Department of Computer Science

November 1993 Fort Carson RSTA Data Collection Final Report

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Technical Report CS-94-118

August 5, 1994

Colorado State University

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August 5, 1994

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[1] This work was sponsored by the Advanced Research Projects Agency (ARPA) under grant DAAH04-93-G-422, monitored by the U.S. Army Research Office.

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1 Introduction

This report describes the data collected between November 1st and 4th at Fort Carson, Colorado. It includes a copy of the original data collection plan, a detailed description of the actual data collected and examples of the data. Members of the BAA-9301 RSTA community can acquire the data from the Martin Marietta FTP server. Detailed descriptions of the image files may be found at the front of Section 3 below.

This data meets all the basic minimum requirements to permit algorithm testing under conditions as set forth in the RSTA scenario specified in the original BAA-9301 presented to the RSTA community. Specifically, this report presents FLIR, LADAR and Color imagery for military vehicles positioned in natural terrain. As a compromise to generate comparable LADAR data to that called for in the original RSTA scenario, vehicles are placed considerably closer to the sensors. This is because the Alliant Techsystems LADAR lacks the range and resolution called for in the planned RSTA LADAR. Modestly wide angle lens are used with the FLIR and Color cameras so that 'pixels on target' values are comparable to those expected in the 0.5 to 1.0 kilometer range with the RSTA sensor suite.

Every effort has been made to make this report accurate. However, as the data collection plan will make clear, this effort was mounted quickly and with only a fraction of the support typically dedicated to data collection efforts. Consequently, there are gaps, omissions, and almost certainly a few errors in the transcriptions of the field notes. For example, the laser range instrument used to gather ground truth ranges to vehicles required manual selection of the 'peak' return values. This was difficult to do, and the comparison of LADAR data with these ground truth measurements presented in Section 3.13 below indicate these ground truth numbers appear to be accurate in some cases and not in others.

The data set presented here contains 39 distinct LADAR, FLIR and color sensor triples obtained from 10 different vehicles arrays. The different vehicles arrays include vehicles in full view, partially occluded and at odd angles to the sensors. It is hoped there is sufficient variety in this imagery to push the limits of all algorithms under development as part of the RSTA program.

2 Data Collection Plan

A data collection effort has been mounted by Martin Marietta (MMC), Colorado State University (CSU) and Alliant Techsystems (ATK) in order to meet immediate needs of the the Surrogate Semiautonomous Vehicle (SSV) Program, Reconnaissance, Surveillance and Target Acquisition (RSTA) effort. The collection is planned for the first week in November at Fort Carson. Testing of sensors and some data collection is also planned for the week prior at the MMC site. At Fort Carson, the Ft. Carson Colorado Army National Guard (CANG) Depot has offered to make several vehicles available and provide drivers who can place the vehicles on the CANG test range.

The data collection effort is highly constrained in terms of time, resources, vehicles and terrain. These constraints have lead it to be dubbed the 'hobby shop' collection, and it is important to keep expectations commensurate with the constraints. That said, the data collection effort will be of great value if it can provide data of similar form and character to that which will be produced by the SSV RSTA sensor suite.

2.1 Objectives

The objective of the data collection is to get data as similar as possible to that which will be produced by the SSV RSTA sensor suite under the Demo B, Demo C and Demo II scenarios of the UGV Demo II program. First and foremost, this means the data collection must involve comparable vehicles, sensors, and terrain.

2.1.1 Vehicles, Sensors and Terrain

The types of vehicles to be viewed are those which might be seen during a RSTA scouting mission. Currently it is expected that four vehicles will be available for the data collection: (1) an M113 APC, (2) an M113 TOW missile carrier, (3) an M-60 Tank, (4) a HMMWV or, if not available, a military pickup truck.

The RSTA sensor suite planned for use in the Demo II program has three sensors: a FLIR, a LADAR and a color CCD camera. In the hobby shop data collection, FLIR data will be collected using the same 3-5 micron AMBER FLIR planned for use in the RSTA sensor suite. Color imagery will be taken using both video and still photography. Collecting LADAR data of similar character to that which will be produced by the yet unbuilt RSTA LADAR is more difficult. The Alliant Techsystems LADAR will be used to collect data, and targets will be placed closer to the sensor in order to get target resolution - 1 pixel per foot on target - comparable to that planned for with the RSTA LADAR at 1km. The Alliant Techsystems LADAR has sufficient range accuracy to provide useful interior detail working at the 1 pixel per foot on target range.

The terrain at the Fort Carson site consists of low hills, open areas, with low-lying desert shrubs, occasional large shrubs and even more occasional trees. This site is not as interesting in terms of terrain features as the MMC test site. However, it is a largely natural setting in a broad sense similar to both the Denver and Fort Hood sites. The Fort Carson site is not large enough to support collection of data at the roughly 1km range planned for the RSTA scenarios. However, with appropriate choice of lenses, FLIR and CCD data comparable to that expected at 1km with the RSTA suite can be acquired.

2.1.2 Uses for the Data

The possible uses of the data produced from this data collection include:

- Multi-sensor matching / fusion
- Specific recognition algorithm testing
- Developing ROC
- Image Stabilization
- Stereo Algorithm Development

The hobby shop data collection should provide data useful to those interested in LADAR and FLIR sensor fusion. The hobby shop data should also serve the needs of those wishing to test specific recognition algorithms. Because of time and resource constraints, hobby shop collection will not provide a large volume of data, and it is probably not going to warrant major statistical performance analysis.

Image stabilization and stereo will not be addressed with the data collected at Fort Carson. However, in the week prior to the Fort Carson collection, October 25 through 29, the MMC team will attempt to collect FLIR data of moving vehicles at ranges of 500m to 1 Km as well as FLIR from a moving vehicle. The MMC team may also make an attempt to gather some limited multiple baseline stereo imagery. During the last week of October the MMC team will also use the AMBER FLIR to image some stationary targets at ranges of 500 m to 1 Km. Ground truth range to vehicles will be recorded using a laser range finder with accuracy in the +/- 1 ft range. The vehicles used during the MMC collection at their Denver site will be employees cars and jeeps, and if possible, a HMMWV being modified for Demo B will be used. (The HMMWV is under mechanical modification and may not be available.)

2.1.3 Variability

The RSTA effort needs to set forth those areas in which it is going to qualitatively advance the current state-of-the-art. Two forms of variability which cause trouble for most all of the current algorithms proposed for RSTA are variation in viewing angle and occlusion. Therefore, data will be collected which pushes each of two these dimensions.

2.1.4 Varying Occlusion and Viewing Angle

Here are the four basic types of imagery which will be collected:

1) Full view un-occluded targets.

2) Hull-down occluded targets.

3) Side occluded targets.

4) Targets at unusual aspects relative to the sensors.

The full view un-occluded targets are intended to serve as a RSTA baseline. The intention is to try to setup these images in a manner analogous to much of the data currently studied by the ATR community. Current ATR algorithms of good quality should be capable of handling this data. Included in this imagery will be some images containing NO vehicles in order to test for false alarms. The other three types should contain data which can not be handled successfully using only current ATR techniques. Therefore, this data will provide an initial benchmark for progress within the RSTA effort.

In the case of occlusion, imagery will be taken with occlusion varying from between about 40 and 75algorithms breakdown at the 50provide some test cases against which to calibrate performance. The hull-down occlusion is qualitatively different from side occlusion, so these two will be treated separately.

The hull-down occlusion data will be acquired by placing vehicles in depressions. As a practical matter, this may limit the amount of variation which can be generated. Another option may be to obtain a sequence of images of a vehicle coming over a rise. This would generate a series of successively less occluded views.

Side occlusion will be generated by moving vehicles out from behind cover. At the Fort Carson site, this is likely to be accomplished by initially hiding a vehicle in a side canyon and then moving it out of the mouth of the canyon. Unfortunately, the canyons are really only shallow washes, and so the viability of this scenario will have to be checked against the terrain cover available at the site.

The fourth type of data of interest is vehicles at unusual orientations to the sensors. In essence, this means a vehicle going up, down, or alongside a far hillside. There are opportunities to collect such data at the Fort Carson site.

As the opportunity arises, variability with respect to internal structure will be exercised in the occluded and unusual aspect data sets. Specifically, an attempt will be made to acquire images with doors opens, turrets rotated to different positions.

2.1.5 Dimension Over Which There is Little Control

There are a number of important dimensions worth mention, but over which the hobby shop data collection will have little control.

Changes in location Issues of varying target pose and occlusion has already been addressed above. This is one of the major dimensions upon which a variety of data will be collected. However, the Fort Carson

Clutter The Fort Carson site limits the ability to introduce moderate amounts of clutter such as trees, large boulders, etc. The terrain consists of dirt roads, dirt tracks up hillsides, grassy areas with low desert shrubs and occasional larger shrubs and trees. Features such as large boulders and single buildings which would add clutter to the scenes are not present. As mentioned above, there are houses visible in the far distance from some vantage points.

Elevation Changes The Fort Carson site does permit the placement of sensors on hills which are about 20 meters above the surrounding fields. This will afford the sensors a view looking slightly down on the vehicles. It may also be possible to place vehicles on the sides of surrounding hills and thus vary their aspect to the sensors.

Image Backgrounds It will take careful sensor positioning to avoid imaging large developed areas at the Fort Carson collection site. This constrains the possible vantage points for the sensors and likewise the possible terrain backdrops. Some of the imagery will have suburban areas in the far background, 5 to 8km. Also, Pikes Peak will be in the background for some shots.

Shadows There aren't many features which cast shadows on the test site, so the data collection will be limited in its ability to test this source of variability.

Thermal Variations The hours during which data can be collected with CANG support are 6am to 3pm. Thus, data will be collected during these times, but there will be no opportunity to vary only the time-of-day temperature profile. To be specific, there isn't time to shoot the same vehicles in the same positions at 3 or 4 different times of the day.

Weather Only a limited time window is available and short of rain or snow, data will be collected under the prevailing conditions.

Vehicle Types The effort is limited by what CANG has on hand and our status as guests - CANG cannot be asked to start driving every different kind of vehicle out to the collection site.

2.1.6 Ground Truth

Given the constraints under which the hobby shop data collection is being conducted, limited ground truth will be available. The range from each sensor to the nearest point on each target will be recorded. This will be done with a laser range finder which is accurate to +/- 1/10 of a foot. At present, there does not appear to be a Theodolyte available for the data collection, and this limits the ability to get accurate aspect angles and relative orientation measurements.

Ideally, the orientation of the vehicles relative to the sensor would be recorded. If there appeared to be a means of acquiring this information which was both feasible in terms of time and promising in terms of accuracy, then it would be pursued. One possibility would be to record range from sensors to three designated points on each vehicle. Whether the resulting range measurements would be accurate enough to precisely infer the vehicle's pose relative to the sensor is a matter still under consideration.

An inclinometer will be brought to the Fort Carson site. This will definitely be used to level the sensors. An effort will also be made to use it to record the the extent to which the vehicles are not level with the ground plane (gravity). However, doing this will be contingent upon finding a horizontal point of reference on each vehicle.

A thermometer for reading the surface temperature of objects will be brought to the Fort Carson site and used to take some reference readings on targets.

The relative geometry of the FLIR, color video and color 35mm cameras will be fixed by mounting all three sensors on a single surface, and placing this atop a tripod. The relative placements in this mounting will be recored. The LADAR will be mounted upon a separate tripod. The relative position, x y and z, of the LADAR relative to the other sensors will be recorded. Every effort will be made to have all sensors level and pointed in the same direction.

A 35mm camera which is not part of the data collection will be used to record the relative positions of sensors and vehicles during the data collection. This will provide and additional record of how sensors and vehicle were placed both relative to each other and relative to terrain.

Rough sketches of the sensor positions, target vehicle positions, and surrounding terrain will be made to accompany each set of data. Measurements of range to targets, and other data such as can be collected, will be indicated on these drawings.

2.1.7 Image Registration

Given the sensor setup just described, the images from different sensors will be registered in only the most approximate sense. Every effort will be made to construct overlapping fields of view. However, the images will not be registered. Moreover, the placement of the LADAR relative to the other sensors may each time one or more of the sensors is moved.

2.1.8 Sensor Calibration

Each sensor will either be calibrated prior to the data collection or special test data adequate to perform calibration will be taken at the Fort Carson site.

2.1.9 FLIR Calibration

The optic, focal length etc., of the Amber FLIR will be calibrated using the same geometric test pattern which will be used to calibrate the color video and 35mm cameras. It is doubtful that a calibrated thermal source will be available to provide thermal calibration for the FLIR at Fort Carson. However, if it should be possible, a 'hot plate' will be brought to Fort Carson.

2.1.10 LADAR Calibration

The LADAR will be Calibrated prior to shipping to Fort Carson. Additional efforts will be made to check calibration at Fort Carson. However, there are a limited number of suitable flat surfaces on the site, and the exact means of performing this calibration is still under consideration.

2.1.11 CCD Color Video and 35mm Calibration

Images of a geometric test pattern will be shot each day at Fort Carson. From these images it will be possible to derived the focal length, image center, horizontal and vertical field of view. Exact details as to which pattern will best serve this purpose are under discussion.

Color images of a color test chart, the Macbeth Checker Board, will be taken to provide some baseline information on the color sensitivity of the color sensors.

2.2 Logistics of Data Collection

Members of the team from MMC, CSU and ATK will meet Sunday night, October 31st in Colorado Springs. Data collection will begin at Fort Carson staring at 6:00am Monday morning. A schedule for the the three days of data collection is presented in the following section. Keep in mind several things when reading this schedule. First, it is constrained by the need to impose on CANG. They are willing to move vehicles about once every two hours, but at this point in time we doubt they would be able to move them more frequently.

2.3 Risk Factors

The principle risk factor is weather. It can easily snow in November in Colorado, and snow on the ground would provide FLIR data of truly unusual character. A second weather related risk is that if the ground is wet, the National Guard is reluctant to move vehicles off the roads. Consequently, we'll have data of vehicles on roads only, and this lacks authenticity and restricts our ability to vary occlusion and viewpoint.

A third risk factor concerns the sensors. Only the color CCD is being collected through two redundant sensors: video and still frame camera. If anything should go wrong with either the AMBER FLIR or the Alliant Techsystems LADAR it would not be possible to collect the corresponding data.

3 Data Collection Results

This section catologues the data and the conditions under which it was acquired. This introduction reviews key information. FLIR, LADAR and Color data is available for stationary vehicles arrayed in different configurations. For the stationary vehicles, imagery from all three sensors is available for each vehicle. These images are not registered, but have overlapping fields of view and tend to place a specific vehicle at the image center. File naming conventions are based upon the date and time of day. For example, 'nov10900' is a file collected at 09:00 hours on November 1st. The suffix 'f' will indicate a FLIR image, 'l' a LADAR image and 'c' a color image.

FLIR and LADAR images are stored in both viff and arf formats. The viff format is used in conjunction with the Khoros system and these files have a '.xv' suffix. The arf images are in the Night Vision Labs arf format and have a '.arf' suffix. The FLIR images are 256x256 images with up to approximately 14 bits of data. The LADAR images are 120x24 with up to 12 bits of data. The color images were taken with a 35mm camera shooting Extachrome 100 Elite slide film and then digitized onto Kodack Photo-CDs. Subwindows, 480x720 pixels, of the 512x768 photo-CD images have been converted to viff RGB image format. Up to 4 times higher resolution color data is available from the photo-CDs.

The LADAR Under normal operating conditions logs an image sequence. In the viff files only the first in this sequence is stored. In the arf versions multiple frames are stored. The naming convention includes a number following the 'l' indicating the number of frames present in the sequence.

LADAR images are typically duplicated, and this is an artifact of the way the data was collected and logged. While in the field, different range specifications were used to alter the appearance of the LADAR imagery as displayed in the field. Typically, a pair of images would be shot for each vehicle. One a long range shot, for instance 100 to 1000 feet, and the other a tight range shot. For example, a shot ranged between 350 to 400 feet for a target at roughly 375 feet. The raw data in the image files are the same in each case, and hence two files will often exist with essentially the same data. The different range values used to view the images in the field are indicated in the table next to each image, and it should be noted that the tight range shots provide a good indication of the range to the target. Apologies are made for confusion this might cause, but both images are kept here for the sake of completeness.

3.1 Relative Sensor Placements

The color video, FLIR and 35mm camera were all rigidly mounted to a single tripod. Therefore, the relative geometry of these sensors did not change. The LADAR was mounted on its own tripod and the distance, measured laterally, between these sensors varied from day to day. This distance was measured to within an inch each day. Figure 1 shows the relative placement of the three sensors for each of the four days of data collection.

In a few cases noted below, the LADAR had to be moved several feet in order to get a clear view of a vehicle. The relative placement of the laser ranging device used to survey the distance to vehicles is also shown. The distance between this device and the other sensors is approximate.

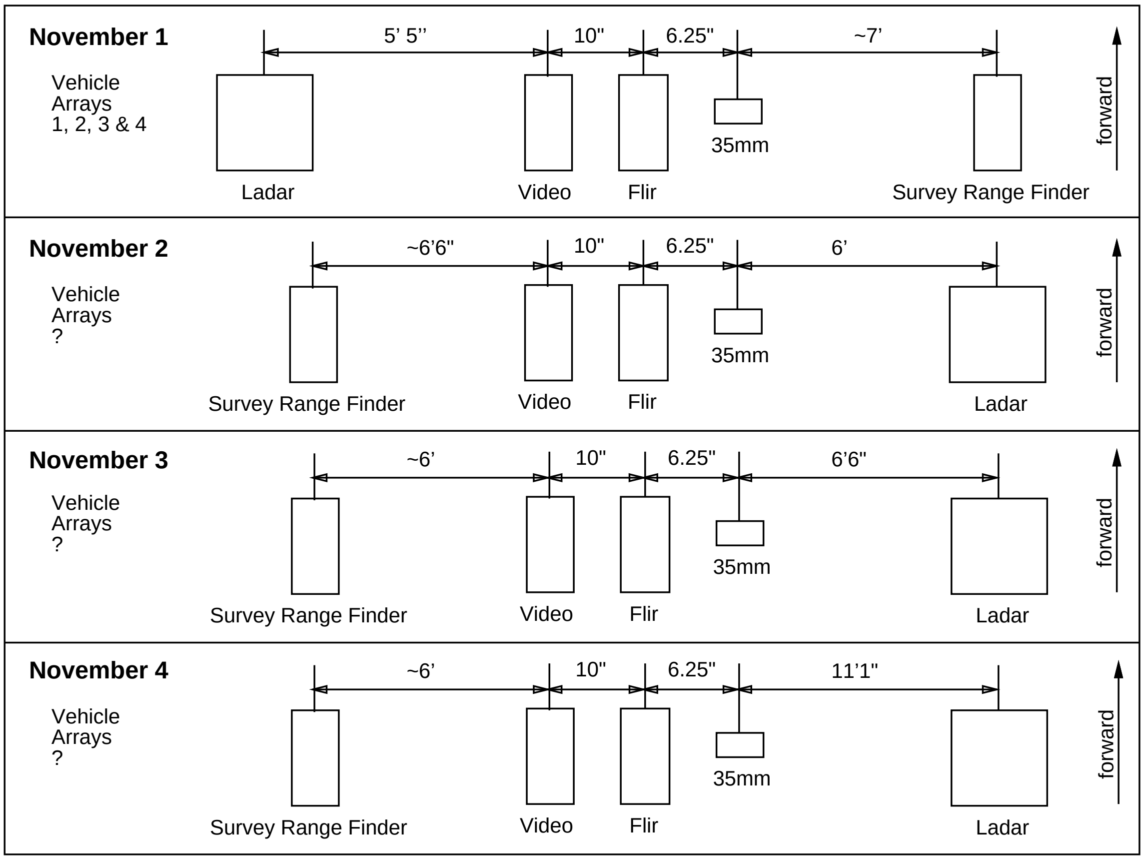


Figure 1: Sketch of relative sensor placements on each day of data collection.

3.2 Vehicle Array 1: Front-on from Hill

This was the first vehicle array for November 1st. The vehicles were all pointed approximately at the sensors and viewed from atop a small hill. Range to vehicles varied between about 390 to 415 feet. Figure 2 shows a sketch of the vehicles relative to the sensors. This sketch is **not** to scale and is only intended to indicate relative placements and relationships to features such as trees and roads.

Notes:

- Vehicles were running until roughly 9:15..
- The turret on the tank was rotated 15 degrees right on the M60.

- Weather was cloudy with a high overcast. The temperature was 40 degrees at 8:00 and 52 by 9:00.
- Wind out of the west about 5 knots at 9:00.

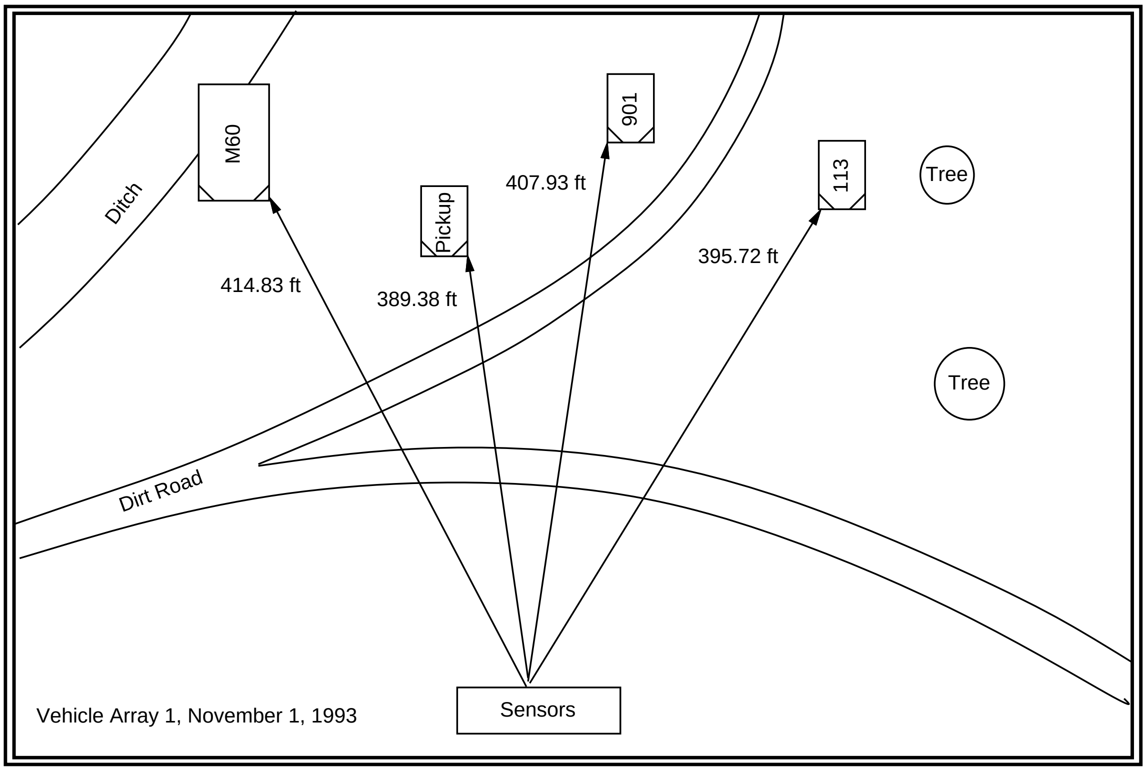


Figure 2: Vehicle Array 1: Front on from hill. This is the first array shot on the morning of November 1st.

A listing of all images taken with this array is given in Table 1. This table is subdivided into a raw accounting of imagery acquired with each of the three sensors followed by a final table indicating which triples can be used to get similar LADAR, FLIR and color views of the same targets.

The vehicles were surveyed using a laser range device accurate to within about 1 inche. A reflector was placed upon the nearest point of each vehicle and the measurement made between a point roughly seven feet north of the sensors and this reflector. The intent was to place the surveying point on a line formed by the other sensors. The measurements to vehicles for vechicle array 1 are given in Table 2.

3.3 Vehicle Array 2: Side-on from Hill

This was the second vehicle array collected on November 1st. The vehicles are in positions similar to those in array 1, but they have been turned to present their sides to the sensors. Range to vehicles varied between about 390 to 420 feet. Figure 3 shows a sketch of the vehicles relative to the sensors. The orientation of the sensors and vehicles with respect to magnetic north is also indicated on this sketch.
Notes:

- Vehicles not running.

LADAR			
File	Video	Comment	Range
nov10900l		Tank	410-430
nov10902l	0-20	Tank	350-450
nov10914l	22-40	Pickup	385-405
nov10916l	46-106	Pickup	350-450
nov10921l	111-140	901	405-425
nov10927l	140-210	901	350-450
nov10930l	210-241	M113	390-410
nov10933l	241-312	M113	350-450
nov10937l	312-340	M113, Trees and Slope	390-410

(a)

FLIR	
File	Comment
nov10903f	Image of all four vehicles
nov10935f	After pickup cooled for about 15 minutes
noise1...10f	10 images of same scene in 2 minutes
cal11-1	Geometric calibration image
cal211-1	Second geometric calibration image

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov10900c	MMC Geometric Calibration	1	3	F-8	1/60	1-1
nov10901c	UMass Geometric Calibration	1	4	F-8	1/60	1-2
nov10902c	UMass Geometric Calibration	1	5	F-8	1/60	1-3
nov10903c	Image of all four vehicles	1	6	F-8	1/60	1-4
nov10904c	Image of all four vehicles	1	8	F-8	1/30	1-5

(c)

Table 1: Images for Vehicle Array 1: a) listing and description of LADAR images, b) listing and description of FLIR imagers and c) listing and description of color images.

Vehicle Positions Ground Truth		
Vehicle	Description	Measured
M60	From sensors to nearest point.	414.83 (415)
Pickup	From sensors to nearest point.	389.38 (389)
M113-901	From sensors to nearest point.	407.93 (410)
M113	From sensors to nearest point.	395.72 (399)

Table 2: Ground truth measurements for Vehicle Array 1. The second measurements in parenthesis are recorded from the LADAR. The differences for the M113-901 and M113 may be explained by placement of LADAR farther from these vehicles.

- The turret on the tank was rotated 15 degrees right on the M60.
- Weather still cloudy with a high overcast. Temperature still in the low 50's, wind still building slightly and now 5 to 10 knots.

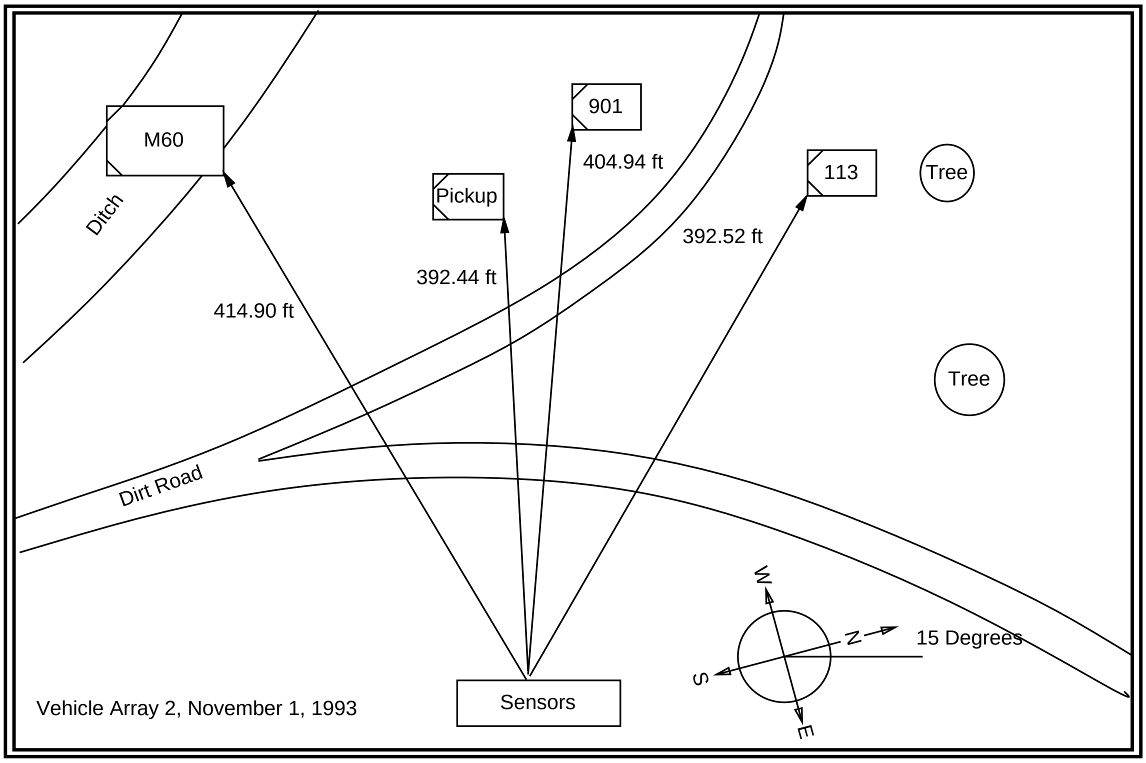


Figure 3: Vehicle Array 2: Side-on from hill. This is the second array shot on the morning of November 1st.

A listing of all images taken with this vehicle array is given in Table 3.

The survey results for vehicle array 2 are summarized in Table 4. For the M113 and M60, measurements were taken to three points on the vehicle. The nearest distance between vehicles is also recorded. In addition to the distance measurements shown, an inclinometer was used to measure the M113 with respect to gravity. The vehicle is down 2.9 degrees in the front and tilted rigth (away from sensors) by 0.4 degrees.

3.4 Vehicle Array 3: Angle-on from Hill

This was the third vehicle array collected on November 1st. The vehicles are in positions similar to those in arrays 1 and 2, but they have been turned to present their right sides and fronts. The vehicles are rotated roughly 45 degrees with respect to a front-on view. Range to vehicles varied between about 380 to 400 feet. Figure 4 shows a sketch of the vehicles relative to the sensors.
Notes:

- Vehicles started at about 11:45, heaters started at 12:00
- On the M60 the turret is pointed straight forward, barrel between 5 and 10 degrees up.

LADAR			
File	Video	Comment	Range
nov10957l	340-413	Tank	410-430
nov11001l	413-440	Tank	350-450
nov11004l	440-510	Pickup	390-410
nov11006l	510-540	Pickup	350-450
nov11010l	540-610	901	400-420
nov11013l	610-640	901	350-450
nov11015l	640-710	M113	350-450
nov11018l	710-740	M113	390-410
nov11124l	740-810	Motor Pool	460-600
nov11128l	812-841	Motor Pool	460-600

(a)

FLIR	
File	Comment
nov10955f	All four vehicles, just moved to 2nd array
nov11000f	All four vehicles pan right
nov11002f	All four vehicles pan left
nov11105f	Motor Pool
nov11137f	Four vehicles after 30 minutes of light insulation

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov10955c	All four vehicles centered	1	10	F-8	1/125	1-6
nov10956c	All four vehicles centered	1	12	F-8	1/60	1-7
nov11000c	All four vehicles pan right	1	14	F-8	1/125	1-8
nov11001c	All four vehicles pan right	1	16	F-8	1/60	1-9
nov11002c	All four vehicles pan left	1	19	F-8	1/250	1-10
nov11003c	All four vehicles pan left	1	20	F-8	1/125	1-11
nov11100c	Color Calibration	1	22	F-8	1/500	1-12
nov11105c	Motor Pool	1	23	F-8	1/500	1-13

(c)

Table 3: Images for Vehicle Array 2: a) listing and description of LADAR images, b) listing and description of FLIR imagers and c) listing and description of color images.

Vehicle Positions Ground Truth		
Vehicle	Description	Measured
M60	To right rear corner	425.82 ft
M60	To left rear corner	414.90 ft
M60	To left front corner	418.98 ft
Pickup	To nearest point	392.44 ft
M113-901	To nearest point	404.94 ft
M113	To left rear corner	392.52 ft
M113	To right rear corner	400.53 ft
M113	To left front corner	393.11 ft
M60 to Pickup	Distance between nearest points	26.5 ft
Pickup to 901	Distance between nearest points	12.5 ft
901 to M113	Distance between nearest points	33.0 ft

Table 4: Ground truth measurements for Vehicle Array 2.

- Weather was brighter from 11:00 to 12:30, cloud cover getting heavier by again by 12:30. Temperature hovering around 50 degrees.

A listing of all images taken with this vehicle array is given in Table 5.

The survey results for vehicle array 3 are summarized in Table 6. For the M113 and M60, measurements were taken to three points on the vehicle. Skin temperature readings were taken for the M113 between 12:30 and 12:50. The hull by the engine registered about 70 degrees Fahrenheit while hull temperature away from the engine was about 60 degrees. Similarly, the hull temperature on the M60 was typically around 60 degrees.

3.5 Vehicle Array 4: Partial Occlusion from Hill

This was the fourth vehicle array collected on November 1st. The sensor viewpoint is identical to that used in the first three arrays. The vehicles have been positioned in order to be partially occluded. Range to vehicles varied between about 280 to 530 feet. Figure 5 shows a sketch of the vehicles relative to the sensors.
Notes:

- Vehicles running until about 14:30.
- M60 turret still pointed forward until 14:30, then turned to point backwards.
- Air temperature still hovering about 50 degrees.

A listing of all images taken with this vehicle array is given in Table 7.

The survey results for vehicle array 4 are summarized in Table 8. For the M113 and M60, measurements were taken to three points on the vehicle.

3.6 Vehicle Array 5: Full View at Close Range

This was the first and only vehicle array collected on November 2nd. It was also left setup and again imagery was taken on the morning of November 3rd. The sensors have been moved down onto the southern most edge of the flat area in which the vehicles were placed on the previous day. This affords

LADAR			
File	Video	Comment	Range
nov11150l	911-940	Tank	390-410
nov11153l	940-1010	Tank	350-450
nov11155l	1010-1040	Tank	300-700
nov11200l	1040-1110	Pickup	300-700
nov11202l	1110-1140	Pickup	350-450
nov11206l	1140-1210	Pickup	380-400
nov11210l	1210-1240	M113-901	380-400
nov11213l	1240-1310	M113-901	350-450
nov11215l		M113-901	300-700
nov11218l	1310-1340	M113	300-700
nov11220l	1340-1410	M113	350-450
nov11224l	1410-1440	M113	380-403

(a)

FLIR	
File	Comment
nov11155f	All four vehicles, engine running 10 minutes
nov11205f	All four vehicles, engine running 20 minutes
nov11215f	All four vehicles, engine running 30 minutes
nov11230f	All four vehicles, engine running 45 minutes

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov11205c	All four vehicles, partial sun	1	27	F-11	1/250	1-14
nov11230c	All four vehicles, indirect sun	1	31	F-11	1/60	1-15

(c)

Table 5: Images for Vehicle Array 3: a) listing and description of LADAR images, b) listing and description of FLIR imagers and c) listing and description of color images.

Vehicle Positions Ground Truth		
Vehicle	Description	Measured
M60	To right rear corner	417.15 ft
M60	To right front corner	398.82 ft
M60	To left front corner	402.27 ft
Pickup	To nearest point	380.47 ft
M113-901	To nearest point	386.00 ft
M113	To right rear corner	396.31 ft
M113	To right front corner	386.00 ft
M113	To left front corner	390.42 ft

Table 6: Ground truth measurements for Vehicle Array 3

LADAR			
File	Video	Comment	Range
nov11312l	1440-1520	Tank (people)	285-305
nov11316l	1520-1550	Tank	150-600
nov11200l	1040-1110	Pickup (same as array 3)	300-700
nov11206l	1140-1210	Pickup (same as array 3)	380-400
nov11320l	1550-1620	M113-901	390-430
nov11325l	1620-1650	M113-901	250-1000
nov11345l	1650-1720	M113	505-530
nov11350l	1720-1750	M113	200-1000

(a)

FLIR	
File	Comment
nov11326f	Right 3 vehicles
nov11329f	Left 3 vehicles
nov11348f	Left 3 vehicles
nov11350f	Right 3 vehicles
nov11442f	Right 3 vehicles
nov11445f	Left 3 vehicles

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov11320c	Color calibration	2	1	F-11	1/60	1-16
nov11325c	Right 3 vehicles	2	4	F-11	1/60	1-17
nov11326c	Right 3 vehicles	2	6	F-11	1/30	1-18
nov11329c	Left 3 vehicles	2	8	F-8	1/250	1-19
nov11330c	Left 3 vehicles	2	10	F-8	1/125	1-20
nov11348c	Left 3 vehicles	2	12	F-8	1/250	1-21
nov11349c	Left 3 vehicles	2	14	F-8	1/125	1-22
nov11350c	Right 3 vehicles	2	17	F-8	1/250	1-23
nov11351c	Right 3 vehicles	2	18	F-8	1/125	1-24
nov11442c	Right 3 vehicles	2	20	F-8	1/250	1-25
nov11443c	Right 3 vehicles	2	22	F-8	1/125	1-26
nov11445c	Left 3 vehicles	2	24	F-8	1/250	1-27
nov11446c	Left 3 vehicles	2	25	F-8	1/125	1-28
nov11500c...1508c	Calibration targets	2	27...35	?	?	1-29 ... 1-37

(c)

Table 7: Images for Vehicle Array 4: a) listing and description of LADAR images, b) listing and description of FLIR imagers and c) listing and description of color images.

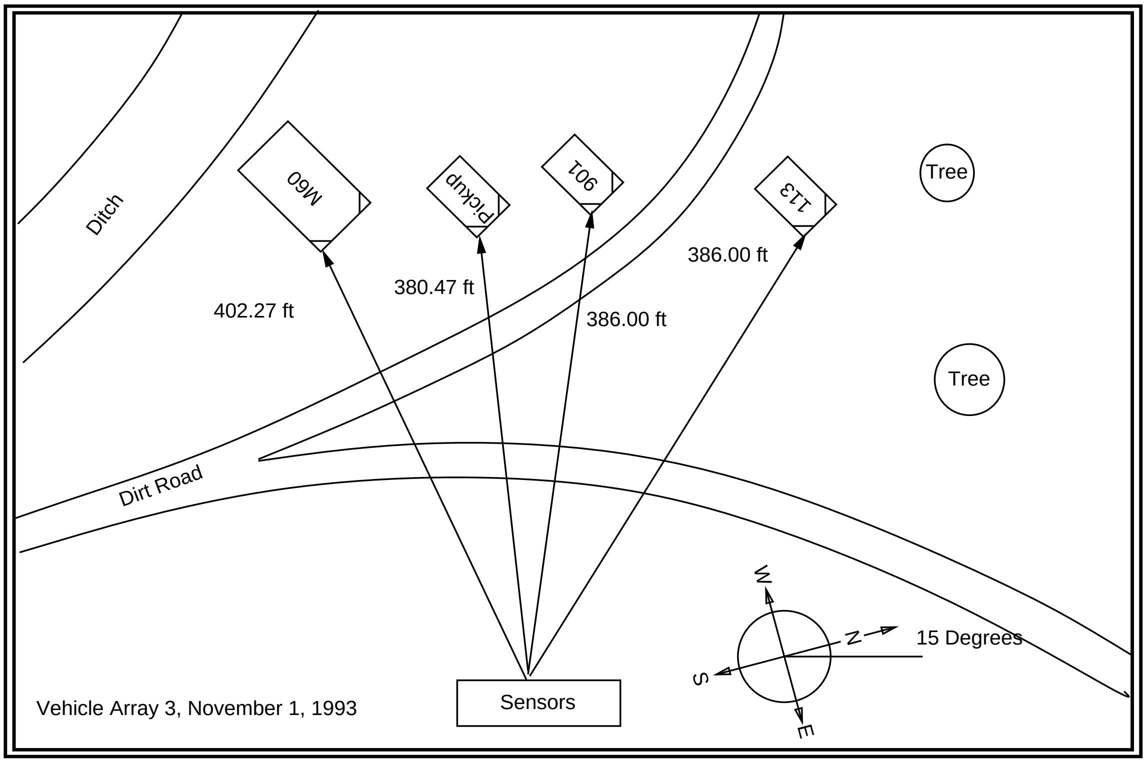


Figure 4: Vehicle Array 3: Angle-on from hill. This is the third array shot on November 1st.

Vehicle Positions Ground Truth		
Vehicle	Description	Measured
M60	To right front corner	280.92 ft
M60	To left front corner	289.88 ft
M60	To right rear corner	291.08 ft
Pickup	To nearest point	380.47 ft
M113-901	To nearest point (left front)	413.42 ft
M113	To left front corner	520.02 ft
M113	To left rear corner	521.05 ft
M113	To right rear corner	528.63 ft

Table 8: Ground truth measurements for Vehicle Array 4

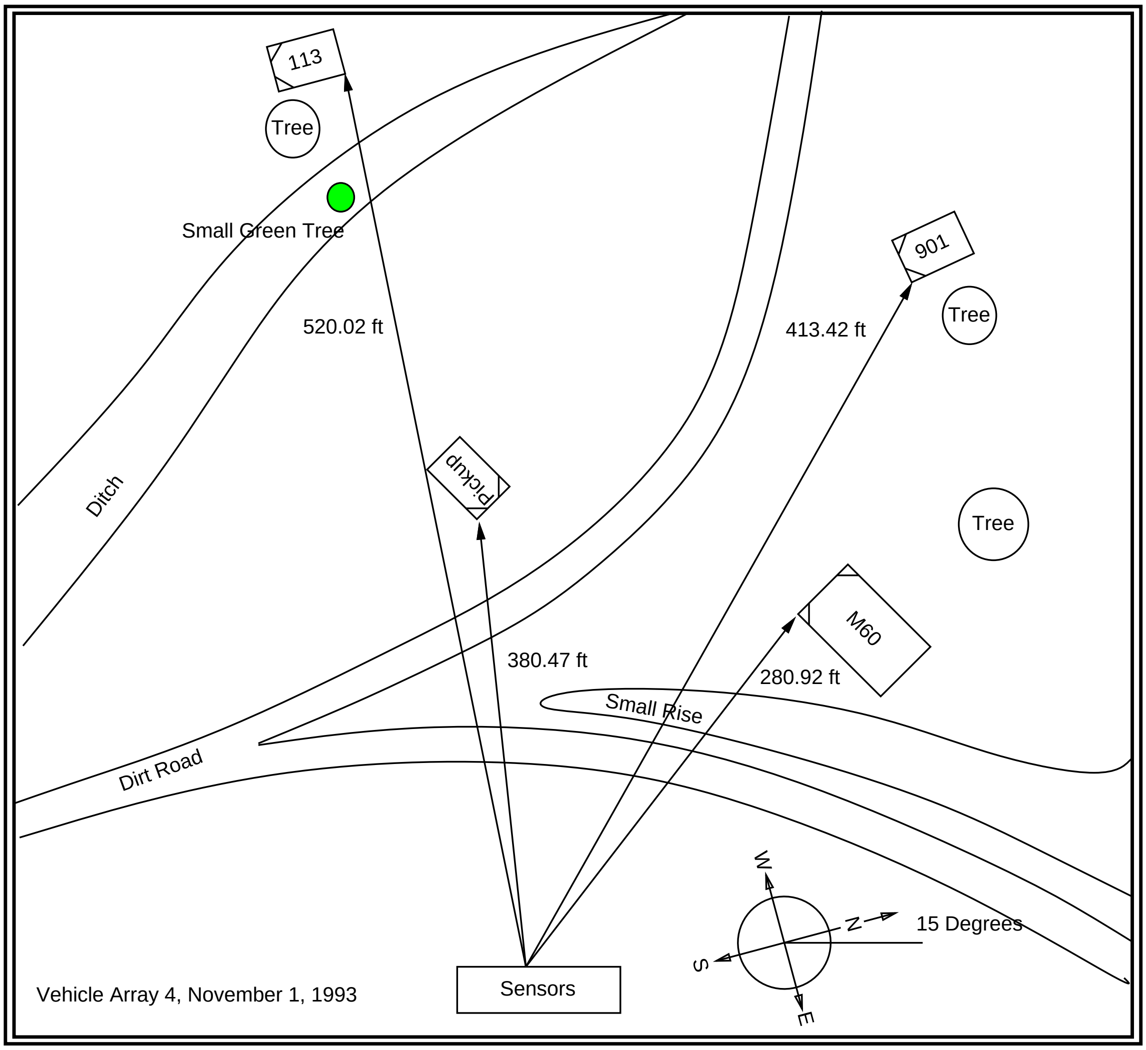


Figure 5: Vehicle Array 4: Partial Occlusion from hill. This is the fourth array shot on November 1st.

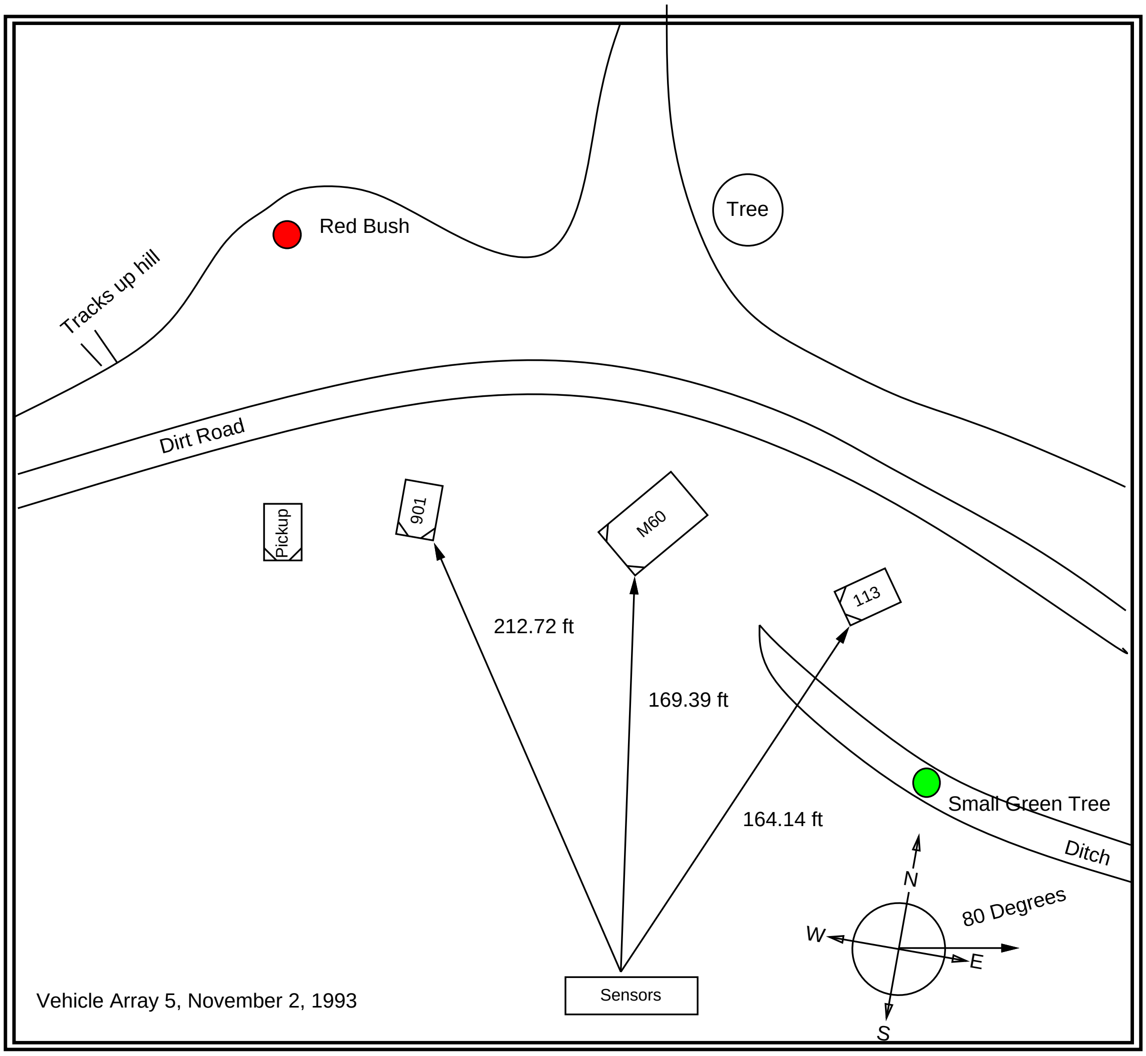


Figure 6: Vehicle Array 5: Full view at close range. This is the first array shot on November 2nd.

the sensors a roughly level view of the vehicles backdropped against low hills. Figure 6 shows a sketch of the vehicles relative to the sensors. As with previous sketches, size and placements are rough.

The intension in this array was to get close range data without any occlusion or unusual viewing angles. The vehicles were between 165 and 220 feet from the sensors. This is too close for most purposes since there are more pixels-on-target for these ranges than should reasonably be expected under the RSTA scenario.

November 2nd was plagued by FLIR calibration problems, and the FLIR data for this vehicle array is suspect. The problem was cleared upon on November 3rd when the next array was photographed.

Notes, November 2nd:

- Vehicles running from about 9:30 until about 12:00
- M60 turret pointed forward.
- Very light snow the night before, perhaps 1/4 inch

Weather and temperature readings, November 2nd:

07:55 Ground temperature 32 degrees, patchy snow very light. Sun very bright.

08:15 Air temperature off the ground 39 degrees.

09:11 Partly cloudy from high fog.

09:45 Fog has burned off.

10:49 Temperature 50 degrees in the sun, clear sky. Wind 10 knots out of the south.

14:30 Air temperature 52 out of the wind, 50 degrees in the wind.

14:31 Temperature readings on vehicles. M60 mid fender in the sun is 59 degrees, rubber on wheels is 69 degrees, rubber skirt on front is 80 degrees.

14:33 Side of the M113-901 out of the sun is 58 degrees, in the sun it is 84 degrees.

14:40 Surface soil temperature readings. In the foreground around vehicles the soil is between 55 and 60 degrees.

14:50 South facing steep dirt track has surface temperatures between 80 and 85 degrees.

15:53 Sky still clear.

16:20 Sunset behind the mountains.

Notes, November 3rd:

08:15 All four vehicles turned on.

08:35 Sun through high clouds in East. Heavy clouds to the north and the west. Wind north/northwest at about 3 to 5 knots. Vehicles same position as yesterday.

09:08 Clouding up.

09:15 Air temperature 47 degrees.

09:18 Sensor placement nearly identical to November 2nd.

09:44 LADAR & 35mm image of Saturn, Notice LADAR dropout.

10:25 Air temperature 52 degrees, still overcast.

A listing of all images taken with this vehicle array on November 2nd is given in Table 9. In addition to the four military vehicles, an image of Ross's Saturn is included.

A listing of all images taken with this vehicle array on the morning of November 3rd is given in Table 10. At the end of collecting the still images (vehicles not moving), all three sensors were used to acquire images of the vehicles in motion. No effort was made to syncrhonize the LADAR with the other two. However, an effort was made to synchronize FLIR and 35mm images. This amounted to taking pictures on one person's mark, and probably means the images are simultaneous to within about one second.

The survey results for vehicle array 5 are summarized in Table 11. Distance to the pickup was not recorded, measurements to 3 points on the remaining 3 vehicles were recorded. In addition, the distances between measurement points was also recorded.

3.7 Vehicle Array 6: Vehicles Distributed with M113-901 in Gully

This was the second vehicle array collected on November 3rd. The sensors are in the same positions as for the first array. The vehicles themselves have been widely seperated at ranges between 343 and 400 feet. Figure 7 shows a sketch of the vehicles relative to the sensors. As with previous sketches, size and placements are rough.
Notes, November 3rd continued:

10:45 Air temperature 53 degrees, still overcast.

11:10 The M60 is tilted on a hill, about a 15 degree incline.

11:16 Air temperature 55 degrees, overcast but occassionally brighter.

11:33 Air temperature 58 degrees, still overcast.

12:20 Temperature up to 79 degrees in the sun, almost no wind.

13:00 Some clouds back, 71 degrees.

13:26 Air temperature 65 degrees, 10 knot windw out of south with hazy sunshine.

A listing of all images taken with this vehicle array on the morning of November 3rd is given in Table 12. At the end of collecting the still images (vehicles not moving), all three sensors were used to acquire images of the vehicles in motion. No effort was made to syncrhonize the LADAR with the other two. However, an effort was made to synchronize FLIR and 35mm images. This amounted to taking pictures on one person's mark, and probably means the images are simultaneous to within about one second.

For the FLIR, all november 3rd shots taken with AGE full and external 2 point calibration. Greg Johnson from Amber Engineering has arrived and recalibrated the FLIR.

Warning on the LADAR image naming conventions. The time encodings are still times for this array, but stop being times after this array. Henceforth both the file name used at the data collection and the approximate times are shown. In this case, the times match, but in subsequent arrays they will not.

The survey results for vehicle array 6 are summarized in Table 13. Distance to the pickup was not recorded, measurements to 3 points on the remaining 3 vehicles were recorded. In addition, the distances between measurement points was also recorded.

LADAR			
File	Video	Comment	Range
nov21105l	1759-1830	Tank	165-190
nov21110l	1830-1900	Tank	50-800
nov21115l	1900-1930	M113	50-600
nov21120l	1930-2000	M113	150-170
nov21125l	2000-2030	M113-901	150-900
nov21130l	2030-2100	M113-901	210-230
nov21135l	2100-2130	Pickup	210-900
nov21140l	2130-2200	Pickup	240-260

(a)

FLIR	
File	Comment
(earlier data may exist not entered in Ross's log)	
nov21553f	M113
nov21605f	M60
nov21625f	M113-901 (sun just went down)
nov21626f	Pickup
nov21641f	Saturn

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov21100c	Color calibration	3	3	F-11	1/250	1-38
nov21101c	Geometric Calibration	3	4	F-11	1/250	1-39
nov21102c	Pickup	3	7	F-11	1/250	1-40
nov21103c	Pickup	3	8	F-11	1/125	1-41
nov21104c	M113-901	3	11	F-11	1/250	1-42
nov21105c	M113-901	3	12	F-11	1/125	1-43
nov21106c	M60	3	15	F-11	1/250	1-44
nov21107c	M60	3	16	F-11	1/125	1-45
nov21108c	M113	3	19	F-11	1/250	1-46
nov21109c	M113	3	20	F-11	1/125	1-47
nov21555c	Color calibration	4	2	F-11	1/250	1-48
nov21556c	M113	4	3	F-11	1/250	1-49
nov21557c	M113	4	5	F-11	1/125	1-50
nov21558c	M60	4	9	F-11	1/250	1-51
nov21559c	M60	4	11	F-11	1/125	1-52
nov21600c	M113-901 and Pickup	4	15	F-11	1/250	1-53
nov21601c	M113-901 and Pickup	4	17	F-11	1/125	1-54
nov21625c	M113-901 and Pickup	4	25	F-11	1/60	1-55
nov21626c	M60	4	26	F-11	1/60	1-56
nov21627c	M113	4	27	F-11	1/60	1-57
nov21628c	Saturn	4	28	F-11	1/60	1-58

(c)

Table 9: Images for Vehicle Array 5, November 2: a) listing and description of LADAR images, b) listing and description of FLIR imagers, c) listing and description of color images.

LADAR			
File	Video	Comment	Range
nov30943l	2202-2230	Ross's Saturn	180-350
nov30955l	2230-2300	M113	150-170
nov31000l	2300-2330	M113	50-600
nov31005l	2330-2400	M60	50-800
nov31010l	2400-2430	M60	165-190
nov31015l	2430-2500	M113-901	150-900
nov31020l	2500-2530	M113-901	210-230
nov31025l	2530-2630	Pickup	210-900
nov31030l	2630-2700	Pickup	240-260
nov31035l	2700-3151	M60 moving with smoke	165-600
nov31040l	"	M60 stationary with smoke	165-600

(a)

FLIR	
File	Comment
nov31001f	M113
nov31003f	M60
nov31007f	M113-901 and Pickup
nov31025f	Clutter and M113, side of hill
nov31027f	Saturn with clutter on hill
nov3M1...19	Moving vehicle sequence

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov31000c	Color calibration	5	2	F-11	1/60	1-59
nov31001c	M113	5	6	F-11	1/30	1-60
nov31003c	M60	5	10	F-11	1/60	1-61
nov31007c	M113-901 and Pickup	5	14	F-11	1/60	1-62
nov31025c	M113 and thermal clutter	5	18	F-11	1/60	1-63
nov31030c	Second Pickup moving	5	21	F-11	1/125	1-64
nov31031c	Second Pickup moving	5	22	F-11	1/125	1-65
nov31032c ...37c	M60 Moving with smoke	5	23 ...28	F-11	1/125	1-66 ...1-71
nov31038c ...40c	M60 Backing up hill with smoke	5	29 ...31	F-11	1/125	1-72 ...1-74

(c)

Table 10: Images for Vehicle Array 5, November 3: a) listing and description of LADAR images, b) listing and description of FLIR imagers, c) listing and description of color images.

Vehicle Positions Ground Truth		
Vehicle	Description	Measured
M60	To right front corner	178.46 ft
M60	To left front corner	169.39 ft
M60	To left rear corner	180.00 ft
M60	Right front to left front	11.5 ft
M60	Left rear to left front	18.0 ft
M113	To right front corner	167.91 ft
M113	To left front corner	164.14 ft
M113	To left rear corner	173.29 ft
M113	Right front to left front	7.04 ft
M113	Left front to left rear	10.92 ft
M113-901	To right front corner	217.97 ft
M113-901	To left front corner	212.72 ft
M113-901	To left rear corner	219.45 ft
M113-901	Right front to left front	7.04 ft
M113-901	Left front to left rear	10.92 ft

Table 11: Ground truth measurements for Vehicle Array 5

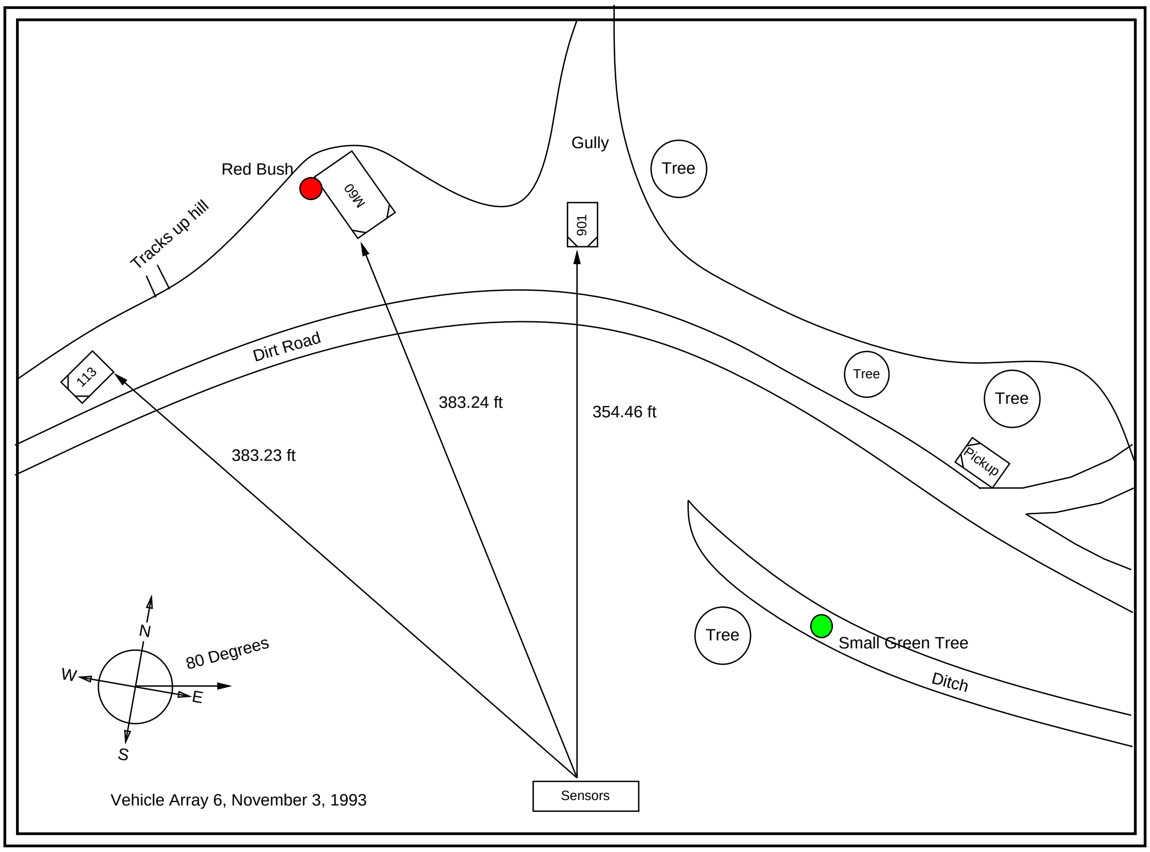


Figure 7: Vehicle Array 6: Vehicles distributed with M113-901 in gully. This is the second array shot on November 3rd.

LADAR				
File	Apprx. Time	Video	Comment	Range
nov31045l	10:45	3151-3239	M60	385-405
nov31050l	10:50	3239-3300	M60	200-900
nov31055l	10:55	3300-3330	M113	390-405
nov31100l	11:00	3330-3400	M113	150-900
nov31105l	11:05	3400-3430	M113-901	340-360
nov31110l	11:10	3430-3500	M113-901	150-900
nov31115l	11:15	3500-3530	Pickup	150-900
nov31120l	11:20	3530-3600	Pickup	275-295

(a)

FLIR	
File	Comment
nov31102f	M113-901 (in gully)
nov31110f	M60 tilted on hill, prominent exhaust plume
nov31112f	M113
nov31115f	Pickup (mild sun behind light clouds)
nov31255f	M113 (mild sun behind light clouds)
nov31300f	M60
nov31301f	M113-901
nov31304f	Pickup
nov3M2_1 ... _?	Vehicles moving to next array

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov31102c	M113-901 (under exposed)	5	32	F-11	1/125	1-75
nov31105c	Color Calibration	6	1	F-11	1/125	1-76
nov31110c	M60	6	3	F-11	1/125	1-77
nov31112c	M113	6	6	F-11	1/125	1-78
nov31115c	Pickup (LADAR in foreground)	6	12	F-11	1/125	1-79
nov31116c	Pickup (LADAR in foreground)	6	13	F-11	1/60	1-80
nov31255c	M113	6	15	F-11	1/500	1-81
nov31256c	M113	6	17	F-11	1/250	1-82
nov31300c	M60	6	20	F-11	1/500	1-83
nov31301c	M60	6	21	F-11	1/250	1-84
nov31302c	M113-901	6	24	F-11	1/500	1-85
nov31303c	M113-901	6	25	F-11	1/250	1-86
nov31304c	Pickup (LADAR in foreground)	6	28	F-11	1/500	1-87
nov31305c	Pickup (LADAR in foreground)	6	29	F-11	1/250	1-88
nov31310c ... 13c	Vehicles in motion	6	31 ... 34	F-11	1/500	1-89 ... 1-92

(c)

Table 12: Images for Vehicle Array 6: a) listing and description of LADAR images, b) listing and description of FLIR imagers, c) listing and description of color images.

Vehicle Positions Ground Truth		
Vehicle	Description	Measured
M60	To left front corner	387.42 ft
M60	To right front corner	383.24 ft
M60	To right rear corner	400.72 ft
M60	Right front to left front	11.25 ft
M60	Right front to right rear	19.25 ft
M113-901	To left rear corner	354.46 ft
M113-901	To left front corner	343.58 ft
M113-901	To right front corner	343.65 ft
M113-901	Right front to left front	7.04 ft
M113-901	Left front to left rear	10.92 ft
M113	To left rear corner	383.48 ft
M113	To right rear corner	390.88 ft
M113	To left front corner	383.29 ft
M113	Left front to left rear	11.00 ft
M113	Left rear to right rear	7.58 ft

Table 13: Ground truth measurements for Vehicle Array 6

3.8 Vehicle Array 7: Vehicles Distributed with M60 in Gully

This was the third vehicle array collected on November 3rd. The sensors are in the same positions as for the first array. Vehicle placement is identical to array 6 except that the M113-901 and M60 have traded places and the M113 is pointed in the other direction. The vehicles are still widely seperated at ranges between 343 and 400 feet. Figure 8 shows a sketch of the vehicles relative to the sensors. As with previous sketches, size and placements are rough.

Two civilian cars have also been imaged, a Toyota and a Saturn. This is particularly interesting in FLIR. The Saturn's plastic sides make it appear radically different from the metal sided Toyota.

In the interests of moving on and collecting a final vehicle array on November 3rd, no ground truth measurements to vehicles were collected for this vehicle array.

A listing of all images taken with this vehicle array is given in Table 14.

3.9 Vehicle Array 8: Vehicles Distributed with M113 on incline

This was the fourth vehicle array collected on November 3rd. The sensors have not been moved. The M113 has been backed up a track on a steep hill. The pickup truck is parked in the open. The M113-901 tow is partially obscured by a tree in the foreground, and the M60 is slightly hull-down in a depression. The sensor to vehicle ranges vary from 350 to 420 feet. Figure 9 shows a sketch of the vehicles relative to the sensors. As with previous sketches, size and placements are rough.
Notes, November 3rd continued:

14:20 All vehicles engines and heaters turned off.

14:42 Air temperature 60 degrees, 10 to 20 knot wind from South.

15:13 Air temperature 59 degrees.

16:02 Air temperature 58 degrees.

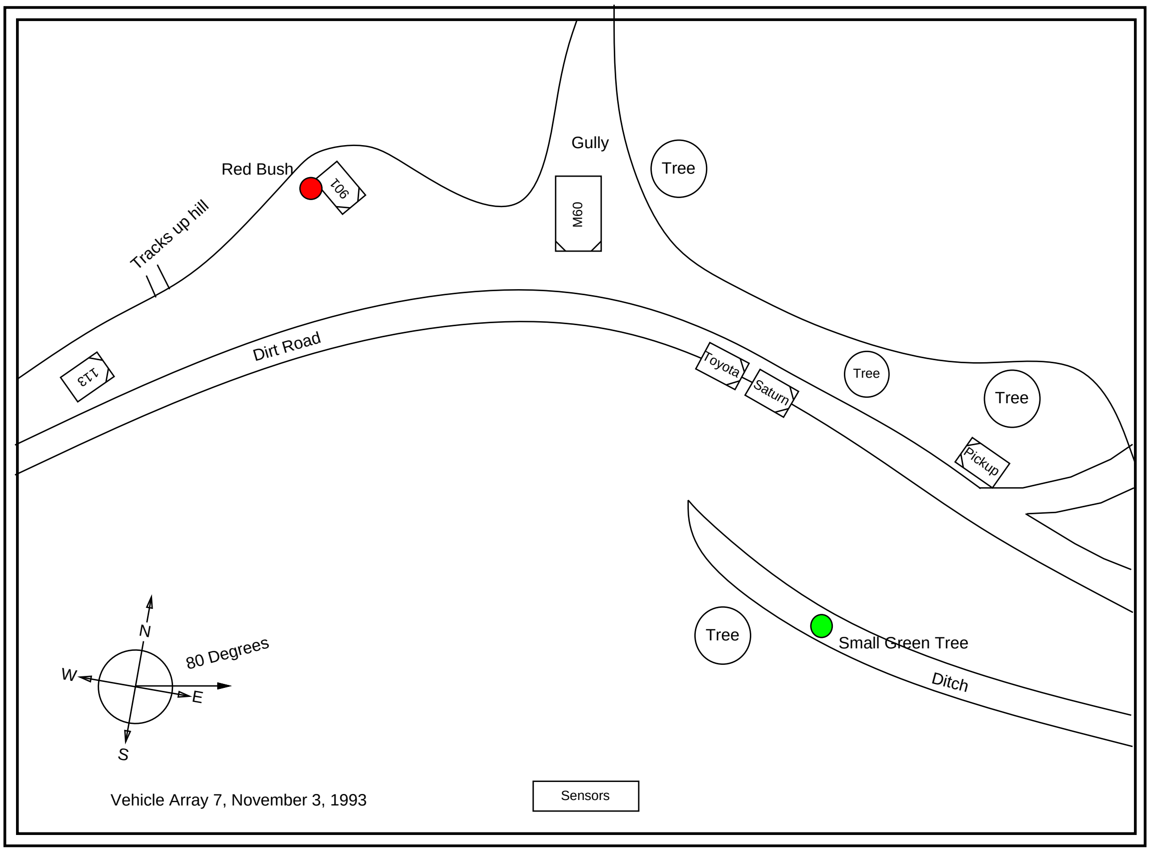


Figure 8: Vehicle Array 7: Vehicles distributed with M60 in gully. This is the third array shot on November 3rd.

LADAR				
File	Apprx. Time	Video	Comment	Range
nov31125l	13:30	3600-4233	M60 with smoke	?
nov31130l	13:37	4233-4300	M113	390-405
nov31135l	13:38		(scratched)	?
nov31140l	13:39	4300-4330	M113	200-900
nov31145l	13:40	4330-4400	M113-901	200-900
nov31150l	13:41	4400-4430	M113-901	385-408
nov31155l	13:42	4430-4500	M60	335-355
nov31160l	13:43	4500-4530	M60	150-900
nov31165l	13:55		People	115-130

(a)

FLIR	
File	Comment
nov31337f	M113
nov31339f	M113-901
nov31342f	M60
nov31345f	Toyota and Saturn
mag7-1-1 ...n	People

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov31330c	Color Calibration	7	2	F-11	1/250	2-1
nov31331c	M60 with smoke	7	3	F-11	1/250	2-2
nov31337c	M113	7	6	F-11	1/250	2-3
nov31338c	M113	7	8	F-11	1/125	2-4
nov31339c	M113-901 (Blazer in foreground)	7	10	F-11	1/250	2-5
nov31340c	M113-901 (Blazer in foreground)	7	12	F-11	1/125	2-6
nov31342c	M60 (in gully)	7	15	F-11	1/250	2-7
nov31343c	M60 (in gully)	7	16	F-11	1/125	2-8
nov31345c	Toyota and Saturn	7	19	F-11	1/250	2-9
nov31346c	Toyota and Saturn	7	20	F-11	1/125	2-10
nov31355c	People	7	24	F-11	1/250	2-11

(c)

Table 14: Images for Vehicle Array 7: a) listing and description of LADAR images, b) listing and description of FLIR imagers, c) listing and description of color images.

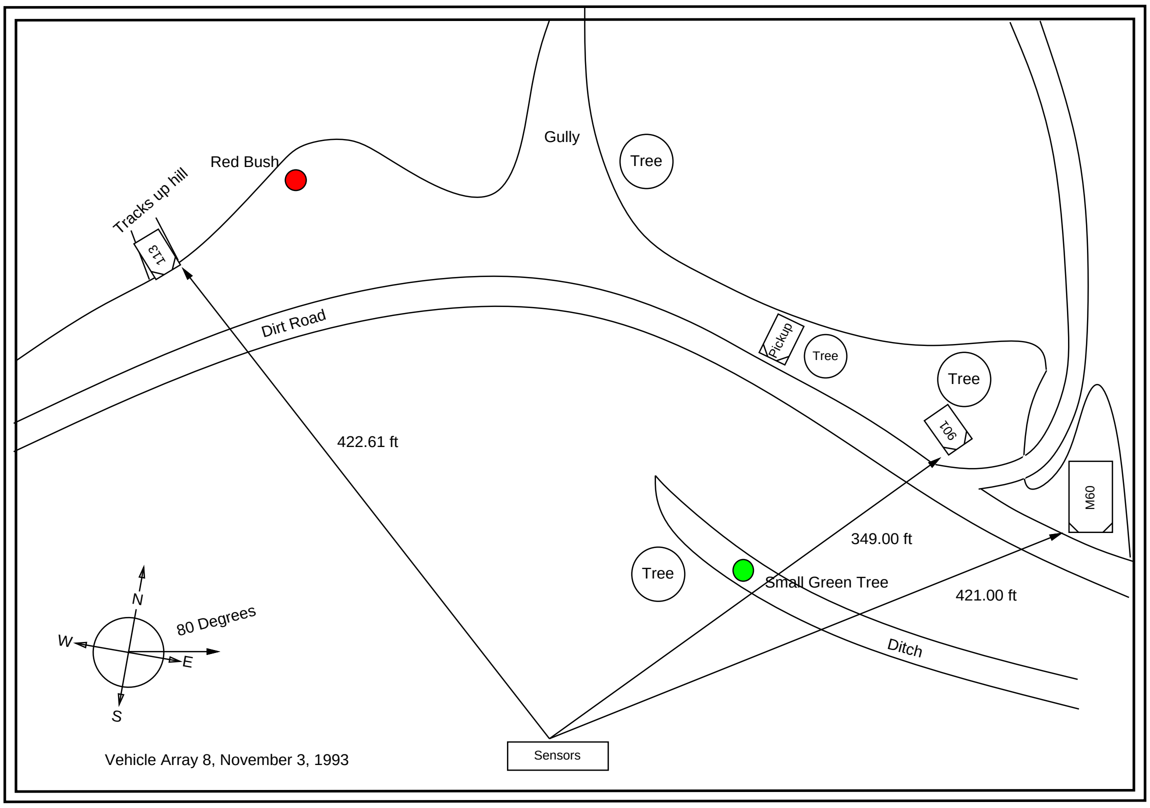


Figure 9: Vehicle Array 8: Vehicles Distributed with M113 on incline. This is the fourth array shot on November 3rd.

LADAR				
File	Apprx. Time	Video	Comment	Range
nov31170l	14:45	4530-4600	M113	430-450
nov31175l	14:50	4600-4630	M113	100-900
nov31180l	14:55	4630-4700	Pickup (Bad)	100-900
nov31185l	15:00	4700-4730	Pickup	100-900
nov31190l	15:00	4730-4800	Pickup	215-235
nov31195l	15:10	4800-4830	M113-901	100-900
nov31200l	15:15	4830-4900	M113-901	330-350
nov31205l	15:20	4900-4930	M60	400-415
nov31210l	15:25	4930-5000	M60	100-900
nov31215l	15:30		Building, 500 Frames	525-535

(a)

FLIR	
File	Comment
nov31447f	M113 (backup on hill)
nov31452f	Pickup Truck
nov31500f	M113-901 (partial behind tree)
nov31504f	M60 (paritally obscured by LADAR)
nov31530f	M60 (in full view)
nov31535f	M113-901 (no equipment in view)
nov31545f	M113-901 (camera moved 2 ft. south)
nov31546f	M113-901 (not behid tree, camera move another 2ft.
nov31550f	Gully with no target in it
nov31553f	M60 in full sun
nov31602f	M113-901 in sun
nov31604f	M113 sun on top at sunset
nov31700f	M60 after sunset
nov31701f	Panning left, no vehicles
nov31702f	M113-901 and Pickup
nov31703f	Pickup in right half of scene
nov31704f	Toyota and Saturn
nov31705f	Gully
nov31706f	Terrain and clutter
nov31707f	Terrain and clutter
nov31708f	M113

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov31447c	M113	7	28	F-11	1/125	2-12
nov31452c	Pickup	7	32	F-11	1/125	2-13
nov31530c	M60	8	13	F-11	1/60	2-14
nov31535c	M113-901	8	18	F-11	1/60	2-15
nov31545c	M113-901 (less occlusion)	8	21	F-11	1/60	2-16
nov31546c	M113-901 (no occlusion)	8	25	F-11	1/60	2-17
nov31550c	Gully (no vehicles)	8	29	F-11	1/60	2-18
nov31553c	M60 in late afternoon sun	8	31	F-11	1/60	2-19
nov31600c	Color Calibration	9	2	F-11	1/60	2-20
nov31602c	M113-901 in very late sun	9	4	F-11	1/60	2-21
nov31604c	M113 in very late sun	9	9	F-11	1/60	2-22

(c)

Table 15: Images for Vehicle Array 8: a) listing and description of LADAR images, b) listing and description of FLIR imagers, c) listing and description of color images.

Vehicle Positions Ground Truth		
Vehicle	Description	Measured
M60	To right front corner	422.45 ft
M60	To right rear corner	421.00 ft
M60	Right front to rear	19.33 ft
M113-901	To left front corner	357.12 ft
M113-901	To right midships	349.00 ft
M113-901	To right front corner	350.47 ft
M113-901	Right midships to right front	6.04 ft
M113-901	Right front to left front	6.88 ft
M113	To nearest point	422.61 ft
M113	Angle nose down	29 degrees

Table 16: Ground truth measurements for Vehicle Array 8

A listing of all images taken with this vehicle array is given in Table 15.
The survey results for vehicle array 8 are summarized in Table 16.

3.10 Vehicle Array 9: Distributed with M113-901 Occluded in Gully

This was the first vehicle array collected on November 4th. The M113 is up on a hill viewed broadside.The M113-901 Tow is partially occluded in the gully. The pickup is in the open and the M60 is in the open but over 500 feet from the sensors. The sensor to vehicle ranges vary from 300 to 530 feet. Figure 10 shows a sketch of the vehicles relative to the sensors. As with previous sketches, size and placements are rough.

The following are the weather and vehicle notes taken during all of November 4th. These notes cover the data collection for both vehicle array 9 and 10.
Notes, November 4th:

07:10 Full sun shining since dawn.

07:15 All vehicles started.

07:42 Air temperature 42 degrees in shade.

08:12 Temperature 52 in the sun.

08:15 Wind 5 to 10 knots out of the north.

08:25 No wind.

09:07 Air temperature 53 degrees in shade.

10:10 Temperature 54 degrees in sun, wind around 10 knots sun partially obscured by clouds.

11:07 Temperature 47 degrees in the sun, more clouds particularly to the north.

11:18 Front is coming in, partial sun where we are but very dark to the North and Northwest. Wind gusting to 15 knots.

11:19 First snowflake has fallen.

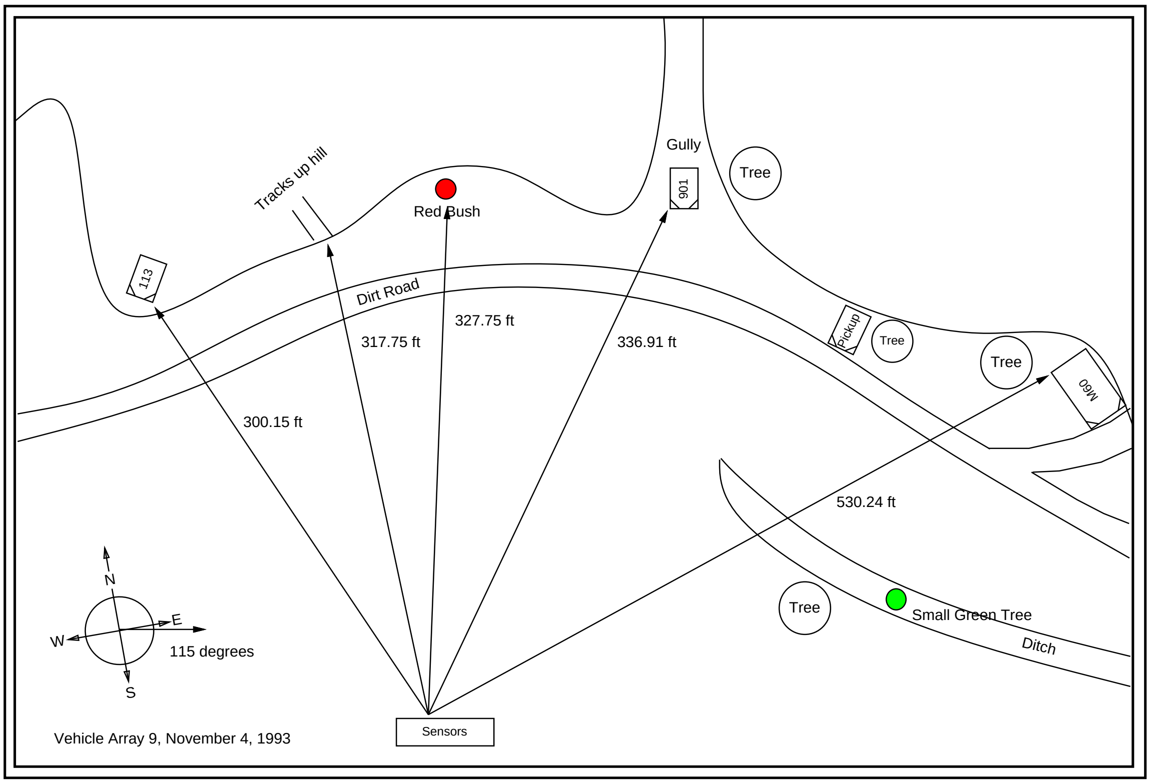


Figure 10: Vehicle Array 9: Distributed with M113-901 occluded in gully. This is the first array shot on November 4th.

11:20 Wind over 20 knots.

11:22 Air temperature 44 degrees and it is now cloudy.

12:25 Sun again, but still seeing stray snowflakes. Air temperature is 45 degrees.

A listing of all images taken with this vehicle array is given in Table 17. The FLIR is set to use a 1.25 millisecond integration time.

The survey results for vehicle array 9 are summarized in Table 18. For the M60, distance were measured to the two ends and a lower and upper measurement made at the center. The vertical distance between center measurements is recorded and it is therefore possible to calculate the degree to which the M60 is leaning in toward the sensors.

3.11 Vehicle Array 10: Distributed with M60 Hull-down on Hill

This was the second vehicle array collected on November 4th. The M113 is slighly hull-down and on the level with the sensors. The M60 is up on a hill in a hull-down position. The M113-901 Tow is behind a bush and up against a small hill. The pickup is in the gully where the M113-901 was in array 9. The sensor to vehicle ranges vary from 285 to 486 feet. Figure 11 shows a sketch of the vehicles relative to the sensors. As with previous sketches, size and placements are rough.

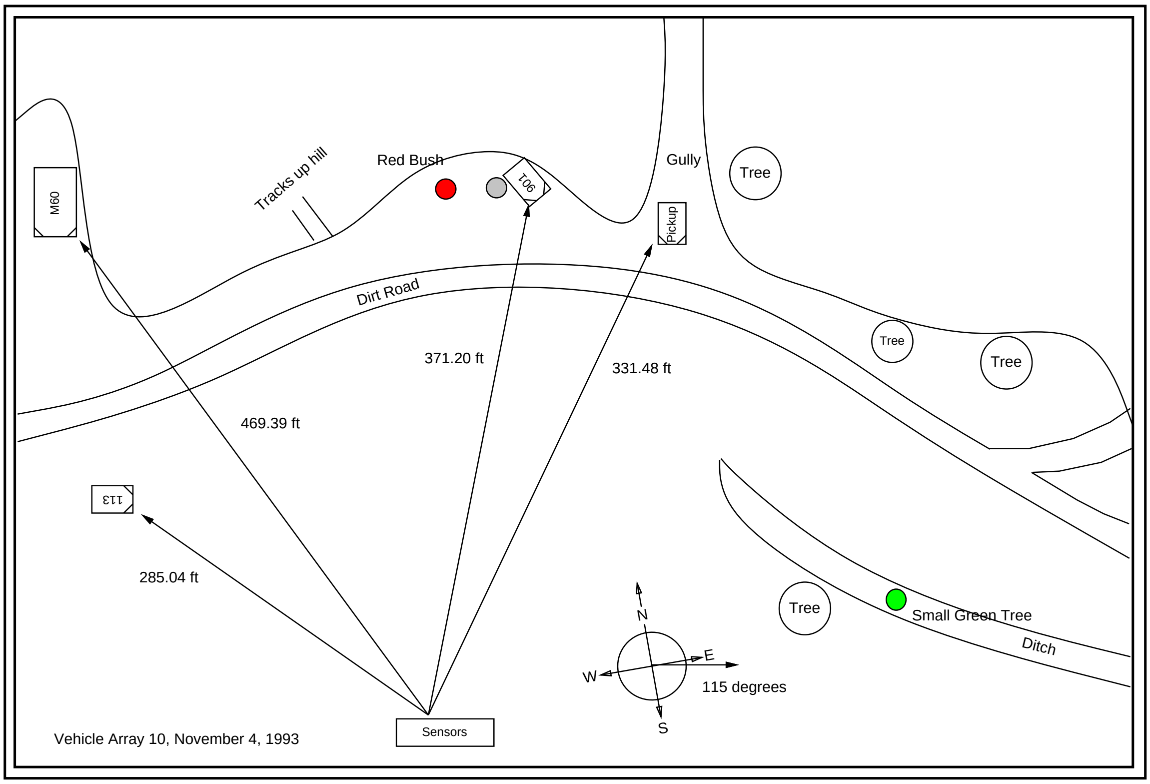


Figure 11: Vehicle Array 10: Distributed with M60 hull-down on hill. This is the second array shot on November 4th.

A listing of all images taken with this vehicle array is given in Table 19. The FLIR is set to use a 1.25 millisecond integration time.

The survey results for vehicle array 10 are summarized in Table 20.

LADAR				
File	Apprx. Time	Video	Comment	Range
nov40750l	7:50		bad image	
nov40755l	7:55	5030-5100	M113	310-330
nov40760l	8:55	5100-5130	M113	100-1000
nov40765l	8:00	5130-5200	Track on hill	100-1000
nov40770l	8:05	5200-5230	Red bush	100-1000
nov40775l	8:10	5230-5300	M113-901	328-345
nov40780l	8:15	5300-5405	M113-901	100-1000
nov40785l	8:20	5405-5430	Pickup	100-1000
nov40790l	8:25	5430-5508	Pickup	377-397
nov40795l	8:30	5508-5530	M60	100-1000
nov40800l	8:35	5530-5600	M60	512-527
nov40805l	11:00	5530-5600	M60 with smoke	430-520

(a)

FLIR	
File	Comment
nov40833f	Bill's Geometric Calibration Target
nov40835f	Bill's Target Flat
nov40836f	Ross' Geometric Calibration Target
nov40857f	M113
nov40859f	Tracks on hill, no vehicles
nov40901f	Red bush, no vehicles
nov40903f	M113-901, partially occluded
nov40905f	Pickup
nov40907f	M60
nov41012f	M113
nov41013f	Tracks on hill, no vehicles
nov41014f	Red bush, no vehicles
nov41016f	M113-901, partially occluded
nov41017f	Pickup
nov41018f	M60
nov4m1 ... 9	M60 backing in smoke

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov40833c	Bill's Geometric Calibration	9	12	F-16	1/500	2-23
nov40835c	Bill's Target Flat	9	13	F-16	1/250	2-24
nov40836c	Ross's Geometric Calibration	9	14	F-16	1/500	2-25
nov40837c	Color Calibration	9	15	F-16	1/500	2-26
nov40857c	M113	9	16	F-16	1/250	2-27
nov40859c	Tracks on hill, no vehicles	9	19	F-16	1/250	2-28
nov40901c	Red bush, no vehicles	9	22	F-16	1/250	2-29
nov40903c	M113-901, partially occluded	9	26	F-16	1/250	2-30
nov40905c	Pickup	9	29	F-16	1/500	2-31
nov40907c	M60	9	32	F-16	1/500	2-32
nov41012c	M113	10	3	F-16	1/500	2-33
nov41013c	Tracks on hill, no vehicles	10	6	F-16	1/250	2-34
nov41014c	Red bush, no vehicles	10	8	F-16	1/250	2-35
nov41016c	M113-901, partially occluded	10	12	F-16	1/250	2-36
nov41017c	Pickup	10	15	F-16	1/250	2-37
nov41018c	M60	10	19	F-16	1/250	2-38
nov41030c ... 39c	M60 backing in smoke	10	20 ... 29	F-16	1/250	2-39 ... 2-48

(c)

Table 17: Images for Vehicle Array 9: a) listing and description of LADAR images, b) listing and description of FLIR imagers, c) listing and description of color images.

Vehicle Positions Ground Truth		
Vehicle	Description	Measured
M60	To lower center	530.55 ft
M60	To upper center	530.24 ft
M60	To right rear	530.42 ft
M60	To left rear	531.82 ft
M60	Right rear to right front	19.88 ft
M60	Lower center to upper center	4.33 ft
M113-901	Upper right front corner	336.96 ft
M113-901	Upper left front corner	341.11 ft
M113-901	Upper right rear corner	345.41 ft
M113-901	Right front to left front	8.00 ft
M113-901	Right front to right rear	10.50 ft
M113	Lower left front corner	300.15 ft
M113	Upper left front corner	300.31 ft
M113	Upper left rear corner	301.02 ft
M113	Lower left to upper left corner	2.88 ft
M113	Left front to left rear corner	11.08 ft

Table 18: Ground truth measurements for Vehicle Array 9

3.12 Natural Object Color Images

On November 2nd a series of color 35mm images were taken with the same camera used to take the vehicle images. Table 21 lists these images.

3.13 Quality of the Ground Truth Range Values

The laser range device used to acquire ground truth range data for the vehicles was tempermental in the field. It was sensitive to inadequate power and also required the operator to make a 'judgment' as to which of several range values poduced the greatest 'peak'. It is therefore not entirely surprising that the ground truth range values acquired with this equipment agrees quite closely with the LADAR data in some cases, but not in others. Although it is difficult to know precisely which instrument is actually returning values closer to the true range values, a comparison of the two is helpful.

The LADAR appears to have been operating very reliably over the course of the data collection. It therefore seems reasonable to assume that when the ground truth values differ significantly from the LADAR data, it is probably the ground truth data which is in error. Conversely, when the two instruments agree and thereby confirm each other, the ground truth data probably quite good. Table 22 summarizes a comparison of the LADAR and ground truth measurements. For each, the min range to vehicles, max range to vehicles, and the average range are recorded. The absolute difference between these is then reported. The ranges for the LADAR data were acquired by hand using an image examiner to display image pixel values on target for each vehicle.

4 Sensor Triples: Mulit-sensor Shots

This section summarizes triples of FLIR, LADAR and color imagery which may be used in conjunction with each other. Tables 23 and 24 identify sets of images which may be thought of as distinct 'shots' of individual vehicles. In addition, two shots are included of scenes not containing vehicles.

LADAR				
File	Apprx. Time	Video	Comment	Range
nov40810l	11:05	5746-5820	M60	475-510
remaining LADAR data lost for this array				

(a)

FLIR	
File	Comment
nov41102f	M113 slightly hull-down
nov41104f	M60 hull-down
nov41107f	M113-901 occluded by brush
nov41109f	Pickup in Gully
nov41118f	M113 slightly hull-down
nov41122f	M60 hull-down
nov41125f	M113-901 occluded by brush
nov41126f	Pickup in Gully
nov41222f	M113 slightly hull-down
nov41224f	M60 hull-down
nov41225f	M113-901 occluded by brush
nov41226f	Pickup in Gully

(b)

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov41102c	M113 slightly hull-down	10	30	F-16	1/125	2-49
nov41104c	M60 hull-down	10	33	F-16	1/125	2-50
nov41107c	M113-901 occluded by brush	11	4	F-16	1/125	2-51
nov41109c	Pickup in Gully	11	7	F-16	1/125	2-52
nov41118c	M113 slightly hull-down	11	10	F-16	1/30	2-53
nov41122c	M60 hull-down	11	13	F-11	1/60	2-54
nov41125c	M113-901 occluded by brush	11	16	F-11	1/60	2-55
nov41126c	Pickup in Gully	11	21	F-11	1/60	2-56
nov41222c	M113 slightly hull-down	11	10	F-11	1/125	2-57
nov41224c	M60 hull-down	11	13	F-11	1/125	2-58
nov41225c	M113-901 occluded by brush	11	16	F-11	1/125	2-59
nov41226c	Pickup in Gully	11	21	F-11	1/125	2-60

(c)

Table 19: Images for Vehicle Array 10: a) listing and description of LADAR images, b) listing and description of FLIR imagers, c) listing and description of color images.

Vehicle Positions Ground Truth		
Vehicle	Description	Measured
M60	To left front corner	469.39 ft
M60	To right front corner	475.18 ft
M60	To left rear corner	486.17 ft
M60	Left front to right front	11.16 ft
M60	Left front to left rear	19.16 ft
M113-901	Upper right front corner	371.20 ft
M113-901	Upper left front corner	376.71 ft
M113-901	Upper right rear corner	378.38 ft
M113-901	Right front to left front	7.75 ft
M113-901	Right front to right rear	11.08 ft
M113	To upper right front corner	285.15 ft
M113	To lower right front corner	285.04 ft
M113	To upper right rear	294.80 ft
M113	Lower right to upper right corner	2.88 ft
M113	Upper right front to right rear	10.83 ft
Pickup	To nearest point	331.38 ft

Table 20: Ground truth measurements for Vehicle Array 10

Color 35mm						
File	Description	Roll	Num	F-Stop	Time	CD
nov20900c	Color calibration	1h	1			2-61
nov20901c	1 in panarama of 5	1h	19			2-62
nov20902c	2 in panarama of 5	1h	20			2-63
nov20903c	3 in panarama of 5	1h	21			2-64
nov20904c	4 in panarama of 5	1h	22			2-65
nov20905c	5 in panarama of 5	1h	23			2-66
nov20906c	Pikes Peak	1h	28			2-67
nov20907c	Dirt road with spinkling of snow	1h	34			2-68
nov21330c	Color calibration	3	35	F-11		2-69
nov21331c	Interstate 25	3	22	F-11		2-70
nov21333c	Roads up hillsides, shaded mound	3	24	F-11		2-71
nov21334c	Looking around hill into gully	3	25	F-11		2-72
nov21335c	Road into gully, fall trees	3	26	F-11		2-73
nov21336c	Gully with some brush in it	3	27	F-11		2-74
nov21337c	Gully with trees on skyline	3	28	F-11		2-75
nov21338c	Hillside, dried rushes	3	29	F-11		2-76
nov21339c	Road up hill, not in foreground	3	30	F-11		2-77
nov21340c	Gully with brush in foreground	3	31	F-11		2-78
nov21341c	Gully and road seen from above	3	32	F-11		2-79
nov21342c	Track on far side of gully	3	33	F-11		2-80
nov21343c	Stand of trees in gully	3	34	F-11		2-81

Table 21: Color images of natural objects.

	LADAR Values			Ground Truth Values			Delta Values		
Vehicle	Low	High	Avg.	Low	High	Avg.	Low	High	Avg.
Vehicle Array One, Nov. 1									
M60	416.91	426.09	421.50	414.83			2.08		
Pickup	390.69	395.93	393.31	389.38			1.31		
M113-901	410.35	419.53	414.94	407.93			2.42		
M113	398.55	401.18	399.87	395.72			2.83		
Vehicle Array Two, Nov. 1									
M60	418.22	424.25	421.24	414.90	425.82	420.36	3.32	1.57	0.88
Pickup	394.62	395.93	395.28	392.44			2.18		
M113-901	406.42	409.04	407.73	404.94			1.48		
M113	394.62	400.91	397.77	392.52	400.53	396.53	2.10	0.38	1.24
Vehicle Array Three, Nov. 1									
M60	398.55	416.91	407.73	398.82	417.15	407.99	0.27	0.24	0.25
Pickup	381.51	397.24	389.38	380.47			1.04		
M113-901	386.76	395.93	391.34	386.00			0.76		
M113	386.76	398.55	392.66	386.00	396.31	391.16	0.76	2.24	1.50
Vehicle Array Four, Nov. 1									
M60	288.43	296.29	292.36	280.92	291.08	286.00	7.51	5.21	6.36
Pickup	381.51	397.24	389.38	380.47			1.04		
M113-901	395.93	402.49	399.21	413.42			17.49		
M113	506.06	524.41	515.24	520.02	528.63	524.33	13.96	4.22	9.09
Vehicle Array Five, Nov. 2									
M60	169.12	180.92	175.02	169.39	180.00	174.70	0.27	0.92	0.33
M113-901	215.01	224.19	219.60	212.72	219.45	216.09	2.29	4.74	3.51
M113	154.70	165.19	159.95	164.14	173.29	168.72	9.44	8.10	8.77
Vehicle Array Five, Nov. 3									
M60	169.12	180.92	175.02	169.39	180.00	174.70	0.27	0.92	0.33
M113-901	216.32	224.19	220.25	212.72	219.45	216.09	3.60	4.74	4.17
M113	153.39	163.88	158.64	164.14	173.29	168.72	10.75	9.41	10.08
Vehicle Array Six, Nov. 3									
M60	388.07	406.42	397.24	383.24	400.72	391.98	4.83	5.70	5.26
M113-901	340.87	350.05	345.46	343.58	354.46	349.02	2.71	4.41	3.56
M113	394.62	397.24	395.93	383.29	390.88	387.09	11.33	6.36	8.85
Vehicle Array Eight, Nov. 3									
Vehicle	Low	High	Avg.	Low	High	Avg.	Low	High	Avg.
M60	403.80	406.42	405.11	421.00	422.45	421.73	17.20	16.03	16.62
M113	432.64	443.13	437.89	422.61			10.03		
Vehicle Array Nine, Nov 4									
M60	516.55	519.17	517.86	530.24	531.82	531.03	13.69	12.65	13.17
M113-901	326.97	340.87	333.92	336.96	345.41	341.19	9.99	4.54	7.26
M113	314.65	319.89	317.27	300.15	301.02	300.59	14.50	18.87	16.69
Vehicle Array Ten, Nov. 4									
M60	489.02	507.11	498.06	469.39	486.17	477.78	19.63	20.94	20.28

Table 22: Comparison of LADAR and ground truth range measurements.

Information is laid out in this format to aid those wishing to select data for benchmarking algorithm performance. In the ideal case, a RSTA algorithm ought to be able to identify the vehicle(s) in each shot as well as positively ruling out the presence of any vehicles in those shots not where no vehicle is present.

In almost all cases, there are multiple images from a given sensor for each shot. Researchers wishing to test algorithms against this dataset may initially pick the most promising images. However, particularly for the FLIR imagery, the images are often taken under different conditions (lighting, thermal loading, etc.) and it will be of interest to use several from each shot.

LADAR, FLIR and Color Triples					
Shot	Array	Description	LADAR	FLIR	Color
1	1	M60	nov10900l, nov10902l	nov10903f, nov10935f	nov10903c
2	1	M113-901	nov10921l, nov10927l	nov10903f, nov10935f	nov10903c
3	1	M113	nov10921l, nov10927l	nov10903f, nov10935f	nov10903c
4	1	M113 & Trees	nov10937l	nov10903f, nov10935f	nov10903c
5	1	Pickup	nov10914l, nov10916l	nov10903f, nov10935f	nov10903c
6	2	M60	nov10957l, nov11001l	nov10955f, nov11002f	nov11002c, nov11003c
7	2	M113-901	nov11010l, nov11013l	nov10955f, nov11000f	nov11000c, nov11001c
8	2	M113	nov11015l, nov11018l	nov10955f, nov11000f	nov11000c, nov11001c
9	2	Pickup	nov11004l, nov11006l	nov10955f, nov11002f	nov11002c, nov11003c
10	3	M60	nov11150l, nov11153l, nov11155l	nov11155f, nov11205f, nov11215f, nov11230f	nov11205c, nov11230c
11	3	M113-901	nov11210l, nov11213l, nov11215l	nov11155f, nov11205f, nov11215f, nov11230f	nov11205c, nov11230c
12	3	M113	nov11218l, nov11220l, nov11224l	nov11155f, nov11205f, nov11215f, nov11230f	nov11205c, nov11230c
13	3	Pickup	nov11200l, nov11202l, nov11206l	nov11155f, nov11205f, nov11215f, nov11230f	nov11205c, nov11230c
14	4	M60	nov11312l, nov11316l	nov11326f, nov11350f, nov11442f	nov11325c, nov11326c, nov11350c, nov11351c, nov11442c, nov11443c
15	4	M113-901	nov11320l, nov11325l	nov11326f, nov11329f, nov11348f, nov11350f, nov11442f, nov11445f	nov11325c, nov11326c, nov11329c, nov11330c, nov11348c, nov11349c, nov11350c, nov11351c, nov11442c, nov11443c, nov11445c, nov11446c
16	4	M113	nov11345l, nov11350l	nov11329f, nov11348f, nov11445f	nov11329c, nov11330c, nov11348c, nov11349c, nov11445c, nov11446c
17	4	Pickup	nov11200l, nov11206l	nov11326f, nov11329f, nov11348f, nov11350f, nov11442f, nov11445f	nov11325c, nov11326c, nov11329c, nov11330c, nov11348c, nov11349c, nov11350c, nov11351c, nov11442c, nov11443c, nov11445c, nov11446c
18	5	M60	nov21105l, nov21110l	nov21605f	nov21106c, nov21107c, nov21558c, nov21559c, nov21626c
19	5	M113-901	nov21125l, nov21130l	nov21625f	nov21104c, nov21105c, nov21600c, nov21601c, nov21625c
20	5	M113	nov21115l, nov21120l	nov21553f	nov21108c, nov21109c, nov21556c, nov21557c, nov21627c
21	5	Pickup	nov21135l, nov21140l	nov21626f	nov21102c, nov21103c, nov21600c, nov21601c,nov21625c

Table 23: Sensor triples summarized for Vehicle Arrays 1 through 5.

LADAR, FLIR and Color Triples					
Shot	Array	Description	LADAR	FLIR	Color
22	6	M60	nov31045l, nov31050l	nov31110f, nov31300f	nov31110c, nov31300c, nov31301c
23	6	M113-901	nov31105l, nov31110l	nov31102f, nov31301f	nov31302c, nov31303c
24	6	M113	nov31055l, nov31100l	nov31112f, nov31255f	nov31255c, nov31256c
25	6	Pickup	nov31115l, nov31120l	nov31115f, nov31304f	nov31115c, nov31116c, nov31304c, nov31305c
26	7	M60	nov31155l, nov31160l	nov31342f	nov31342c, nov31343c
27	7	M113-901	nov31145l, nov31150l	nov31339f	nov31339c, nov31340c
28	7	M113	nov31130l, nov31140l	nov31337f	nov31337c, nov31338c
29	8	M60	nov31205l, nov31210l	nov31504f, nov31553f, nov31700f,	nov31530c, nov31553c
30	8	M113-901	nov31195l, nov31200l	nov31500f, nov31535f, nov31545f, nov31546f, nov31602f, nov31702f	nov31535c, nov31545c, nov31546c, nov31602c
31	8	M113	nov31170l, nov31175l	nov31447f, nov31604f, nov31708f	nov31447c, nov31604c
32	8	Pickup	nov31185l, nov31190l	nov31452f, nov31703f	nov31452c
33	9	M60	nov40795l, nov40800l	nov40907f, nov41018f	nov40907c, nov41018c
34	9	M113-901	nov40775l, nov40780l	nov40903f, nov41016f	nov40903c, nov41016c
35	9	M113	nov40755l, nov40760l	nov40857f, nov41012f	nov40857c, nov41012c
36	9	Pickup	nov40785l, nov40790l	nov40905f, nov41017f	nov40905c, nov41017c
37	9	Track on hill	nov40765l	nov40859f, nov41013f	nov40859c, nov41013c
38	9	Red bush	nov40770l	nov40901f, nov41014f	nov40901c, nov41014c
39	10	M60	nov40810l	nov41104f, nov41224f	nov41104c, nov41122c, nov41224c
40	10	M113-901		nov41107f, nov41125f, nov41225f	nov41107c, nov41125c, nov41225c
41	10	M113		nov41102f, nov41118f, nov41222f	nov41102c, nov41118c, nov41222c
42	10	Pickup		nov41109f, nov41126f, nov41226f	nov41109c, nov41126c, nov41226c

Table 24: Sensor triples summarized for Vehicle Arrays 6 through 10.

5 A Sampling of Data

This section presents a small sample of the images. These images were selected to give a feel for the variety of data collected. Unfortunately, only grey-scale versions of the color imagery can be reproduced here. In addition, the pixel values in the FLIR and LADAR images ranges from 0 to roughly 4,000. Therefore, detail is present in this data that is not easily seen in the postscript copies reproduced here. To compensate, the LADAR is displayed in two ways, with one showing the entire range and a second highlighting the range values near the range of the vehicle.

5.1 Shot 6 and 7

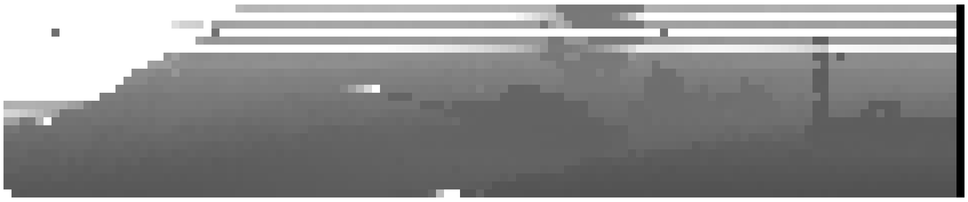
The first set of images presented in Figures 12 through 15 show all four vehicles broadside to the sensors. This set corresponds to shots 6 and 7 in Table 23. These images provide a clear view of the vehicles as well as the area in which most all of this data was acquired. The images are from vehicle array 2. Figure 12 shows the grey-scale version of the color image nov10955c. Figure 13 shows a histogram equalized version of FLIR image nov10955f. Figures 14 and 15 show the LADAR data for the the M60 and M113-901. These are taken from images nov10957l and nov11010l respectively.

Figure 12: Image nov10955c as greyscale image.

5.2 Shot 24

The second set of images presented in Figures 16 through 18 show the M113 sitting by itself with no occlusion and seen from the side. This set corresponds to shot 24 in Table 24. The range to the vehicle

Figure 13: Histogram equalized version of FLIR image nov10955f.

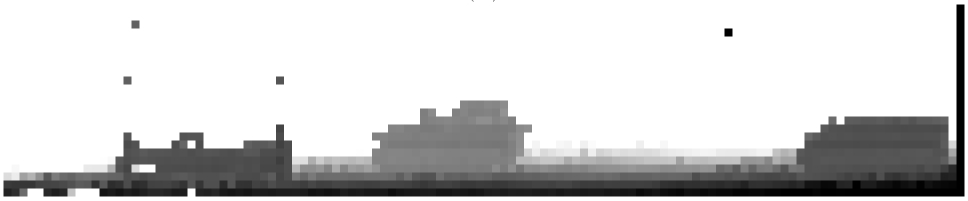


(a)

(b)

Figure 14: LADAR image nov10957l showing M60. a) full 100 to 1,000 foot range, b) range highlighted about vehicle.

(a)



(b)

Figure 15: LADAR image nov11010l showing M113-901. a) full 100 to 1,000 foot range, b) range highlighted about vehicle.

is 383 feet. Figure 16 shows the greyscale version of color image nov31255. Figure 17 shows the FLIR image nov31255f. The image in the Figure has been compressed to 8 bits and then mapped to display values 128 to 255 in the range black to white. Figure 18 shows the LADAR image nov31055l.

5.3 Shot 28

The fourth set of images show the M60 at a range 530 feet and partially occluded by a small rise in the terrain. This set corresponds to shot 28 in Table 24. Figure 19 shows the greyscale version of color image nov31553c. Figure 20 shows the FLIR image nov31553f. The image in the Figure has been compressed to 8 bits and then mapped to display values 0 to 128 in the range black to white. Figure 21 shows the LADAR image nov31055l.

5.4 Shot 31

The next set of images show the M113 coming down a steep hill. Range to the vehicle is 422 feet. This set corresponds to shot 31 in Table 24. This set of images should be somewhat more challenging since the M113 is seen front on and, more importantly, the M113 is nose down by over 20 degrees. The range to the vehicle is 422 feet. Figure 22 shows the greyscale version of color image nov31446c. Figure 23 shows the FLIR image nov31447f. The image in the Figure has been compressed to 8 bits and then mapped to display values 128 to 255 in the range black to white. Figure 24 shows the LADAR image nov31170l.

5.5 Shot 34

The final set of images show the M113-901 backed into a gully and only partially visible. The range to the vehicle is 335 feet. This set corresponds to shot 34 in Table 24. Figure 25 shows the greyscale version of color image nov40903c. Figure 26 shows the FLIR image nov40903. The image in the Figure has been compressed to 8 bits and then mapped to display values 0 to 128 in the range black to white. Figure 27 shows the LADAR image nov40775l.

Figure 16: Image nov31255c of M113 as greyscale image.

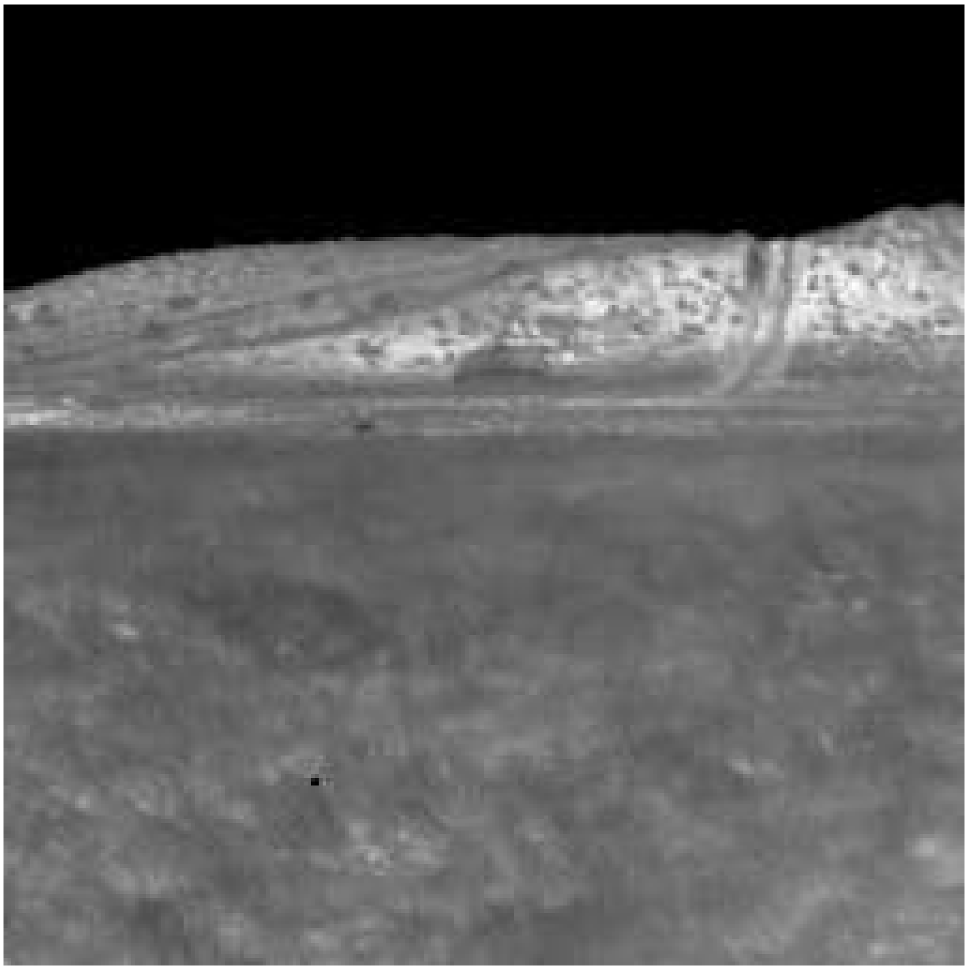
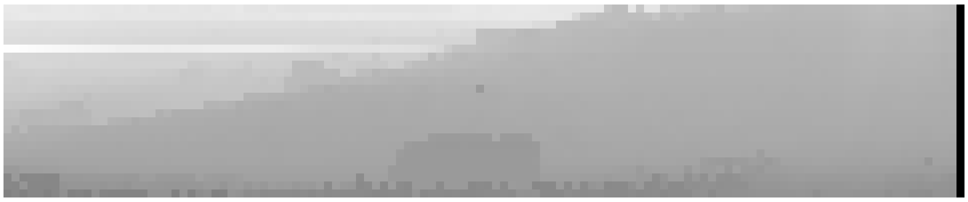
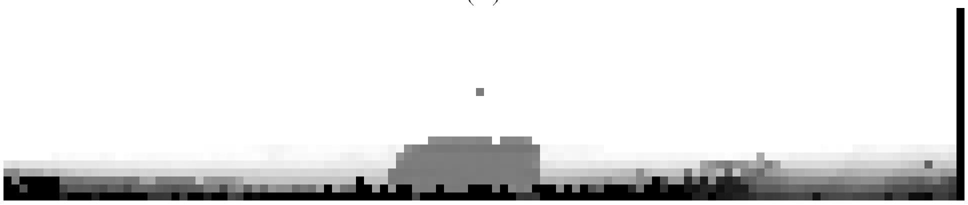


Figure 17: FLIR image nov31255f of M113 upper range mapped 0 to 255.



(a)

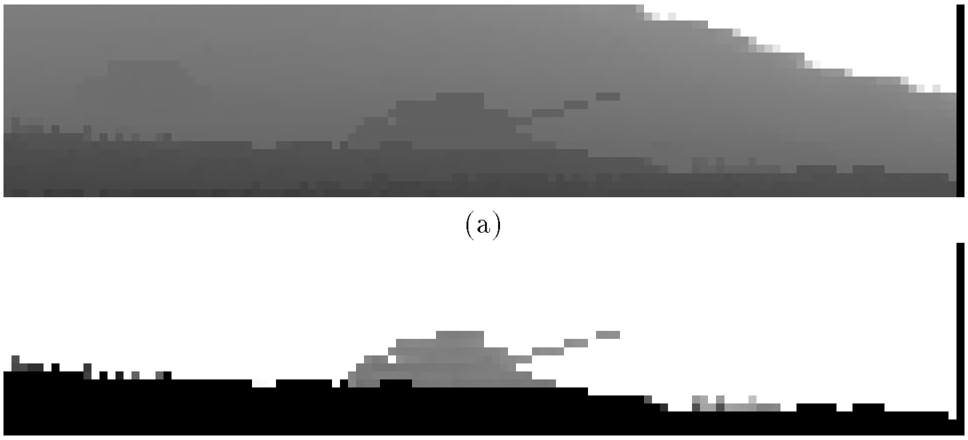


(b)

Figure 18: LADAR image nov31055l showing M60. a) full 100 to 1,000 foot range, b) range highlighted about vehicle.

Figure 19: Image nov31553c of M113 as greyscale image.

Figure 20: FLIR image nov31553f of M113 lower range mapped to 0 to 255.



(a)

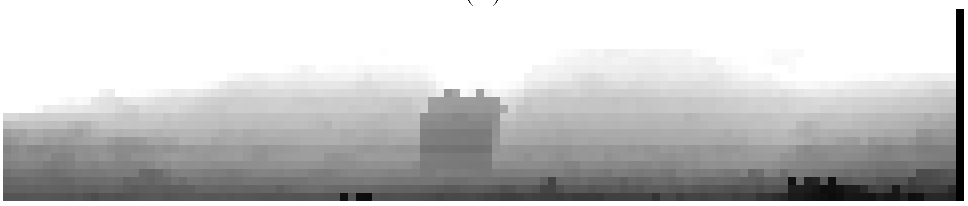
(b)

Figure 21: LADAR image nov31205l showing M113. a) full 100 to 1,000 foot range, b) range highlighted about vehicle.

Figure 22: Image nov31447c of M113 as greyscale image.

Figure 23: FLIR image nov31447f of M113 upper range mapped to 0 to 255.

(a)



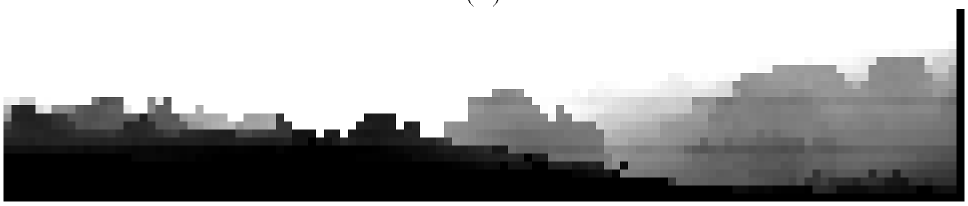
(b)

Figure 24: LADAR image nov31170l showing M113. a) full 100 to 1,000 foot range, b) range highlighted about vehicle.

Figure 25: Image nov40903c of M113 as greyscale image.

Figure 26: FLIR image nov40903f of M113 lower range mapped to 0 to 255.

(a)



(b)

Figure 27: LADAR image nov40775l showing M113. a) full 100 to 1,000 foot range, b) range highlighted about vehicle.