Smart Weapons Operability Enhancement (SWOE) Program Joint Test and Evaluation Program Test Design

J.P. Welsh

U.S. Army Cold Regions Research
and Engineering Laboratory
Hanover, NH

SWOE Report 92-5
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FOREWORD

SWOE Report 92-5, June 1992, was prepared by Dr. J.P. Welsh of U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.

This report is a contribution to the Smart Weapons Operability Enhancement (SWOE) Program. SWOE is a coordinated, Army, Navy, Marine Corps, Air Force and DARPA program initiated to enhance performance of future smart weapon systems through an integrated process of applying knowledge of the broadest possible range of battlefield conditions.

Performance of smart weapons can vary widely, depending on the environment in which the systems operate. Temporal and spatial dynamics significantly impact weapon performance. Testing of developmental weapon systems has been limited to a few selected combinations of targets and environment conditions, primarily because of the high costs of full-scale field tests and limited access to the areas or events for which performance data are required.

Performance predictions are needed for a broad range of background environmental conditions and targets. Meeting this need takes advantage of significant DoD investments by Army, Navy, Marine Corps and Air Force in 1) basic and applied environmental research, data collection, analysis, modeling and rendering capabilities, 2) extensive target measurement capabilities and geometry models, and 3) currently available computational capabilities. The SWOE program takes advantage of these DoD investments to produce an integrated process.

SWOE is developing, validating, and demonstrating the capability of this integrated process to handle complex target and background environment interactions for a world-wide range of battlefield conditions. SWOE is providing the DoD smart weapons and autonomous target recognition (ATR) communities with a validated capability to integrate measurement, information base, modeling and scene rendering techniques for complex environments. The result of a DoD-wide partnership, this effort works in concert with both advanced weapon system developers and major weapon system test and evaluation programs.

The SWOE program started in FY89 under Balanced Technology Initiative (BTI) sponsorship. Present sponsorship is by the U.S. Army Corps of Engineers (lead service), the individual services, and the Joint Test and Evaluation (JT&E) program of the Office of the Director of Defense Research and Engineering (DDR&E), Office of the Secretary of Defense (OSD).

The Program Director is Dr. L.E. Link, Technical Director of the U.S. Army, Cold Regions Research and Engineering Laboratory (CRREL). The Program Manager is Dr. J.P. Welsh, CRREL. The Integration Manager is Mr. Richard Palmer, CRREL. The task areas and their managers are as follows: Modeling Task Area, LTC George G. Koenig, USAF, Geophysics Laboratory (GL), of the Air Force Phillips Laboratories; Information Bases Task Area, Mr. Harold W. West, PE, U.S. Army Engineer, Waterways Experiment Station (WES); Scene Rendering Task Area, Mr. Mike Hardaway, Corps of Engineers, Topographic Engineering Center (TEC); Validation Task Area, Dr. Jon Martin, Atmospheric Sciences Laboratory (ASL) of the Army Materiel Command.

Executive Summary

Performance of smart weapon systems has been unpredictable and unreliable for extrapolation to the global range of battlefield conditions and the ever increasing diversity of operational requirements. This problem has been clearly demonstrated for the majority of developing smart weapon systems. The present generation of smart weapons may still require a person, in the loop, to perform important decision making functions. The future generation will be more autonomous, more sophisticated and even more vulnerable to unpredictable and unreliable performance. High costs, limited access to representative sets of battlefield like conditions, and the vast array of variability for backgrounds and targets have precluded comprehensive full scale real world testing of smart weapon systems. Expedient and less expensive ways to obtain more comprehensive performance information for the global range of battlefield conditions and variety of smart weapon systems is required. DoD needs an integrated process to design, test, evaluate and extrapolate smart weapon performance for the global range and combinations of battlefield backgrounds and targets. A valid integrated scene generation process can meet parts of this DoD need. Ready access to a representative range of backgrounds and targets information will serve to enhance and extrapolate smart weapon systems performance. This Program Test Design document contains a description of the: background, objectives, approach, experimental design, schedule, budget, data management, analysis, and data disposition for the Smart Weapons Operability Enhancement (SWOE) Joint Test and Evaluation (JT&E) Program. The goal of this program is to validate the SWOE integrated scene generation process, the SWOE Process. The SWOE Process utilizes measurements, information bases, physics based energy exchange models, physical object geometry models, target geometry models and rendering techniques to generate synthetic scenes for a virtually infinite variety of anticipated battlefield scenarios.

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1.0 INTRODUCTION

This Program Test Design document contains a description of the: background, objectives, approach, experimental design, schedule, budget, data management, analysis, and data disposition for the Smart Weapons Operability Enhancement (SWOE) Joint Test and Evaluation (JT&E) Program. The goal of this program is to validate the SWOE integrated scene generation process. The SWOE Process produces synthetic scenes from an integration of measurements, information bases, numerical models, and rendering. The Process uses basic physics formulations, to simulate the dominant energy exchange phenomena that impact smart weapon system performance. Figure 1 is an example of a product of the SWOE Process.

1.1 BACKGROUND

Performance of smart weapon systems has been unpredictable and unreliable for extrapolation to the global range of battlefield conditions and the ever increasing diversity of operational requirements. This problem has been clearly demonstrated for the majority of developing smart weapon systems. The present generation of smart weapons may still require a person, in the loop, to perform important decision making functions. The future generation will be more autonomous, more sophisticated and even more vulnerable to unpredictable and unreliable performance. DoD needs an integrated process to design, test, evaluate and extrapolate weapon performance for the global range and combinations of battlefield backgrounds, targets and conditions. A valid integrated scene generation process can meet parts of this DoD need. A representative range of backgrounds and targets information will serve to enhance and extrapolate smart weapon performance.

One DoD approach has been described as the application of a test-fix-test methodology for the test and evaluation phase of developing a smart weapon system. The Captive Flight Test is a primary vehicle for this approach. Captive flight tests typically relate the performance of components of each weapon system to a limited range of prepared for battlefield like conditions and a limited variety target set. The complexity of each real world battle scenario is enormous; consider the immense variety of background conditions, variety and arrangement of targets and possible tactical formations/arrangements/maneuvers, etc. Efforts to design and test smart weapon systems for this staggering array of variability using only a few relatively benign target-in-background scenes have not been entirely successful. Many of the shortfalls in performance have been attributed to the enormous range of variation in space and time characteristically displayed by the targets and the associated background features.

FIGURE 1. SWOE Process generated scene for Hunter Liggett, California, including targets (M60 and M113)

Hunter Liggett, California
Radiance, 1500h, 20 Sep 1989
Radiance Range 0.0013 w/cm^2/sr to 0.0046 w/cm^2/sr

This is most often recognized as a problem when the targets can not be discriminated from the associated background. There are situations when the target and a background feature or object have the same signature, i.e. a false alarm. This issue is paramount to solving the problems encountered by the autonomous target recognition (ATR) and camouflage, concealment, counter-measures and deception (CCCD) communities.

The cost of conducting full scale captive flight tests, already high, continues to rise. At the same time, the quantity, quality, and variety of data required grows in proportion to the increasing complexity of smart weapon systems and the ever higher expectations for their performance.

High costs, limited access to representative sets of battlefield like conditions, and the vast array of variability for backgrounds and targets have precluded comprehensive full scale real world testing of smart weapon systems. Expedient and less expensive ways to obtain more comprehensive performance information for the global range of battlefield conditions and variety of smart weapon systems is required.

An integrated scene generation process provides a capability to obtain more comprehensive performance data for a greater variety of backgrounds and targets. High speed workstations, special purpose graphics and visualization software and special purpose hardware (parallel processors, etc.) have advanced scene generation capabilities significantly, especially in the visual part of the spectrum. Continuing technology base efforts, by all the military services, have resulted in the ability to generate physics based background scenes, particularly IR, including targets, with a high degree of realism and precision. The Smart Weapons Operability Enhancement (SWOE) program has leveraged and integrated products from DoD wide, all military services, technology programs to assemble an integrated scene generation process.

1.2 OBJECTIVES

The primary test objective is to validate the SWOE integrated scene generation process. The SWOE Process utilizes measurements, information bases, physics based energy exchange models, physical object geometry models, target geometry models and rendering techniques to generate synthetic scenes for a virtually infinite variety of anticipated battlefield conditions. The secondary test objective is the collection of selected field data. Field test times and places are selected to consider critical factors in battlefield scenarios that cause false alarms such as transition and crossover type effects. The field data is necessary for the validation of the SWOE Process; it is also a useful stand alone product. Every effort will be made to collect field data appropriate to the broadest range of user community requirements. This will require that a variety of look alike battlefield conditions, target sets and doctrine driven tactical arrangements be emulated. Simultaneous, in space and time, multi-spectral data, especially IR and MMW, relevant to DoD wide weapon system specifications are to be collected. Appendix I lists DoD resources to assist in the determination of specifications and description of battlefield scenarios.

2.0 PROGRAM DESCRIPTION

The goal of this Joint Test is to validate the SWOE Process. The SWOE integrated scene generation process is focused on the target and background conditions which significantly impact the performance of smart weapon systems, particularly the factors and conditions that cause false alarms.

2.1 APPROACH

Validate the SWOE integrated scene generation process. This approach requires the generation of physics based synthetic scenes to predict the range of background and target variability, the selective collection of field data, generation of scenes matched to the conditions encountered during field data collection and comparison of the collected scenes to the synthetic scenes. Scene comparisons will be made using numerically repeatable statistical hypothesis testing techniques. The data collection methods are more or less routine for the execution of this effort. The unique aspects of this approach have to do with the uses of predictions based on synthetically generated scenes. The synthetically generated scenes (physics based) will be used to estimate the range of variation of the dominant factors that impact weapon performance. Measures of variability (histograms, etc.) from the synthetically generated scenes will be used to estimate and numerically describe the lower and upper boundaries to the within and between scene factors and features variation. These estimators will be used to develop the test matrix and the sampling and measurement procedures for the field data collection portions of this Joint Test.

2.2 DESCRIPTION OF THE SWOE PROCESS

Technical reports describing the evolution and detailed aspects of the SWOE Process are listed in Appendix II.

Measurements are required to build information bases; they are the tie to the real world. Information bases are needed to describe the battlefield like conditions, the scenario, and to initialize and run the SWOE Process. The key issue for the measurement effort is to obtain representative samples. These samples will be used to infer energy interactions within and between a large variety of materials.

Information bases are needed for a global variety of battlefield backgrounds and targets. They are needed to develop site-to-site and area-to-area comparison and extrapolation methods. The information bases contain all spatial and attribute data required to define the background (land, water, atmosphere, sky, etc.). The architecture of the information bases is driven largely by the requirements of the numerical models and the scene rendering techniques.

The information bases contain three categorical types of data: digital terrain data (e.g., topography, soil types, vegetation types); physical, thermal, and spectral terrain attribute data (e.g., moisture content, emissivity, reflectance); and meteorological (weather and atmospheric) data (e.g., air temperature, visibility, etc.).

Digital terrain data are representations of portions of the earth's surface stored in computer-compatible format. These data depict characteristics such as elevation, vegetation types, soil types, and other relevant environmental information. Digital terrain data used in the scene generation process is stored in raster and vector formats and managed by a geographic information system (GIS).

The physics-based energy signature prediction models used in the SWOE Process require quantitative descriptions of the physical, thermal, spectral, etc. attributes of the dominant background and target features. These data are most efficiently stored and retrieved in tabular format; in a relational database management system (RDBMS). The RDBMS associates each stored numerical value with the corresponding feature as depicted in the GIS.

Meteorological data are needed for the SWOE Process and have particular importance to the radiation field prediction models. Both surface weather and upper atmospheric profile data are required. These data are also stored in tabular format in the RDBMS.

The goal of the modeling effort within the SWOE Process is to assemble and integrate three dimensional (3-D) fundamental physics models of the dominant environment phenomena and objects (natural & manmade) especially for the IR and MMW spectral regions. Discrete objects modeled are: trees, with & without leaves, buildings, vehicles, roads, bridges, etc. Models of the energy budget are significantly effected by heterogeneity in the 3-D distribution of energy emitters and scatters. SWOE thermal models are used to calculate the surface temperatures for a wide variety of surfaces, including vegetated and non-vegetated surfaces, bodies of water, and snow and ice-covered surfaces. The model results are applicable to all seasons.

The thermal models are driven by routinely collected types of weather data, such as standard surface weather observations and radiosonde data. Default databases of seasonally dependent thermal properties are provided as a set of standard surfaces commonly encountered in scene simulation. The SWOE thermal models package accommodates various vegetation effects. The effects of simple vegetation, such as grasses and crops, and forests can be included in the 1-D heat balance of soils. A separate 3-D model of the thermal balance for individual trees is also included. Two geometric representations of trees, based on measurements of actual trees, have been included for calculating the temperature fields for trees.

The radiation fields from the atmosphere are also drivers of the thermal models. The atmospheric radiation budget is calculated using a modified version of LOWTRAN7, which is a standard atmosphere radiance and transmission model code used by the DoD.

The SWOE Radiance models package contains two parallel computational approaches, one for terrain and one for 3-D objects (currently individual trees and selected military targets). The terrain radiance approach is built around a new Fortran model, called IBRM ("Improved Background Radiance Model"). Radiance values for 3-D objects are computed with the Hardbody module of the SPIRITS code, a U.S. Government standard for aircraft. Both radiance model approaches utilize the same basic algorithms and phenomenology, which include:

- radiance's computed spectrally at 2 to 20 cm^{-1} resolution, and bandpass integrated (with optional filter function) only after atmospheric effects are added;
- radiance sources of thermal emission, the sun, the sky, and surrounding terrain;
- sky emission from broken clouds;
- solar shadowing;
- spectral directional emissivities for each material;
- a spectral bidirectional reflectivity for each material;
- spectral atmospheric transmission and radiance (thermal and solar scatter) along all paths connecting the terrain, sun, sky, and sensor, utilizing the Air Force MODTRAN model (an upgrade to LOWTRAN7). A separate model, SHADOW, automatically generates faceted shadows of the 3-D objects for inclusion within the scene.

The terrain is modeled with a set of textured polygons which overlay the topography grid. The polygon definitions and geometry are determined as part of the information base effort. The radiance models compute a list of in-band radiance's for each polygon, based in part on temperatures computed by the SWOE thermal models. Trees and targets are described with a triangular geometry, typically with 3000 to 20,000 triangles per object. Tree geometry's are based on trunk and branch measurements taken from archived and published sets of real tree measurements. Faceted leaves are generated using a fractal technique. The resulting geometry, plus a file with a separate temperature for each triangle, are input to Hardbody for the tree radiance computations.

Targets require a set of computed target temperatures for the scene specified conditions; Hardbody then computes the radiance values. Utility software is provided to convert thermal computations to the Hardbody format. Hardbody computations include facet-to-facet reflections. Clouds are one of the more important modulators of the surface energy balance. The SWOE model package considers the influence of clouds on solar and infrared downwelling fluxes During the thermal loading phase, also known as the model spin-up phase, a simple model is used to modulate the broadband downwelling flux in appropriate spectral regions based on the geographic location of the scene, time, surface characteristics (slope and albedo), atmospheric conditions, cloud amount, and cloud type. This approach does not provide the radiant field information required at the time of the scene simulation. At scene simulation time a modified version of LOWTRAN is used to calculate the spectrally dependent solar direct and diffuse, and infrared downwelling flux. This information is used in the computation of reflections off of and between scene elements; and absorption and scattering by atmospheric gases, aerosols, and clouds. Cloud shadows, at the time of the scene simulation, are generated by the Cloud Scene Simulation Model (CSSM).

The CSSM uses a Successive Random Additions (SRA) fractal algorithm to generate the horizontal distribution of the clouds based on the cloud amount and type (stratiform, cirriform, or cumuliform). 1-D SRA and 2-D SRA algorithms are used to generate the upper and lower surface of the cloud while a 3-D SRA algorithm is used to modulate the liquid water density (LWD) information at each cloud grid point in the cloud volume. The mean LWD information as a function of cloud type and altitude has been obtained from an extensive cloud database. In the future, the LWD information will be used to determine the cloud microphysical and optical properties for use in a model that will calculate the full 3-D cloud radiative interactions. The scene generated cloud characteristics are controlled by the Hurst and Lacunarity parameters in the SRA algorithm. Model default values controlled by the cloud type are used in the cloud simulation, but the user can modify these parameters. Cloud shadows are determined using a ray tracing technique, the 3-D cloud spatial distribution, and the solar azimuth and zenith angle or scene location and time of year and day.

The SWOE rendering software provides the capability necessary to create 2-D visualization of 3-D objects and background features. The software uses the depth buffer approach to resolve hidden surfaces. The output is a projection of the data contained in the information base onto a 2-D image or pixel file. The input files contain the physics models, initialization information, haze and lighting, and viewpoint. These inputs are used to generate the pixel data to create an image. The general sequence of steps for rendering follows:

Viewpoint manager – processes input initialization data and viewpoint information to generate a sun vector, ambient and diffuse lighting parameters, bounding planes, and the world space to a viewpoint space transformation matrix, which is referred to as "viewpoint data".

World manager – uses viewpoint data and bounding planes to select root nodes in the data base for the terrain region. A node is defined as a subset of the information base which contains position data, information for level of detail (LOD) and field of view (FOV), materials properties, etc., and pointers to the items associated with each node.

Node processor – traverses the node tree and uses the bounding planes to determine which nodes are in the FOV. The FOV test creates a list of active nodes, loads texture maps and allocates nodes to the correct LOD.

Item processor – transforms sun vectors, calculates triangle face normals, eliminates back faces, determines polygon coloring and shading, converts vertices to viewpoint space, clips to hither plane, and projects polygons to screen space.

Pretiler – clips polygon to screen space and creates triangles with incremental color, depth, and texture information.

Tiler – produces pixels for display for each triangle through the graphics processor, and may modify color attributes of textured items.

The result of the rendering is a 2-D pixel space representation of the radiometric energy arriving at the aperture of a sensor for a specified viewing geometry.

2.2 DATA ELEMENT DECOMPOSITION

Over a hundred parameters are used in the SWOE Process. Of these hundred or so parameters, only about 10 % must be measured for each of the planned SWOE field data collection efforts. This section describes the data elements.

A rating scheme has been established for the data requirements that is intended to provide guidance for collection of data at the SWOE field tests. The rating scheme is:

M - Mandatory Measurement. The parameter is required by the models and no alternative source of data is acceptable.

D - Desired Measurement. The parameter is required by the models, but acceptable alternate sources exist, such as climatologies, parameterization, etc.

O - Optional Measurement. The parameter can be calculated from physical relationships or the parameter is one that is useful for model validation.

N - Not Feasible to Measure. Parameter is currently hardwired into the models via the use of default values.

Tables 1 - 6 lists the parameters required for the SWOE physics models. The Tables include the rating for each parameter, the units used by the physics models, the desired accuracy, the recommended sampling rate, and the recommended time period over which averaged parameters are requested.

SURFACE WEATHER PARAMETERS

Table 1 lists the surface weather parameters required for the SWOE physics models. The parameters listed are standard surface weather data that are assumed to be collected at the standard instrument shelter height of 2 m. In the case of precipitation type, the differentiation of rain or snow is sufficient for the SWOE models. It is noted that all of the parameters listed in the Table except the visibility are mandatory measurements. The visibility is an optional measurement because of the generally small impact it has on the models. The only exception to this is in the presence of fog.

TABLE 1 SURFACE WEATHER DATA

Surface Weather Data

Parameter	Require	Units	Desired Accuracy	Sampling Rate	Average
Pressure	M	mb	0.1	1/min	15 min
Temperature*	M	C	0.1	1/min	15 min
Relative Humidity	M	%	1	1/min	15 min
Scalar Wind Speed	M	m/s	0.1	1/min	15 min
Wind Direction	M	deg	1	1/min	15 min
Visibility	D	km	1	1/min	15 min
Precipitation Rate	M	mm/hr	0.1	1/15 min	-
Precipitation Type	M	-	-	1/15 min	-

(M - Mandatory D - Desired O - Optional N - Not Feasible)
* Measured at Instrument Shelter Height (2 m)

SOLAR AND INFRARED FLUXES

A number of radiative parameters are required to provide the energy inputs into the SWOE physics models. Table 2 lists the solar and infrared radiation parameters that are required. All of these parameters are identified as either desired or optional measurements because the SWOE Process includes a model to calculate the solar and infrared radiative fluxes. Field measurements, therefore, serve to provide additional model validation.

TABLE 2. SOLAR AND INFRARED RADIATIVE PARAMETERS REQUIRED BY THE SWOE PHYSICS MODELS

Solar/Infrared Flux Data

Parameter	Requirement	Units	Desired Accuracy	Sampling Rate	Average
Total Global Solar Flux	D/O	watts/m^2	1.0	1/min	15 min
Direct Solar Flux	O	watts/m^2	1.0	1/min	15 min
Diffuse Solar Flux	O	watts/m^2	1.0	1/min	15 min
Downwelling Infrared Flux	D/O	watts/m^2	1.0	1/min	15 min

(M - Mandatory D - Desired O - Optional N - Not Feasible)

CLOUD PARAMETERS

Table 3 lists the cloud parameters required by the SWOE models. The parameters included in the Table are ones that are based on data from routine surface weather observations. Of the parameters included in the list, only two are mandatory measurements, the amount and type of the low clouds. All of the other parameters have a small to negligible impact on the physics. It is stressed, however, that this will change if SWOE begins simulations involving other than ground-based scenarios. In those cases, the observations concerning the middle and high clouds will become mandatory.

TABLE 3. CLOUD PARAMETERS REQUIRED BY THE SWOE MODELS.

Cloud Data

Parameter	Requirement	Units	Desired Accuracy	Sampling Rate
Low Cloud Amount	M	–	–	1/hour
Low Cloud Type	M	–	–	1/hour
Low Cloud Height	O	km	100 m	1/hour
Middle Cloud Amount	O	–	–	1/hour
Middle Cloud Type	O	–	–	1/hour
Middle Cloud Height	O	km	100 m	1/hour
High Cloud Amount	O	–	–	1/hour
High Cloud Type	O	–	–	1/hour
High Cloud Height	O	km	100 m	1/hour

(M - Mandatory D - Desired O - Optional N - Not Feasible)

UPPER AIR PARAMETERS

Table 4 lists the upper air parameters required. As noted in the Table, all of the parameters are not mandatory. If the SWOE atmospheric radiation model is used to calculate the solar and infrared radiative fluxes, it is desirable to have upper atmospheric measurements of the temperature, pressure, and relative humidity but not mandatory. This is because a feature exists in the atmospheric radiation model to scale standard atmospheric temperature profiles to the air temperature at the surface. The upper air wind speed and direction are not required at all in the current SWOE models.

TABLE 4. UPPER AIR PARAMETERS REQUIRED BY THE SWOE MODELS

Upper Air Data

Parameter	Requirement	Units	Desired Accuracy
Pressure	D	mb	0.1
Temperature	D	C	0.1
Relative Humidity	D	%	1
Scalar Wind Speed	O	m/s	0.1
Wind Direction	O	deg	1

(M - Mandatory D - Desired O - Optional N - Not Feasible)

Notes: Data should be collected at or near time of flights; Provide data in significant level format; Data collection up to 30kft is acceptable

SOIL PROPERTIES

Table 5 lists the soil parameters required by the SWOE physics models. Currently, a library of default soil types is built-in to the SWOE thermal models containing all of the material property information required. The measurement of the various soil properties is a challenging task in a field setting, hence the majority of the properties are listed as Not Feasible to measure. However, the information on the types of soils present is a mandatory measurement.

TABLE 5. SOIL PROPERTIES REQUIRED BY THE SWOE MODELS

Soil Properties

Parameter	Requirement	Units
Top Layer Thickness	D	cm
Top Soil Type (Silt, Sand,...)	M	-
Lower Layer Thickness	O	cm
Lower Layer Type (Silt, Sand, ...)	O	-
Surface Albedo	N	-
Infrared Emissivity	N	-
Density of Dry Materials	O	kg/m^3
Bulk Density of Dry Materials	O	kg/m^3
Heat Capacity of Dry Materials	N	J/(kg K)
Thermal Conductivity of Dry Materials	N	W/(m K)

(M - Mandatory D - Desired O - Optional N - Not Feasible)

SIMPLE VEGETATION PROPERTIES

The SWOE physics models include simple vegetation, such as grass. Table 6 lists the parameters required to describe simple vegetation in the SWOE models. As noted in the Table, none of the parameters involve mandatory measurements.

TABLE 6. SIMPLE VEGETATION PROPERTIES REQUIRED BY THE SWOE PHYSICS MODELS

Simple Vegetation Properties

Parameter	Requirement	Units
Average Height	D	cm
Fractional Coverage	D	%
State of the Vegetation	N	-
Solar Absorptivity	N	-
Infrared Emissivity	N	-

(M - Mandatory D - Desired O - Optional N - Not Feasible)

There are two aspects to ground truth which must be handled. First is the ground truthing or characterization of the test environment in real time. This includes the meteorological conditions, the atmospheric characterization, and solar loading as well as the soil and vegetation types especially their spatial distributions. Ground truth also includes radiometric measurements of the dominant scene components. The second aspect of ground truth is the characterization of the target set. This includes location, orientation, type, operational condition, recent operating history and representative radiometric measurements. Table 7 summarizes some of the measurement requirements for ground truth.

The ground vehicle target set should contain a representative range of equipment. Tanks, APC's, mobile missile launchers, artillery pieces and other types of high value targets, both US and foreign systems are candidates.. The individual targets to be used in the SWOE Joint Test must have numerical geometric models available. Whenever possible, tactical deployment of targets should be made in the numbers and spacing appropriate to typical operations and doctrine. This includes the use of CCD and countermeasures whenever possible.

TABLE 7 MEASUREMENT REQUIREMENTS FOR GROUND TRUTH

Surface	*Targets & 3-D Objects*
• Material Properties And Their Distributions • Vegetation, Snow & Ice, etc.: 3-D Spatial & Temporal Distributions for Temperature & Phase (Gas, Solid, Liquid) • Bi-Directional Reflectance & Directional Emittance for Materials • Surface Albedo And Emissivity • Roughness Characterization for The Terrain	• Identification • Locations • Orientations • Materials, Characteristics & Their Distributions • Presence Of Countermeasures • Operational Condition - e.g. Hot, Cold, Idling, Hatch Open, etc.

2.3 AIRBORNE SENSORS

An airborne collection capability is required which has state of the art calibrated IR sensors in both the 3-5 and 8-14 micrometer bands. In the MMW bands, a fully polarimetric, 35 GHz and 94 GHz capability is required. There should also be a full color visual system as well. Complimentary systems should be boresighted, where possible, and the platform must have some reliable form of stabilization and positioning (mandatory for image registration). Data recording and data reduction should be automated because of the large amount of data to be collected and processed over the life of the program. Several possible test platforms have been identified as being capable to do the collection and recording task. None are capable of meeting the complete requirement in its present condition although some are closer than others. Summary of airborne sensor platform capabilities are arrayed in Table 8.

2.4 EXPERIMENTAL DESIGN

The experimental design is driven by the requirement to include the widest possible range of variation expected for real battlefield scenarios. The range of variation is representative of many phenomena, all possibly interacting, resulting in the myriad of combinations of conditions encountered. Times and places have been selected to quantitatively establish the range of variation for the dominant sources of false alarms, etc., that impact smart weapon performance; including transition and crossover effects. Practical constraints are operating here in the chosen approach to

TABLE 8. SUMMARY OF AIRBORNE SENSOR PLATFORM CAPABILITIES.

Instrumentation Item		Textron	ASETS	LEAR	BASES	FISTA	WES
	Transmit Waveform	FMCW	N/A	N/A	N/A	N/A	N/A
	Transmit polarization(s)	RHC					
	Transmit power	80 mW					
35 GHz	Transmit bandwidth (MHz)	500 (~ 1 ft)					
Radar	Receive Polarization(s)	RHC, LHC					
	Receiver outputs	Amplitude Only					
	Output device	Analog Tape					
	Beamwidth	2.8°					
	Transmit Waveform	FMCW	Stepped Frequency	FMCW	N/A	N/A	N/A
	Transmit polarization(s)	RHC	RR, LL or HH, VV	LHC			
	Transmit power	30 mW	15 Watts (peak)	15 MW			
95 GHz	Transmit bandwidth (MHz)	500 (~ 1 ft)	1000 (~ .5 ft)	640			
Radar	Receive Polarization(s)	RHC, LHC	Co-Pol, Cross-Pol	RHC, LHC			
	Receiver outputs	Amplitude Only	Co-Amp, I, Q/ Cross-Amp, I, Q	Amp only			
	Output device	Analog Tape	HDDT	HDDT			
	Beamwidth	1.0°	0.8°	0.9°			
	Temperature range (C)	-20°-400°	-20°-1500°	N/A		0°-1000°	
	Detector type	HgCdTe	InSb		InSb	Platinum Silicide	
	Pixels per line	512	350		243	120	
	Lines per frame	256	280		280	280	
Mid-Wave	FOV	5° - 20°	7° - 25°		7°	4.6° - 6.8°	
Infrared	Resolution (mrad)	3.5	1.1		1.1	.4 .x 8	1.25
	Coolant	LN2	LN2		LN2	LN2	LN2
	Duration	3 hrs	2 hrs		1 hr	4 - 6 hrs	3 hrs
	Data Output	Analog, RS-170	Digital, 12 bits		Digital, 10 bits	Analog/digital, 12 bits	Digital , 11 bits
	Output Device	VHS	HDDR		HDDR	SMPTE/Beta Cam	ULDS
	Temperature range (C)	-20°-400°	-20°-1500°	N/A	?	0°-1000°	?
	Detector type	HgCdTe	InSb		HgCdTe	HgCdTe	HgCdTe
	Pixels per line	512	350		243	512	710
	Lines per frame	256	280		280	384	1024
Long-Wave	FOV	5° - 20°	7° - 25°		7°	4.0° - 6.89°	42°
Infrared	Resolution (mrad)	1.8	1.1		1.1	.36 x .47	125
	Coolant	LN2	LN2		LN2	LN2	LN2
	Duration	3 hrs	2 hrs		1 hr	4-6 hrs	3 hrs
	Data Output	Analog,RS-170	Digital,12 bits		Digital, 10 bits	Analog	Digital , 11 bits
	Output Device	VHS	HDDR		HDDR	SMPTE/Beta Cam	ULDS
	Aircraft type	UH-1	C-130	UH-1	UH-1	NKC 135A	UH-60
	Altitude	100' - 1000'	200' - 20,000'	100'-1000'	100'-1000'	Safety - 40,000'	80'-400'
	Airspeed	30-40 kts	100-250 kts	40-100 kts	40-100 kts	N/A	30-120 kts
Aircraft/	Time of flight	~ 1.25 hrs	6 hrs	1.5 hrs	1 hr	4-6 hrs	3 hrs
Stabilization	Inertial stabilization	2 axis-gyro	5 axis gyro	3 axis gyro	2 axis gyro	none (hand track)	in bank
	Azimuth scan coverage	60°	360	30°	-13° to Horizon	0° - 40°	42°
	Elevation scan coverage	360°	360°	90°	Horiz to Horiz	70° - 90°	-
	Environmentally sealed	No	Yes	Yes	Yes	No	Yes

validation. All possible combinations are not reasonably available for a captive flight test field exercise. The solution is to try to obtain samples for at least two different battlefield scenarios, preferably examples which are analogous to some expected theater of operations. One way to do this is to use two different geographic and climatic locations (one arid and one temperate) and to focus on selected transition and crossover dependent features and effects. These considerations drive the validation process in selection of times and places for selective field data collection. Grayling, Michigan will be used as a NATO European analog for the 'fall to winter' and 'spring to summer' transition periods. Yuma, Arizona will be used as the desert or southwest Asia analog for the 'spring winds' and 'summer bloom' transition periods.

2.4 DESIGN MATRIX

The design matrix is shown in Table 9. There are several assumptions which are important to this approach to developing the design matrix. First, the length of time to complete this effort is three years. Second, the maturity of the physics based models

TABLE 9 PROGRAM DESIGN MATRIX

Location*	Priority	Selected Events	Dates	Phenomena, Conditions
Grayling (European Analog)	1	Fall, Winter Transition	15 Sep To 20 Oct	Leaves/No Leaves, Freezing, Low Sun Angles, Shadows, Decreasing Length Of Day
	2	Winter	15 Jan To 15 Feb	Lowest Ambient Temperature, Low Sun Angles, Shadows
	1	Spring, Summer Transition	20 Mar To 15 May	No Leaves/Leaves, Freeze-Thaw Cycles, Shadows, Increasing Length Of Day
	2	Summer	10 Jul To 30 Jul	Highest Ambient Temperature, Highest Sun Angles, Shadows
Yuma (Southwest Asia Analog)	2	Winter	15 Dec To 10 Jan	Lowest Ambient Temperature, Low Sun Angles, Shadows ,Rain
	1	Summer	10 Jun To 15 Jul	Highest Ambient Temperature, Highest Sun Angles, Shadows
	1	Spring Summer Transition	15 Mar To 30 Apr	Desert Winds, Desert Bloom

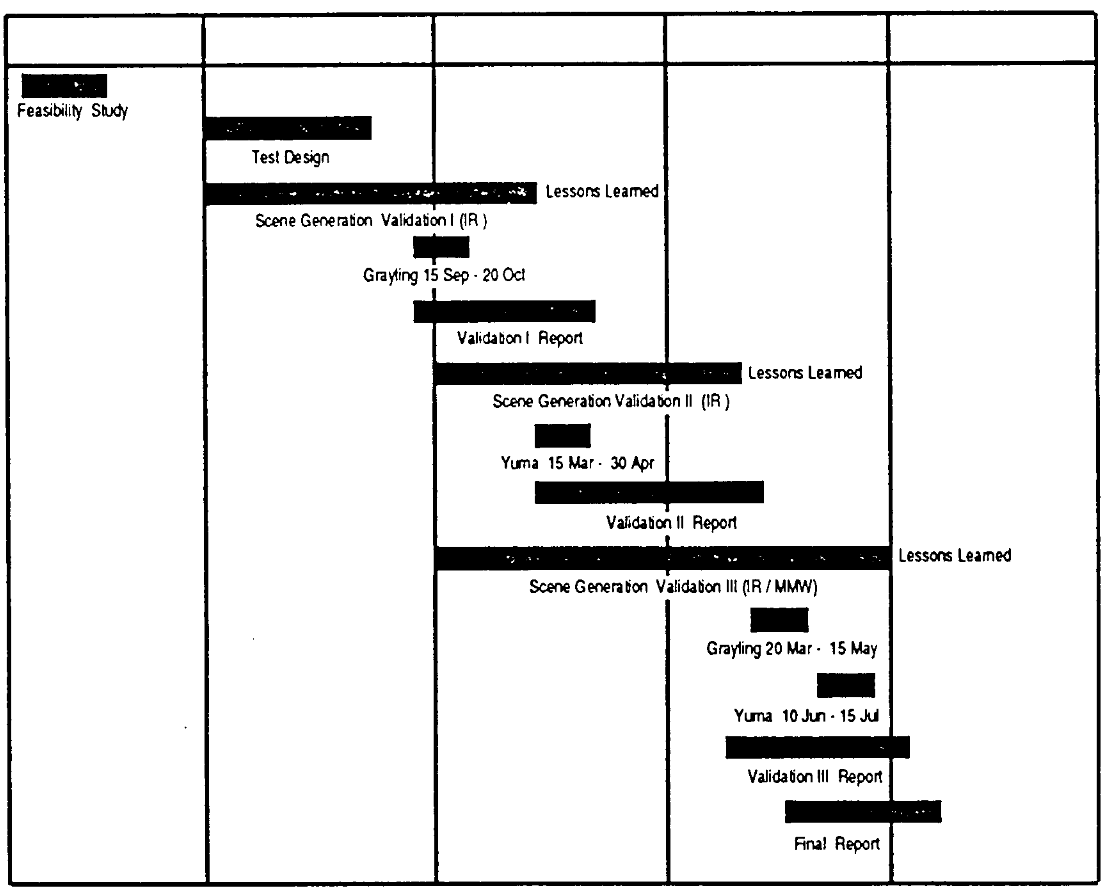
* including representative target set

needed to generate scenes is not equal for the IR and MMW spectral bands. IR model development is significantly ahead of MMW model and rendering developments. It is anticipated that MMW capabilities will have matured sufficiently by FY94 for adequate MMW scene generation. Third, no more than two field data collection activities per year can be supported. Fourth, a thorough validation on a couple of locations with transition and crossover type events is more important than several spot validations on a larger number of different locations. Other assumptions are implicit in the approach but these few are critical to the overall test design.

2.5 SCHEDULE

Figure 2 shows the planned SWOE JT&E schedule. The schedule emphasizes IR capabilities at the beginning of the program and then expands to include MMW and finally considers combined spectral capabilities. It includes four field test activities

FIGURE 2 SWOE JT&E PLANNED SCHEDULE



(Priority 1) in the Design Matrix. The schedule for field activities is sensitive to goals to obtain representative samples for validation of the SWOE Process for seasonal and regional ranges of variation including the crossover and transition events. These goals are important for both the validation and selective field data collection activities. The schedule also leverages the Air Force and Army Chicken Little Project Office target set and set up costs associated with current captive flight test projects.

2.6 BUDGET

A summary of the estimated costs is shown in Table 10. No new billets or additional service funds are required to implement this Joint test. The level of service funds currently programmed indicates commitment in support of the objectives of this program. The service funds are not dependent on the JT&E funding for the joint test.

Table 10 SUMMARY COST ESTIMATE OF SWOE JT&E

CATEGORY	FY 92 $K	FY 93 $K	FY 94 $K	TOTAL $K
Process Validation Total	3,250	5,950	5,950	15,250
Service Funds Programmed (O&M Funds not required)	5,850	7,100	5,750	18,700
TOTAL Program Cost	9,200	13,050	11,700	33,950
JT&E Funds Required	3,350	5,950	5,950	15,250

2.7 DATA MANAGEMENT

The SWOE Joint Test Program will involve the collection of various types of data to support the validation of the SWOE Process. Rigorous data reduction and calibration procedures will be utilized to ensure that the validation effort is not influenced by measurement sensor errors. The data will be collected for two major captive flight tests at each of two different locations. This will result in a very large data set being made available to the DoD community.

This data management section describes the types and quantities of data to be collected and generated. The archival and dissemination techniques are discussed in the Data Disposition section, 3.1.

2.7.1 DATA TYPE

The SWOE program will collect a significant quantity of radiometric infrared (IR) and active MMW radar data. Data will be collected from airborne platforms on high density digital tapes (HDDT) and will consist of instrumentation data, inertial stabilization measurement data, and other platform related data. The reduced data will ultimately reside on a common media. Ground data will be collected

2.7.2 DATA QUANTITY

The quantity of data to be collected for a given mission will vary depending on the type of sensors available on the platform and for the ground measurements. For radar systems the quantity will depend on the operating modes of the available system. Some of the missions will be flown with the radar operating in a strip-map mode, while other missions will be flown in a spotlight mode to support two-dimensional radar imaging. In either case, the radar will collect dual transmit / dual receive polarization data. In other words, four polarization combinations of data will be collected, ensuring that the full polarization scattering matrix (Mueller Matrix) will be collected. In the IR spectrum, dual-color IR data will be collected at a 25 Hz field rate, regardless of the mode of radar operation. Typical missions will last approximately one hour resulting in approximately two gigabytes of information per mission. In reduced form, this data set will be approximately 0.5 gigabytes of co-registered / co-boresighted data. For each data collection effort (4 total), there are 40 hours of data collection planned, resulting in a total of approximately 320 gigabytes of raw data, and approximately 80 gigabytes of reduced data for analysis and dissemination.

3.0 DATA DISPOSITION

All data collected and produced from the SWOE Process, for JT&E, will be assembled and archived to permit recovery for and availability to the broadest possible range of users.

3.1 DISTRIBUTION CONTROL

All of the collected scene type data will be stored as imagery, allowing the co-registered IR/MMW/ground truth data to be disseminated as a single series of scene imagery files. Database users can either search through the on-line labels themselves, or request the TABILS staff to provide them with SWOE data that meet certain criteria according to their specific requirements. Once the particular data are identified, they can be retrieved from the archives by invoking the unique identifiers. Actual imagery data will be provided on 4mm or 8mm cartridges in a neutral format, i.e. not machine or model dependent.

SWOE will provide data to any organization specified by OSD in addition to its being available to the extensive TABILS and TRISIG present users' lists. Tracking charts will be maintained identifying recipients of the SWOE data. These charts include the date the data is mailed, the program being supported, and the requirement for the data. Items such as photos, mission logs and reports will be maintained by TABILS and made available to data base users as needed. Orlando Technology Inc. (OTI), a data management office, will store these items for SWOE. OTI uses a digitizing scanning device to archive photos and text on high-density 5.25 inch optical disk platters. This Optical Archival, Retrieval and Review System (OARRS) has the capability to store classified or unclassified text and photos. Each item has a unique identifier for easy storage and retrieval. These documents and photos, etc. can be requested through TABILS.

3.2 ARCHIVES

Airborne platform data will be collected on HDDTs and reduced to computer-compatible media during a rigorous data reduction process. Data reduction involves review of the video tapes to determine times at which the sensors are over-flying the desired background area. These times will be used to down-load the raw data to high-speed magnetic disks to apply the calibration and data registration procedures. Once the reduced and calibrated data are present on the magnetic disks, the data will be transferred to 8mm helical scan tapes for dissemination as registered imagery data. All data will be labeled with the site code, mission number, pass number and scene number, resulting in a unique identifier for each mission image. The data will be archived in the Target and Background Information Library System (TABILS) database which is maintained by the Chicken Little Program Office and contains the most comprehensive set of target and background signature data available in the DoD community. Although some software development and modifications will have to be done to accommodate the dual-mode nature of the data and the additional weather parameters required as inputs to the models, the procedures for adding data to TABILS are well established. These include software processes to merge the field data with the meteorological parameters and with the formatted parameter labels which are created by the TABILS from the mission logs, video tapes and other field related information. When all items are merged, they will be archived together on the optical disk storage system. The established procedure for handling TABILS data includes storage in an environmentally controlled space for processing, duplication of both classified and unclassified data. In addition, the extensive weather and other parameter labels that describe the data will be loaded into the remotely-accessible on-line system, and made available for interactive queries and searches by OSD approved TABILS users from their own terminals. The extensive weather data collected by the METVAN and other sources will also be archived separately on an optical disk dedicated to weather files.

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This Program Test Design document contains a description of the background, objectives, approach, experimental design, schedule, budget, data management, analysis and data disposition for the Smart Weapons Operability Enhancement (SWOE) Joint Test and Evaluation Program. The goal of this program is to validate the SWOE integrated scene generation process, the SWOE process.

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