4.0 V&V STATUS AND USAGE HISTORY

This portion of ASP-I summarizes applications *RADGUNS* has been used to support, and the extent to which those applications have been supported by documented verification and validation. Information on prior accreditations of the model is also provided in the paragraphs below.

In 1992, ENTEK, Inc. was tasked to research and review prior VV&A activities on *RADGUNS*. The current version at that time was v.1.7. This section summarizes those findings with a few additions applicable to later model versions. In May of 1996, a questionnaire was sent to the *RADGUNS* user community seeking information about the use and V&V of *RADGUNS*. This section will be updated as those responses are received.

Although some model V&V has been performed in the past, almost no documentation of such efforts is available to the user community. The few formal documents that do exist have lengthy release approval processes, and have not yet been received for review. Verification and validation efforts have, in general, been limited to testing of software modules and correcting problems reported by users. Most of the work previously documented for *RADGUNS* does not conform to the MORS definition of either verification or validation. Although officials of government agencies have determined that *RADGUNS* was acceptable for specific studies, no formal accreditation of *RADGUNS* has been made.

4.1 V&V STATUS

Table 4-1 lists all V&V documents and related efforts known to date.

TABLE 4-1. Summary of *RADGUNS* V&V Documents.

Date	Type of V&V	Report Title	Organization
2/15/83	Face Validation	*RADGUNS* Jammer Test Analysis Report	Corvus Research, Inc.
2/15/83 (rev. 10/88)	Face Validation	*RADGUNS* Optical Tracker Model Test Analysis Report	Corvus Research, Inc.
10/89	Face Validation	Results of Work Toward Armitage Ellipsoid Model of Target	Corvus Research, Inc.
10/90	V&V Planning	*RADGUNS* Verification and Validation Test Plan	Corvus Research, Inc. and FSTC
3/90	V&V Support	*RADGUNS* Verification and Validation Program Maintenance Manual	Corvus Research, Inc. and FSTC
11/95	Logical Verification	Phase II Accreditation Support Package for *RADGUNS*, Section 2.0 Conceptual Model Specification	ENTEK, Inc. for SMART
5/96	Desk checking and software testing	Phase III Accreditation Support Package for *RADGUNS*, Section 2.0 Verification Results	ENTEK, Inc. for SMART

TABLE 4-1. Summary of *RADGUNS* V&V Documents. (Contd.)

Date	Type of V&V	Report Title	Organization
11/95	Inputs for Face Validation	Phase II Accreditation Support Package for *RADGUNS*, Section 3.0 Sensitivity Analysis	ASI for SMART
5/96	Comparison with Test Data & Measurements	Phase III Accreditation Support Package for *RADGUNS*, Section 3.0 Validation Results - Function Level, and Section 4.0 Validation Results - Model Level	ASI for SMART

Most of the verification done during the development and implementation of *RADGUNS* has not been documented. Source documents such as schematics, drawings, photographs, and test reports (usually produced by the intelligence community) were examined to determine how circuits and subsystems could be simulated by software. Initially, such investigations resulted in the development of functional block diagrams by Dr. Robert Ramey of the University of Virginia under contract to NGIC (then FSTC). Portions of these have been incorporated into the Top-Level Design documentation found in Section 2.0 of ASP-II. They represent the most important verification sources identified to date, as they were the ones used to design and develop the initial software modules used to build *RADGUNS*.

The SMART Project has performed logical and detailed verification on nine functional elements. Except for this, little formal documentation of verification efforts exists outside the FORTRAN code itself. Developers cite specific reference documents in some routines where formulas, data constants, or functions are derived, but confirmation of the correctness of these derivations by an independent, outside source has not been documented (except those functions verified by SMART).

The *RADGUNS* V&V Test Plan identifies source documents and copies of pertinent pages or excerpts from them that will support verification by a third party. The verification activities described in the document, however, do not conform to the strict MORS definition. Verification testing is described as follows:

The test will consist of a series of executions of the model using different test parameter files in order to verify the performance of as many combinations of functions as possible. Since there is a virtually infinite number of combinations of parameters, the testing will in no way be exhaustive. Test scenarios will be selected so that the limits of the system will be tested as completely as possible.

The intent of this testing is to exercise the model through a range of reasonable input scenarios to determine whether reasonable output values are produced. This process represents an old view of the verification process in which the question as to whether the model produced reasonable results was satisfied. This process was often confused with validation when comparisons to non-existent performance data were impossible for each case. This confusion among definitions is also apparent in the Maintenance Manual which defines verification as follows:

Verification—Testing and inspection to show that the simulation matches published specifications for the system being simulated.

While this definition more closely approaches the MORS one, it is broader in its inclusion of testing. If the specifications for the system refer to transfer functions and data values that were used in the design of the simulation, it is correct. If the reference is extended to performance of the system under given conditions, then such testing and inspection become validation activities.

It is clear that the intent of these two documents was to provide a means for addressing requirements for the verification and maintenance of software under development. As new segments of code for enhancements or subsystems were added, testing was necessary to ensure that new versions of the model ran in a similar fashion to the previous version for a range of cases, so that newly introduced bugs could be tracked down and fixed. Furthermore, the need for inspection of software was recognized as a means to insure that system specifications were properly implemented.

As with verification, validation work on *RADGUNS* has been conducted according to different definitions, but has achieved effective, although limited, results. The two documents published by Corvus Research, Inc. and FSTC also attempted to deal with the need for validation. Although the title of the Test Plan includes the term validation, no specific reference is made in the plan to the validation process. Rather it seems that validation could be assumed if verification were accomplished, which could be true, but is usually so only for a limited number of test cases. Again the synonymous use of both terms without distinction between them led to an accomplishment of neither under the newer, more strict definitions.

The Verification and Validation Program Maintenance Manual defines validation as follows:

> Validation—Testing and inspection to show that the simulation matches real-world performance.

This corresponds closely to the MORS definition but was beyond the scope of what was actually required by the Maintenance Manual. In addition, the system application description included does not identify any validation tests that could be performed on *RADGUNS* models to show the degree to which they were accurate representations of real world systems. There were probably several reasons for this, among them the lack of test data on systems such as those being simulated and the associated uncertainty regarding their actual performance in the real world. It was also probably realized that complete validation of simulations such as those in *RADGUNS* would require much more time and effort than was originally intended for maintenance of the program and production of the documentation.

Development of *RADGUNS* models has usually (whenever possible) been accompanied by validation efforts on the part of NGIC and ASI whenever possible. Tracking and shooting performance of the ZSU-23-4 simulation was derived from data produced by the GRAPH ANGLE and AQUILA testing efforts. These data and reports are maintained at NGIC and are not available for release to outside agencies. Results of comparisons between *RADGUNS* and these two test programs have not been formally documented. Test data on most of the other systems simulated are not readily available and as a result, they are modeled as modified replicas of the ZSU-23-4 simulation. It is hoped that similarity of functional implementations in software will improve the cost-effectiveness of V&V efforts through application of results for 23mm systems to others employing similar functions.

The SMART Project has established access to a variety of T&E programs. Some of these have produced an abundance of data, others have failed to produce any data, and yet others have produced data that is not available for general distribution. One of the more important validation results applicable to v.1.9 was the evaluation of radar (angle and range) tracking performance via comparisons with test data using three different aircraft that is documented in Section 4 of ASP-III. Further work on the radar antenna, receiver, and signal processing functions will be made available in updates to the ASP planned by the SMART Project.

After investigations conducted to produce this report, as well as repeated queries over several years, no information suggesting that any of the *RADGUNS* models had been officially accredited by an agency or for use in a program has been found. Even though its usage was verified by a number of analysts involved with development programs or test and evaluation activities, no documentation of its accreditation was identified by those users.

One case of an accreditation failure for *RADGUNS* v.1.7 was briefed by LCDR Hattery to the SMART Senior Steering Group in February of 1994, but documentation associated with this instance has not been published. It was clear from the briefing that the approach taken by the accreditation agent, which was the U.S. Army Materiel Systems Analysis Activity (AMSAA), in the form of Mr. Wyoming “Duke” Paris and Mr. Peter Reich, was an expert review of the model in light of requirements to address specific problems associated with cost and operational effectiveness analyses (COEAs) for the Commanche helicopter program. The simulation was found to be inadequate for required purposes in three areas:

a. Failure to address the AMSAA-developed “Salvo Formula”,

b. Failure to address Doppler returns from the blades of a hovering helicopter, and

c. An assessment of tracking performance that was described as “overly optimistic”.

Even though the Salvo Formula was added as a user-selectable probability of hit and kill methodology in v.1.8 and rotor Doppler returns were added in v.2.0, the results of tracking V&V efforts suggest that agreement with intelligence information will further improve tracking performance. It is therefore unlikely that either the current or future versions of *RADGUNS* will be deemed suitable for use in analyses to support the Commanche Program.

As of this writing, other government agencies are examining the *RADGUNS* model and seek to make supportable accreditation decisions based upon recent V&V or analysis efforts. Users with information on assessments of the model are encouraged to provide a summary to the SMART Project, NGIC, or ASI for inclusion in this document.

4.2 USAGE HISTORY

RADGUNS has been used in a variety of analytical and assessment efforts and it is likely that results of some of those studies were applied to decisions regarding procurement of, or enhancements to, weapon systems and/or platforms. In the community involved with decisions and trade-offs that affect aircraft survivability and weapon lethality, *RADGUNS* is often used to assess platform, mission, and scenario situations in order to provide probability inputs to campaign or theater level simulations. The results of these also impact decisions as to numbers and types of weapons and platforms that would be necessary to accomplish possible future objectives.

The addition of ECM technique simulation has served to broaden the scope of application into evaluations of jamming system effectiveness and briefings at the JTCG/AS Methodology Subgroup meeting in February of 1994 supported this notion. Personnel from the U. S. Strategic Command (USSTRATCOM) and the 513th Engineering Test Squadron (ETS) reported successful application of ECM techniques in the model to scenarios derived for flight testing of USAF bombers.

At the same meeting, Mr. Mike Bennett from SURVIAC reported results of a broad sensitivity analysis that had been conducted to examine parametric effects over ranges of model applicability as well as to provide expected results for a spectrum of common uses. One of the more significant findings was differences in kill probabilities that could be attributed to using single, distributed vulnerable areas instead of discrete component vulnerable areas that are displaced from the target centroid. This effect is pronounced for large targets that may be easier to hit, but harder to kill due to locations of critical components like engines and pilots. The final report of his results is available through SURVIAC and its contents are summarized in Table 4-2.

One of the most frequent users of the model is NGIC, where a host of analysts attempt to assess and evaluate specific scenarios and objectives for operational force commanders and mission planners. Unfortunately, little documentation of these efforts can be made available to the user community, but the frequency of usage supports their belief in the adequacy of the model to accurately simulate the threat systems of interest. A few former uses that can be discussed and described for interested users are listed in Table 4-3.

TABLE 4-2. SURVIAC Parametric Analysis Summary.

(Report Section) PARAMETER	RANGE	Results Shown To: Det Rng	TrA In	End Fld	P_k	P_h	P_k Impact - Gun Number: 1	2	3	4	P_h Impact - Gun Number: 1	2	3	4	Comments
(Section 3) Aircraft Altitude	50-2500m-Gun 1 50-4000m-Gun 2 50-5500m-Gun 3 50-12500m-Gun 4	X	X	X	X	X	S	Mod	L	L	MS	MS	L	L	Gun 1 - P_k impact L for 1 offset only, P_h for 2 offsets Gun 2 - P_k impact L for 3 offsets, P_h the same
(Section 4) Aircraft Size (Presented Area)	25-1000% of baseline for 2 offsets	NA	NA	NA	X		MS	MS	MS	MS					Gun 1 - Average P_k sensitive 25-500% baseline presented area Gun 2 - Average P_k sensitive 25-500% baseline presented area Gun 3 - Average P_k sensitive 25-500% baseline presented area Gun 4 - Average P_k sensitive 25-500% baseline presented area
(Section 5) Aircraft RCS Size	0.0001-100m^2 "Fuzzball"	X	X	X	X	X	MS	MS	L	MS	Mod	MS	Mod	MS	Gun 1 - P_k sensitive for RCS less than 0.01m^2 Gun 2 - P_k and P_h sensitive for RCS between 0.0001-1.0m^2 Gun 4 - P_k and P_h sensitive for RCS less than 0.1m^2
(Section 6) Aircraft Velocity	50-500m/sec	X	X	X	X	X	S	S	Mod-L	L	MS	Mod	L	L	P_k and P_h sensitivities tend to increase with offset from gun
(Section 7) Aircraft Width/Height Ratio	Ratios from 1 to 5				X	X	S	NA	NA	S	S	NA	NA	S	Results not sensitive over range of aspects for typical aircraft
(Section 8) Clutter/Multipath	Sand and farmland cover Combinations 50-250m altitude	X		X	X	X	S	S	S	MS	S	S	S	MS	Detection range impacted, but P_k and P_h only impacted at 50-100m altitudes. These results for tactical aircraft size with 10m^2 RCS
(Section 9) Flight Path Climb-Dive Types	Dive Angle 15-30 degrees			X	X	X	L	Mod	S	MS	L	Mod	S	MS	Gun 2 - Small P_k and P_h impact for offset - large for others Gun 4 - P_k and P_h large effect for offset - almost none for others
(Section 10) Flight Path-Nap of the Earth	Baseline offset and altitudes			X	X	X	NA	S	NA	S	NA	S	NA	S	Only Guns 2 & 4 evaluated. Small differences (5% or less when compared with baseline
(Section 11) Flight Path-Sinusoidal Jinks	1-50%			X	X	X	L	MS	L	L	L	MS	L	L	Gun 2 - Large P_k and P_h impacts for "close in". Little for more further out from gun Gun 4 - P_k and P_h approach 0 for ≥ 20%
		SENSITIVITIES S – Slight/None over most of range Mod – Some over most of range L – Large over most of range X – Data presented					MS – Mixed over most of range Blank – Data not presented NA – Data not evaluated								UNITS m – meter m/s – meters/second

TABLE 4-2. SURVIAC Parametric Analysis Summary. (Contd.)

		Results Shown For					P_k Impact - Gun Number				P_h Impact - Gun Number				Comments
(Report Section) PARAMETER	RANGE	Det Rng	Trk Err	End Pnt	P_k	P_h	1	2	3	4	1	2	3	4	
(Section 12) Gun Burst/Rest Length	3 combinations: Short/Short (-); Long/Long (+); Continuous Fire	NA	NA	X	X	X	M-S	M-S	L	NA	M-S	M-S	L	NA	Gun 1 - P_k impact L, 1 offset only P_h S effects Gun 2 - P_k impact L, 2 offsets only, P_h same Gun 3 - P_k impact L, 3 offsets, P_h all offsets Gun 4 - No runs
(Section 13) Relative Gun Capability	All 22 RADGUNS 1.0 gun systems	NA	NA	NA	X	NA	Comparison All gun systems				NA	NA	NA	NA	All gun systems P_k compared versus same target. Vulnerability data not available for all calibers, so P_h not compared. P_k averaged over offset and compared for all guns in Figures 12.31-12.34
(Section 14) Flight Path Masking	0-15 degrees			X	X	X	X	X	X	X	X	X	X	X	Parametric on mask angle. Procedure presented for evaluating masking in RADGUNS 1.0
(Section 15) Flight Path Offset	Gun 1 - 0-3000m Gun 2 - 0-4500m Gun 3 - 0-6750m Gun 4 - 0-12750m	X	X	X	X	X	S	MS	L	L	L	L	L	L	
(Section 16) Gun Firing Rate	±50% of nominal values	NA	NA	X	X	X	MS	S	M-S	L	MS	S	M-S	L	Gun 1 - P_h sensitive only for 2400m, P_k for 1200 & 2400m offsets Gun 3 - P_k & P_h gradually increase with firing rate, except at 6450m offset where they show gradual decrease. Gun 4 - Largest sensitivities with lower firing rates
(Section 17) Target Track Radar/Optical Mode	4 guns with approximate radar & optical track modes		X	X	X	X	MS	MS	M-S	M-S	MS	MS	M-S	M-S	Gun 1 - P_k & P_h sensitive for non-zero offsets Gun 2 - P_k & P_h sensitive for non-zero offsets Gun 3 - Some P_k & P_h sensitivity for all offsets Gun 4 - P_k & P_h sensitive for all but zero offset
(Section 18) RADGUNS & AMSAA Ratio P_k & P_h	4 baseline gun systems at altitude/offset combinations				X	X	L	MS	L	L	L	MS	L	L	Differences and magnitudes depend on gun type and flight path offset
(Section 19) Flight Path - Circular Helix	Velocity 500KT Bank angle 30-70 degrees	X	X	X	X	X	M-S	S	S	L	M-S	S	S	L	Gun 2 - only impact at 500KTS Gun 3 - only impact at 500KTS in 70 degrees bank angle
		SENSITIVITIES S – Slight/None over most of range M-S – Some over most of range L – Large over most of range X – Data presented					MS – Mixed over most of range Blank – Data not presented NA – Data not evaluated								UNITS m – meters m/s – meters/second

TABLE 4-2. SURVIAC Parametric Analysis Summary. (Contd.)

(Report Section) PARAMETER	RANGE	Results Shown To					P_h Impact - Gun Number				P_k Impact - Gun Number				Comments
		Det Rng	Trk Err	End Trk	P_h	P_k	1	2	3	4	1	2	3	4	
(Section 20) Flight Path - Disturbance	Actual TC flight path at "standard" offsets	X		X	X	X	S	S	M	L	MS	S	M	L	Gun 1 - P_h & P_k impact only for 2400m offset flight path Gun 2 - P_h & P_k impact only for 2400m offset flight path Gun 3 - P_h & P_k impact for offsets greater than 2150m
(Section 21) Aircraft - Multiply Redundant Components Inclusion	Hardened & unhardened 2 pilot, 2 engine aircraft	NE	NE	NE	NE	X	NE	NE	NE	NE	MS	MS	S	S	Little impact only for any gun & unhardened aircraft Little impact for Guns 1 & 2 & unhardened aircraft Little impact for Guns 3 & 4 & unhardened aircraft
(Section 22) Aircraft - Inclusion of Impact Velocity Dependent Vulnerable Area	0-3500 ft in 500 ft increments 12.7 mm & 14.5 mm threats	NE	NE	NE	NE	X		NOT RUN				NOT RUN			Large impact on P_k at striking velocity variations 12.7 mm threat.
(Section 23) Aircraft - RCS Shapes	"Fanman," "Bowtie," & "Spider" shapes 1 thru 0.0001 m2	X	X	X	X	X	S	MS	MS	MS	S	MS	MS	MS	Generally, some limits in P_k ranges for 0.001 and 0.0001 m² RCS and target offsets
(Section 24) ECM Techniques	Various stand off & tuned techniques versus Gun 2		X Range Only	X	X	X	NE	MS	NE	NE	NE	MS	NE	NE	2 techniques involving broadband noise or passive reflectors produced large RMS range track error increases. They resulted in large P_h & P_k decreases. Rest produced small or no impact.
(Section 25) Aircraft - 6 vs 25 Aspect Vulnerability Data Input	14.5 mm API & Guns 1 & 4 HEI				X	X	S	NE	NE	S	NE	NE	NE	NE	P_h & P_k for 14.5 mm - some (10-12%) differences. P_k could only be evaluated for HE projectile threats. Very small impact.
		SENSITIVITIES S – Slight/None over most of range Med – Some over most of range L – Large over most of range X – Data presented					MS – Mixed over most of range Blank – Data not presented NE – Data not evaluated								UNITS m – meters m2 – meters squared

TABLE 4-2. SURVIAC Parametric Analysis Summary. (Contd.)

		Results Shown For					P_k Impact - Gun Number				P_h Impact - Gun Number				Comments
(Report Section) PARAMETER	RANGE	Det Rng	Trk Err	End Trd	P_k	P_h	1	2	3	4	1	2	3	4	
(Section 20) Actual Tactical Aircraft RCS - Fixed RCS Comparisons	Actual tactical Aircraft RCS & 10 m² Fixed RCS	X		X	X	X	S	S	S	NA	S	S	S	Med	Gun 1 - Individual case & overall data show appreciable P_k/P_h differences, but avg almost none Gun 2 - No discernible individual or average data show much P_k/P_h difference Gun 3 - No discernible individual or average data show much P_k/P_h differences Gun 4 - Individual & average P_h data show appreciable differences
(Section 27) Distributed vs Lumped Aircraft Vulnerability Inputs	Large & small, hardened & unhardened aircraft					X	NA	NA	NA	NA	MS	NA	MS	NA	Gun 1 - Precision lumped lower than P_h distributed over all aircraft for "large" hard aircraft. Less difference in "large" unhardened aircraft. Essentially no differences for "small" aircraft. Gun 3 - Some P_h differences for "large" aircraft. No P_h differences for "small" aircraft.
		SENSITIVITIES S – Slight/None over most of range Med – Some over most of range L – Large over most of range X – Data presented					MS – Mixed over most of range Blank – Data not presented NA – Data not evaluated								UNITS m – meters m² – meters squared

TABLE 4-3. *RADGUNS* Usage Summary.

Date	Application	Comments on Adequacy	Accredited (Y/N)	Doc # (If Yes)	Organization: POC: Phone/FAX
10/92	UAV Survivability	Adequate for slow-moving, small target Ph/Pk contour maps	No		ASI Systems Barry O'Neal (619) 375-1442
10/92	STAMIDS Survivability	Adequate for slow-moving, small target Ph/Pk contour maps	No		ASI Systems Barry O'Neal (619) 375-1442
08/94	MLR COEA	Created special takeoff and landing flight paths for helicopter targets	No		NAWCWPNS Lee Kappelman (619) 375-1442
10/94	Sensitivity Analysis	Recommended changes to Pk method for multiple vulnerable area targets	No		SURVIAC Mike Bennett (513) 429-9509
8/96	JSF JIRD II	Suitable for inputs to mission analysis	Yes	Draft	NAWCWPNS Michelle Kilikauskas (619) 927-1260

The UAV Survivability study was performed for the U.S. Army Short Range Unmanned Aerial Vehicle (SRUAV) program to provide inputs to their source selection between two competing designs. *RADGUNS* was used to produce Pk contours for both vehicles and several threats. Due to the slow speed of both vehicles, none of the models exhibited any difficulty with tracking them, so the differences between them tended to be reflections of their vulnerable areas, which were derived from studies performed at SURVIAC.

The STAMIDS study was performed for the Standoff Minefield Detection System Program at about the same time as the UAV study. It also examined engagements with several *RADGUNS* threats, but special search pattern flight paths were developed using BlueMax and used as inputs. As with the UAVs, the STAMIDS vehicle was readily tracked by most threat models and graphs were constructed to show how much of the search pattern could be completed before killing the vehicle. It was concluded that some type of countermeasure would be required to make the system effective in a threat environment, mostly due to its low speed operational regime.

The Medium Lift Replacement (MLR) COEA examined several designs as potential replacements for existing helicopters and was particularly focused on the take-off and landing phases that would be executed in a combat rescue and/or replenishment environment. Because BlueMax was not well suited to produce flight path data for helicopters and no aerodynamic data for the proposed candidates existed, a series of equations were implemented to allow user description of a take-off and/or landing sequence in which the helicopter also rotated about is vertical axis while ascending or descending. These maneuvers served to present different vulnerable areas to the threats at different times, which resulted in a considerable range of target vulnerability.

The sensitivity analysis performed by Mike Bennett at SURVIAC focused on model level outcomes as a function of normal ranges of user input parameters. The model behaved as expected in most cases, but the single, distributed vulnerable area (see Section 27) was deemed inappropriate for large targets (bombers) where vulnerability is often widely dispersed with respect to the aircraft center of gravity. The J534 branch of the U.S. Strategic Command (USSTRATCOM) provided resources to expand the target models for the B-1B and B-52 aircraft so that multiple vulnerable components could be addressed. Changes to allow specification of multiple components and their redundancy were completed in the summer of 1996 and will be distributed with the 2.1 version of *RADGUNS*.

The accreditation of *RADGUNS* for use in the Phase II Joint Interim Requirements Definition (JIRD) for the Joint Strike Fighter (JSF) Program marks the first of its kind in support of acquisition program analysis and also addressed the ESAMS, Suppressor, and Brawler models. Requirements and MOEs for the analysis were developed by a design of experiments (DOE) team and were used to evaluate M&S capabilities to address them by an independent accreditation support team. Members of the SMART Project Office provided interfaces between the two teams and the JSF sponsor. The only area of model performance that did not receive a satisfactory assessment was the target acquisition radar, for which no validation data has been identified and which is also the area of most model deficiencies in the simulation of propagation effects (i.e., clutter and multipath). Most of these deficiencies are targeted for correction via the inclusion of a common environment model that is being developed by the authors of the ALARM code. This accreditation report is expected to be augmented by a similar one for the Phase III JIRD analysis.

4.3 IMPLICATIONS FOR MODEL USE

As with other simulations of this type, validation efforts based on comparisons with test data cannot address the performance of the model or system throughout the full range of capability. Each test tends to provide a data point against which model outputs for the specific set of input conditions can be compared. The SMART validation process has been applied to specific FEs and model CAIs using data that has been made available by various test programs and results of these comparisons have been documented in ASP-III for *RADGUNS* along with verification results on a similar number of FEs. This ASP documentation, produced by the SMART Project, represents the first formal record of V&V results for the model and should provide information to users seeking accreditation.

Recent validation efforts have shown good correlation between modeled and measured data in the thermal noise, antenna gain, angle track, range track, gun movement, and ballistics FEs for one threat system. Given certain assumptions about the data used, assessments of model CAIs including tracking and shooting performance have also shown good correlation. Nevertheless, these assessments will not placate users who believe that the model already tracks better than the actual systems simulated, so use of the model by some will remain dependent upon the desired result. SMART has obtained some optical tracking data and an assessment of this operator dependent function is planned for Version 2.0. Tests involving shooting at moving targets are not likely to be addressed unless funded from other sources. This is somewhat disturbing given the fact that probability of kill is the measure of performance most often sought by users of the model.

The User Manual states that *RADGUNS* models are used to evaluate effectiveness of AAA systems against aerial targets and, conversely, to evaluate the effectiveness of airborne target characteristics (RCS, maneuvers, ECM, etc.) against specific AAA systems. In the determination of AAA system effectiveness, the ability to detect, acquire, track, and shoot down aerial targets are measures typically analyzed by users. From the aircraft survivability perspective, these same measures are viewed from the other side in an effort to determine the degree to which signatures, tactics, and countermeasures can reduce target susceptibility to the threat. V&V efforts thus far suggest that performance of AAA systems in general, and one in particular, is well represented by the submodels that simulate target tracking and shooting. Problems with target acquisition have been related to a lack of prior V&V and difficulties associated with V&V of phenomena that are based upon clutter and multipath effects. Unfortunately, this deficiency impacts assessment of RCS effectiveness in the target detection and acquisition process, but reasonable results can still be achieved using the threshold detection algorithm if reasonable values for a threat are known and can be input by the user. Similarly, radar tracking and operator performance can be degraded via user input to improve target survivability. In its default configuration, however, the *RADGUNS* models represent something close to optimum levels of AAA system performance simply because all potential sources of noise or disruption of the engagement process are not simulated and all performance parameters as to the systems of interest are not known. From the survivability perspective, it is safe to say that the models do not underestimate threat system capability, which is desirable when planning for the worst case scenario and attempting to evaluate and design robust countermeasures. Finally, the issue of killing targets is highly dependent upon the validity of the vulnerable area data available, which is why the probability of hitting the target or expected number of hits per engagement is the preferred measure of model performance. Appropriate vulnerability data for many of the threats and targets available in *RADGUNS* does not exist and some liberties with interpolation and/or extrapolation have been taken over the years. Users seeking Pk values should be careful when basing conclusions on target data that has not been authenticated or certified as derived from a valid source.

The user list provided in Appendix E should provide a potential user with contacts that can be consulted with questions regarding specific applications. The fact that the model has been in use by numerous Army, Air Force, and Navy agencies over the past ten years should also provide some indication of acceptance by the community. Contributions of any documentation related to usage or V&V efforts would be appreciated by ASI, NGIC, and the SMART Project Office.