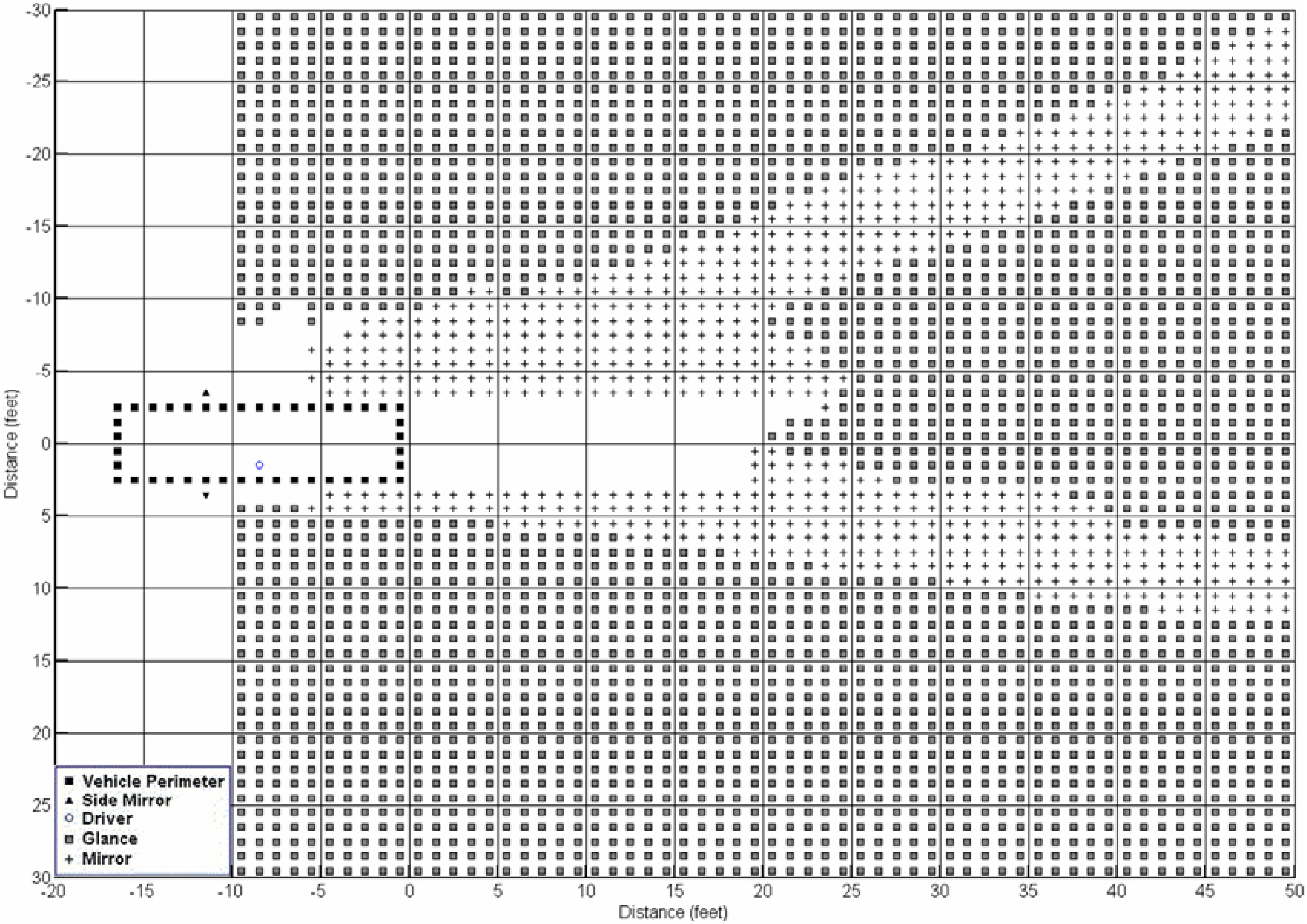


Figure 103. FOV Plot for a 2007 Kia Sedona with 5th Percentile Female Driver

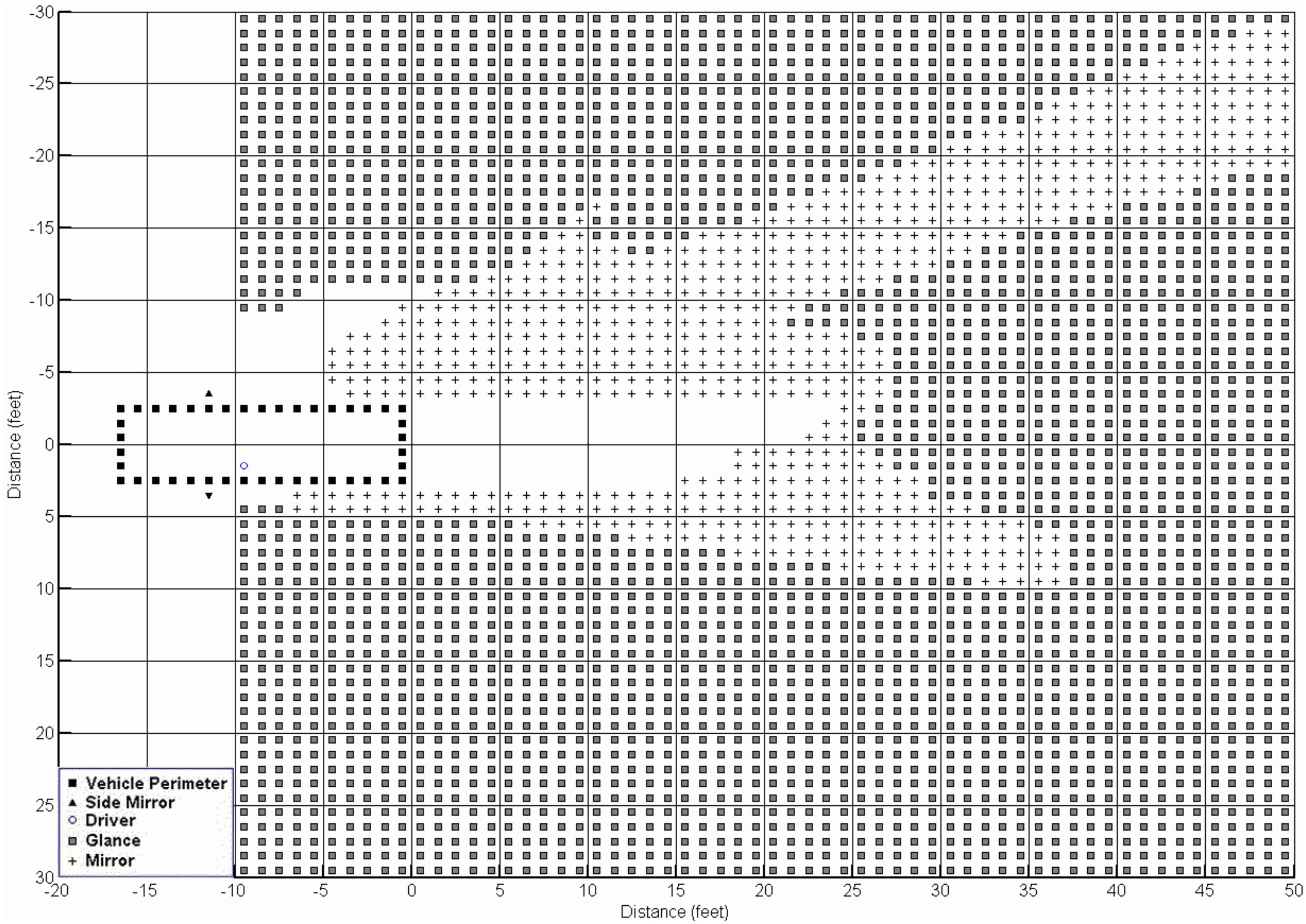


Figure 104. FOV Plot for a 2007 Mercury Monterey with 50th Percentile Male Driver

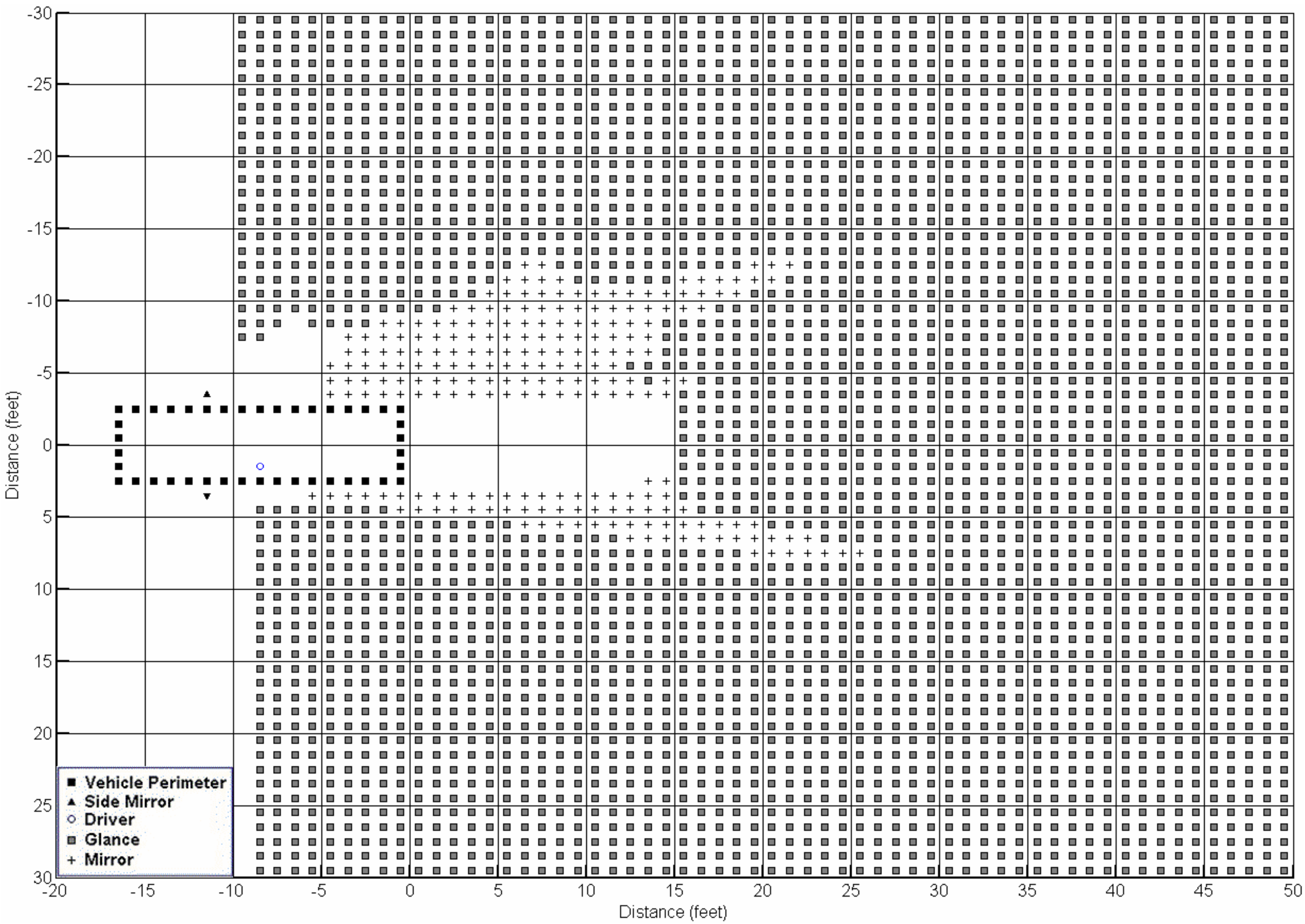


Figure 105. FOV Plot for a 2007 Mercury Monterey with 5th Percentile Female Driver

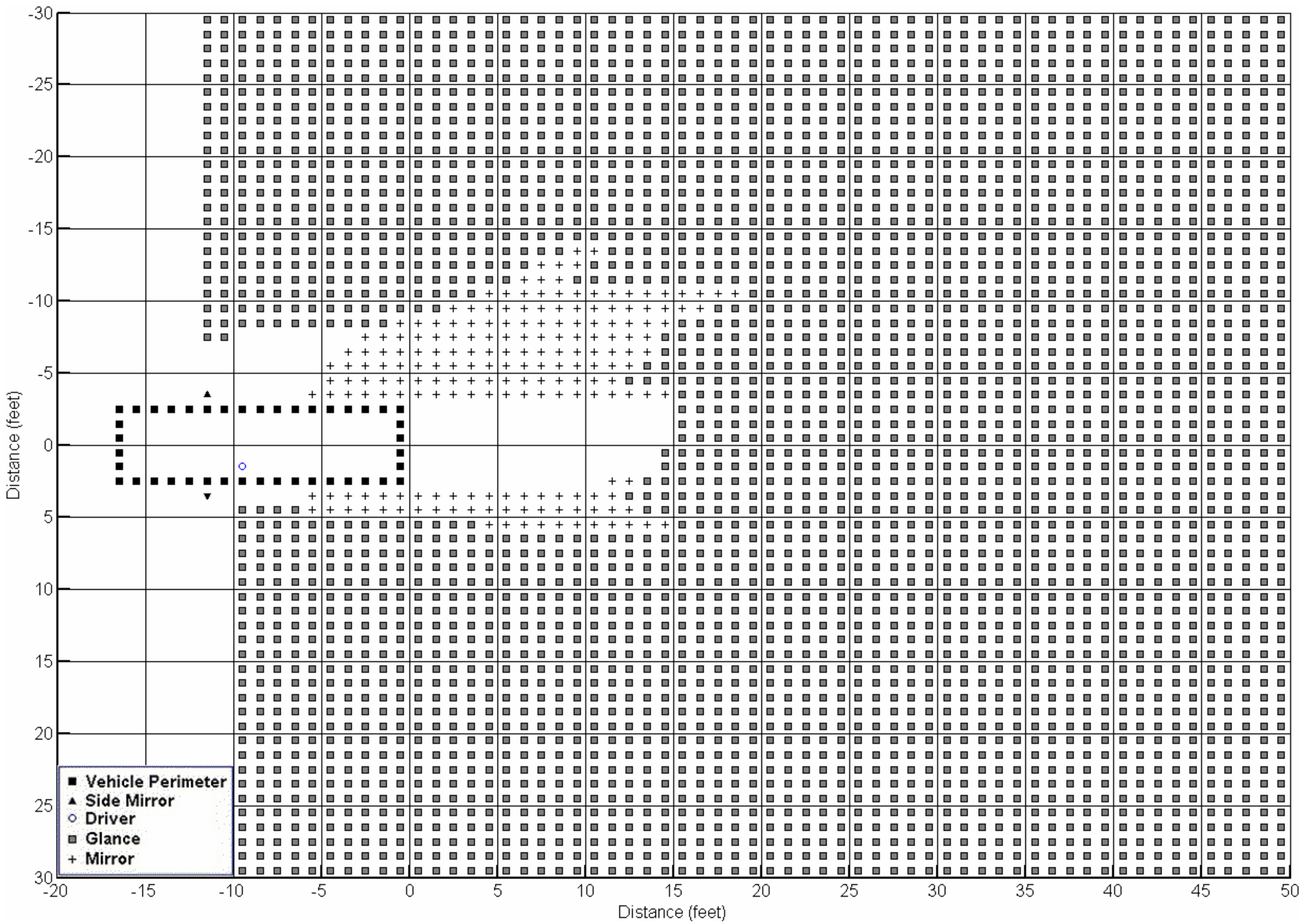


Figure 106. FOV Plot for a 2007 Toyota Sienna LE with 50th Percentile Male Driver

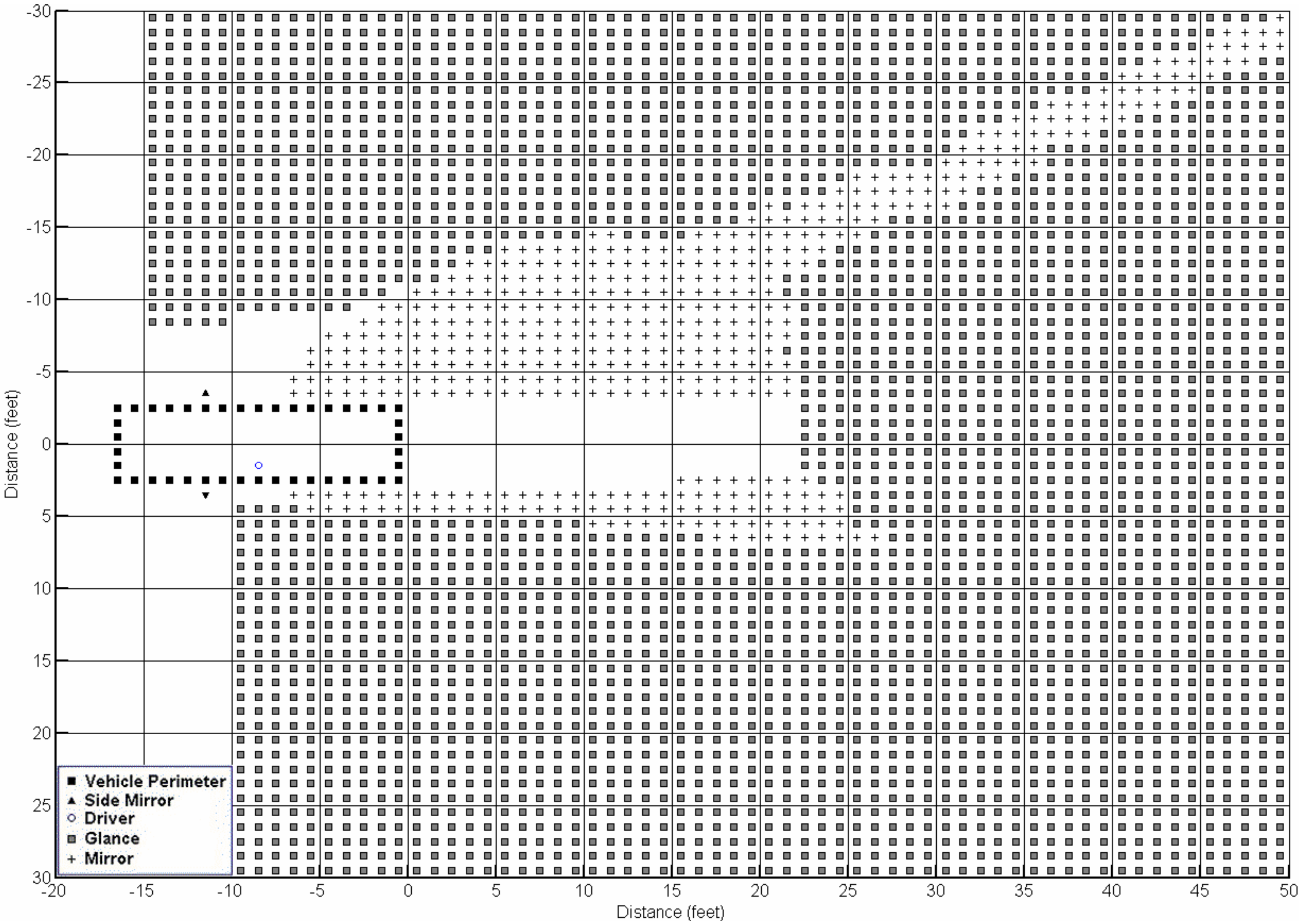
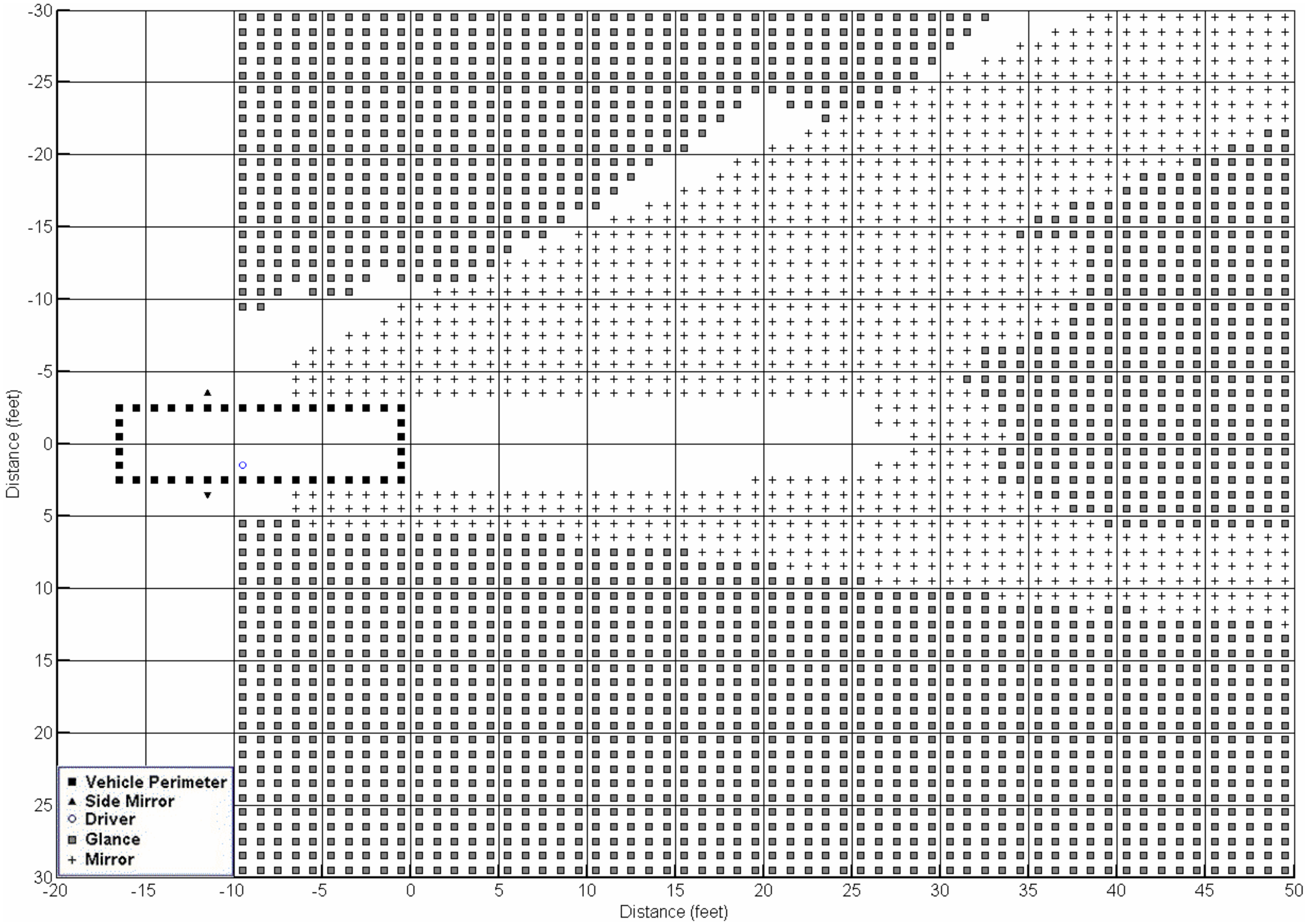


Figure 107. FOV Plot for a 2007 Toyota Sienna LE with 5th Percentile Female Driver



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**National Highway
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