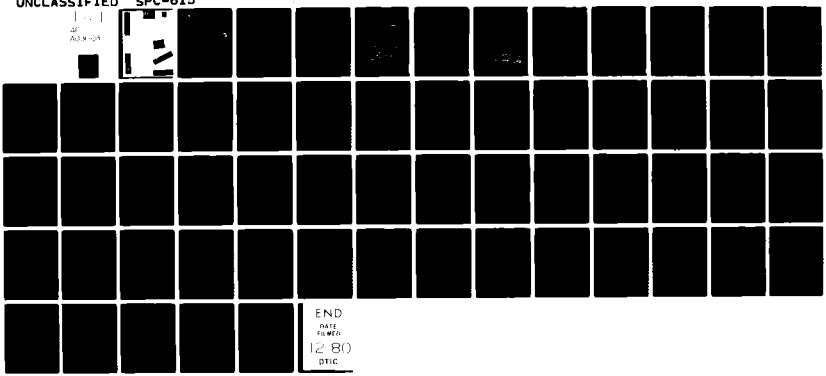
AD-A091 603 SYSTEM PLANNING CORP ARLINGTON VA F/G 17/8
A SURVEY OF SIMULATION AND TEST RESULTS FOR ASSESSING RPV PERFO--ETC(U)
JUL 80 M H CROWELL DAAK50-80-C-0011
UNCLASSIFIED SPC-615 NL



DDC FILE COPY

AD A091603

LEVEL II

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

NOV 13 1980

G

80 10 7 048

SYSTEM PLANNING CORPORATION
1500 Wilson Boulevard • Arlington, Virginia 22209 • (703) 841-2800

(2)

SPC Log No. 80-3279
Copy 022

(6)

A SURVEY OF SIMULATION AND TEST RESULTS FOR ASSESSING RPV PERFORMANCE IN A WBIC ENVIRONMENT

(9) FINAL REPORT,
(14) SPC-515

DTIC
ELECTE
NOV 13 1980
D
C

(11) July 1980

(12) 51

(10) M. H. Crowell

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

Prepared for
Project Manager's Office
Tactical Airborne Remotely Piloted Vehicle/Drone Systems
U.S. Army Aviation Research and Development Command
St. Louis, Missouri 63120

(15)

Contract DAAK50-80-C-0011

406932

15

Accession For
NTIS GRA&I
DTIC TAB
Unannounced
Justification Per FL-182 on file
By
Distribution/
Availability Codes
Avail and/or
Dist Special
A

CONTENTS

I. EXECUTIVE SUMMARY 1

A. Purpose 1
B. RPV Missions 1
C. Approach 2
D. Findings 3

II. IDENTIFICATION OF RPV MISSION TASKS 7

A. Target Acquisition 9
B. Target Designation 9
C. Artillery Adjustment 9
D. Reconnaissance 10
E. Damage Assessment 10

III. SELECTED WBIC MODELS AND MODELING TECHNIQUES SUITABLE FOR ASSESSING THE RPV MISSION PAYLOAD PERFORMANCE 11

A. SPC Historical Data Base for European Weather 11
B. OPAQUE Historical Data Base 12
C. LOWTRAN Computer Code 12
D. DANTRAN Computer Code 12
E. Natural Aerosol Extinction Module 13
F. Laser Line Absorption Routine 13
G. Turbulence-Induced Pointing Jitter 14
H. Radiative Environment and Contrast Module 14
I. Millimeter-Wave Model 15
J. TAVETS Model 16
K. Dust Obscuration Module 16
L. Smoke Obscuration Routine 17
M. Battlefield Environment Laser Designated Weapon System Simulation 17

IV. REVIEW OF SELECTED WBIC TESTS 19

A. Manportable Common Thermal Night Sight Smoke Test (July 1977) 19

B. Smoke Week I Test (November 1977) 21

C. Grafenwoehr II Realistic Battlefield Sensor Trials - Winter (November 1978) 24

D. Grafenwoehr II Realistic Battlefield Sensor Trials - Summer (July 1979) 26

E. Dusty Infrared Test-I (October 1978) 28

F. Smoke Week II Test (November 1978) 30

G. Dusty Infrared Test-II (July 1979) 33

H. A Measurement and Data Reduction Program on Optical Atmospheric Quantities in Europe (1977-80) 35

V. RECOMMENDED MODELING APPROACHES FOR ANALYZING THE EFFECTS OF WBIC ENVIRONMENTS 39

A. Detect and Identify Target 39

B. Range to the Target to Determine Its Location 43

C. Identify and Locate Impacts of Artillery Shells From Weapons That Are Being Directed 43

D. Designate Target for Laser-Guided Weapons or Pave Penny 44

E. Provide Reconnaissance Information 45

F. Assess Target Damage 46

APPENDIX: GLOSSARY, REFERENCES, AND DISTRIBUTION 47

I. [illegible]

A. PURPOSE

The purpose of this report [illegible] results and recommend selected models that can be used [illegible] motely Piloted Vehicle (RPV) mission payload performance [illegible] weather and battle-induced contaminants in operational [illegible]

B. RPV MISSIONS

The effect of weather and battle-induced contaminants [illegible] payload performance must be evaluated for each of the missions [illegible] is expected to perform. For purposes of this analysis, five [illegible] defined:

- (1) Target acquisition: Detecting, recognizing, and [illegible] emy elements and providing their location for [illegible] by fire support.
- (2) Target designation: Using laser designators [illegible] point targets for engagement with laser-guided [illegible] Copperhead and Hellfire. (In addition, [illegible] target areas for acquisition by laser spot [illegible] Air Force's Pave Penny system.)
- (3) Artillery adjustment: Functioning [illegible] directing or adjusting field artillery [illegible]
- (4) Reconnaissance: [illegible] the enemy [illegible] graphic, [illegible]
- (5) [illegible] target.

C. APPROACH

The approach used in this study consisted of two [illegible] mission type was divided into two separate and distinguishable [illegible] ments (i.e., fly to the target area and loiter in the target area [illegible] characterized according to several mission tasks (e.g., [illegible] target designation). Second, WBIC modeling techniques and [illegible] results were reviewed for their suitability for assessing the [illegible] formance of the RPV during each critical mission task in the following [illegible] environments:

- Smoke and dust from high-explosive artillery rounds
- Smoke from artillery-delivered smoke rounds
- Smoke from burning vehicles
- Smoke generated for self-protection
- Adverse weather.

Aerosols created by these sources may cause substantial degradation in RPV system performance by reducing target signatures as viewed with television (TV) or forward-looking infrared (FLIR) sensors. Suitable modeling techniques and test data must reflect the effects of (1) temporal and spatial variations of WBIC environments, such as those associated with the growth of dust clouds from exploding munitions; and (2) smoke clouds generated by fog oil generators.

A methodology was structured, based on a previously published SPC approach for analyzing mission payload performance, as a means for evaluating research identified during this survey.[1] This is an incremental analysis methodology and was applied to assess the RPV TV sensor performance in a European weather environment for visual discrimination tasks (e.g., target detection or recognition). With this methodology, surveyed modeling techniques must meet three requirements for them to be suitable for assessing the effects of WBIC environments on RPV payload performance.

---

[1] An Approach to Analysis of RPV Sensor Performance in [illegible] Environments, System Planning Corporation, [illegible] Confidential).

- They [illegible]
- They [illegible]
- They must be capable of [illegible] FLIR vs TV).

The suitability of test results performed [illegible] assessed based on their applicability to support [illegible] eling techniques and because they have one or more of the [illegible] tures:

- They can demonstrate the effects of a [illegible] ment on tactical or developmental electro[illegible] fing in the visual, infrared, or millimeter [illegible] trum.
- They can provide data for use in quantifying [illegible] WBIC environments.
- They can demonstrate the feasibility of using [illegible] quantifying WBIC environments through field testing.

D. FINDINGS

Based on the approach used in this study, 13 [illegible] WBIC tests have been found to be useful in assessing the [illegible] environments on RPV payload performance. Together, they [illegible] derive estimates of most effects of WBIC environments on [illegible] performance for the mission tasks. The three areas [illegible] associated with them for RPV analyses are:

- Vertical variations in [illegible] identified modeling [illegible] tical variations in [illegible] tors, there are insufficient [illegible] occurrence of these vertical [illegible]
- Thermal signatures of [illegible] signature [illegible] in the European [illegible] mate the frequencies of [illegible] signatures.

- Operator performance in operational environments - Mode[illegible] niques for quantifying the ability of an RPV operator to [illegible] fully accomplish mission tasks (e.g. directing artillery [illegible] designating a target) have not been validated.

Further model refinement and additional testing are identified for these areas.

1. WBIC Modeling Techniques

The 13 recommended modeling techniques are listed below:

a. Modeling techniques for estimating the effects of naturally occurring weather factors:

(1) Analysis of historical weather data base developed from the archival records available from the U.S. Air Force Environmental Technical Applications Center (ETAC) to predict monthly and seasonal variations in weather factors.

(2) Analysis of historical data from the test entitled "A Measurement Program on Optical Atmospheric Quantities in Europe (OPAQUE)" to estimate selected variations in atmospheric characteristics on a monthly or seasonal basis.

(3) Use of the LOWTRAN IV computer code, as modified by Atmospheric Sciences Laboratory (ASL), to estimate atmospheric transmittance in selected portions of the infrared spectral region.

(4) Use of the DANTRAN computer code to estimate atmospheric transmittance in selected portions of the infrared spectral region with an accuracy suitable for operational analyses and with a lower computer cost than required by LOWTRAN IV.

(5) Use of the Natural Aerosol Extinction Model based on data collected during tests at Grafenwoehr, Germany, and Fort A. P. Hill, Virginia, and augmented by the vertical profiles developed by ASL.

(6) Use of the Laser Line Absorption Routine (LZTRAN) computer program to calculate the atmospheric molecular absorption coefficients for lasers operating at a wavelength of 1.06 μ.

(7) Use of the Turbulence-Induced Pointing Jitter (TIPJ) algorithm developed by the U.S. Army Missile Command for estimating (a) the expected laser spot size, (b) an estimate of propagation conditions, (c) fluctuations of the power spectrum in the laser spot, and (d) the amount of beam wander around the line of sight of the designator.

(8) Use of the Radiant Environment [illegible] by ASL for estimating the apparent contrast [illegible] viewed from the location of the sensor being [illegible] flectivity and emissivity properties of the [illegible] ground being viewed, (b) the transmittance of the [illegible] including any obscurant clouds, and (c) the [illegible] of the natural radiative environment in the visual [illegible] infrared spectral region (i.e., 0.4 to 1.0 μm).

(9) Use of the modeling technique for near-millimeter [illegible] lected by ASL to estimate the atmospheric attenuation effects of water vapor, oxygen, rainfall rates, and fog for four frequencies: 35, 94, 140, and 220 GHz.

(10) Use of the Thermodynamic Armored Vehicle and Environmental Thermal Signatures (TAVETS) Model for estimating day-to-day diurnal variations in thermal radiance and signatures for armored vehicles and background scene components.

b. Modeling techniques for estimating atmospheric characteristics in WBIC environments:

(11) Use of the DIRTRAN algorithm to estimate aerosol density distributions and atmospheric transmittance of dust clouds resulting from explosive charges.

(12) Use of the Electro-Optical Systems Atmospheric Effects Library (EO-SAEL) Smoke Obscuration Model that is based on a computer code developed by the U.S. Army Night Vision and Electro-Optics Laboratory for any of four smoke types: white phosphorous, plasticized white phosphorous, hexachloroethane, and fog oil for the visual and infrared portions of the spectrum.

c. Modeling technique for estimating laser designator performance in WBIC environments:

(13) Use of the Battlefield Environment Laser Designator Weapon System Simulation (BELDWSS) approach for evaluating complex three-dimensional interactions resulting from variations in laser designator performance, target characteristics, optical atmospheric characteristics, and the laser tracker.

2. WBIC Tests

The salient results for the eight WBIC tests are summarized below:

(1) The Manportable Common Thermal Night Smoke Test (July 1977) demonstrated the effects of a quantified WBIC environment on the performance of selected tactical and developmental tracking or guidance links that used electro-optical sensors.

(2) The Smoke Week I Test (November 1977) quantified WBIC environments created by U.S. inventory smoke munitions to support smoke obscuration modeling activities and provided data on the effects of screening smokes on the performance of electro-optical systems and millimeter wave radars.

(3) The Grafenwoehr II Realistic Battlefield Sensor Winter Trials (November 1978) assessed the effects of obscurants caused by artillery barrages in a European environment on sensors operating in the visual, infrared, and millimeter portions of the spectrum.

(4) The Grafenwoehr II Realistic Battlefield Sensor Summer Trials (July 1979) assembled a data base for supporting WBIC modeling, and provided data to demonstrate the difference in the severity of environmental effects resulting from artillery barrages in a summer (as opposed to a winter) climate. The test was a follow-on to the winter test conducted at Grafenwöehr.

(5) The Dusty Infrared Test-I (October 1978) examined the technology and instrumentation approaches required to analyze and model WBIC environments.

(6) The Smoke Week II Test (November 1978) provided well characterized obscurant clouds to accommodate testing of the GLLD/Copperhead system and to evaluate U.S. inventory, available foreign, and experimental sources of obscurants.

(7) The Dusty Infrared Test-II (July 1979) compared craters created by detonation of artillery munitions and high explosives for characterized soil conditions. Techniques for measuring aerosol, meteorology parameters and the use of a helicopter as an instrumentation platform were demonstrated.

(8) A series of tests entitled "A Measurement Program on Optical Atmospheric Quantities in Europe (OPAQUE)" (1977-80) were designed to obtain historical data in a European environment for atmospheric effects on sensors operating in the visual and infrared portions of the spectrum.

II. IDENTIFICATION OF RPV MISSION TASKS

The approach used in this study to identify the results of existing research that can be used to estimate RPV payload performance was based on the incremental analysis plan developed by SPC.[1] The specific approach selected for this increment of research is a two-phase methodology. The first phase divides the five different RPV missions defined for this analysis into two separate mission elements--(1) fly to the target area and (2) loiter in the target area--and then characterizes each mission according to one or more of the following mission tasks: (1) detect and identify the target, (2) range to the target to determine its exact location, (3) identify and locate impacts of artillery shells fired from weapons being directed by the RPV, (4) designate targets for strike by laser-guided weapons or for acquisition by laser spot trackers such as the Air Force's Pave Penny systems, (5) provide reconnaissance information, and (6) assess target damage. The second phase of this methodology is a review of existing WBIC modeling techniques and supporting test results to determine their applicability for assessing the effects of WBIC environments on the performance of the RPV payload.

This approach was selected because the RPV system operator must accomplish the various mission tasks in a timely manner. The required timeliness of task completion may be different for each type of mission. For example, when the RPV system is operating as either a laser designator or an artillery spotter, the needed timeliness of task completion will be

---

[1] An Approach to Analysis of RPV Sensor Performance in Battlefield Environments, System Planning Corporation, Report 439, April 1979, Confidential.

affected by the timing requirements of supporting weapon systems. However, if the primary purpose of the mission is reconnaissance or assessment of damage resulting from a previous engagement, an occassional interruption in the line of sight (LOS) due to smoke, for example, may have a negligible effect on mission success. In fact, due to the maneuverability of the RPV, it should often be possible to select a completely unobstructed view of the target or target area. However, during the target designation mission, the relative orientation between the RPV, target, and weapon delivery system will be restricted. Therefore, the effect of WBIC on the RPV's ability to perform its mission depends on the type of mission considered.

To demonstrate this approach for assessing the effect of a WBIC environment on the performance of the RPV mission payload, the following sections examine the tasks that have been identified for each of the five missions selected for this analysis:

- Target acquisition - Detecting, recognizing, and identifying enemy elements and providing their location for immediate response by fire support.
- Target designation - Using laser designators to illuminate hard point targets for engagement with laser-guided weapons such as Copperhead and Hellfire. (In addition, the RPV can designate target areas for acquisition by laser spot trackers such as the Air Force's Pave Penny system.)
- Artillery adjustment - Functioning as "forward observers" and directing or adjusting field artillery fire.
- Reconnaissance - Obtaining, by visual observation and the laser ranging system, information about the activity and resources of the enemy; or securing data concerning meteorological, hydrographic, or geographical characteristics of a particular area.
- Damage assessment - Determining the effects of an attack on a target.

A. TARGET ACQUISITION

During this mission, the RPV is used to locate and identify targets with sufficient accuracy for immediate response by a fire support element. In general, because the RPV will be cued, it will be able to fly to the approximate location of the target. Thus, the tasks associated with this mission are (1) detect and identify the target and (2) range to the target to determine its exact location.

B. TARGET DESIGNATION

The first two tasks of this mission are similar to those of the target acquisition mission (detection/identification and ranging). The third task, target designation, requires that the target be illuminated for a period of a few seconds during which precise coordination with the weapons delivery system is essential. Thus, the successful completion of this mission may be critically dependent on transient obscuration events created by the battlefield environment. In addition, this mission requires that the autotracker be capable of holding the designator aimpoint on the target with the precision required for successful weapon delivery.

C. ARTILLERY ADJUSTMENT

Artillery adjustment requires close coordination between the RPV operator and the fire direction center in charge of the artillery. The RPV operator must be able to observe and identify the impacts of shells delivered by the weapons that he is coordinating. Hence, the task that is uniquely associated with the artillery adjustment mission is to identify round impacts and locate them relative to the target. In addition, like the target acquisition and designation missions, artillery adjustment can also require application of the target detection/identification and ranging tasks.

D. RECONNAISSANCE

The purpose of the reconnaissance mission is to gather intelligence on the activities and resources of the enemy or to collect data concerning the meteorological, hydrographic, or geographic characteristics of a particular area. It requires that the RPV sensor be able to provide useful imagery of a wide variety of natural and manmade objects. The critical mission tasks that provide reconnaissance information are difficult to define with technical precision; however, it is likely that they would be characterized by visual discrimination tasks (e.g., target detection and identification).

E. DAMAGE ASSESSMENT

The tasks required for the damage assessment mission can also be characterized by visual discrimination tasks. For example, the actual determination that a tank is inoperable will require a wide range of visual cues (e.g., the presence of flames or smoke clouds). For purposes of this study, it will be assumed that the damage assessment mission employs essentially the same detection/identification task as that employed in the target acquisition mission.

III. SELECTED WBIC MODELS AND MODELING TECHNIQUES SUITABLE FOR ASSESSING THE RPV MISSION PAYLOAD PERFORMANCE

The methodology described in Chapter II was used as a basis to evaluate WBIC models and simulations for assessing the performance of the RPV mission payload during different portions of selected missions. Brief descriptions of selected modeling techniques that are suitable for use with this methodology are provided in this chapter.

A. SPC HISTORICAL DATA BASE FOR EUROPEAN WEATHER

SPC has developed a historical data base [Ref. 1] to provide estimates for key weather parameters for selected sites in Europe. The data, assembled from the U.S. Air Force Environmental Technical Applications Center and other sources, have been edited to ensure that suitable estimates can be derived for the following parameters:

- Cloud cover
- Ceiling
- Visibility
- Insolation
- Air temperature
- Windspeed
- Dewpoint
- Humidity

This data base can be used as input for the recommended modeling techniques to determine performance of the RPV payload based on analyses for day/night time periods averaged over monthly, seasonal, or yearly intervals.

B. OPAQUE HISTORICAL DATA BASE

Historical data are being developed under the auspices of the Measurement Program on Optical Atmospheric Quantities in Europe (OPAQUE) at seven different locations. The only data currently available were acquired at the German Army Proving Ground near Meppen, FRG, and have not been fully validated [Ref. 2]. After more data are processed and released, analyses can be used to provide estimates of frequencies of occurrence of the following values:

- Ratios of sky-to-ground radiance
- Atmospheric transmittance in the visual and infrared (IR) spectral regions
- Insolation
- Atmospheric stability conditions that affect dust and smoke cloud formations
- Atmospheric turbulence that affects the performance of laser designators.

C. LOWTRAN COMPUTER CODE

The LOWTRAN code modified by Atmospheric Sciences Laboratory (ASL) [Ref. 3] provides a means for calculating the atmospheric transmittance and radiance through atmospheres containing absorbing and scattering molecules throughout the spectral range from 0.25 to 28.5 μm at intervals of 5 cm^{-1} with a resolution for the major absorbers of 20 cm^{-1}.

D. DANTRAN COMPUTER CODE

DANTRAN is a computer code designed by SPC [Ref. 4] to provide engineering accuracy approximations to the Air Force Geophysics Laboratory's LOWTRAN IV Atmospheric Transmittance Computer Code for selected spectral regions [Ref. 5]. During comprehensive performance analyses of electro-optical (E-O) sensors operating in the IR portion of the spectrum, transmission calculations are often required for a sample of weather parameters large enough to establish confidence in the derived statistical

distributions. DANTRAN was designed to emulate the atmospheric transmission outputs of LOWTRAN IV and to reduce the costs and computer requirements of this method of estimating the dependence of sensor performance for different spectral regions, path lengths, and weather conditions.

E. NATURAL AEROSOL EXTINCTION MODULE

The aerosol model developed by ASL is based on the experimental data acquired by NV&EOL during tests at Grafenwoehr and Baumholder, Germany; and at Fort A. P. Hill, Virginia [Ref. 6]. The algorithms that constitute the model were developed in the form of scaling relationships. The present ASL model includes equations that account for variations in aerosol densities at different altitudes of ground level. The input data requirements are:

- Visibility range
- Type of aerosol (i.e., wet or dry fog, or haze).
- Vertical variations in aerosol densities.

F. LASER LINE ABSORPTION ROUTINE

The LZTRAN computer code provides the means for calculating the atmospheric molecular absorption coefficients for 53 different wavelengths, including 1.06 μm [Ref. 3]. The LZTRAN code has been validated by comparison with field data obtained by the Naval Research Laboratory. Because this model does not include effects caused by aerosols, results obtained with LZTRAN must be augmented with other approaches when assessing the performance of laser designators in WBIC environments. The theoretical approach recommended by ASL for estimating the effects of aerosols on laser backscatter is based on Monte Carlo analysis (BASCAT) and may have applicability to analyses of RPV performance [Ref. 3].

The input data requirements for the LZTRAN computer code are:

- Air temperature
- Dewpoint temperature.

The input data requirements for BASCAT are:

- An optical depth parameter of the cloud that quantified the distance a photon can travel without scattering
- The dimensions of the cloud.

G. TURBULENCE-INDUCED POINTING JITTER

The TURB computer routine [Ref. 3] was developed by the U.S. Army Missile Command, Redstone Arsenal, and incorporated into the Electro-Optical Systems Atmospheric Effects Library (EO-SAEL) Smoke Obscuration Model. TURB provides estimates of laser spot size at the target, propagation conditions, power spectrum of the fluctuations, and beam wander around the LOS of the laser designator at either the target or seeker. The input data required for analysis are:

- The laser wavelength
- The laser transmitting aperture diameter
- The range from the transmitter to the target
- The distribution of the optical strength of turbulence along the path
- The effective wind velocity perpendicular to the path.

H. RADIATIVE ENVIRONMENT AND CONTRAST MODULE

The performance of an operator using an E-O sensor operating in the visual and near-IR (i.e., 0.4 to 1.1 μm) portions of the spectrum in WRIC environments can be characterized by his ability to distinguish between system response to signals received from targets and backgrounds. The quantity often used in systems analyses to represent the target against the background (i.e., target contrast or signature) is the ratio of the difference between target radiance and background radiance to the background radiance. In general, the perceived contrast at the seeker is degraded by atmospheric effects that cause attenuation and scattering of energy from both the desired signal and other extraterrestrial sources (i.e., the sun

and moon) and terrestrial sources (e.g., automobile headlights, burning vehicles).

Because there are many factors that critically affect model predictions (e.g., densities, size distribution, and indices of aerosol refraction; target, background, and meteorological conditions), the approach selected by ASL was to use an engineering model (SPOT) that addresses principal components of the radiative environment and is included in the radiative environment contrast module of EO-SAEL [Ref. 3]. The input data requirements are:

- Direct and reflected spectral irradiance at the receiver due to extraterrestrial sources
- Path radiance due to scattering of energy and atmospheric emissions
- Reflectance of target and background.

I. MILLIMETER-WAVE MODEL

The major sources of obscuration due to naturally occurring weather conditions at millimeter-wave frequencies are water vapor, oxygen absorption, and attenuation due to rain and fog. These phenomena have been modeled for 35, 94, 140, and 220 GHz and incorporated into EO-SAEL [Ref. 3]. Attenuation effects caused by snow and dust are not included due to the absence of sufficient data to develop a credible model. The input data requirements include the following:

- Humidity
- Temperature
- Atmospheric pressure
- Rainfall rate
- Visibility
- Liquid water content of atmosphere.

J. TAVETS MODEL

The Thermodynamic Armored Vehicle and Environmental Thermal Signatures (TAVETS) model developed during the analysis and evaluation of the Joint Operational Test of Imaging Infrared (IIR) Maverick [Refs. 7, 8, and 9] provides estimates of radiant temperatures and thermal signatures of ground-based tactical targets. The TAVETS model estimates day-to-day diurnal variations in the radiant temperatures of targets and background components. Model inputs that are required include the following:

- Values for parameters of the TAVETS model (e.g., thermal masses, time constants) for targets and background components
- Daily values of insolation
- Daily values of minimum air temperature.

Because of the limited scope of existing data bases on foreign armored vehicles, the TAVETS model is calibrated only for the M60A1 tank for viewing aspects that correspond to small depression angles below the horizon (i.e., 0 to 10 degrees) and for weather conditions for which Visual Flight Rules (VFR) apply.

K. DUST OBSCURATION MODULE

The dust obscuration module developed by ASL (DIRTRAN) provides a methodology for modeling the growth, movement, and diffusion of dust clouds resulting from the explosion of artillery shells and other high-explosive charges [Ref. 3]. DIRTRAN calculates the volume of explosion-generated craters in different soils and accounts for moisture content and vegetative cover by use of empirical correlations. Required model inputs include the following:

- Windspeed
- Wind direction
- Pasquill stability category
- Soil type and ground cover
- Explosive type and charge
- Air density.

L. SMOKE OBSCURATION ROUTINE

The smoke obscuration computer routine developed by ASL can be used to estimate the effects of smoke clouds created by single or multiple sources that use white phosphorous (WP), plasticized white phosphorous (PWP), hexachloroethane (HC), and fog oil [Ref. 3]. This model is based on a computer code developed by NV&EOL. Estimates of cloud characteristics can be made for time increments during the course of cloud evolution. Required model inputs include the following:

- Windspeed
- Wind direction
- Humidity
- Pasquill stability category
- Air temperature and gradient
- Smoke type
- Burn time
- Charge weight for smoke sources or fuel burn rate for fog oil.

M. BATTLEFIELD ENVIRONMENT LASER DESIGNATED WEAPON SYSTEM SIMULATION

The BELDWSS computer model is a major expansion of the Laser Designated Weapon System Simulation (LDWSS) developed by the Guidance and Control Directorate of the U.S. Army Missile Command (MICOM) Technology Laboratories, Redstone Arsenal, AL [Ref. 10]. BELDWSS is basically a one-on-one engagement model that simulates the dynamics of the interface between a laser designator and a semiactive laser-guided weapon system. Required model inputs include the following:

- Statistical characterization of pulse-by-pulse laser spot positions
- Three-dimensional target reflectivity model
- Empirically verified model of tracking characteristics of laser spot seeker
- Six-degree-of-freedom digital simulation of the terminal-homing guidance law and airframe dynamics.

The present three-dimensional target reflectivity model has not been validated for viewing aspects that are anticipated during RPV missions (i.e., depression angles below the horizon of more than 10 degrees) [Ref. 11].

IV. REVIEW OF SELECTED WBIC TESTS

A review of the literature reveals that numerous field tests have been conducted that relate to the performance of systems employing E-O sensors and that examine atmospheric transmittance in the visual, infrared, or near-millimeter spectral regions. These tests had a wide range of goals and objectives, and many of them are not well suited to provide data that are useful in RPV analysis. However, there have been a number of tests, particularly some of the recent major Army tests involving extensive instrumentation and large numbers of Army E-O systems, that provide data that can be used to support RPV performance analysis in WBIC environments.

This chapter identifies those tests and data that have been selected for application in analyses of RPV performance. These tests are listed in chronological order. As an aid to analysis of RPV performance, brief summaries of the objectives, design features, and salient results are included for each test.

A. MANPORTABLE COMMON THERMAL NIGHT SIGHT SMOKE TEST (JULY 1977)

Although an earlier smoke test with E-O sensors was conducted during the summer of 1976 [Ref. 12], the Manportable Common Thermal Night Sight Smoke Test [Ref. 13] was the first that incorporated a comprehensive instrumentation approach for measuring atmospheric transmittance and aerosol densities in the presence of operational and developmental E-O systems. The effect of smoke upon system performance was quantified by the amount of time that the operator assessed that the system was inoperable.

PRECEDING PAGE BLANK-NOT FILMED

1. Test Objectives

- Determine the performance of selected thermal night sights in a measured smoke environment.
- Evaluate the compatibility of selected tactical and developmental tracking of guidance links with thermal night sights in a smoke environment.

2. Test Design Features

a. Instrumentation

- 0.6328-μm and 10.6-μm lasers to measure atmospheric transmission
- 1.06-μm Light Direction Finding and Ranging (LIDAR) system to characterize smoke clouds
- 32-meter tower to record conventional meteorological data (wind speed and direction were recorded 2, 6, and 10 meters above ground level (AGL))
- Photopic and infrared sensors to record smoke cloud development and movement.

b. Equipment Tested

- Tube-launched, optically tracked, wire-guided (TOW) missile day sight and thermal sight
- Dragon missile day sight and thermal night sight
- Beam-rider experimental systems using a gallium arsenic (GaAs) guidance sensor
- Beam-rider experimental system using a CO_2 guidance sensor
- Flare tracking link for Robust Jab
- Ground laser locator designator (GLLD).

c. Smoke Types and Sources From U.S. Inventory

- M5 Pot, hexachloroethane (HC)
- 4.2-in. mortar shell, white phosphorous (WP)
- 4.2-in. mortar shell, plasticized white phosphorous (PWP)
- 2.75-in. rocket, white phosphorous wick (WPW).

3. Test Results

- The highest smoke cloud aerosol concentrations, measured in terms of concentration density times path length (CL), were greater than 10 g/m^3 and were maintained for a period of 200 seconds or longer.
- The GaAs tactical beam rider outperformed the TOW trackers.
- The performance of all sensors was substantially degraded during these tests.

This test had four important limitations:

- System performance was determined only for horizontal paths close to the ground.
- The performance of the FLIR was not evaluated separately from the weapon system.
- The time required for the FLIR operator to accomplish visual discrimination tasks was not measured.
- Only U.S. smokes were tested.

As a result, the above test results should be qualified accordingly when they are extrapolated to other systems and environments.

B. SMOKE WEEK I TEST (NOVEMBER 1977)

The Smoke Week I Test was the first of a scheduled series of tests coordinated and planned by the Office of the Project Manager Smoke/Obscurants for the benefit of other Army organizations, other branches of the Armed Forces, and national defense contractors [Ref. 14].

Because previous tests, such as that described in Section A, indicated that (1) the performance of E-O systems could be degraded substantially due to the effects of WBIC environments and (2) the effects of WBIC varied greatly for different systems, the objectives for this test were tailored to the particular nature of the systems under evaluation. In addition, the tests did not incorporate design features to obtain test data related to the effect of obscurants when ground-based targets are viewed from airborne platforms.

1. Test Objectives

- Obtain data on development of smoke clouds created by inventory and foreign smoke weapons.
- Obtain data on optical characteristics of smoke clouds created by inventory and foreign smoke weapons.
- Obtain data required by the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) smoke obscuration model for evaluation of existing inventory munitions.
- Obtain data on the effects of screening smokes on the optical properties of existing and developmental E-O systems.

2. Test Design Features

a. Instrumentation

- Standard meteorological station
- Equipment for measuring wind characteristics at 4 and 8 meters AGL
- Equipment for measuring air temperature at 0.5 to 8 meters AGL
- Atmospheric transmissometers for measuring through the smoke clouds along selected horizontal paths
- Instruments for checking Pasquill stability category
- Dual-channel nephelometer for measuring atmospheric scattering.

b. Equipment Tested

- Hughes Aircraft Company's multielement tracker
- Production TOW launcher and night sight (AN/TAS-4)
- TOW night sight (AN/TAS-4)
- TOW mission beacon
- Texas Instrument video tracker
- Video thermal tracker
- Beam-rider experimental system using a CO_2 laser
- Beam-rider experimental system using a GaAs laser
- GLLD
- Three experimental radar sets operating at 35, 95, and 140 GHz
- U.S. Army Tank Thermal Sight (TTS).

c. Smoke Sources, Munition Caliber, and Smoke Type

- M84A1, 105 mm, HC
- L8A1, not applicable, red phosphorous (RP)
- M328A1, 4.2 in, PWP
- Foreign, 82 mm, WP
- Foreign, 120 mm, WP
- Foreign, 122 mm, WP
- Foreign, 130 mm, WP
- M110E2, 155 mm, WP.

3. Test Results

- The smoke and dust clouds caused some degradation to specific systems in all runs if they were in the appropriate line of sight (LOS).
- Sufficient data were obtained to make correlations between measured values of CL and extinction coefficients for the smoke clouds analyzed.
- Threshold values of CL that would degrade system performanc were estimated from measured data.

The data obtained during this test provide correlations between CL values and system performance. However, certain qualifications must be considered if these results are used to assess the operational performance of the RPV mission payload in WBIC environments, due to the following limitations:

- Obscuration data were acquired along selected paths close t the ground.
- The major measure of effectiveness (MOE) for system performance was restricted to estimating the amount of time the system was totally inoperable as opposed to the more stringent criteria of whether the operator could successfully complete a mission.
- All munitions were fired statically.

C. GRAFENWOEHR II REALISTIC BATTLEFIELD SENSOR TRIALS - WINTER (NOVEMBER 1978)

The Grafenwoehr II Realistic Battlefield Sensor Trails - Winter (Graf II Winter) [Ref. 15] was the second in a series of field experiments conducted to obtain data that can be used to estimate the performance of E-O sensor systems in a European environment.[1] The effects of the smoke and dust clouds on sensor performance were quantified by having the system operator record the amount of elapsed time that a target was obscured during a barrage.

1. Test Objectives

- Assess the effects of obscurants caused by an artillery barrage upon E-O sensors.
- Measure atmospheric transmittance in the visual, infrared, and near-millimeter spectral regions through dust resulting from the impact of high-explosive munitions.
- Measure spatial extent and transport of dust clouds resulting from high explosives.
- Validate artillery dust models.
- Increase scope of the European data base of target signatures and atmospheric characteristics.

2. Test Design Features

a. Instrumentation

- Silicon-vidicon camera to record the environment
- LIDAR systems operating at both 1.06- and 10.6-μm wavelengths
- Radar transmissometer operating at 95 GHz
- E-O transmissometers operating in the 0.8- to 1.1-μm, 3.4- to 4.1-μm, and 8.1- to 12.0-μm spectral regions

---

[1]Earlier testing, called Graf I Electro-Optics Tests [Ref. 16], was designed to estimate the effects of naturally occurring weather factors in a European environment.

- Multispectral sensor station that included the following systems:

  -- Silicon television

  -- 3- to 5-μm thermal imager

  -- 8- to 12-μm thermal imager

  -- Millimeter imager operating at 32 GHz

  -- Battlefield surveillance radar

  -- Day TV

  -- Laser rangefinder operating at 1.06 μm

  -- Stereo photo cameras to measure dust cloud sizing and transport characteristics

  -- Signature measurement station that included a set of contrast panels and a sky terrain scanner.

b. Types of Artillery Missions Simulated

Five types of artillery barrages were executed that simulated the following types of missions:

- Single-round mission
- Preparatory fire on hard points
- Counterbattery fire
- Neutralization mission
- Annihilation mission.

3. Test Results

- For night operations, FLIR performance is significantly superior to that of active TV.
- For day operations, under fair to poor atmospheric conditions, FLIR performance is superior to that of TV and visual systems.
- The acquired data base has:

  -- Validated the absorption portion of the LOWTRAN IV model.

  -- Demonstrated that further model development for estimating the effects of aerosols on atmospheric transmittance in the infrared spectral region is required for the LOWTRAN IV model.

-- Demonstrated that sensors operating in the 8- to 12-μm spectral region provide superior performance to those operating in the 3- to 5-μm spectral region in thick fogs.

This test provided good empirical data that can be used to scale the effects of artillery barrages. The following limitations should be considered, however, when extrapolating these test results to other locations and environments that would be suitable for analyzing the effects of a WBIC environment on RPV performance:

- Only one type of soil and soil cover was tested (i.e., moist soil with a cover of heavy vegetation)
- Accurate estimates for CL for the dust and debris are not available.
- All measurements were made along paths close to ground level.

D. GRAFENWOEHR II REALISTIC BATTLEFIELD SENSOR TRIALS - SUMMER (JULY 1979)

Grafenwoehr II Realistic Battlefield Sensor Trials - Summer (Graf II Summer) [Ref. 17] was a follow-on activity to the Graf II Winter trials. Both tests were a joint effort between U.S. and FRG armed forces. The effect of the simulated WBIC environments was quantified by the time intervals for which the selected targets were obscured as perceived by the system operator.

1. Test Objectives

- Measure obscurant and clutter effects due to artillery high-explosive and smoke round barrages on imaging target acquisition and laser sensors from ground-to-ground and air-to-ground platforms.
- Measure the optical, infrared, and near-millimeter propagation through the resulting obscuration, colinear with recorded visible and thermal imagery.
- Obtain obscurant modeling data to support modeling of the dynamics of smoke and dust clouds for a single round (fired statically or from a weapon) based upon soil characteristics, atmospheric stability factors, and meteorological conditions.

2. Test Design Features

a. Instrumentation

- Standard meteorological instruments
- Atmospheric transmissometers in the following regions:

  --0.4 to 0.7 μm
  --0.8 to 1.1 μm
  --3.4 to 4.1 μm
  --3.0 to 5.0 μm
  --8.0 to 17.0 μm
  --94 GHz
  --47 GHz

- Precision radiometer (PRT-5)
- Soil analysis station
- Particle size and concentration instruments.

b. Types of Artillery Missions Simulated

Twenty-six separate artillery barrages were executed that varied from single-round missions to barrage intensities corresponding to greater than two rounds per second per km of path length along the simulated forward edge of the battle area (FEBA).

c. Equipment Tested

- Day TV operating in the 0.8- to 1.1-μm spectral region
- Tank thermal sight
- Night Observation Device, Long Range (NODLR) operating in the 3- to 5-μm spectral region
- Light Observation Helicopter Target Acquisition and Designation System (LOHTADS) FLIR operating in the 8- to 12-μm spectral region
- Chow Circuit FLIR (pseudo d.c. restorer)
- Day TV operating in the 0.4- to 0.7-μm spectral region
- MIRADCOM guidance link operating with a 10.6-μm source
- Identification friend or foe (IFF) system operating with a 0.9-μm source.

3. Test Results

- The duration of target obscuration for similar barrage intensities and weather conditions was much greater during the Graf II Summer trials than those observed during Graf II Winter trials.
- Recorded data from these trials can be used to estimate the percent of time that the target will be continuously obscured for different barrage intensities for any of the measured spectral regions.
- The relative performance of different sensors can be estimated for different barrage intensities and different soil types.

These test results provide good empirical data that can be used for scaling the WBIC effect of artillery barrages in a European environment. When used to assess the effect of WBIC environments on RPV performance, the following limitations should be considered:

- Only one soil type was tested (dry).
- All measurements were made along approximately horizontal paths close to the ground.
- Although comprehensive instrumentation was used to monitor dust and smoke cloud dynamics, these data have not been published at the time of this review.

E. DUSTY INFRARED TEST-I (OCTOBER 1978)

Dusty Infrared Test-I (DIRT-I) was conducted in the fall of 1978 in the extreme southeast corner of White Sands Missile Range, NM [Ref. 18]. The gently sloping terrain was graded to remove all vegetation.

1. Test Objective

The primary objective of DIRT-I was to test some of the technology and instrumentation approaches required to analyze and model WBIC environments.

2. Test Design Features

a. Instrumentation

- Use of a helicopter as an instrumentation platform
- Standard meteorological station
- SRI MARK IX LIDAR operating at a wavelength of 0.694 μm
- ASL LIDAR operating at a wavelength of 10.6 μm
- Tank thermal sight operating in the spectral region of 8 to 12 μm
- Multispectral digital imagery operating in the 0.5- to 0.7-μm, 1.06-μm, 3.0- to 5.0-μm, and 8.0- to 14.0-μm spectral bands
- Light scintillometer to measure optical turbulence
- Fourier transform spectrometer
- Millimeter transmissometers operating at 94 and 140 GHz
- Photopic documentary cameras
- Particle size distribution instruments
- Andersen air sampler to measure particulate samples
- Soil characterization instruments
- Crater measuring equipment
- Gas sampling equipment.

b. Sources of Dust and Smoke Clouds

Dust and smoke clouds were created by the following scheduled events:

- In groups of three, explosive charges were detonated that varied in weight from 0.54 to 13.6 kg of TNT shortly after sunrise as a dress rehearsal.
- In groups of three, explosive charges were detonated that varied in weight from 6.8 to 54.4 kg of TNT.
- As a single event, 140 explosive charges were detonated. The weight of each charge was 6.8 kg, and they were uniformly distributed over a rectangular area of 90 by 285 meters.
- In groups of 12, explosive charges were detonated that varied in weight from 1.4 to 10.9 kg of TNT.
- In groups of four, howitzer weapons were used to fire 155-mm high-explosive rounds at a single target point.

- A fire was created by burning a fuel mixture in a trench. The mixture consisted of 38 liters of diesel fuel, 2 liters of motor oil, and 1 rubber tire placed in each of 8 containers. This mixture produced large volumes of black smoke for the duration of the test, approximately 37 minutes.

3. Test Results

- Difficulties were encountered with the use of the helicopter as an instrumentation platform--namely, safety considerations precluded flying into the smoke and dust clouds, and the downwash from the helicopter could influence the cloud formations.
- A substantial data base was acquired for use in various modeling approaches.
- Soil characteristics have a large impact on crater size.
- The characteristics of dust clouds created by detonating tube-delivered munitions and explosive charges in soil cleared of vegetation were measured.
- It is difficult to predict the amount of explosive charge required to create a crater equivalent to that created by a tube-delivered high-explosive round.

The data base acquired during the DIRT-I test has been used in developing and validating obscuration models. However, simple extrapolation of test results will have limited utility for assessing the effect of WBIC environments upon RPV performance since no smoke generators were used.

F. SMOKE WEEK II TEST (NOVEMBER 1978)

Smoke Week II [Ref. 19] was scheduled for Test Range C-52 at Eglin Air Force Base, FL, to provide an environment with higher humidity than that experienced at Dugway Proving Ground, UT, where Smoke Week I was executed. The effects of the WBIC environment were quantified in terms of atmospheric attenuation and the time interval during which operators assessed that their systems were inoperative.

1. Test Objectives

- Create well-characterized obscurant clouds under field conditions.
- Evaluate various inventory, foreign, and experimental obscurants.
- Evaluate new techniques for the measurements and characterization of obscurants under field conditions.
- Accommodate testing of the GLLD/Copperhead system because of pending Army System Acquisition Review Council (ASARC) program decision reviews.

2. Test Design Features

a. Instrumentation

- Conventional meteorological station
- Particle size interferometer
- LIDAR systems operating with wavelengths of 0.69 and 10.6 μm
- Two-dimensional spectral imaging system
- Tank thermal sight
- Automatic acquisition IR seeker
- Experimental beam rider systems using either GaAs or CO_2 lasers
- Copperhead seeker mounted 100 meters AGL
- Copperhead seeker and a boresighted TV camera mounted on a helicopter platform
- Laser-guided bomb seeker at 50 meters AGL
- Infrared imagers and TOW telescope
- Three millimeter-wave experimental radars operating at frequencies of 35, 94, and 140 GHz and tested over a horizontal path approximately 2 meters AGL.

b. Obscurant Sources, Munition Caliber, and Obscurant Type

- Canister, 155 mm, HC
- Zuni, 5 in., WP
- Rocket, 2.75 in., WPW
- XM825, 155 mm, WP (wedge)
- XM803, 155 mm, RP (wedge)
- Foreign, 120 mm, WP
- Foreign, 122 mm, WP

- Smoke generator, fog oil
- 142-g M8 grenade, developmental type 1
- 142-g M8 grenade, developmental type 2
- 300-g container, developmental
- M48 tanks, vehicular dust
- Shell (2.3-kg charge), 105 mm, high-explosive dust
- Shell (6.8-kg charge), 155 mm, high-explosive dust
- Burning hulk (an inoperative M34), fuel smoke

3. Test Results

- The test results provided a good data base for evaluating the relative effectiveness of smoke clouds created by U.S. inventory munitions and generators and selected foreign smoke munitions.
- The obscurant effects of dust were quantified for different weather conditions.
- The test demonstrated the potential of developmental obscurants to degrade the performance of visual, infrared, and millimeter-wave tactical sensors in field environments.
- The relative sensitivities of inventory systems to different types of obscurants were estimated for several different environments.
- The maximum attenuation observed for the radars during any of the trials was only 9 percent for the 140-GHz radar. This attenuation was attributed to a dust cloud generated by detonating 90 pounds of C4 high explosive only 65 meters from the radar LOS.

The data base acquired with the Copperhead seeker during the captive flights will be applicable to analysis of RPV system performance in WBIC environments. In addition, the data base acquired during Smoke Week II has been used to support the validation studies of smoke and obscuration models used in E-O SAEL. These validated models will be useful in evaluating the performance of the RPV mission payload. However, it is anticipated that these models will require further development to support RPV analyses because the data base assembled during Smoke Week II was acquired using instruments mounted on ground-based platforms or fixed towers with a maximum height of 100 meters AGL.

G. DUSTY INFRARED TEST-II (JULY 1979)

Dusty Infrared Test-II (DIRT-II) is a continuation of a U.S. Army Atmospheric Sciences Laboratory research program designed to provide a better understanding of the effects of battlefield dust on atmospheric transmission [Ref. 20]. DIRT-II was combined with the Munitions Bare Charge Equivalence Test and executed as a cooperative experiment with the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

1. Test Objectives

- Compare craters formed by the detonation of artillery munitions and high explosives.
- Measure dust cloud growth, movement, and diffusion characteristics.
- Characterize soil types in the test area.
- Measure mesoscale meteorological parameters (i.e., meteorological phenomena approximately 1 to 100 km in horizontal extent).
- Measure E-O transmission properties of dust clouds.
- Demonstrate that an RPV could be used as an instrumentation platform.

2. Test Design Features

a. Instrumentation

- Standard meteorological station
- Atmospheric transmissometers for wavelengths of 0.55, 1.06, and 10.6 μm
- Instruments for measuring digital imagery of dust clouds
- Instruments for measuring atmospheric transmittance and backscatter of a radar operating at 95 GHz
- Photopic film cameras
- Optical scintillometer
- Acoustic sounder
- Chemical analyzer for particulates
- RPV for sampling particles.

b. Test Site Characteristics

- The instrumented optical path was slightly over 2 km long.
- The site was compatible for both tube-delivered and statically fired artillery rounds.

c. Munition Types and Charges

The firing schedule comprised 50 static detonations and 30 tube-delivered firings. The different types of rounds or charges and charge weights tested are listed below:

- 105 mm, 2.3-kg charge
- 155 mm, 6.76-kg charge
- 4.2-in. mortar, 3.38-kg charge
- C4 explosive, 1.81-kg charge
- C4 explosive, 3.63-kg charge
- C4 explosive, 4.54-kg charge
- C4 explosive, 7.26-kg charge
- C4 explosive, 12.25-kg charge

3. Test Results

- Empirically derived models for estimating crater size and depth were developed by using curve-fitting techniques.
- The feasibility of using an RPV with a 9.1-kg payload as an instrumentation platform was demonstrated.
- A large data base was developed that can be used to validate and refine obscurant models.

The results from this test can be used to develop modeling approaches for estimating the growth, movement, and diffusion characteristics of the dirt and dust cloud created during a firefight. Once they are validated, these models will be useful in assessing the effect of a WBIC environment on the performance of the RPV mission payload.

H. A MEASUREMENT AND DATA REDUCTION PROGRAM ON OPTICAL ATMOSPHERIC QUANTITIES IN EUROPE (1977-80)

The Measurement Program on Optical Atmospheric Quantities in Europe (OPAQUE) is sponsored by the Defense Research Group of the North American Council (NATO). This test was started during 1977 and is still continuing. The specific objectives for the OPAQUE program are presented in a proposal [Ref. 2] prepared by the forerunner of Research Study Group 8 of Panel IV, which coordinates research activities between NATO countries relating to measurements and studies of light transmission and image propagation through the atmosphere in the visual and infrared spectral regions.

1. Test Objectives

- Develop a data base of atmospheric optical and infrared parameters that affect military systems.
- Obtain coordinated support from representatives from the following participating countries:

  -- United States
  -- United Kingdom
  -- Canada
  -- Denmark
  -- Federal Republic of Germany
  -- France
  -- Netherlands

- Establish the following seven sites for obtaining OPAQUE data:

  -- German Army Proving Ground near Meppen, FRG
  -- Birkhof near Stuttgart, FRG
  -- Lolland, Denmark, jointly operated by representatives of the governments of Canada and Denmark
  -- Ypenberg, Netherlands, near The Hague
  -- Christchurch, England, near the south coast
  -- Bruz, France, located in Brittany
  -- Trapani, Italy, at the western tip of Sicily.

- Record automatically measured data every 30 minutes and manually measured data at time intervals not to exceed 3 hours.

2. Test Design Features

a. Instrumentation

- Required instrumentation consisted of equipment for measuring:
  - -- Standard meteorological conditions
  - -- Extinction coefficient in the visible portion of the spectrum
  - -- Horizontal global illuminance (sky plus sun or moon)
  - -- Horizontal sky illuminance with sun or moon occulted at culmination
  - -- Vertical illuminance at four azimuths (north, east, south, and west)
  - -- Path radiance toward the east at night
  - -- Path illuminance at four azimuths during the day (north, east, south, and west)
  - -- Spectral insolation characteristics
  - -- Atmospheric transmittance in the 3.4- to 5.0-μm and 8.0- to 12-μm spectral bands over selected path lengths
  - -- Temperature fluctuations.
- Recommended additional instrumentation consisted of equipment for measuring:
  - -- Rawinsonde data
  - -- Atmospheric transmittance in the 0.6- to 1.2-μm spectral region
  - -- Atmospheric transmittance for lasers operating at wavelengths of 0.9, 1.06, and 10.6 μm
  - -- Contrast loss in the visual portion of the spectrum
  - -- Optical turbulence
  - -- Infrared image degradation
  - -- Aerosol density distribution and particulate analysis.

b. Other Features

- Data base recorded with a common format
- Calibration achieved with identical equipment and procedures
- Representatives of U.S. Air Force and FRG collect data from airborne platform during selected time intervals.

3. Test Results

Only limited test results are available due to NATO coordination sche dules at the time of this review. Nevertheless, it is becoming increasingly apparent that this program is amassing substantial amounts of data recorded in a common format and with a level of quality control that is no available from other sources for the following parameters:

- Extinction coefficients for the visible portion of the spectrum
- Sky radiance
- Path radiance
- Atmospheric transmittance in the 8- to 12-μm spectral region
- Temperature fluctuation characteristics.

As a result, OPAQUE will provide the most comprehensive available historical data base for atmospheric characteristics that affect the performance of E-O sensors operating in the visual and infrared portions of the spectrum and will be useful in assessing the effects of the European weather environment on RPV performance. However, OPAQUE has not identified a vali dated methodology for extrapolating the data acquired near ground level to altitudes comparable to those required during RPV missions.

V. RECOMMENDED MODELING APPROACHES FOR ANALYZING THE EFFECTS OF WBIC ENVIRONMENTS

This chapter outlines applications of the recommended modeling techniques and potential problem areas that may require additional tests and evaluations to adequately analyze the RPV payload performance for each of the six mission tasks identified in Chapter II and listed below:

- Detect and identify target
- Range to the target to determine its exact location
- Identify and locate impacts of artillery shells fired from weapons being directed by the RPV
- Designate target for strike by laser-guided weapons or for acquisition by laser spot trackers such as the Air Force's Pave Penny
- Provide reconnaissance information
- Assess target damage

A. DETECT AND IDENTIFY TARGET

The basic task associated with this mission element has been parameterized by previous investigators in terms of visual discrimination tasks [Refs. 21, 22]. This approach is used for estimating the performance of TV or FLIR imaging systems. It parameterizes the performance of the man-machine system by the signal-to-noise ratio (S/N) (in terms of contrast-limited resolution) that is required to perform such tasks as target detection, target recognition, and target identification. This modeling approach provides the techniques for estimating the effects of the following factors:

- Atmospheric absorption and scattering
- System spectral responsivity
- Range from the RPV sensor to the target

PRECEDING PAGE BLANK-NOT FILMED

- Electronic and optical hardware characteristics
- Target signature[1]
- Target size.

The resolution requirements are based on the familiar Johnson criteria [Ref. 21] that correlate the visual discrimination task with the number of perceivable resolvable line pairs, as measured at the threshold of performance,[2] which must span the minimum target dimension to achieve the desired visual discrimination task. The number of line pairs of resolution required to span the minimum dimension of the target, also known as the discrimination factor, is given for each of three visual discrimination tasks in the list below:

Classification Discrimination Level	Discrimination Factor, N_i	Meaning
Detection	1	An object is present.
Recognition	4	The class to which the object belongs may be discerned (e.g., tank, truck, man, etc.).
Identification	7	The target can be described to the limit of the observer's knowledge (e.g., T-62 tank, friendly jeep, etc.).

With this method of parameterizing the resolution requirements, the minimum resolvable temperature (MRT) or minimum resolvable contrast (MRC) needed to accomplish a visual discrimination task corresponds to that required to recognize a bar pattern containing N_i line pairs that has a minimum dimension equal to the minimum dimension of the target. For an infrared system, these bars are designed to replicate a blackbody for radiance

---

[1]Defined as spatially averaged target-to-background thermal contrasts expressed in degrees Celsius for FLIR systems and target contrast for TV systems.

[2]Achieved when 50 percent of the operator's decisions are made correctly.

in the spectral range of the FLIR. To establish target contrast of ΔT, every other bar is held at the background temperature, and the remaining bars are held at the temperature of $T + \Delta T$. Similar bar patterns that provide a visual contrast are used to analyze TV systems (Ref. 21].

The time required for an operator to achieve target detection and identification is a function of the following variables:

- Target type
- Target size
- Target signature
- Atmospheric transmittance and path radiance
- Sensor characteristics.

A parametric model developed by NV&EOL [Ref. 23] can be used to estimate the time required to accomplish this task in different weather environments. This model requires separate estimates for the atmospheric transmittance and target signature.

1. Effects of Variations in Weather Conditions

The effects of weather factors (e.g., visibility, humidity) on atmospheric transmittance during each of the mission elements and, hence, on RPV sensor performance, can be estimated by using any of the following models [Refs. 3, 4]:

- Modified LOWTRAN IV
- DANTRAN
- Natural aerosol extinction module
- Radiative environment and contrast module.

Although all of these models produce similar results for moderately good visibility, they model the effects of aerosols in slightly different ways. The lack of a suitable data base precludes a clear choice of one model to the exclusion of the others. Further, existing data are insufficient for purposes of estimating the frequencies of occurrence for different distributions of aerosol densities.

For those mission elements that require target designation for either target location or weapon delivery, the LZTRAN computer code that has been validated by the Naval Research Laboratory is recommended for estimating the atmospheric effects resulting from natural factors.

In addition to atmospheric transmittance, variations in weather factors (e.g., insolation, cloud cover) will affect performance of the RPV mission payload by causing variations in thermal signatures of targets and background scene components [Ref. 7]. The TAVETS model can be used for estimating day-to-day diurnal variations in thermal radiance and signatures based on weather observables [Refs. 8, 9].

Because of insufficient data on foreign armored vehicles and on the thermal characteristics of backgrounds in the European environment, additional test and evaluation resources may be required in this area.

2. Effects of WBIC Environments

During those missions that do not require critical timelines for achieving target identification, transient obscurant events would probably have a negligible effect on RPV performance and, hence, may not have to be analyzed. However, the Soviets do have the capability to create contiguous smoke clouds for extended periods of time. The effects of these smoke clouds and the resources required to generate them can be estimated by the smoke obscuration computer routine that is based on research conducted by NV&EOL and integrated into the EO-SAEL smoke model [Ref. 3]. For steady state dirt and dust clouds created by artillery barrages, the DIRTRAN model that is incorporated into E-O SAEL is recommended. Because all realistic models for dust from moving vehicles require detailed input data (i.e., vehicle type, speed, wind duration, and soil characteristics), no validated methodology was identified for extrapolating test results acquired in a particular environment to other environments. Additional test and evaluation resources will be required to accurately model dust clouds created by moving vehicles.

B. RANGE TO THE TARGET TO DETERMINE ITS LOCATION

For missions that require target location with noncritical timelines (task accomplishment within a few minutes), only screening smokes can have substantial effect on RPV mission payload performance because of airframe mobility and the relatively short duration of other obscurants. Thus, the recommended obscurant models for analyzing this mission task are the E-O SAEL smoke and DIRTRAN models. The laser absorption routine (LZTRAN) and the turbulence-induced pointing jitter (TURB) computer codes can be used to estimate the effects of naturally occurring weather factors on the atmospheric transmittance and scattering characteristics of laser energy. Because TURB is based on a Monte Carlo routine and requires data that may not be available, additional testing may be required. In particular, the ability of the RPV system operator to estimate the range to a target is uncertain because the effects of obscurant clouds are different for the FLIR sensors than for the laser sensors.

C. IDENTIFY AND LOCATE IMPACTS OF ARTILLERY SHELLS FROM WEAPONS THAT ARE BEING DIRECTED

The actual location of the impacts of artillery shells can be determined in many cases by using the laser designator to range to the smoke and dust clouds created by the impacts. Because the smoke and dust clouds will be transitory events, this mission element will require that the operator accomplish the task of locating impacts during a short time interval. Thus, if the impacts are within the field of view of the sensor, only a few additional such transient events will create smoke or dust clouds sufficient to cause problems with identification of the impacts.

As with the previously discussed mission element, the effects of screening smoke would be modeled separately. However, during periods of intense fire or when an area target is being attacked--at which time numerous rounds of various types may be arriving in the field of view almost simultaneously, thus causing considerable uncertainty about the arrival time of any particular incoming round--the presence of many dust and smoke clouds may make this task and its analysis very difficult. Because of the

lack of test data and the absence of validated models for complex situations, additional test and evaluation resources will probably be required to adequately assess the effects of WBIC environments on this mission task.

An estimate of the operator's ability to locate the impacts of artillery rounds can be obtained by assuming that the task is equivalent to a particular visual discrimination task. However, the anticipated variations in the size and radiance of the resulting dust clouds may produce substantial variations in the calculated operator performance. Hence, additional test and evaluation resources may be required to adequately assess the effects on RPV performance.

D. DESIGNATE TARGET FOR LASER-GUIDED WEAPONS OR PAVE PENNY

This mission element is probably the most difficult to analyze because (1) achieving a high probability of kill is critically dependent on the ability to designate the target accurately and (2) target designation must be continuous during a critical time period. Typical WBIC environments may reduce the effectiveness of the RPV system either by causing tracking errors in the autotracking system or by creating a temporary interruption in the LOS between the target and either the designator or the weapon during a critical part of the weapon delivery sequence of events.

The Battlefield Environment Laser Designated Weapon System Simulation (BELDWSS) modeling approach developed by the Guidance and Control Directorate of the U.S. Army Missile Command (MICOM) is designed to analyze the physical interface between the laser designator and weapon system through the laser spot reflected from the target. This approach uses a detailed three-dimensional target reflectivity model and an empirically verified model of the laser designator performance [Ref. 10]. The existing model of target reflectivity has not been fully validated for target viewing aspects compatible with RPV missions.

Because estimates of RPV mission payload performance based on BELDWSS simulations will be critically dependent on modeled autotracker performance that cannot be validated until after flight tests, interim modeling

approaches should be considered. Potential interim approaches for obtaining preliminary estimates of the effects of WBIC environments on RPV performance during this mission task are:

- Identify WBIC environments that preclude a successful laser designator mission because either the TV or FLIR sensors are inoperative.
- Identify WBIC environments by analyses of existing test data or execution of small tests that preclude a successful laser designator mission because the laser energy is either excessively attenuated or scattered.
- Analyze existing simulation data on the execution of simulation tests to estimate the time required for an operator to identify and acquire satisfactory lock-on with an autotracker while viewing video imagery comparable to the type that will be provided by the RPV system.

These interim approaches will be based on a combination of test data obtained from similar systems (other TV and FLIR autotrackers) and analytical models of autotracking hardware design. Modeling approaches identified in this report (e.g., DANTRAN computer code, TAVETS model) can be used to calculate video S/N and other WBIC-dependent parameters that affect autotracker performance.

E. PROVIDE RECONNAISSANCE INFORMATION

During many reconnaissance missions, transient smoke or dust clouds may provide valuable visual cues for determining the nature of battlefield activity. For those cases in which screening smoke is used to provide cover for a tactical operation or to create uncertainties about the activity on the battlefield, the E-O SAEL smoke and DIRTRAN models are recommended for estimating the effects of both the screening smoke and smoke from burning vehicles.

Because this review of modeling techniques did not identify any validated models that could be used to estimate performance of the RPV mission payload while the operator is acquiring reconnaissance information, it is recommended that the operator performance be assessed by analyzing his ability to accomplish the visual discrimination task of target recognition

as described above. While this modeling technique will provide a baseline level of performance, additional test and evaluation resources may be required to adequately assess the effects of WBIC environments on RPV performance during this type of mission.

F. ASSESS TARGET DAMAGE

In the review of modeling techniques for the damage assessment mission task, no attempt was made to distinguish between the easier subtasks (e.g., determining whether artillery shells impacted in a designated area) and the more difficult subtasks (e.g., determining whether a damaged system is operable or inoperable). Therefore, it is recommended that the RPV operator performance be analyzed by using at least two visual discrimination tasks (e.g., target detection, target identification). This modeling technique will provide a baseline level of performance. However, because there are many different operational scenarios that include different tactics for the employment of obscurants, additional test and evaluation resources may be required to adequately assess the effects of WBIC environments on operator performance during the accomplishment of this mission task.

Appendix

GLOSSARY, REFERENCES, AND DISTRIBUTION

GLOSSARY

AGL	above ground level
ASARC	Army System Acquisition Review Council
ASL	Atmospheric Sciences Laboratory (U.S. Army Electronics Research and Development Command)
BELDWSS	Battlefield Environment Laser Designated Weapon System Simulation
CO_2	carbon dioxide
DANTRAN	computer code for estimating atmospheric transmittance in the infrared portion of the spectrum
DIRT	Dusty Infrared Test
DIRTRAN	Disturbed Infrared Transmission (ASL computer model)
E-O	electro-optical
E-O SAEL	Electro-Optical Systems Atmospheric Effects Library
ETAC	Environmental Tactical Applications Center (U.S. Air Force)
FEBA	forward edge of the battle area
FLIR	forward-looking infrared
GaAs	gallium arsenic
GLLD	ground laser locator designator
HC	hexachloroethane
IFF	identification friend or foe
IIR	imaging infrared
IR	infrared
JTCG/ME	Joint Technical Coordinating Group for Munitions Effectiveness
LDWSS	Laser Designated Weapon System Simulation
LIDAR	Light Direction Finding and Ranging (System)
LOHTADS	Light Observation Helicopter Target Acquisition and Designation System

LOS	line of sight
LOWTRAN	computer code for estimating atmospheric transmittance in the infrared portion of the spectrum
LZTRAN	computer code for calculating laser line absorption due to gaseous absorption
MICOM	Missile Command (U.S. Army)
MIRADCOM	Missile Research and Development Command (U.S. Army)
MOE	measure of effectiveness
MRC	minimum resolvable contrast
MRT	minimum resolvable temperature
NODLR	Night Observation Device, Long Range
NV&EOL	Night Vision and Electro-Optics Laboratory (U.S. Army)
OPAQUE	A Measurement Program on Optical Atmospheric Quantities in Europe
PWP	plasticized white phosphorous
RP	red phosphorous
RPV	Remotely Piloted Vehicle
S/N	signal-to-noise ratio
TAVETS	Thermodynamic Armored Vehicle and Environmental Thermal Signatures (model)
TOW	tube-launched, optically tracked, wire-guided (missile)
TTS	Tank Thermal Sight
TURB	Turbulence-Induced Pointing Jitter (MICOM computer routine)
TV	television
VFR	Visual Flight Rules
WBIC	weather and battle-induced contaminants
WP	white phosphorous
WPW	white phosphorous wick

REFERENCES

1. Comparison of Canadian and German Weather, System Planning Corporation, Report No. 425, March 1979, Unclassified.

2. OPAQUE - A Measurement Program on Optical Atmospheric Quantities in Europe, Vol. I, Air Force Geophysics Laboratory (OPA), Report No. AFGL-TR-78-0011, January 1978, Unclassified.

3. The Electro-Optical Systems Atmospheric Effects Library Vol. I: Technical Documentation, Atmospheric Sciences Laboratory, Report No. ASL-TR-0047, December 1979, Unclassified.

4. Low-Cost Infrared Atmospheric Transmission Model (DANTRAN), System Planning Corporation, Report No. 533, December 1979, Unclassified.

5. Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 4, Air Force Geophysics Laboratory (OPI), Report No. AFGL-TR-78-0053, 28 February 1978, Unclassified.

6. E. S. Shields, NV&EOL GAP Aerosol Atmospheric Models, NV&EOL Internal Memorandum, Unclassified.

7. Joint Operational Test and Evaluation of Imaging Infrared Maverick System, System Planning Corporation, Report 317, 1 August 1977, Secret/No Foreign Dissem.

8. Calibration of a Thermodynamic Armored Vehicle and Environmental Thermal Signature Model for the M-60 Tank, System Planning Corporation, Report No. 559, January 1980, Confidential.

9. M. Crowell, "Thermodynamic Modeling of Infrared Radiation From Scene Components in the 8- to 12-Micron Spectral Range," Proceedings of the Society of Photo-Optical Instrumentation Engineers, Vol. 219, Electro-Optical Technology for Autonomous Vehicles, Held in Los Angeles, February 6-7, 1980, Unclassified.

10. BELDWSS - An Extension of LDWSS to Threat Battlefield Obscurants, U.S. Army Missile R&D Command, Redstone Arsenal, AL, Special Report No. T-79-20, May 1979, Unclassified.

11. Assessment of LDWSS/BELDWSS for Use in RPV Performance Analysis, System Planning Corporation, Report No. 588, May 1980, Unclassified.

12. Time Series Evaluation of Selected Electro-Optical Links Operating in Tactical Smokes, U.S. Army Missile Command, Redstone Arsenal, AL, Report No. RE-77-9, 19 January 1977, Confidential.

13. Manportable Common Thermal Night Sight Smoke Test at White Sands Missile Range, Harry Diamond Laboratories, July 1977, Confidential.

14. Smoke Week I (SW-I) Electro-Optical (EO) Systems Performance in Characterized Smoke Environment at Dugway Proving Ground, UT, Aberdeen Proving Ground, MD, Report No. AD-2015-328, November 1977, Confidential.

15. J. Moulton and T. Cassidy, "Grafenwoehr II Realistic Battlefield Sensors Trials -- Winter," Proceedings of the Infrared Information Center Symposia, Vol. 24, Infrared Information and Analysis (IRIA) Center, Held in San Diego, 15-17 May 1979, Secret.

16. Moulton, Bergemann, Sola, "European Winter Atmospheric Optical Environment," 24th National IRIS, Naval Training Center, August 1976, Confidential.

17. T. Cassidy and J. Neubauer, "Grafenwoehr II Realistic Battlefield Summer Trials," Proceedings of the Smoke/Obscurants Symposium IV, Vol. I, Aberdeen Proving Ground, MD, Report No. DRCPM-SMK-T-001-80, June 1980, Confidential.

18. Measured Effects of Battlefield Dust and Smoke on Visible, Infrared and Millimeter Wavelength Propagation: A Preliminary Report on Dusty Infrared Test-I (DIRT-I), Atmospheric Sciences Laboratory, White Sands Missile Range, January 1979, Unclassified.

19. Smoke Week II (SW-II): Electro-Optical (EO) System Performance in Characterized Obscurant Environment at Eglin Air Force Base, FL, Aberdeen Proving Ground, MD, March 1979, Unclassified.

20. B. Kennedy, B. Carnes, and J. Mason, "Dusty Infrared Test-II (DIRT-II)," Proceedings of the Smoke/Obscurants Symposium IV, Vol. I, Aberdeen Proving Ground, MD, Report No. DRCPM-SMK-T-001-80, June 1980, Confidential.

21. Night Vision Laboratory Static Performance Model for Thermal Viewing Systems, U.S. Army Electronics Command, Night Vision Laboratory, Ft. Belvoir, Technical Report ECOM-7043, April 1975, Unclassified.

22. The Fundamentals of Thermal Imaging Systems, Naval Research Laboratory, Reports Nos. NRL 8311 and EOTPO 46, 10 May 1979, Unclassified.

23. "A Search Prediction Model," Proceedings of the Joint Meeting of the IRIS Specialty Groups on Infrared Detectors and Imaging, Vol. I, Infrared Information and Analysis Center, Report No. 132900-4-X(I), August 1978, Unclassified.

DISTRIBUTION LIST

Department of Defense	No. of Copie
Deputy Under Secretary of Defense for Research and Engineering (Tactical Warfare Programs) The Pentagon, Room 3E1044 Washington, DC 20301 Attention: Mr. C. Bernard	1
Dr. John Transue	1
Office of the Assistant Secretary of Defense (Program Analysis and Evaluation) The Pentagon, Room 2E330 Washington, DC 20301 Attention: Mr. T. P. Christie	1
Director, Defense Test and Evaluation Tactical Systems Test and Evaluation Office of the Under Secretary of Defense for Research and Engineering The Pentagon, Room 2B284 Washington, DC 20301	1
Office of the Under Secretary of Defense for Research and Engineering (ENLS) The Pentagon, Room 3D129 Washington, DC 20301 Attention: Col Albert Friday, Jr.	1
Office of the Test Director Joint Services EOGW CM Test Program White Sands Missile Range, NM 88002 Attention: DRXDE-TD	1
Defense Documentation Center Cameron Station Alexandria, VA 22314	2

Department of the Army

Office of the Under Secretary of the Army
The Pentagon, Room 2E614
Washington, DC 20310
Attention: Mr. Hunter M. Woodall, Jr. 1

Office of the Deputy Under Secretary of the Army
The Pentagon, Room 2E261
Washington, DC 20310
Attention: SAUS-OR (Mr. Fallin) 1

Commander
U.S. Army Materiel Development and Readiness Command
5001 Eisenhower Avenue
Alexandria, VA 22333
Attention: DRCDE-R (Mr. Sedlak) 1

Headquarters
Department of the Army
Washington, DC 20310
Attention: DAMA (LTC Hardman) 1
DAMO (MAJ Franklin) 1

Tactical Airborne Remotely Piloted Vehicle/Drone Systems
U.S. Army Aviation Research and Development Command
4300 Goodfellow Blvd.
St. Louis, MO 63120
Attention: Project Manager 6

Commander
U.S. Army Aviation Systems Command
Project Manager AAH Project Office
4300 Goodfellow Blvd.
St. Louis, MO 63120
Attention: Mr. Reago 1

Commander
U.S. Army Combined Arms Center
TSM, RPV (ATSF-TSM-R)
Fort Sill, OK 73503
Attention: COL Patterson 1

Commander
U.S. Army Electronics Research and Development Command
Ft. Belvoir, VA 22060
Attention: DELNV-SI (Mr. Sherman) 1
DELNV-VI (Mr. Moulton) 1
DELNV-VI (Mr. D'Agostino) 1

Commander
U.S. Army Armaments Research and Development Command
Aberdeen Proving Ground, MD 21005
Attention: DRCPM-SMK 1

Director
U.S. Army Materiel Systems Analysis Activity
Aberdeen Proving Ground, MD 21005
Attention: DRXSY-T (Mr. Topper) 1
DRXSY-RW (Mr. Scungio) 1

Atmospheric Sciences Laboratory
White Sands Missile Range, NM 88002
Attention: DELAS-EO (Dr. F. Niles) 1

Director
TRADOC System Analysis Agency
White Sands Missile Range, NM 88002
Attention: ATAA-TDA 1

Commander
U.S. Army Operational Test and Evaluation Agency
5600 Columbia Pike
Falls Church, VA 22041
Attention: CST-TM-FA 1

Commander
U.S. Army Electronic Research and Development Command
2800 Powder Mill Road
Adelphi, MD 20783
Attention: DRDEL-CCM (Mr. Pepper) 1

Commander
U.S. Army Missile Research and Development Command
Redstone Arsenal, AL 35809
Attention: DRSMI-REI (Mr. R. C. Passmore) 1
DRSMI-REO (Mr. H. Anderson) 1
DRCPM-HDE (Mr. G. Starkey) 1
DRSMI-RGT (Dr. R. Yates) 1

Commander
U.S. Army Electronic Proving Ground
Ft. Huachuca, AZ 85613
Attention: STEEP-MT-ES (Mr. Morris) 1

Commander
U.S. Army Training and Doctrine Command
Ft. Monroe, VA 23651
Attention: ATCD-F-A (Mr. O'Connor) 1

Director
U.S. Army Ballistic Research Laboratories
Aberdeen Proving Ground, MD 21005
Attention: DRDAR-BM (Mr. H. Reed) 1

Chief
Office of Missile Electronic Warfare
White Sands Missile Range, NM 88002
Attention: DELEW (Mr. Agar) 1

Project Manager's Office, Smoke/Obscurants
Aberdeen Proving Ground, MD 21005
Attention: DRCPM-SMK-T (Mr. G. Nelson) 1

Department of the Air Force

HQ USAF/RDSL
The Pentagon, Room 4D282
Washington, DC 20330
Attention: Capt. R. Bonesteel 1

Air Force Avionics Laboratory
Wright-Patterson AFB, OH 45433
Attention: AFWAL/AARI (Maj. J. Pryce) 1
AFWAL/AAAD (Mr. C. Gauder) 1
AFWAL/AAAD (Mr. R. Matson) 1
AFWAL/AAAS (Ms. D. Summers) 1
AFWAL/RWI3 (Mr. H. Geltmacher) 1

DoD Climatology Officer
Det. 2, HQ ADWS
Washington, DC 20330
Attention: Capt. Donald Buchanan 1

AF/SAGF
The Pentagon, Room 1D380B
Washington, DC 20330
Attention: Maj. Edward F. Kolczynski 1

Maverick Systems Project Office
Wright-Patterson AFB, OH 45433 1

Air Force Geophysics Laboratory
Hanscom AFB, MA 01731
Attention: AFGL/OPI (Dr. McClatchey) 1
AFGL/OPA (Dr. R. Fenn) 1

Department of the Navy

Commander
Naval Weapon Center
China Lake, CA 93555
Attention: Code 3157 (Dr. Bergman) 1

Commander
Naval Air Systems Command
Washington, DC 20361
Attention: AIR-03P23 (Dr. Habayeb) 1

Commander
Naval Research Laboratory
Washington, DC 20360
Attention: Code 6550 (Dr. A. Fenner Milton) 1

Other

System Planning Corporation
1500 Wilson Boulevard
Arlington, VA 22209 15

Institute for Defense Analyses
400 Army-Navy Drive
Arlington, VA 22202
Attention: Mr. Lucien M. Biberman 1

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: SPC 615

2. GOVT ACCESSION NO.: AD-A091 603

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): A SURVEY OF SIMULATION AND TEST RESULTS FOR ASSESSING RPV PERFORMANCE IN A WBIC ENVIRONMENT

5. TYPE OF REPORT & PERIOD COVERED: Final Report

6. PERFORMING ORG. REPORT NUMBER: 80-3279

7. AUTHOR(s): M. H. Crowell

8. CONTRACT OR GRANT NUMBER(s): DAAK50-80-C-0011

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
System Planning Corporation
1500 Wilson Boulevard
Arlington, Virginia 22209

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:

11. CONTROLLING OFFICE NAME AND ADDRESS:
Tactical Airborne Remotely Piloted Vehicle/ Drone Systems
U.S. Army Aviation Research & Development Command
4300 Goodfellow Blvd., St. Louis, MO 63120

12. REPORT DATE: July 1980

13. NUMBER OF PAGES: 55

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
U.S. Army Aviation Research & Development Command
ATTN: DRDAV-PDA
4300 Goodfellow Blvd.
St. Louis, MO 63120

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A

16. DISTRIBUTION STATEMENT (of this Report):

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):

18. SUPPLEMENTARY NOTES:

19. KEY WORDS (Continue on reverse side if necessary and identify by block number):

Remotely Piloted Vehicle	obscurants	Copperhead
laser-guided weapon	aerosols	field testing
smoke	performance analysis	atmospheric testing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The report reviews selected modeling techniques and supporting field test data that are applicable to performance analyses of the RPV mission payload in an operational environment. The rationale for selecting these modeling techniques was based on earlier research described in An Approach to Analysis of RPV Sensor Performance in Battlefield Environments, System Planning Corporation, Report No. 439, April 1979, Confidential.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FILM

2