

ARMY RESEARCH LABORATORY



A Hitch Angle Measurement Device

by Raymond Von Wahlde

ARL-MR-406

September 1998

19980928 030

Approved for public release; distribution is unlimited.

EXCELLENCE IN QUALITY

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Abstract

As part of a project to demonstrate that an unmanned ground vehicle (UGV) could remotely back up with a trailer, a simple proof-of-concept device was designed to measure the angle between a high-mobility multipurpose wheeled vehicle (HMMWV) pintle hook and a trailer tow bar. A suitable algorithm could compute the UGV steering angle required for a trailer to follow a given reverse path and would be a function of the angle between the UGV and the trailer. This report gives the details of a design for a hitch angle measurement device (HAMD) to be used as input to a steering transfer function. Derivation of the transfer function is not included.

Table of Contents

	<u>Page</u>
List of Figures	v
List of Tables	vii
1. Introduction	1
2. HAMD	3
2.1 HAMD Operation	7
2.2 HAMD Assembly Instructions	8
3. Conclusions	10
Appendix A: Bill of Materials and Drawings	13
Appendix B: Rotary Variable Inductance Transducer (RVIT) Specifications	23
Appendix C: Gear Head Specifications	27
Distribution List	31
Report Documentation Page	35

INTENTIONALLY LEFT BLANK.

List of Figures

<u>Figure</u>	<u>Page</u>
1. Teleoperated HMMWVs	2
2. HAMD	4
3. HAMD: Exploded View	5
4. RVIT/Gear Head Subassembly: Exploded View	6
5. HAMD: Operation	7
A-1. Beam Mount and Gear Head Adapter Plates	17
A-2. RVIT Mount and Pivot Mount Plates	18
A-3. Bearing Hold-Down and Pivot Shaft	19
A-4. Angle Measurement Bar and Guide	20
A-5. Housing and Cap	21
A-6. Spacer and Shaft Adapter	22
C-1. Gear Head Face Remover Tool	29

INTENTIONALLY LEFT BLANK.

List of Tables

<u>Table</u>	<u>Page</u>
A-1. Bill of Materials	15
B-1. Performance Specifications for the RVIT-15-60 Series Rotary Position Sensor Single-Voltage Power Supply	25
B-2. RVIT Calibration RVIT-15-60	26
C-1. Gear Head Specifications	29

INTENTIONALLY LEFT BLANK.

1. Introduction

The U.S. Army Research Laboratory (ARL) has helped develop a small fleet of teleoperated high-mobility multipurpose wheeled vehicles (HMMWV) (Figure 1) for use in battlefield environments in which it may be too hazardous for a soldier to operate.¹ This example of an unmanned ground vehicle (UGV) is remotely controlled by an operator but has a certain degree of robotic autonomy. There are many potential missions to be performed by robotic vehicles. These include but are not limited to:

- reconnaissance,
- remote sentry,
- telepresence,
- smoke generation,
- mine detection/countermine,
- mine deployment/recovery,
- target acquisition,
- target designation,
- battle damage assessment,
- nuclear, biological, and chemical detection,
- meteorological assessment,
- electronic warfare, and
- weapon platform (e.g., recoilless rifle, smart mortar).

¹ Haas, G. A., P. David, and B. T. Haug. "Target Acquisition and Engagement From an Unmanned Ground Vehicle: The Robotics Test Bed of DEMO 1." ARL-TR-1063, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, 1996.

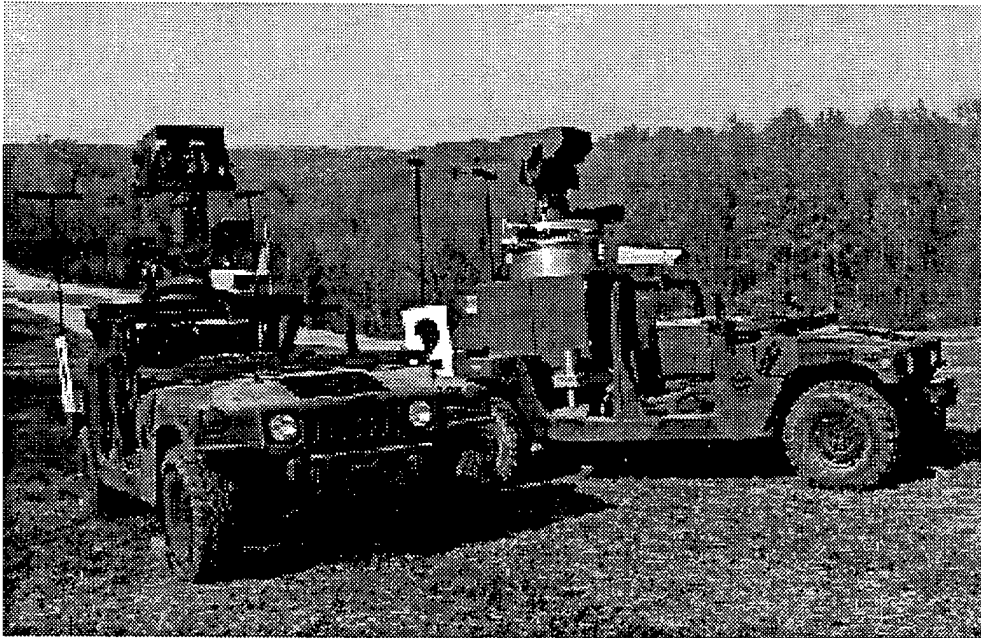


Figure 1. Teleoperated HMMWVs.

Rather than design different robotic vehicles for each mission, a UGV could serve as a multiuse carrier of modular mission packages. This approach would eliminate parallel expenditures on robotic vehicle development and would allow a user to direct limited resources toward mission function. Many of these mission packages could reside on a deployable UGV-towable trailer that could be dropped off and picked up by a UGV. This would provide greater mission flexibility by freeing expensive robotic mobility resources for other missions. A trailer-mounted weapon platform would protect a UGV from exposure to weapon launch shocks and overpressures.

A disadvantage of an UGV-towable trailer is the requirement for remote decoupling and recoupling of the trailer. In addition to a mechanical coupling between the UGV and trailer, there would also be a need for a power and, possibly, a data link coupler/decoupler.

The greatest difficulty in remotely operating a UGV with a trailer would, at first glance, seem to be backing up with the trailer. Moving in reverse with a trailer can be a tricky operation, as anyone

who has ever backed up a car with a boat trailer can attest. One might think that the difficulty of the task would be compounded if done remotely, but that may not be the case. If a suitable algorithm could compute the UGV steering angle required for a trailer to follow a given reverse path, then the task of remote backing could be made as easy as remotely driving forward. The remote operator would simply be provided with a trailer's-eye view and steer the trailer as one would steer the UGV. Such a steering transfer function would be a function of the angle between the UGV and the trailer.²

As part of a project to demonstrate that a UGV could remotely back up with a trailer, a device was designed to measure the angle between a HMMWV pintle hook and a trailer tow bar. This report gives the details of a design for a hitch angle measurement device (HAMD) to be used as input to a steering transfer function. Derivation of the transfer function is not included.

2. HAMD

The HAMD (shown in Figure 2) is mounted on the HMMWV beam to which the tailgate is fastened (the "D" beam). The unit is housed in a cover to protect the internal components from mud, rain, etc. (cover removed in figure for clarity). This simple proof-of-concept device was easily and inexpensively made utilizing off-the-shelf components and a minimum of machining. A bill of materials and component drawings can be found in Appendix A.

An exploded view of the HAMD is shown in Figure 3. The angle measurement rod pivots on a hinge assembly comprised of a shaft held by ball bearings. The shaft is connected to a rotary variable inductance transducer (RVIT) via a bellows coupling and a transducer gear head (Figure 4). Specifications for the RVIT and gear head are found in Appendices B and C, respectively. The flexible bellows coupling transmits the rotary movement of the shaft to the gear head without torsional error. Small inaccuracies in alignment are taken up by the coupling. The gear head attaches to the RVIT and reduces the rotary movement by a factor of 3 to 1. A 360° motion of the gear head

² Larsson, U., C. Zell, K. Hyypä, and A. Wernersson. "Navigating an Articulated Vehicle and Reversing With a Trailer." *1994 IEEE International Conference on Robotics and Automation*, San Diego, CA, May 1994.

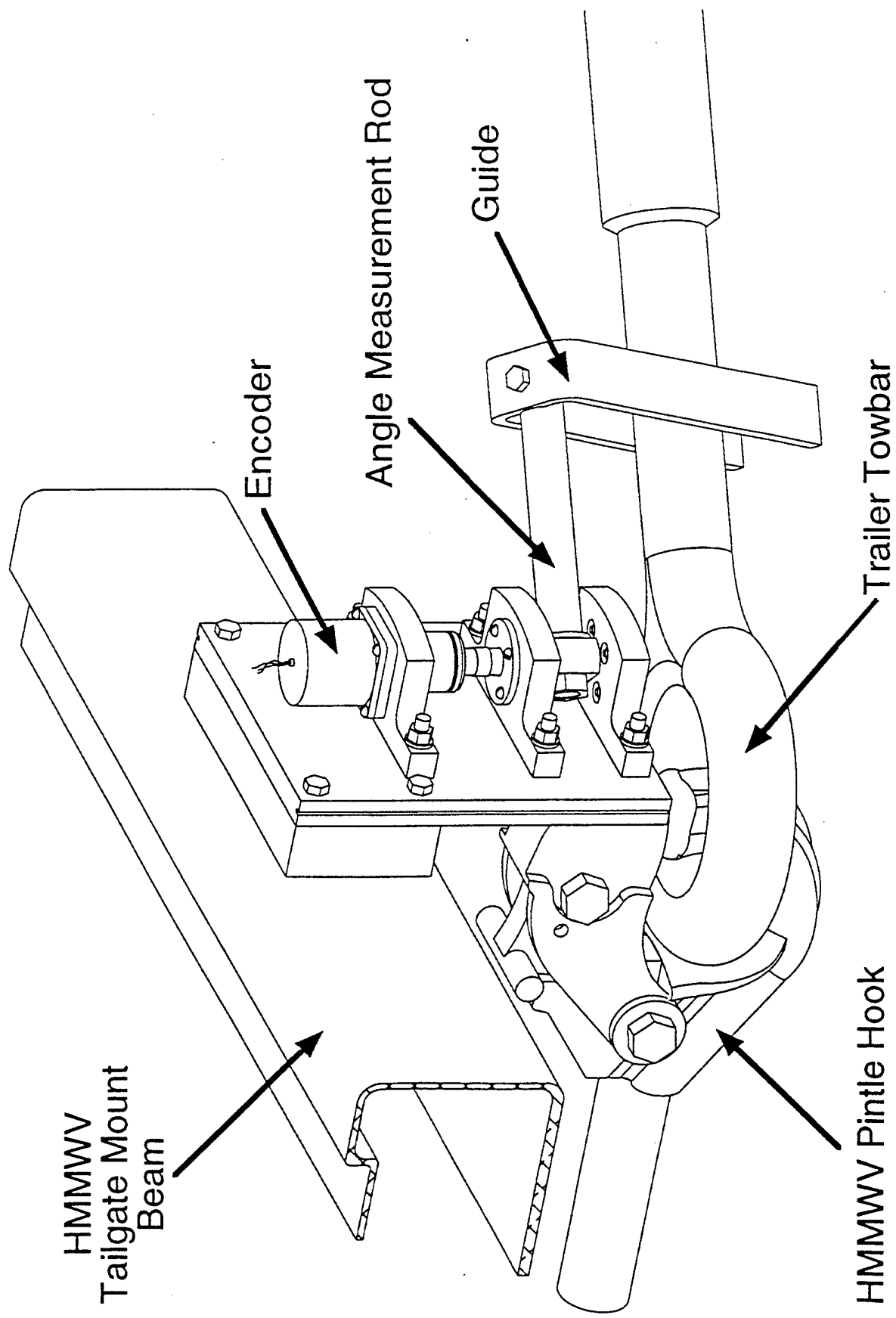


Figure 2. HAMD.

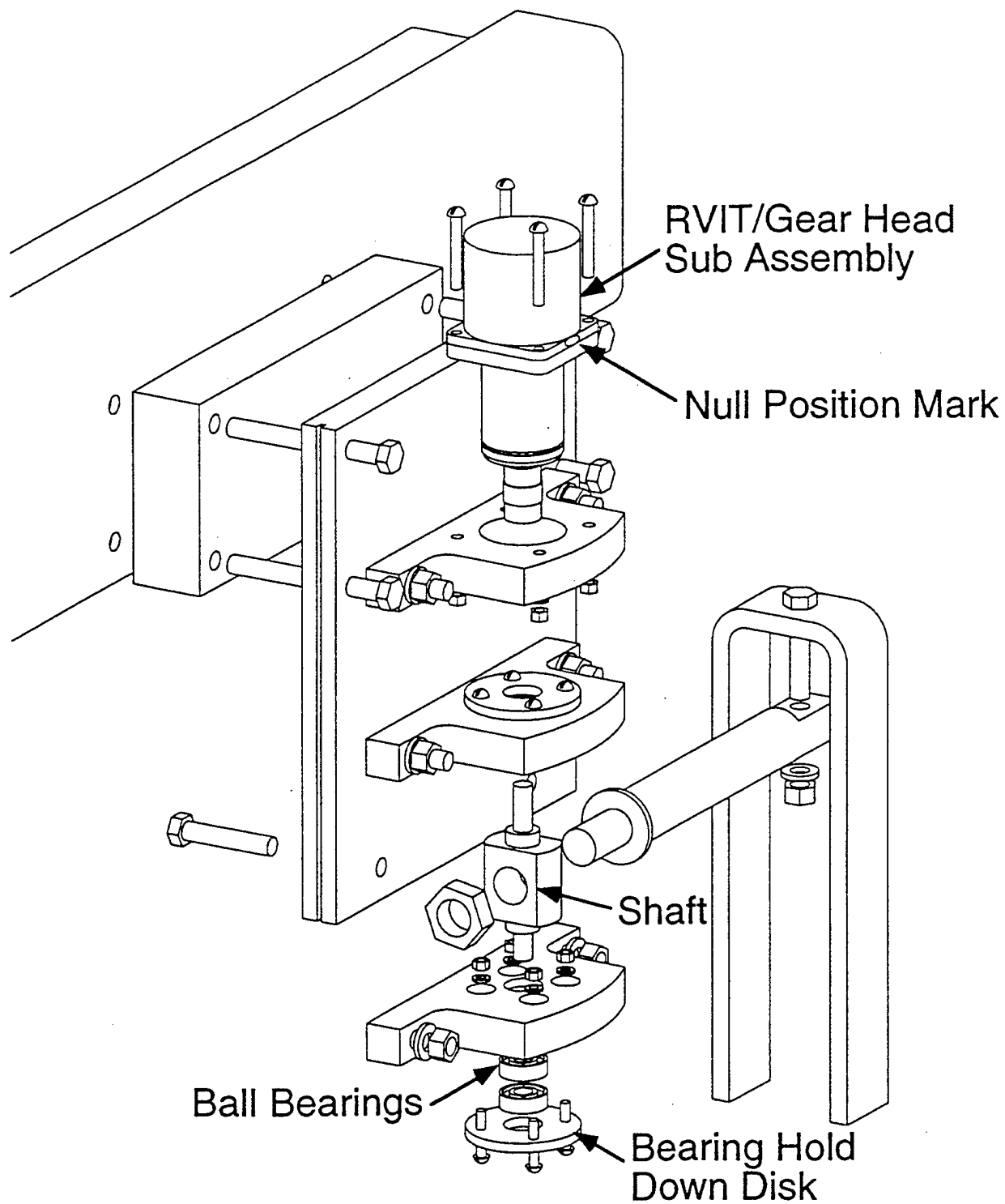


Figure 3. HAMD Exploded View.

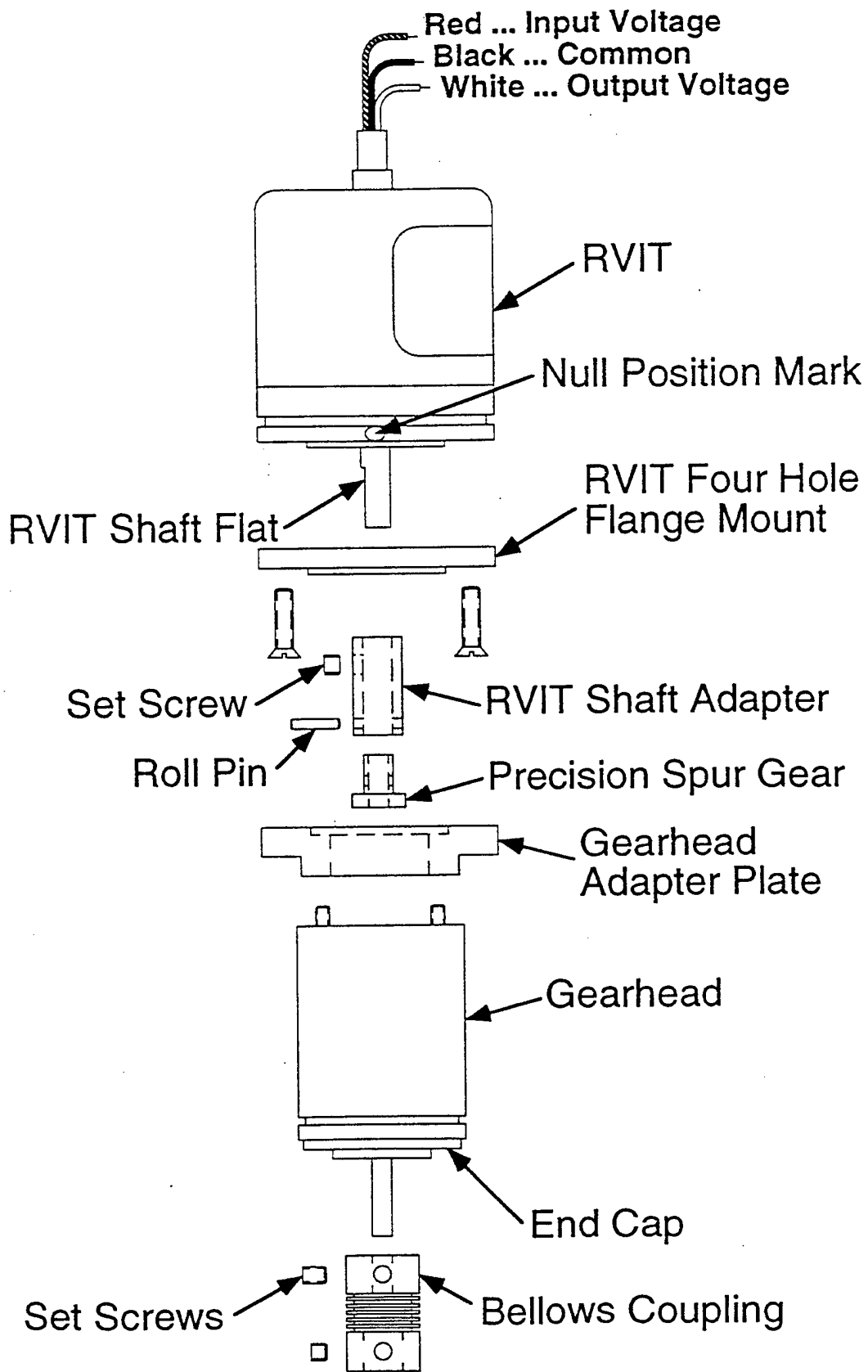


Figure 4. RVIT/Gear Head Subassembly: Exploded View.

shaft maps to a 120° motion of the RVIT shaft, which is the range of the RVIT. The voltage output from the RVIT is proportional to the angle between the trailer and HMMWV.

2.1 HAMD Operation. Figure 5 shows the HAMD in operation. As the trailer tow bar pivots about the HMMWV pintle hook, it contacts a two-pronged guide that straddles the shaft of the tow bar and is attached to the end of the angle measurement rod. The tow bar and the angle rod pivot about different axes because the HAMD is mounted aft of the pintle hook and because the tow bar's pivot axis is not constant due to movement between the eye of the tow bar and the pintle hook. For this reason, as the tow bar moves, the guide is free to rotate about the centerline of the angle rod and slide along the shaft of the tow bar. The prongs of the guide remain perpendicular to the centerline of the tow bar. In this manner, the centerlines of the angle rod and tow bar remain parallel and the guide moves the angle rod through the same angle as the tow bar. Because the tow bar can move up and down, forward and back, and roll between the guide, neither the towing load nor the loads due to the bouncing of the trailer are transmitted to the HAMD.

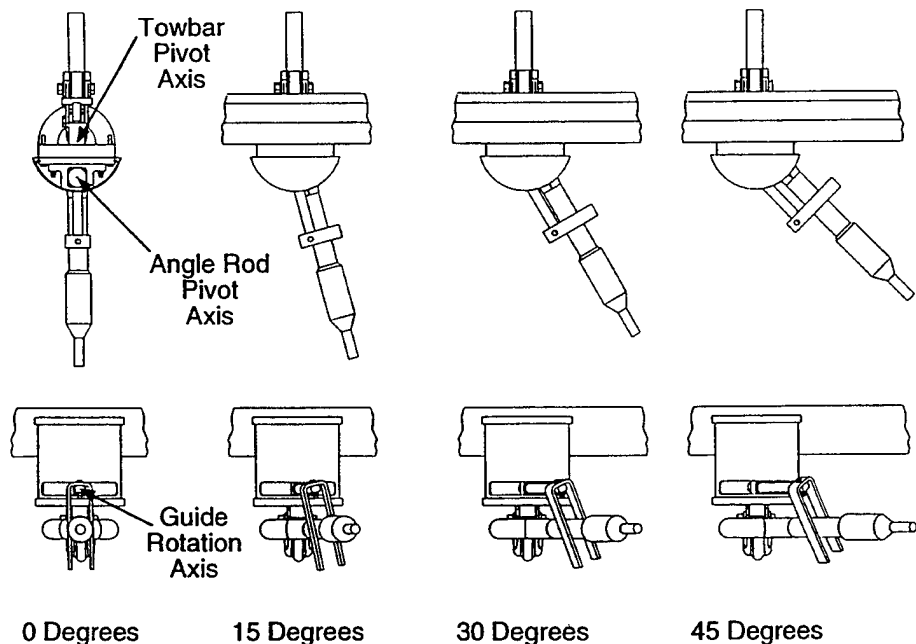


Figure 5. HAMD: Operation.

2.2 HAMD Assembly Instructions. The HAMD is designed for easy assembly. Most parts simply bolt together using 1/4-20 UNC bolts and nuts with lock washers. The following are steps to assemble the shaft subassembly (refer to Figure 3 and the drawings in Appendix A).

- (1) Place the ball bearings in the pivot mount plates.
- (2) Secure the bearings with the bearing hold-down disks.
- (3) Bolt the bottom pivot mount plate to the D-beam mount plate.
- (4) Put the short end of the shaft into the bottom bearings subassembly.
- (5) Slide the top bearing subassembly onto the long end of the shaft.
- (6) Ensure that the shaft rotates freely.
- (7) Bolt the top pivot mount plate to the D-beam mount plate.

The RVIT has a null position that is indicated by a white dot on the RVIT's housing. When the flat on the RVIT shaft is aligned with the null mark, the output from the RVIT is 0 V. A clockwise shaft rotation (looking down the shaft at the RVIT) increases the output voltage. The RVIT should be mounted with the null mark facing the trailer. Thus, when the rear of the trailer swings toward the passenger side of the HMMWV, the RVIT will output a positive voltage. Likewise, when the rear of the trailer swings toward the driver's side of the HMMWV, the RVIT will output a negative voltage.

The gear head is a zero-backlash 3:1 ratio reducer. Backlash is a measure of how well mating gears fit together. Care must be taken to properly engage the precision spur gear on the RVIT shaft to the gear head. The following are steps to assemble the RVIT/gear head subassembly (refer to Figures 3 and 4 and Appendices A, B, and C).

- (1) Bolt the RVIT mount plate to the D-beam mount plate.
- (2) Attach the four-hole flange mount to the RVIT.

- (3) Secure the precision spur gear to the RVIT shaft adapter with a roll pin.
- (4) Attach the gear subassembly to the shaft of the RVIT. Tighten the set screw on the flat portion of the shaft.
- (5) Remove the end cap from the shaft end of the gear head by removing two screws and then pulling the cap off using the tool shown in Appendix C.
- (6) Attach the gear head adapter plate with the two screws sticking out from the gear head.
- (7) Beneath the end cap of the gear head, find the only slotted shaft. Holding the input shaft and the housing of the gear head, turn the slotted shaft with a screwdriver counterclockwise approximately 30° .
- (8) Gently place the gear head onto the RVIT and slightly turn the screwdriver back and forth until the spur gear is engaged with the gear head.
- (9) Release the shaft and housing of the gear head. Be sure to hold the RVIT and gear head together through the remaining steps.
- (10) Replace the end cap of the gear head.
- (11) Slip the bellows coupling onto the shaft of the gear head. Tighten the set screws.
- (12) With the white null position mark pointing outward, attach the RVIT/gear head subassembly to the RVIT mount plate with four screws and nuts, slipping the bellows coupling onto the shaft of the hinge assembly.
- (13) Connect the RVIT to a power supply and voltmeter.
- (14) Rotate the shaft of the hinge assembly so that the flat faces are parallel with the D-beam mount plate.
- (15) Holding the shaft, rotate the bellows coupling until the output of the RVIT is 0 V.
- (16) Tighten the bellows coupling set screws on the pivot shaft.

The following are steps to attach the HAMD to a HMMWV.

- (1) Drill four holes in the HMMWV D-beam centered about the pintle hook using the D-beam mount plate spacer as a guide. The lower two holes should be about 19 mm (0.75 in) from the bottom of the D-beam.

- (2) Bolt the HAMD to the D-beam.
- (3) Place the large washer onto the threaded end of the angle measurement bar and put the angle bar into the hole in the shaft.
- (4) Tighten the large nut onto the angle bar. Tighten the set screw in the nut.
- (5) Connect the trailer tow bar to the HMMWV pintle hook.
- (6) Straddle the shaft of the tow bar with the prongs of the guide and the bolt the guide onto the end of the angle measurement bar.

The following are steps to place the sheet metal housing onto the HAMD.

- (1) Remove the guide and angle measurement bar.
- (2) Slide the sheet metal housing into the grooves of the D-beam mount plate and push down onto the HAMD.
- (3) Place the large washer onto the angle measurement bar and pass the angle bar through the slot in the housing and into the hole in the shaft.
- (4) Tighten the large nut onto the shaft and then tighten the set screw in the nut.
- (5) Secure the bottom housing cap with screws.
- (6) Pass the RVIT wires through the top housing cap and then secure with screws.

3. Conclusions

During this project, several other concepts for measuring the angle between a HMMWV and trailer were briefly considered. These included other mechanical methods for detecting the motion of the tow bar. There were also two ideas that did not rely on any mechanical connection. One involved a light sensor on the HMMWV that would detect the orientation of an array of light-emitting diodes (LED) on the trailer. The other concept sought to use range sensors from autofocus cameras to measure the distances to the trailer's two corners and compute the trailer angle from this geometry. However, the latter two ideas required more effort developing electronics and software than time or

resources permitted. The other mechanical methods needed sensors that were not on hand. The HAMD presented in this report began with the RVIT and was designed around the physical geometry of the HMMWV and trailer.

Computer-aided design (CAD) and computer-aided modeling (CAM) played an important role in the design of the HAMD. The device was virtually prototyped before a single component was machined. Both two-dimensional (2-D) mechanical drawings and three-dimensional (3-D) solid models were made, and each assisted in the creation of the other. A virtual mechanism model demonstrated the operation of the HAMD before it was ever bolted to a HMMWV. As a result, the HAMD functioned as expected and provided a method of measuring the angle between a HMMWV and a trailer.

INTENTIONALLY LEFT BLANK.

Appendix A:

Bill of Materials and Drawings

INTENTIONALLY LEFT BLANK.

Table A-1. Bill of Materials

Item	Drawing No.	Qty.
Mount Plate to High-Mobility Multipurpose Wheeled Vehicle (HMMWV)	SK18007169301	1
Adapter Plate for Gear Head	SK18007169302	1
Mount Plate for Rotary Variable Inductance Transducer (RVIT)	SK18007169303	1
Pivot Mount	SK18007169304	2
Ball Bearing Hold-Down Disk	SK18007169305	2
Pivot Shaft for Angle Bar	SK18007169306	1
Angle Measurement Bar	SK18007169307	1
Guide for Tow Bar	SK18007169308	1
Sheet Metal Housing	SK18007169309	1
Cap for Housing	SK18007169310	2
Spacer for Mount Plate	SK18007169311	1
RVIT Shaft Adapter	SK18007169312	1
Gear Head Face Remover	SK18007169313	1
RVIT-15-60	P/N 03180003-000	1
Precision Gear Head (3:1 Ratio)	Model T642A03S	1
Bellows Coupling	P/N S9901Z-G404-24	1
Bearing Hold-Down Disks	5-40 × 5/8-in machine screw, pan-head slotted	8
	5-40 machine screw nut and no. 5 split-lock washer	8 ea.
RVIT and Pivot Mount Plates	1/4-in-20 × 1 1/4-in bolt, hex head	6
	1/4-in-20 hex nut and 1/4-in split-lock washer	6 ea.
RVIT Gear Head Assembly	6-32 × 1-in machine screw, pan- or round-head slotted	4
	6-32 machine screw nut and no. 6 split-lock washer	4 ea.
Mount Plate to HMMWV	1/4-in-20 × 1 1/4-in bolt, hex head	4
	1/4-in-20 hex nut and 1/4-in split-lock washer	4 ea.
Angle Bar to Pivot Shaft	1/2-in-13 hex nut, 5/16-in height	1
	1/2-in split-lock washer	1

Table A-1. Bill of Materials (continued)

Guide to Angle Bar	1/4-in-20 × 1 1/4-in bolt, hex head	1
	1/4-in-20 hex nut and 1/4-in split-lock washer	1 ea.
Housing Caps	8-32 × 3/8-in machine screw, round-head slotted	4
Gear Head Face Remover	4-40 × 1 1/2-in machine screw, pan-head slotted	4
Angle Measurement Bar	1/2-in-13 hex nut, 5/16-in height and 1/2-in washer	1 ea.

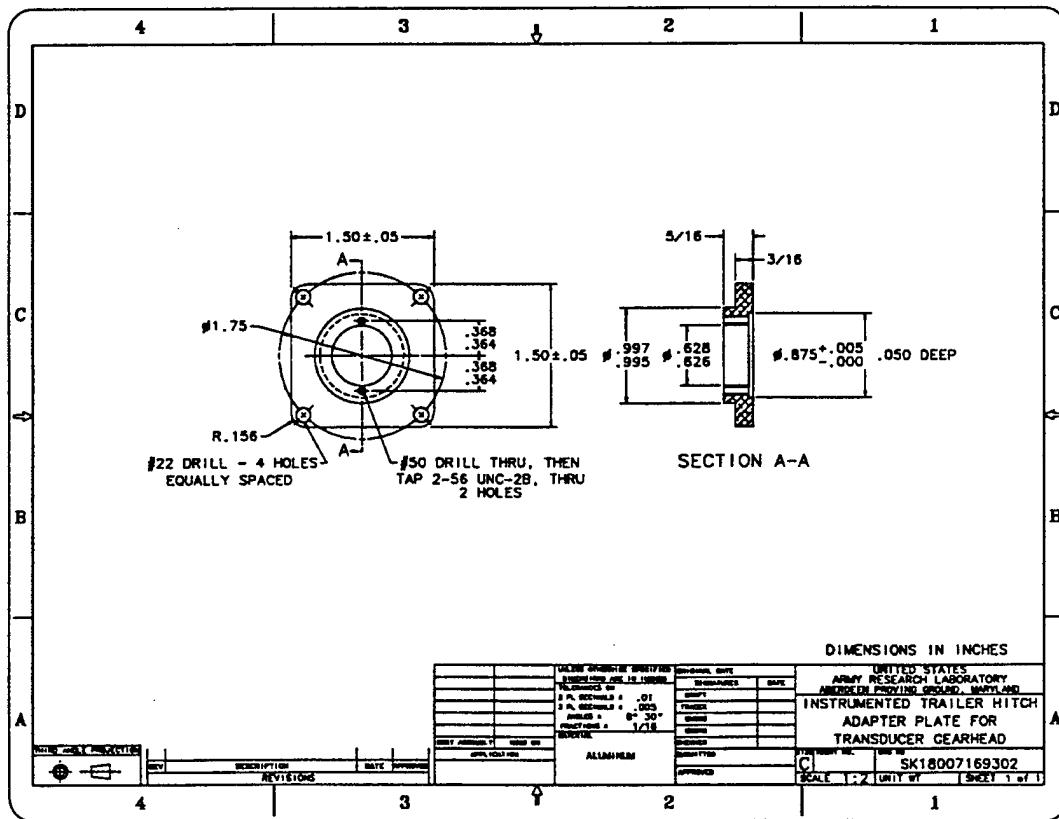
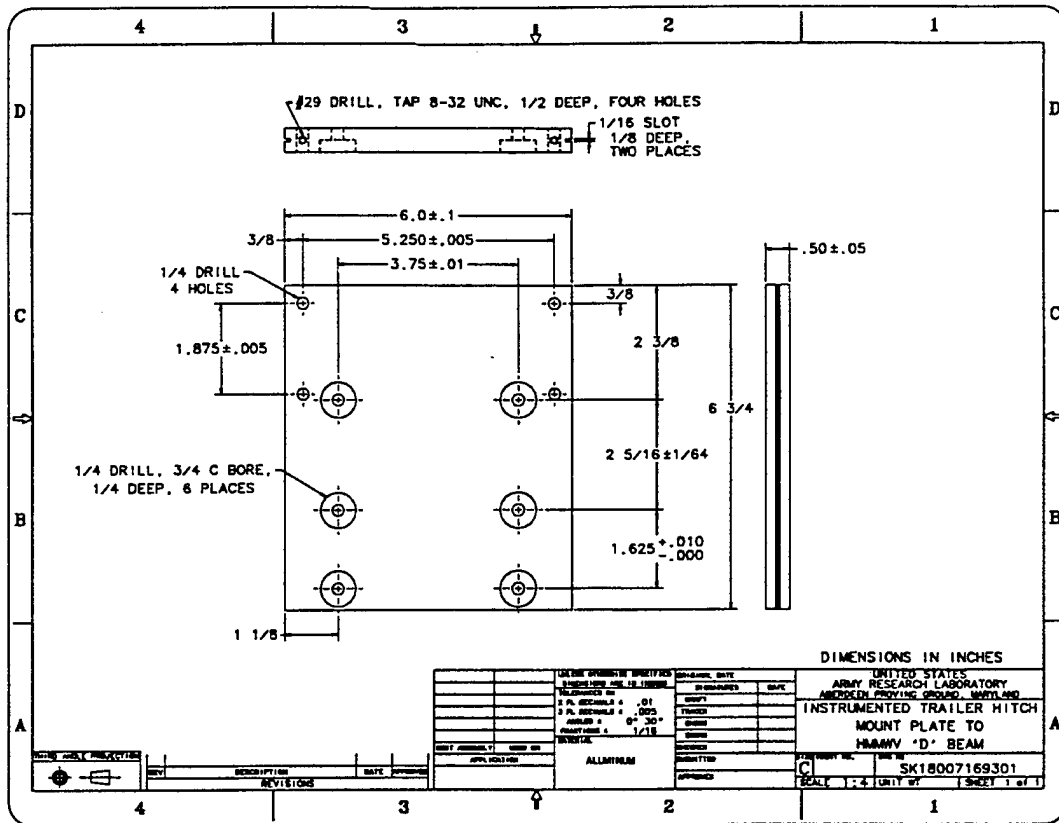


Figure A-1. Beam Mount and Gear Head Adapter Plates.

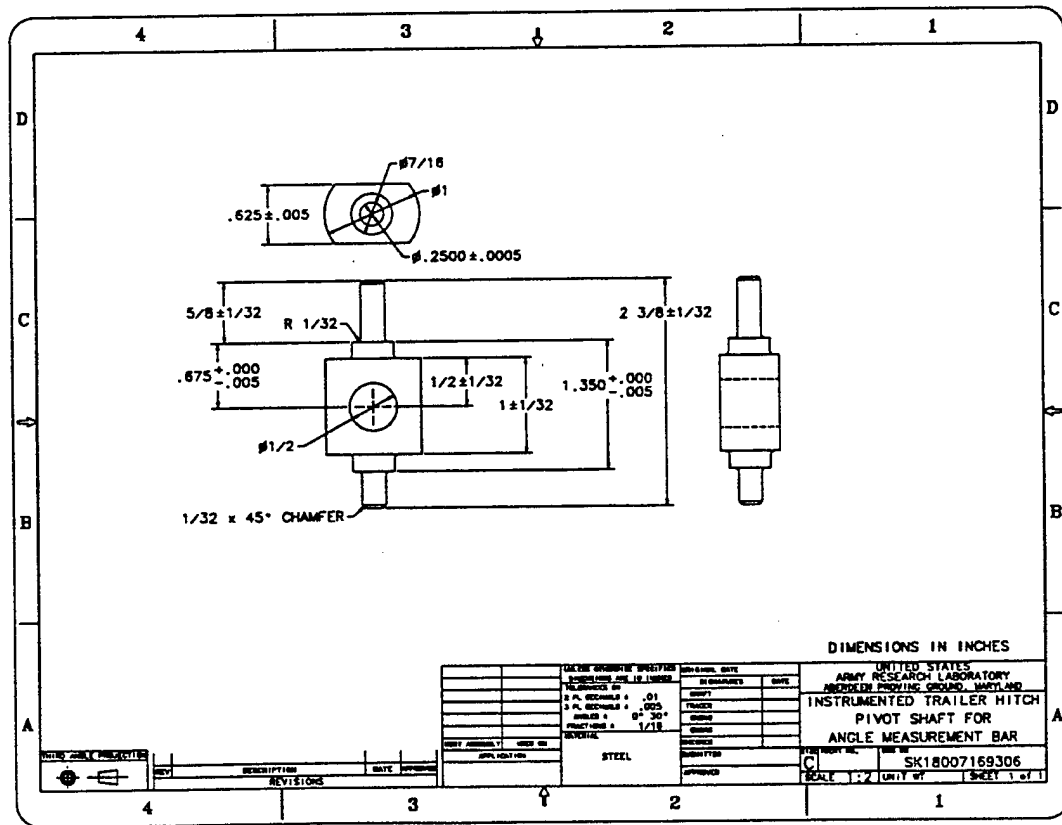
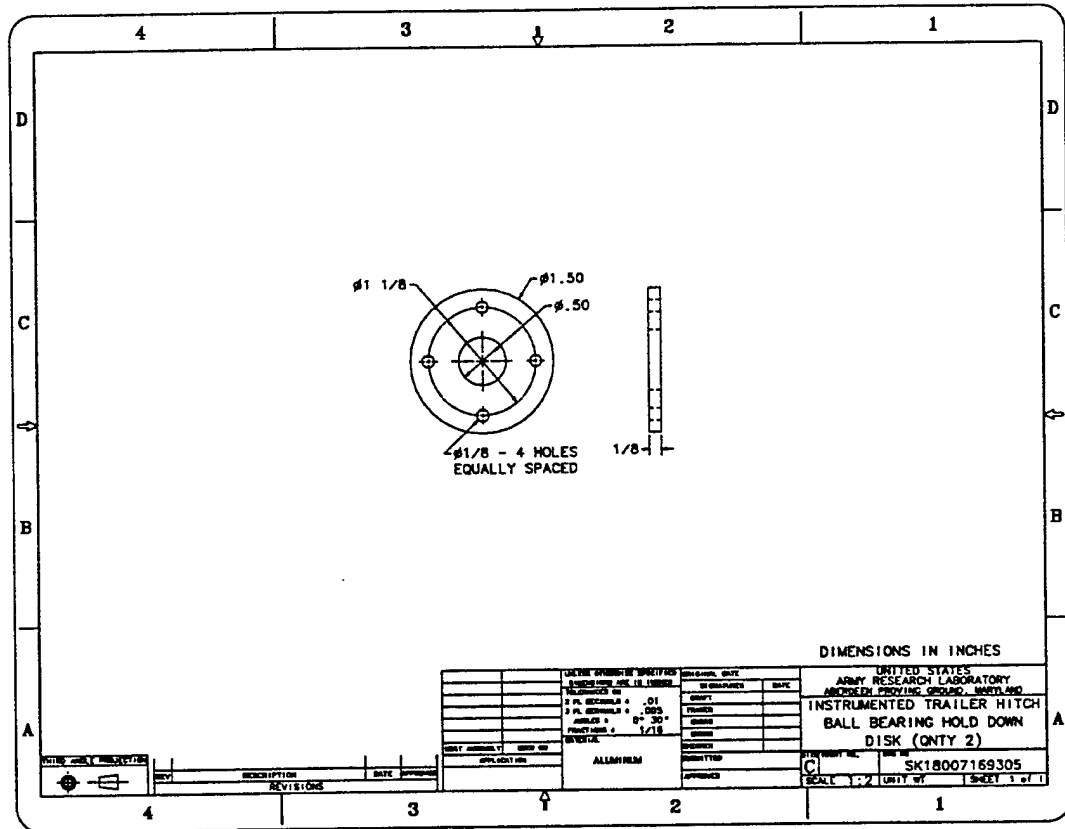


Figure A-3. Bearing Hold-Down and Pivot Shaft.

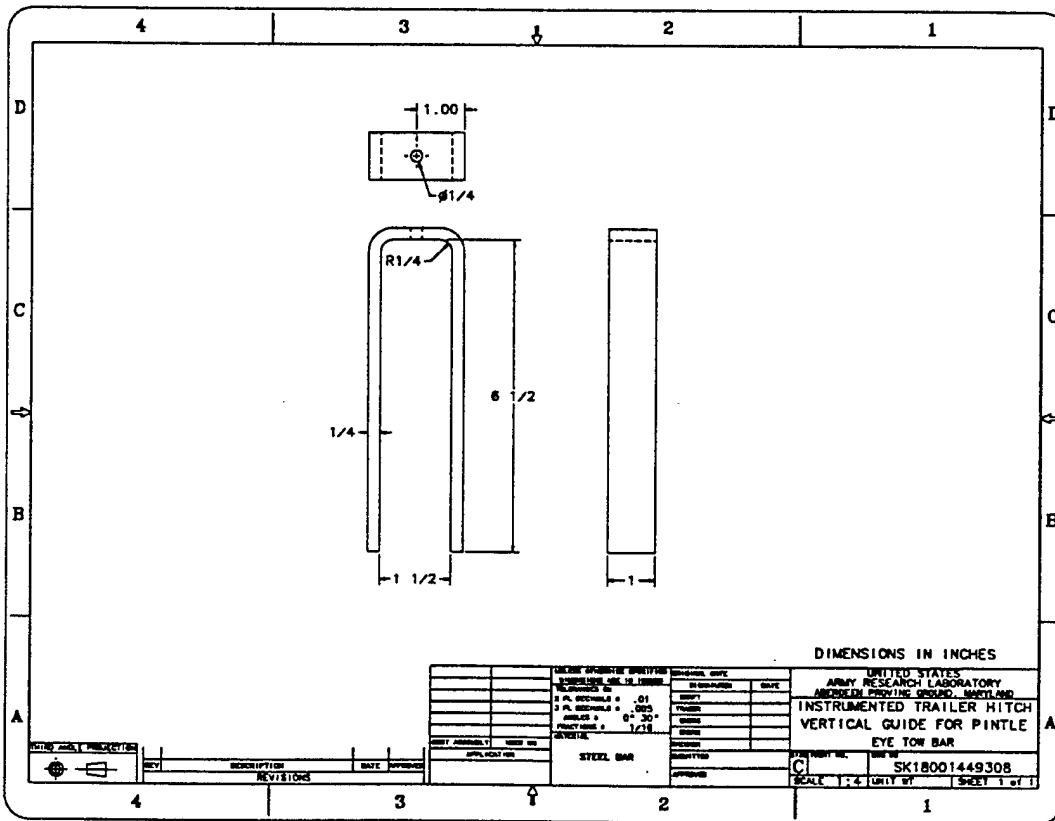
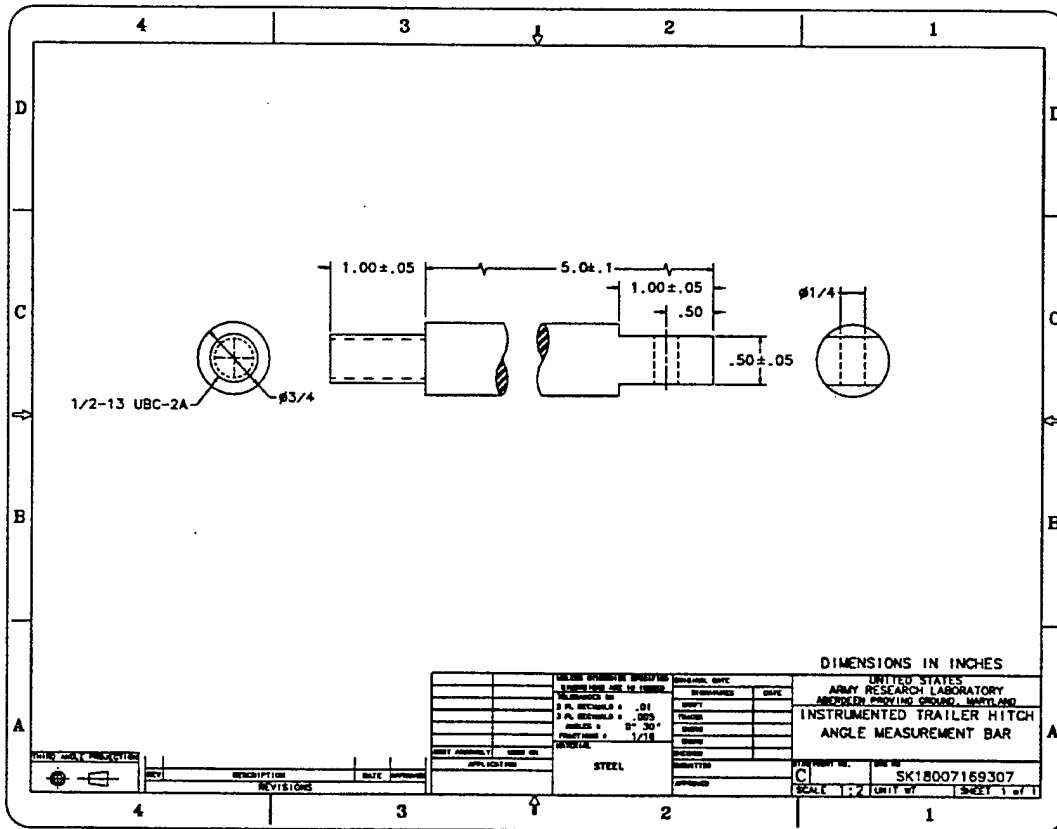


Figure A-4. Angle Measurement Bar and Guide.

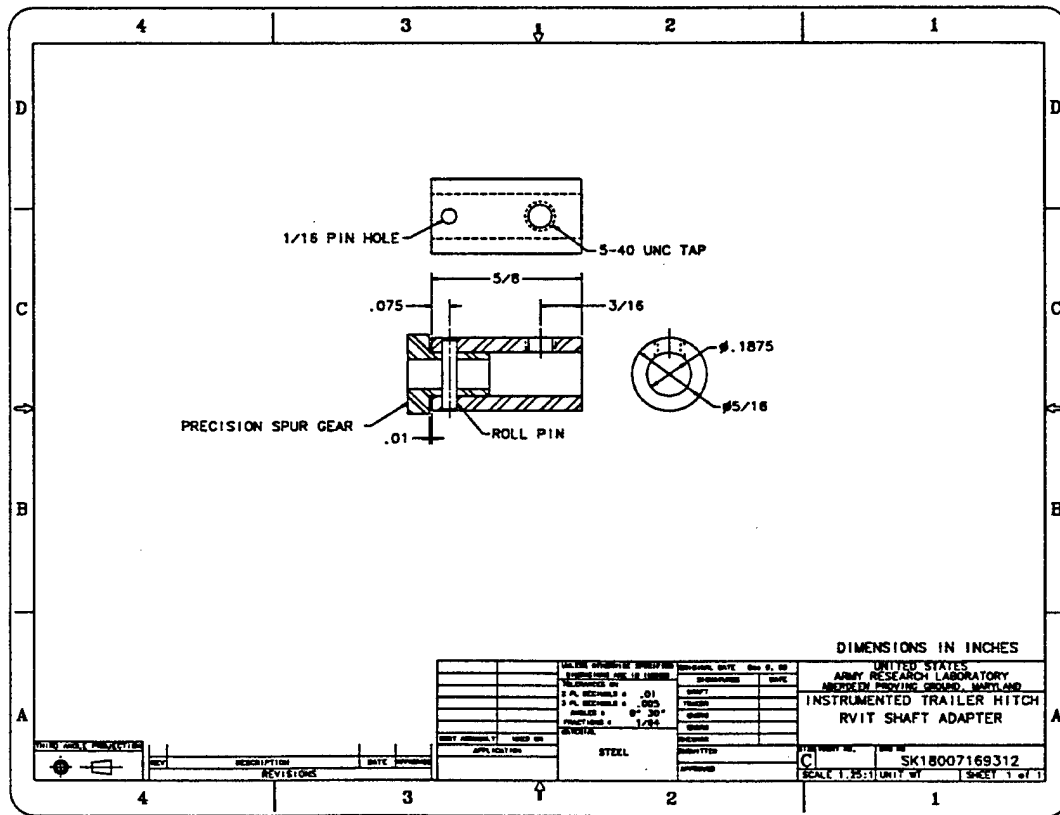
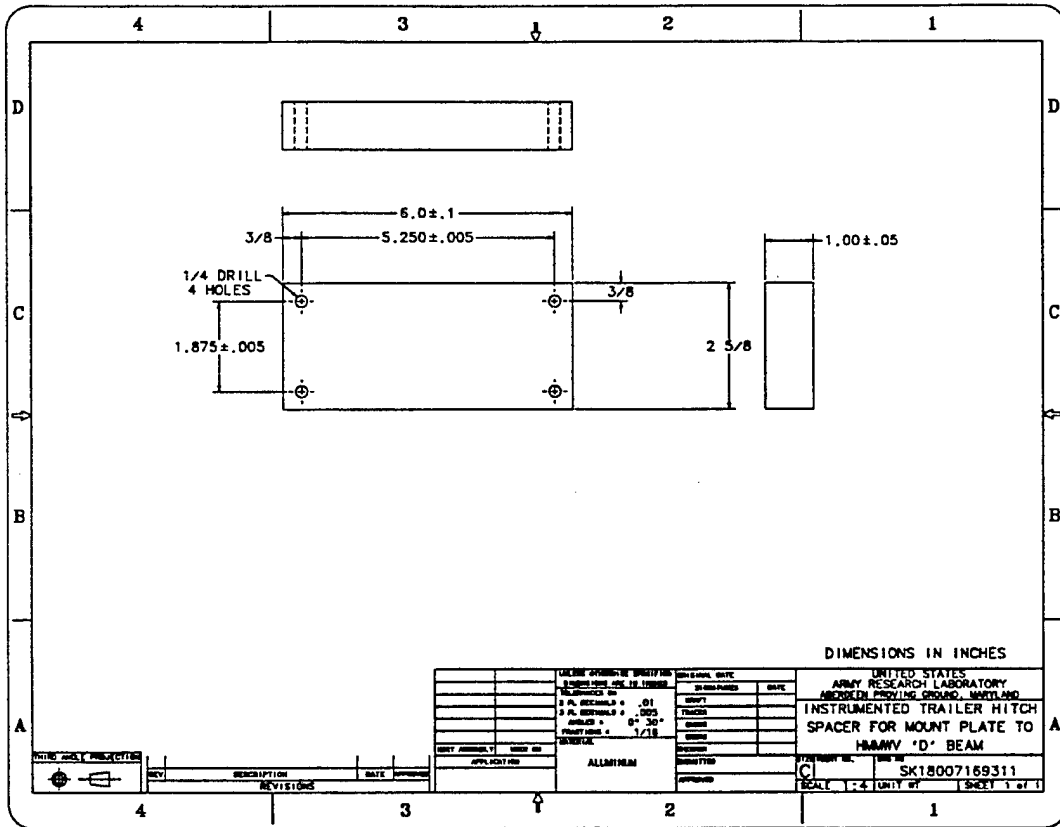


Figure A-6. Spacer and Shaft Adapter.

Appendix B:
Rotary Variable Inductance Transducer (RVIT)
Specifications

INTENTIONALLY LEFT BLANK.

The wiring configuration is as follows.

RED Input Voltage.

BLACK Common.

WHITE Output Voltage.

To wire a rotary variable inductance transducer (RVIT)-15-60, connect +5-V regulated input supply to RED and power supply common to BLACK. Output voltage, measured on WHITE (with respect to BLACK), will vary -3 V to +3 V as the shaft is rotated clockwise from -60° to +60° about the null position.

Table B-1. Performance Specifications for the RVIT-15-60 Series Rotary Position Sensor Single-Voltage Power Supply*

Angular Factor	-60° to +60°
Input Voltage ($\pm 5\%$)	+5 V
Output Voltage ($\pm 5\%$)	-3 V to +3 V
Input Current	25 mA (nominal)
Output Current	5 mA (maximum)
Output Impedance	1 Ω (maximum)
Frequency Response (-3 dB)	25 Hz (typical)
Nonlinearity	<0.25% fo full-scale output
Nonrepeatability and Hysteresis	<0.01% of full-scale output
Temperature Coefficient	< $\pm 0.02\%$ of full-scale output/ $^{\circ}\text{F}$
Operating Temperature Range	0° C to +70° C
Storage Temperature Range	-55° C to +125° C
Maximum Shaft Load—Radial	44.5 N
Maximum Shaft Load—Axial	44.5 N
Weight	70 g

* Schaevitz Engineering, Pennsauken, NJ.

Table B-2. RVIT Calibration RVIT-15-60

Measured (°)	Measured (V Direct Current [DC])	Calculated (V DC)	Deviation (V DC)
60.00	+3.0282	+3.0319	-0.0037
55.00	+2.7797	+2.7787	+0.0010
50.00	+2.5284	+2.5254	+0.0030
45.00	+2.2756	+2.2722	+0.0034
40.00	+2.0226	+2.0190	+0.0036
35.00	+1.7681	+1.7658	+0.0023
30.00	+1.5132	+1.5126	+0.0006
25.00	+1.2589	+1.2593	-0.0004
20.00	+1.0030	+1.0061	-0.0031
15.00	+0.7495	+0.7529	-0.0034
10.00	+0.4968	+0.4997	-0.0029
5.00	+0.2443	+0.2465	-0.0022
-5.00	-0.2618	-0.2602	-0.0016
-10.00	-0.5147	-0.5134	-0.0013
-15.00	-0.7675	-0.7666	-0.0009
-20.00	-1.0203	-1.0198	-0.0005
-25.00	-1.2730	-1.2730	+0.0000
-30.00	-1.5262	-1.5263	+0.0001
-35.00	-1.7796	-1.7795	-0.0001
-40.00	-2.0324	-2.0327	+0.0003
-45.00	-2.2854	-2.2859	+0.0005
-50.00	-2.5384	-2.5391	+0.0007
-55.00	-2.7912	-2.7924	+0.0012
-60.00	-3.0422	-3.0456	+0.0034

NOTES: S/N = 1066, date = 09/03/93, range = $\pm 60^\circ$, scale factor = 0.05069 V DC/ $^\circ$, null (actual) = -0.00006 V DC, linearity = 0.07% (least-squares calculation).

Appendix C:
Gear Head Specifications

INTENTIONALLY LEFT BLANK.

Table C-1. Gear Head Specifications

Description: transducer gear head, bu-ord size, zero backlash, Sterling Instrument catalogue no. S9111A-T642A03S	
Manufacturer: Sterling Instrument, division of Designatronics Inc., New Hyde Park, NY	
Maximum Backlash	<1 arc min
Maximum Operating Torque	20 oz-in minimum
Total Transmission Error	12 arc minutes maximum
Integrated Transmission Error	12 arc minutes maximum
Housing Material	aluminum alloy 2024-T4
Housing Finish	black anodized
Gears and Shaft Material	stainless steel 416
Gears and Shaft Finish	passivated
Bearings	precision ball
Description: precision bellows coupling, pin type, zero backlash, Sterling Instrument catalogue no. S9901Z-G404-24	
Bellows Material	phos. bronze, brass pins
Angular Misalignment	5° maximum
Maximum Speed	2,000 rpm

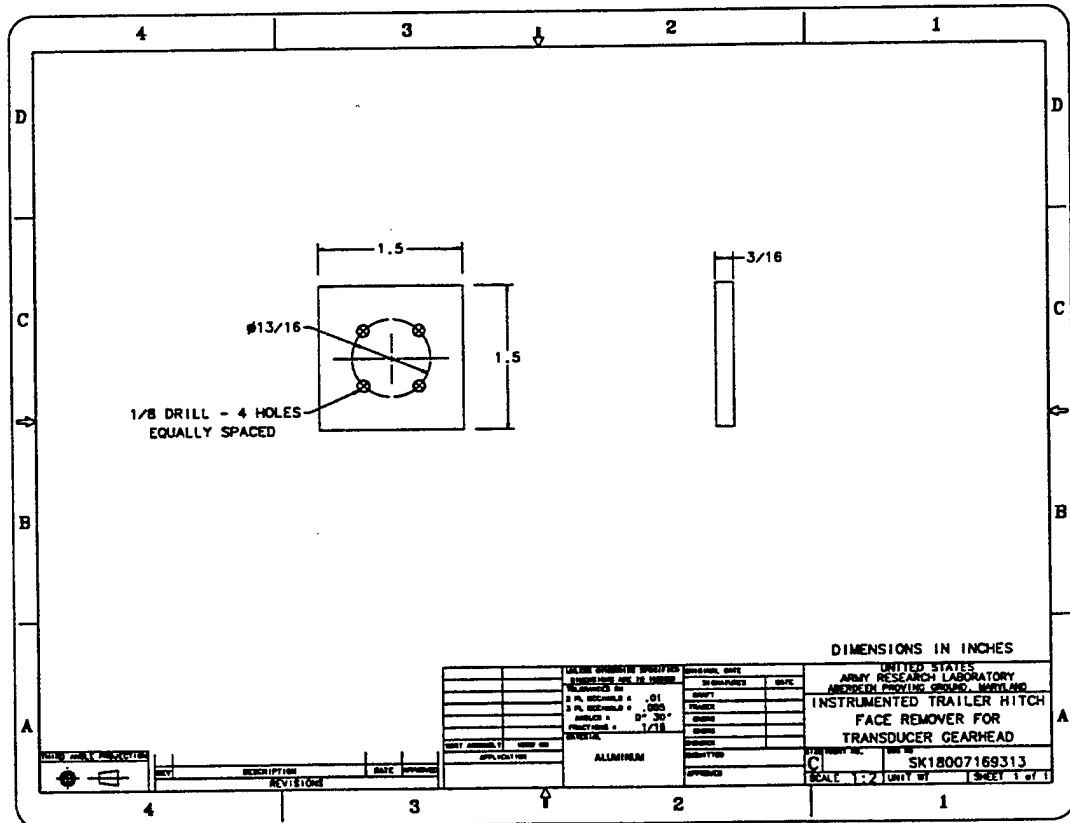


Figure C-1. Gear Head Face Remover Tool.

INTENTIONALLY LEFT BLANK.

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
2	DEFENSE TECHNICAL INFORMATION CENTER DTIC DDA 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1	HQDA DAMO FDQ DENNIS SCHMIDT 400 ARMY PENTAGON WASHINGTON DC 20310-0460
1	OSD OUSD(A&T)/ODDDR&E(R) R J TREW THE PENTAGON WASHINGTON DC 20301-7100
1	CECOM SP & TRRSTRL COMMCTN DIV AMSEL RD ST MC M H SOICHER FT MONMOUTH NJ 07703-5203
1	PRIN DPTY FOR TCHNLGY HQ US ARMY MATCOM AMCDCG T M FISETTE 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	DPTY CG FOR RDE HQ US ARMY MATCOM AMCRD MG BEAUCHAMP 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	INST FOR ADVNCD TCHNLGY THE UNIV OF TEXAS AT AUSTIN PO BOX 202797 AUSTIN TX 78720-2797
1	GPS JOINT PROG OFC DIR COL J CLAY 2435 VELA WAY STE 1613 LOS ANGELES AFB CA 90245-5500

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	DARPA B KASPAR 3701 N FAIRFAX DR ARLINGTON VA 22203-1714
1	NAVAL SURFACE WARFARE CTR CODE B07 J PENNELLA 17320 DAHLGREN RD BLDG 1470 RM 1101 DAHLGREN VA 22448-5100
1	US MILITARY ACADEMY MATH SCI CTR OF EXCELLENCE DEPT OF MATHEMATICAL SCI MDN A MAJ DON ENGEN THAYER HALL WEST POINT NY 10996-1786
1	DIRECTOR US ARMY RESEARCH LAB AMSRL CS AL TA 2800 POWDER MILL RD ADELPHI MD 20783-1145
3	DIRECTOR US ARMY RESEARCH LAB AMSRL CI LL 2800 POWDER MILL RD ADELPHI MD 20783-1145
	<u>ABERDEEN PROVING GROUND</u>
4	DIR USARL AMSRL CI LP (305)

NO. OF
COPIES ORGANIZATION

ABERDEEN PROVING GROUND

13 DIR USARL
AMSRL WM BB
C SHOEMAKER
R PHELPS
J BORNSTEIN
B HAUG
T VONG
R VON WAHLDE (2 CPS)
T BROSSEAU
M KREGEL
G HAAS
J SPANGLER
R YALAMANCHILI
AMSRL WM BA M HOLLIS

NO. OF
COPIES ORGANIZATION

3 LULEÅ UNIV OF TECHNOLOGY
UNIV CAMPUS PROSÖN
ULF LARSSON
KALEVI HYYPPÄ
ÅKE WERNERSSON
S-971 87
97187 LULEÅ SWEDEN

INTENTIONALLY LEFT BLANK.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE September 1998	3. REPORT TYPE AND DATES COVERED Final, FY93		
4. TITLE AND SUBTITLE A Hitch Angle Measurement Device			5. FUNDING NUMBERS FY93CURE	
6. AUTHOR(S) Raymond Von Wahlde				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory Attn: AMSRL-WM-BB Aberdeen Proving Ground, MD 21005-5066			8. PERFORMING ORGANIZATION REPORT NUMBER ARL-MR-406	
9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) As part of a project to demonstrate that an unmanned ground vehicle (UGV) could remotely back up with a trailer, a simple proof-of-concept device was designed to measure the angle between a high-mobility multipurpose wheeled vehicle (HMMWV) pintle hook and a trailer tow bar. A suitable algorithm could compute the UGV steering angle required for a trailer to follow a given reverse path and would be a function of the angle between the UGV and the trailer. This report gives the details of a design for a hitch angle measurement device (HAMD) to be used as input to a steering transfer function. Derivation of the transfer function is not included.				
14. SUBJECT TERMS angle measurement, hitch, unmanned vehicle			15. NUMBER OF PAGES 34	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

INTENTIONALLY LEFT BLANK.

USER EVALUATION SHEET/CHANGE OF ADDRESS

This Laboratory undertakes a continuing effort to improve the quality of the reports it publishes. Your comments/answers to the items/questions below will aid us in our efforts.

1. ARL Report Number/Author ARL-MR-406 (Von Wahlde) Date of Report September 1998

2. Date Report Received _____

3. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which the report will be used.) _____

4. Specifically, how is the report being used? (Information source, design data, procedure, source of ideas, etc.) _____

5. Has the information in this report led to any quantitative savings as far as man-hours or dollars saved, operating costs avoided, or efficiencies achieved, etc? If so, please elaborate. _____

6. General Comments. What do you think should be changed to improve future reports? (Indicate changes to organization, technical content, format, etc.) _____

CURRENT
ADDRESS

Organization

Name

E-mail Name

Street or P.O. Box No.

City, State, Zip Code

7. If indicating a Change of Address or Address Correction, please provide the Current or Correct address above and the Old or Incorrect address below.

OLD
ADDRESS

Organization

Name

Street or P.O. Box No.

City, State, Zip Code

(Remove this sheet, fold as indicated, tape closed, and mail.)
(DO NOT STAPLE)