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14. ABSTRACT
The procedures in this Test Operating Procedure (TOP) describe the actions needed to test UGVs in Line-of-Sight and Non-Line-of-Sight environments.

15. SUBJECT TERMS
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US ARMY DEVELOPMENTAL TEST COMMAND
TEST OPERATIONS PROCEDURE

Test Operations Procedure (TOP) 2-2-543 24 November 2008
DTIC AD No.:

LINE-OF-SIGHT/NON-LINE-OF-SIGHT (LOS/NLOS) TESTING OF UNMANNED GROUND VEHICLE (UGV) SYSTEMS

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1. SCOPE.

This TOP describes a systematic approach to Line-of-Sight/Non Line-of-Sight (LOS/NLOS) testing of Unmanned Ground Vehicles (UGVs). The objective is to ensure that testing of each UGV includes measures to enhance system safety, and that hazards which could reduce system safety are eliminated or controlled to an acceptable level of risk.

1.1 Purpose.

The purpose of this document is to provide a systematic approach to LOS/NLOS testing of UGVs in order to ensure that the overall safety of the system is adequate and that the performance of the UGV meets with expectations. This document provides uniform procedures that may be applied to the testing of UGVs. Test results should be thorough enough to identify hazards of a system and to verify performance of the system within system requirements.

1.2 Applicability.

This document applies to remote-controlled and teleoperated ground vehicles.

1.3 Activities Addressed.

The information contained herein applies to LOS/NLOS testing of robotic systems. Tailoring of test procedures to the specific needs of the system and its intended use are encouraged.

1.4 Limitations.

This document applies to LOS/NLOS testing of UGVs only. Methodologies for testing of Unmanned Aerial Vehicles (UAVs) or Unmanned Submersible Vehicles (USVs) are not covered in this document. This document does not apply to automated subsystems that do not directly affect people or objects outside of the vehicle such as automated internal weapon loading systems or automated tracking subsystems, nor to automated driver-assist functions that require full-time on-board driver attention to perform a task such as cruise control, anti-lock brake systems, or self-leveling systems.

2. FACILITIES AND INSTRUMENTATION.

2.1 Test Facilities and Conditions.

Testing should be conducted with exclusive use of test courses to mitigate potential safety hazards to personnel, buildings, and test items.

2.2 Instrumentation.

a. Instrumentation requirements for LOS/NLOS testing of UGVs will rely extensively on sensors to provide information regarding the environment in which the UGV is operating. Instrumentation should be employed to measure the following:

(1) Vehicle and OCU position on test course (±1 m).

(2) Communications latency between OCU and vehicle (±1 microsecond)

(3) RF environment

(4) Communications signal strength

b. A Global Position System (GPS) device with the highest possible resolution will be used to mark the positions of the OCU and vehicle. The GPS will be used to determine the distance at which LOS/NLOS communications between the OCU and vehicle are lost.

c. In general, instrumentation will continue to be used in traditional physical test roles to gather pertinent component level data using accelerometers, thermocouples, etc.

d. Safety measures for UGV testing outlined in TOP 2-2-540[1*] should be adhered to for LOS/NLOS testing.

e. Prior to testing, a digital spectrum analyzer will be used to examine the spectral composition of radio frequency (RF) in the testing area. The data collected will be evaluated to ensure that RF signals in the testing area will not cause interference with the test item.

3. REQUIRED TEST CONDITIONS.

a. Prior to the start of testing, all test personnel will receive operator familiarization and training on the test item.

b. All test personnel will be briefed on any potential hazards associated with the specific test item. All guidelines for standoff distances and other safety related issues will be followed.

c. Test personnel will maintain contact with the test course supervisors during testing. All Standing Operating Procedures (SOPs) regarding test course use will be followed.

d. Prior to testing, entry points to the test course will be blocked with barricades and signs reflecting robotic testing in progress. Range lights will be turned on where available.

e. Video coverage of the test event will be provided as necessary.

[*] Superscript numbers correspond to those in Appendix B, References.

f. Photographs of the test set up will be obtained.

4. TEST PROCEDURES.

a. LOS.

(1) Perform this test along a flat, paved straightaway in an open area free from overhanging trees or other obstacles that might impede the RF connection between the Operator's Control Unit (OCU) and vehicle.

(2) Perform an operational check prior to testing to determine baseline status. Evaluate system performance throughout testing, and perform operational checks at least every 61 m (200 ft). Perform an operational check at the completion of testing to determine any degradation of performance.

(3) The UGV will be situated beside or directly in front of the OCU.

(4) The UGV will be driven away from the OCU at a speed no greater than 16 km/hr (10 mph) to the maximum required LOS operating distance or until a degraded mode is indicated by any of the following:

(a) The OCU video feed reverts to the blue screen for more than 3 seconds.

(b) A data link failure occurs.

(c) Any other system fault (such as loss of steering or sensor control) occurs.

(5) Record a description of any loss or degradation of function, to include a categorization of the severity of the fault.

(6) Record the distance between the OCU and the vehicle at the time of the failure.

(7) Repeat the above procedure at least three times for comparison purposes and to establish consistency of system performance.

b. NLOS, natural terrain. During all NLOS testing, a secondary safety driver should be used to maintain LOS with the UGV at all times.

(1) In order to establish the NLOS natural terrain environment, conduct testing in an area containing a natural obstruction. The test may be conducted along the curve of a course, with thick foliage present along the inside of the curve, as shown in Figure 1.

(2) Perform an operational check prior to testing to determine baseline status. Evaluate system performance throughout testing, and perform operational checks at least every 16 m (200 feet). Perform an operational check at the completion of testing to determine any degradation of performance.

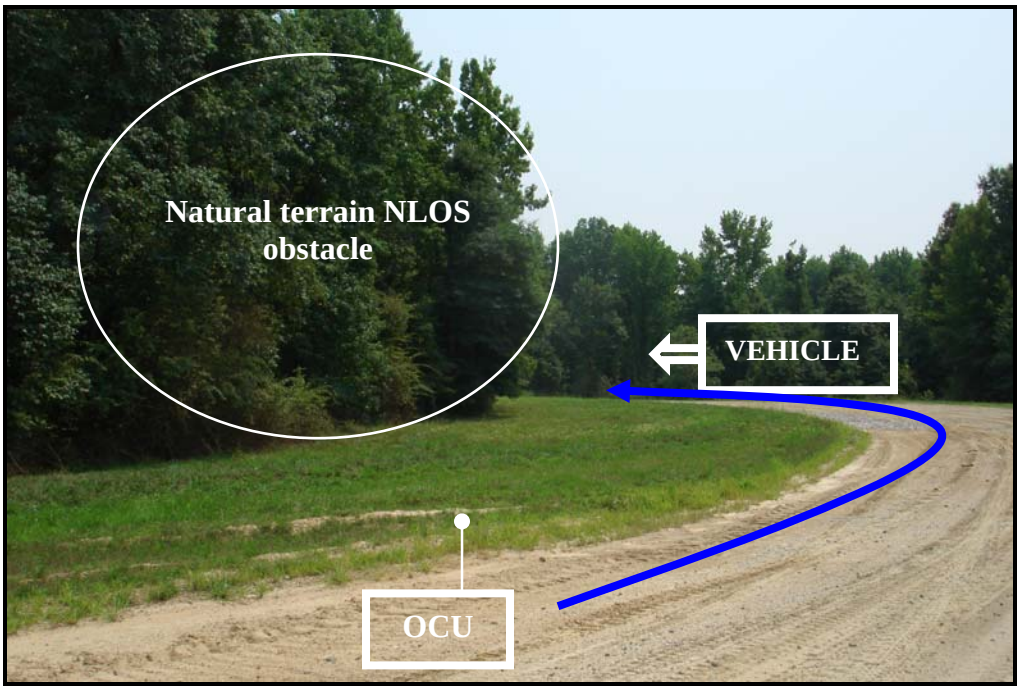

Figure 1. Natural obstacle for NLOS operations

(3) Document the density and composition of the natural obstacle with photographs.

(4) The UGV will be situated beside or directly in front of the OCU at the beginning of the curve in the test course.

(5) The UGV will be driven away from the OCU (as shown above in Figure 1) at a speed no greater than 16 km/hr (10 mph) to the maximum required NLOS natural terrain operating distance or until a degraded mode is indicated by any of the following:

(a) The OCU video feed reverts to the blue screen for more than 3 seconds.

(b) A data link failure occurs.

(c) Any other system fault (such as loss of steering or sensor control) occurs.

(6) Record a description of any loss or degradation of function, to include a categorization of the severity of the fault.

(7) Record the distance between the OCU and the vehicle at the time of the failure.

(8) Repeat the above procedure at least three times for comparison purposes and to establish consistency of system performance.

c. NLOS, urban environment. During all NLOS testing, a secondary safety driver should be used to maintain LOS with the UGV at all times.

(1) The NLOS urban environment should consist of several buildings or simulated buildings situated close together with network of paths or roads between them. For the purpose of test documentation, the dimensions of each building, building materials used in each building, distances between the buildings, the length of each path or road, and GPS coordinates throughout the test site should be recorded.

(2) Perform an operational check prior to testing to determine baseline status. Evaluate system performance throughout testing, and perform operational checks at least every 61 m (200 ft). Perform an operational check at the completion of testing to determine any degradation of performance.

(3) The UGV will be situated beside or directly in front of the OCU. Test iterations will be conducted both with the OCU positioned outside the urban environment and with the OCU positioned inside the urban environment.

(4) The UGV will be driven away from the OCU and around buildings at a speed no greater than 10 mph to the maximum required NLOS urban environment operating distance or until a degraded mode is indicated by any of the following:

(a) The OCU video feed reverts to the blue screen for more than 3 seconds.

(b) A data link failure occurs.

(c) Any other system fault (such as loss of steering or sensor control) occurs.

(5) Record a description of any loss or degradation of function, to include a categorization of the severity of the fault.

(6) Using a GPS, record the linear distance between the OCU and the vehicle at the time of the failure. Record the number of buildings between the OCU and vehicle at the time of the failure, as well as the dimensions of each building and the building materials that comprise each building between the OCU and vehicle.

(7) Repeat each above procedure at least three times for comparison purposes and to establish consistency of system performance.

d. NLOS, convoy operations (OCU stationary, vehicle stationary). During all NLOS testing, a secondary safety driver should be used to maintain LOS with the UGV at all times.

(1) Convoy operations should be conducted on a flat, paved test course, as well as on secondary (dirt) roads and cross-country trails. For this test, operations will be executed with the OCU, UGV, and all convoy vehicles stationary in order to establish a baseline against which moving convoy test results can be measured.

(2) Perform an operational check prior to testing to determine baseline status. Evaluate system performance and perform operational checks throughout testing. Perform an operational check at the completion of testing to determine any degradation of performance.

(3) Identify vehicles that would typically convoy with the test item in an operational scenario. For the purpose of this example, the convoy will consist of commonly used small and large vehicles; the High Mobility Multipurpose Wheeled Vehicle (HMMWV) may be used to represent a commonly used smaller vehicle, and the Family of Medium Tactical Vehicles (FMTVs) may be used to represent a commonly used larger vehicle. Instrument all vehicles in the convoy with GPS.

(4) Dismountable OCU in open air, stationary operations. The OCU will be stationary and in the open air (not on board a vehicle); this test will only be performed for systems wherein the OCU is not integrated into a command vehicle, or is designed to be dismountable from its command vehicle. Place one intervening vehicle between the OCU and the vehicle, and conduct operational checks. Increase the number of intervening vehicles between the OCU and UGV until the system requirement is met or until a degraded mode is indicated by any of the following:

(a) The OCU video feed reverts to the blue screen for more than 3 seconds.

(b) A data link failure occurs.

(c) Any other system fault (such as loss of steering or sensor control) occurs.

(5) Record a description of any loss or degradation of function, to include a categorization of the severity of the fault.

(6) OCU on board a command vehicle, stationary operations. The OCU will be stationary and on board a command vehicle. Place one intervening vehicle between the OCU and the UGV, and conduct operational checks. Increase the number of intervening vehicles between the OCU and UGV until the system requirement is met or until a degraded mode is indicated by any of the following:

(a) The OCU video feed reverts to the blue screen for more than 3 seconds.

(b) A data link failure occurs.

(c) Any other system fault (such as loss of steering or sensor control) occurs.

(7) Record a description of any loss or degradation of function, to include a categorization of the severity of the fault.

(8) Using a GPS, record the linear distance between the OCU and the vehicle at the time of the failure. Record the number and type of vehicles between the OCU and vehicle at the time of the failure, as well as the distances between each vehicle in the convoy.

(9) Repeat each above procedure at least three times for comparison purposes and to establish consistency of system performance.

e. NLOS, convoy operations (moving operations). During all NLOS testing, a secondary safety driver should be used to maintain LOS with the UGV at all times.

(1) Convoy moving operations should be conducted on a flat, paved test course, as well as on secondary (dirt) roads and cross-country trails. For this test, operations will be executed with the OCU, UGV, and all convoy vehicles moving.

(2) The OCU will be on board a command vehicle.

(3) Place one intervening vehicle between the OCU and the vehicle.

(4) The OCU operator will accelerate the UGV. The command vehicle and the intervening vehicle will accelerate with the UGV. Initially, a distance of approximately 100 m (328 ft) will be kept between the UGV and the rest of the convoy; this distance will be expanded to at least 300 m (984 ft) or until the control link is lost. A distance of approximately 50 m (164 ft) will be kept between each of the remainder of the convoy vehicles.

(5) An additional intervening vehicle will be added to the convoy after each successful convoy operation. This maneuver will be performed until the system requirement is met or until a degraded mode is indicated by any of the following:

(a) The OCU video feed reverts to the blue screen for more than 3 seconds.

(b) A data link failure occurs.

(c) Any other system fault (such as loss of steering or sensor control) occurs.

(6) Record a description of any loss or degradation of function, to include a categorization of the severity of the fault.

(7) Using a GPS, record the linear distance between the OCU and the vehicle at the time of the failure. Record the number of vehicles and type and position of each vehicle in the convoy at the time of the failure, as well as the distances between each vehicle in the convoy.

(8) Repeat the above procedure at least three times for comparison purposes and to establish consistency of system performance.

5. DATA REQUIRED.

a. Documentation will be provided detailing all aspects of testing including the following:

(1) Vehicle serial number.

(2) Photographs of test site and setup.

(3) Video and data link operating frequency.

(4) Distance between OCU and UGV when video or data link was lost.

(5) Any failure or limitation of the operational checklist during testing.

(6) Detailed description of obstacles to be used during NLOS testing, including photographs, GPS coordinates, test course dimensions, and the following:

(a) NLOS (Natural Terrain, Wooded). The natural terrain should be represented in photographs and otherwise measured, where possible.

(b) NLOS (Natural Terrain, Hills). The geodetically surveyed elevation of the hill or hills.

(c) NLOS (Urban Terrain). The dimensions, layout, and construction materials that comprise the buildings.

(d) NLOS (Convoy Operations). Provide a list of vehicles used, distances between vehicles, speeds of travel for all vehicles, and communication equipment that may be installed and used on the obstacle vehicles during operations.

6. PRESENTATION OF DATA.

a. Describe the inspection, specific test procedures, and results for each item using narration, tables, photographs, charts, and graphs as appropriate or as outlined in procedures and data required.

b. Reduce, summarize, and analyze data from each subtest appropriate to the subtest data topic and failure definitions derived specifically for the item and the subtest category.

APPENDIX A. ABBREVIATIONS.

DOD	Department of Defense
FOV	Field of View
IR	Infrared
JAUS	Joint Architecture of Unmanned Systems
JGRE	Joint Ground Robotics Enterprise
OCU	Operator Control Unit
RF	Radio Frequency
SUT	System under test
TIRS	Test Incident Reports
TOP	Test Operations Procedure
UGV	Unmanned Ground Vehicle

APPENDIX B. REFERENCES

1. TOP 2-2-540, Testing of Unmanned Ground Vehicle (UGV) Systems, 30 June 2008.

For information only (related publications).

a. TOP 2-2-542, Safe Operation of Weaponized Unmanned Ground Vehicle (UGV) Systems, 8 July 2008.

b. TOP 3-2-812, Field of Vision - Vehicles, 23 February 1966.

c. Unmanned Systems Safety Guide for DOD Acquisition, 27 June 2007.

Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Test Business Management Division (TEDT-TMB), US Army Developmental Test Command, 314 Longs Corner Road Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity: US Army Aberdeen Test Center (TEDT-AT-AD-F), 400 Colleran Road, Aberdeen Proving Ground, MD 21005-5059. Additional copies can be requested through the following website: http://itops.dtc.army.mil/RequestForDocuments.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.