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**"QUICKLOOK" POWER ASSESSMENTS
FOR
ARMY SYSTEMS**

TECHNICAL REPORT

18 May 1992

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The views and/or findings contained in this report are those of the authors and
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decision unless so designated by other documentation.

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<p>The study's purpose was to conduct quick electrical and environmental control assessments of Army systems to support Project Managers. Five assessments were undertaken along with changes in the System Assessment Model which automates the assessment's computations. An assessment was conducted on the Deployed Medical System operating in a contaminated environment - it had insufficient air conditioning capacity and poor setup. The next generation Ground Base Radar assessment revealed a large requirement for electric power (>500kW) and chilled water to cool the semiconductor amplifiers. The Individual Power program was assessed and placed on a critical path schedule with resource requirements. The Electronic Fighting Vehicle System was assessed for environmental control; the Army's and the integrator's estimate of electric power dissipated varied considerably; a graph of power dissipated versus air conditioning required was provided, plus some recommended improvements. Finally, the electric power requirements and distribution for Force Provider (an in-theater, tent/container rest and relaxation facility) proceeded to collect data necessary for the assessment but lacked a facility layout.</p>			
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requirements for up to eight Army systems. The need for the rapid response and "Quicklook" power assessments is to provide responsive action to the requests of Program Managers and users. The ultimate objective of the power assessment program is to optimize the number or capacities of Mobile Electric Power units and environmental control units in the Army while enhancing mission performance.

BASIC APPROACH

The effort was conducted in three tasks. Task I called for data gathering and Task II required analysis and reporting. Tasks I and II were conducted for all assessments. The Individual Power report was a large critical path network. Data was gathered for Force Provider but a layout was not provided so the power network could not be established. Task III was study documentation in a Technical Report and this Study Gist.

REASON FOR PERFORMING STUDY

The study was conducted to assess and validate electric power requirements for Army systems.

IMPACT OF STUDY

Each assessment which was conducted resulted in the validation of an existing condition or assessment, or provided recommendations for change in a systems capacity or design.

SPONSOR

US Army Belvoir Research, Development and Engineering Center (BELVOIR)

PRINCIPAL INVESTIGATOR

Mr. John M. Daugherty, Science Applications International Corporation (SAIC), with subcontract support from Mr. George H. Hayes, VSE Corporation.

ADDRESS WHERE COMMENTS AND QUESTIONS CAN BE SENT

Commander, US Army Belvoir Research, Development and Engineering Center,
ATTN: STRBE-FEA (Mr. Gregg Brainard), Ft. Belvoir, VA 22060-5606

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**"QUICKLOOK" POWER ASSESSMENTS
FOR
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TABLE OF CONTENTS

<u>PARAGRAPH</u>	<u>TITLE</u>	<u>PAGE</u>
1.0	INTRODUCTION.	1
1.1	PURPOSE OF STUDY	1
1.2	BACKGROUND	1
1.2.1	GENERAL	1
1.2.2	PROGRAM MANAGEMENT RESPONSIBILITIES	2
1.2.3	PROGRAM STATUS	2
1.3	SUMMARY	2
2.0	STUDY APPROACH.	3
2.1	WORK ACCOMPLISHED FOR TASKS I AND II	3
2.1.1	DEPMEDS OPERATING IN A CONTAMINATED ENVIRONMENT	3
2.1.2	GROUND BASED RADAR	3
2.1.3	IMPROVEMENTS TO THE SHELTER SYSTEM ASSESSMENT MODEL	4
2.1.4	INDIVIDUAL POWER	4
2.1.5	ELECTRONIC VEHICLE FIGHTING SYSTEM (EFVS)	5
2.1.6	FORCE PROVIDER	5
2.2	DOCUMENTATION - TASK III	6
3.0	CONCLUSIONS	6
3.1	DEPMEDS OPERATING IN A CONTAMINATED ENVIRONMENT	6
3.2	GROUND BASED RADAR	6
3.3	SAM MODEL IMPROVEMENT	6
3.4	INDIVIDUAL POWER	7
3.5	ELECTRONIC VEHICLE FIGHTING SYSTEM (EFVS)	7
3.6	FORCE PROVIDER	7
4.0	RECOMMENDATIONS	7
4.1	DEPMEDS OPERATING IN A CONTAMINATED ENVIRONMENT	7
4.2	GROUND BASED RADAR	7
4.3	SAM MODEL IMPROVEMENT	7
4.4	INDIVIDUAL POWER	8
4.5	ELECTRONIC VEHICLE FIGHTING SYSTEM (EFVS)	8
4.6	FORCE PROVIDER	8
 <u>APPENDIX</u>		
A.	STATEMENT OF WORK (SOW)	A-1
B.	TECHNICAL REPORT COVER SHEETS	B-1

"QUICKLOOK" POWER ASSESSMENTS FOR ARMY SYSTEMS

TECHNICAL REPORT

1.0 INTRODUCTION

In the 1980s, the Belvoir System Assessment Team found case after case where Mobile Electric Power (MEP) units had operating levels averaging 25 percent of their capacity. In striving to operate MEP units at a much greater load and efficiency, it was found the materiel developers had no consistent standards for estimating requirements for environmental control units (ECUs) and MEP units. In some cases, developers would sum the total electrical power requirements for all devices on the system. There was no consideration for equipment duty cycles or equipment which would not operate concurrently. At least one case was found where the air conditioning and electric resistance heaters had been added together to determine the electric power requirements. Another philosophy encountered in the development community was to specify the next larger size "just to make sure we had enough".

To attack the problem of "too much", the Belvoir Systems assessment team provided policy and tools which could be used to perform assessments, and a team which could rapidly respond to field requests for system assessments. The policy requiring system assessments is that set forth in Army Acquisition Executive Policy Memorandum 90-3. Procedures were established describing how to conduct a system assessment, and a computer model was developed as a tool to simplify and standardize the determination of ECU and electric power requirements. In addition to the policy and tools available to now support system assessments, an assessment team stands ready to go to the field on short notice (a few days) to gather data for an assessment. This technical report describes the activities of the contractor-supported assessments conducted under the task.

1.1 PURPOSE OF STUDY

The study was conducted to assess and validate electric power requirements for Army systems.

1.2 BACKGROUND

1.2.1 General. Since power assessments were institutionalized in AR 70-1 in 1988, there has been an increasing need to support requests from the field to conduct heating, air conditioning and electric power assessments. Power consumption of electrical equipment is determined, or

measured and the needs for heating, cooling and electric power are assessed and validated. Power consumption data on electrical components is used to update the power consumer portion of the Belvoir Generator Allocation Program (BGAP) database. Conducting these assessments has been valuable to the Army because they usually result in reducing the requirements for MEP units and ECUs. In some cases, as in this study, one system was well below the cooling capacity required to perform its mission, so a recommendation was made to significantly increase its ECU capacity.

1.2.2 Program Management Responsibilities. The Belvoir System Assessment Team (STRBE-FEA) is an element of the Environmental Control and Systems Support Division, Logistics Equipment Directorate of the Belvoir Research, Development and Engineering Directorate. The System Assessment Team is responsible for providing policy, guidance and assistance in the conduct of electric power and environmental control assessments for the Army. In carrying out this responsibility, policy and guidance are in place as stated earlier, the System Assessment Model is operational and constantly being improved, and a team is ready to respond to requests for assessments on short notice.

1.2.3 Program Status. The system assessment task is a continuing enterprise. During the period of this task (May 1991 to May 1992), five different systems were assessed. It is anticipated that assessments will continue for some time and may increase in intricacy as more complex systems evolve. Assessments conducted early in a developing program are particularly valuable because the team is able to identify all the players, providing a synergistic effect by bringing the players to a common understanding about how electric power and environmental needs are sized for systems. It also allows the team to interject state-of-the-art techniques such as "soft start" and variable speed compressors, along with delayed starts for fan motors in air conditioning units. These developments decrease electric power surges, prolong equipment life, and require smaller components.

1.3 SUMMARY

The study provided assessments for five different programs. In one case, DEPMEDS, the air conditioning capacity was well below that required for the mission. In the case of the Electronic Fighting Vehicle System, the integrating contractor estimated about twice the heat energy from operating equipment compared to the Army developer's estimate. Such disparities are highlighted to the developer for resolution.

2.0 STUDY APPROACH

The study was divided into three tasks. A copy of the approved Statement of Work (SOW) is provided in Appendix A (The completion date of the study was formally extended to 18 May 1992). It is organized by system assessed for Task I, Gather Assessment Data from the Field, and Task II, Evaluate Data and Prepare "Quicklook" Report. The system discussions are followed by Task III, Documentation. Appendix B contains the cover sheets of the technical reports which were prepared. The following paragraphs provide descriptions of the work accomplished for each task.

2.1 WORK ACCOMPLISHED FOR TASKS I AND II

2.1.1 DEPMEDS Operating in a Contaminated Environment. The subject system was undergoing Test and Evaluation at Fort Indiantown Gap during the summer of 1991. The configuration consisted of three TEMPER tents and three International Standards Organization (ISO) shelters interconnected with passageways. The nine C-100 air conditioning units used to cool the system were not of sufficient capacity since the interior temperature was 89°F while the outside temperature was 85°F. The Assessment Team consisting of Messrs. Howard, Daugherty, Hayes and Sullivan, and Ms. Voltz, with instrumentation to measure temperatures and air velocity, traveled to the site on 12-13 August 1991.

The central tent of the facility, a 48-foot TEMPER, was instrumented with thermocouples and a hot-wire anemometer was used to take air velocities. Data were taken during the hottest time of the day when there happened to be about a 20-percent cloud cover on both 12 and 13 August 1991. In bringing the system to steady state and collecting data on 12 August, several conditions were corrected with respect to the setup. Data was again gathered on 13 August after the corrections were made causing the interior temperature to drop under 70°F. Weather data was obtained from the US Air Force weather station at the Army airfield. The final data were then placed in the Shelter System Assessment Model with the results provided in a report.

The DEPMEDS system is the responsibility of Natick Research, Development and Engineering Center which reviewed the Technical Report. Changes were made to the report based upon Natick's comments. A primary result of the analysis using the computer model was that with a 120°F exterior temperature, the system needs much greater air conditioning capacity. The report also contained several recommendations for improving the setup to provide better efficiency for the cooling system.

2.1.2 Ground Based Radar. The Theater Missile Defense Ground Based Radar is in its conceptual stage and is a large, powerful, next generation radar which will use solid state devices. It will operate to protect the Corps area of operations. An assessment was requested to define its environmental control and electric power requirements for its intended operational environment. The proponent for this system is the Project Manager - Ground Based Radar, Strategic Defense Command, Huntsville, AL. A trip was made to Huntsville by John Daugherty on 28-29 August 1991.

This next generation radar will employ solid state devices to replace the traveling wave tubes. Even though the solid state devices are more efficient, they are much more powerful than their current counterparts. The solid state devices generate so much heat at their base, they require chilled water cooling rather than convection cooling with forced, cooled air. The system also requires on the order of 600 kW of electric power so that prime power units of 500 to 750 kW will be necessary. Also, the equipment installed is so heavy that containers, rather than ISO shelters must be used for the system. The unique characteristics of the next generation ground based radar were passed along to the Army's MEP and ECU proponents who are coordinating system needs directly with Huntsville.

One of the concerns at Huntsville was air transportability of the large MEP units. They want a standard military MEP unit for supportability, but the large MEP units will not fit into a C-130 aircraft. They were told the standard units could be reconfigured to a maximum height of 102 inches, the maximum height for a C-130. It has since been determined that a wheel mounted, 750 kW prime power unit (called the 750 light) has a height of 102 inches specifically to make it transportable on a C-130.

2.1.3 Improvements to the Shelter System Assessment Model (SAM). SAM is frequently used by the system assessment team members. There have been some problems with its input/output (I/O) and computations, particularly with differences noted between the transient and steady state comparative output. The contractor assessment team was asked to review and change the SAM codes to improve the model's I/O and computations.

The difficulties with the transient portion of the program were related to TEMPER tents with flies deployed to provide shade and with substantial heat transfer through the floors which are in contact with the ground. The errors, which could overstate the cooling requirement by 20 - 30 percent, were evaluated, corrected and tested.

The I/O problems solved were:

- "NO ROW TO SATISFY THE WHERE CLAUSE" resolved.
- The USAGE RATE displayed differed from the actual calculated rate resolved.
- The type of electric power displayed was corrected.
- The THERMAL CAPACITANCE output was changed to THERMAL MASS.

2.1.4 Individual Power. The Individual Power Program concerns power generation for the individual soldier using small engine-generators, improved batteries, or fuel cells. A powered exoskeleton to assist soldier mobility is included in the latter stages of the program. A number of technologies were being brought together from several agencies and from within BELVOIR to develop and analyze individual power alternatives. The assessment team developed and analyzed a critical path schedule for the program. A critical path network and a resource printout were provided. John Daugherty developed this critical path network and resource list during the period from 20 December 1991 until 7 February 1992.

2.1.5 Electronic Fighting Vehicle System (EFVS). The EFVS is a M2 Bradley chassis with an armored cab and shelter suitable for housing a wide variety of C³ equipment. EFVS has its own internal power generation system with backup, ECU, chemical filters and is protected against High Altitude Electromagnetic Pulse (HAEMP). None of the mission equipment was installed so power measurements were not obtained. Instead, electric power estimates made by the Army (Vint Hill) and the integrating contractor (Electrospace Systems Inc.) were used. The electric power estimates were converted from kW to British Thermal Units per Hour (BTU/H). The former estimated the power at 43,025 BTU/H while the latter estimated greater power usage which required a cooling capacity of 71,594 BTU/H. The power dissipated within the shelter is the main driver of the cooling requirement. Arnold Castro, Ed Starkovich, John Daugherty and George Hayes traveled to Richardson (near Dallas), TX from 18-20 March 1992 to the Electrospace facility to obtain data and initiate the analysis.

The materials in all surfaces including Kevlar[®] were defined in detail to determine the heat transfer coefficients. One of the key variables in the heat dissipation was the amount of power from the tactical jammer (12.2 kW total power estimated) which is radiated outside the shelter. SAM was run using several outside ambient temperatures with the results plotted on a graph. The graph shows the amount of heat dissipated inside the shelter on one axis with the air conditioning required on the other axis. The two lines on the graph are for hot-humid and hot-dry conditions. Using this technique, the amount of air conditioning required can be easily picked off the graph when the actual power requirements are known. The current air conditioning capacity of 57,000 BTU/H is sufficient for the Army power estimate, but not enough for the Electrospace estimate. The worst case need for heating is 28,000 BTU/H and the ECU has a 37,000 BTU/H heating capability - heating is not a problem.

The air conditioning evaporator (cooling unit) was mounted on the ceiling of the shelter with its outlet at the ceiling. This configuration would require the cooled air to move against the heated air rising from the equipment racks, or a compound duct to transport the cooled air to the bottom of the racks. A better approach would be to move the evaporator to the floor with the cooled air coming out at the floor level.

2.1.6 Force Provider. Force provider had been called the Collective Support Package. This is a tent city with containerized facilities for kitchens, latrines, showers, etc., which resembles the Air Force's bare base facility. The primary purpose for Force Provider is to provide an in-theater rest and relaxation facility. There could be many secondary uses such as a reception center or temporary facilities in disaster areas. The requested assessment was to determine and layout the electric power needs for Force Provider. Work started on 3 April 1992 by John Daugherty, and was completed in May 1992.

In preparation to conduct the Force Provider assessment, several preliminary steps were taken. The draft Mission Need Statement and Force Provider Concept Statement were reviewed and outlined to identify discrepancies between the two. Logistics planning factors were extracted from FM 101-10-1 to estimate requirements for water, waste, electric power and medical facilities. A visit was made to the Prime Power Battalion (Provisional) of the Corps of

Engineers Engineering and Housing Support Center to obtain detailed data on prime power units (500kW and up), power distribution centers and operating procedures found in draft FM 5-422, Engineer Prime Power Operations, along with the requirements identified in AR 700-128, Prime Power Program to obtain the loan of prime power units. A list of smaller generators for Force Provider start-up was made and verified. Distribution Illumination System, Electrical (DISE) data was gathered. Everything needed to complete the assessment was available except for a camp layout and some of the facility details such as the electric power required to support water recycling, laundry equipment, etc.

A layout prepared by Natick Research, Development and Engineering Center requires further development. The Quartermaster School is not yet ready to provide their input. Captain Nour of the BELVOIR Water Technology Team may be assigned the task to prepare and staff a Force Provider layout.

The Air Force has a facility similar to Force Provider which they call the Bare Base Program. A copy of Air Force Pamphlet 92-12 Volume III (Draft), Bare Base Facilities, was requested.

2.2 DOCUMENTATION - TASK III

This draft of the Technical Report and Study Gist is provided the Government for review and comment.

3.0 CONCLUSIONS

3.1 DEPMEDS OPERATING IN A CONTAMINATED ENVIRONMENT

DEPMEDS cooling requirements greatly exceeded the equipment provided. Actions have been recommended to Natick to improve the efficiency of the cooling system, such as taking the bends out of flexible ducts and shading components.

3.2 GROUND BASED RADAR

This next generation system has great needs for cooling, electric power and standard containers (not ISO shelters) to mount equipment. Cognizant personnel have been made aware of these special needs to insure the orderly development of the system. BELVOIR is prepared to assist with large MEP units, chilled water cooling, and standard containers.

3.3 SAM MODEL IMPROVEMENTS

All of the deficiencies reported in SAM, both functional and I/O, have been evaluated and corrected, but further testing is recommended.

3.4 INDIVIDUAL POWER

The various components of the Individual Power Program were brought together into a critical path schedule and a resource report.

3.5 ELECTRONIC VEHICLE FIGHTING SYSTEM

This next generation C³ platform is being configured as a tactical jammer by the Signals Warfare Laboratory. Since the electronic equipment is not yet available, and there is a wide discrepancy between the Army and the integrator's electric power dissipation estimates, a graph was provided with air conditioning plotted as a function of power dissipated. When the final, measured electric power requirements are known, the amount of air conditioning required may be pulled from the graph. Also, the air conditioning evaporator provides cooled air at the ceiling level which is not amenable to efficient equipment rack cooling.

3.6 FORCE PROVIDER

Force Provider will provide a tent/containerized in-theater facility for rest and relaxation, or it could be used for refugees, reception, or for emergencies or disasters. Most of the input data needed to assess the electric power requirements has been developed. The Force Provider overall shelter and equipment layout has not yet been completed and staffed.

4.0 RECOMMENDATIONS

4.1 DEPMEDS OPERATING IN A CONTAMINATED ENVIRONMENT

It is recommended that the support equipment for DEPMEDS be properly installed with installation techniques being placed in the Field Manual. It is further recommended that the entire facility be assessed for heating and cooling needs to properly size ECUs and chemical filters needed to meet mission requirements.

4.2 GROUND BASED RADAR

It is recommended that BELVOIR proponents for large MEP units, ECUs and containers maintain contact with the Project Manager - Ground Based Radar, to insure the developing system is adequately supported and coordinated.

4.3 SAM MODEL IMPROVEMENTS

It is recommended that SAM corrections inserted as a result of this task be tested more thoroughly.

4.4 INDIVIDUAL POWER

There are no recommendations concerning the Individual Power Program.

4.5 ELECTRONIC VEHICLE FIGHTING SYSTEM

It is recommended that the installed equipment power requirements be identified in detail, and considering duty cycles, and use of the graph provided to determine ECU requirements. It is further recommended that the evaporator be moved to the floor so that the equipment cooling air will move upward through the equipment racks.

4.6 FORCE PROVIDER

It is recommended that a generic layout for Force Provider be produced so the definition and distribution of electric power may be completed. It is further recommended that this assessment be conducted for a facility with and without air conditioning.

APPENDIX A
"QUICKLOOK" POWER ASSESSMENTS
FOR
ARMY SYSTEMS

STATEMENT OF WORK

STATEMENT OF WORK AND SERVICES

TASK ORDER TITLE: "Quicklook" Power Assessments for Army Systems

TASK LOCATION: This work will be accomplished at the contractor's facilities, through visits to the US Army Belvoir Research, Development and Engineering Center (BELVOIR), and to field sites as directed by the Technical Advisor (TA)/BELVOIR Assessment Team.

1. Background: Since power assessments were institutionalized in AR 70-1 in 1987, there has been an increased need to support requests from the field to conduct assessments. The assessments are conducted on developed (6.4+) or fielded systems. Power consumption of electrical equipment is measured and the cooling and electrical power is assessed and validated. Power consumption data on electrical components is used to update the Belvoir Generator Allocation Program (BGAP). Conducting these assessments has been valuable to the Army because they have reduced requirements for mobile electric power (MEP) units and environmental control units (ECUs). BGAP is used by the combat development (CBIDEV) community to plan for future organizations. SAIC Developed BGAP in a previous effort.

2. Objective: The objective of this task is to provide a capability to rapidly travel to the field, conduct system measurements, and report validated power requirements for up to eight (8) Army systems. The need for the rapid response and "Quicklook" assessments is to provide responsive action to the requests of Program managers and users. The ultimate objective of the power assessment program is to decrease the number or capacities of MEP units and ECUs in the Army, without sacrificing mission performance.

2.1 Program Approach: The tasks required to meet the objective are: travel to the field to gather data and perform field measurements; evaluate the collected data and prepare a short assessment report; and prepare a final technical report and study gist.

3.0 Task I. Gather Assessment Data from the Field. The Government TA will designate the systems on which electric power and environmental control assessments will be conducted, and the site at which data will be gathered. The contractor will travel to the designated sites (up to eight (8)), identify the system's subsystems and take detailed measurements of electrical subsystems power consumption. The contractor shall measure the physical characteristics of the system in sufficient detail to later determine the heat transfer properties for environmental control. Finally, the contractor shall determine the use scenario including which subsystems must operate simultaneously and which would not be used simultaneously. (C.4.1a)

3.1 Task II. Evaluate Data and Prepare "Quicklook" Report. For each system, the contractor shall evaluate the data collected and prepare a "Quicklook" report of about five pages with the following contents:

Section 1. System Summary

- Section 2. System Power Requirements and Driving Factors
- Section 3. Areas of Uncertainty
- Section 4. Areas for Improvement
- Section 5. Conclusions and Recommendations

The contractor shall deliver "Quicklook" Reports within three (3) weeks after completion of the associated field trip. (C.4.1)

3.2 Task III. Documentation. The contractor will document the results and findings of all evaluations into a Final Technical Report and Study Gist. (C.4.1e)

4.0 DELIVERABLES: The contractor shall submit monthly Contractor's Progress, Status, & Management Reports. Final Technical Report and Study Gist. Two copies of the Final Technical Report and Study Gist shall be mailed to:

Defense Technical Information Center
Cameron Station
ATTN: DOA-2
Alexandria, VA 22314

5.0 GOVERNMENT FURNISHED EQUIPMENT: None.

6.0 CLASSIFICATION: Unclassified

7.0 CONTRACT LINE ITEMS: CLIN 0003AA, Systems/Hardware Integration and CLIN 0003AB, Management Science. Work performed and services provided shall be in accordance with Section B and Section C (C.4.1a, and c) of the basic contract. Deliverables shall be in accordance with Section F.2, CLIN 0004, and the attached DD Form 1423, Exhibit "A."

7.1 DESCRIPTION OF REQUIRED TRAVEL: Six (6) trips of 2½ days for two persons to St. Louis.

8.0 PERFORMANCE PERIOD: Date of award to six (6) months.

APPENDIX B
"QUICKLOOK' POWER ASSESSMENTS
FOR
ARMY SYSTEMS
TECHNICAL REPORT COVER SHEETS

**"QUICKLOOK" ASSESSMENT
OF THE
DEPMEDS HOSPITAL DEMONSTRATION PROJECT
CONFIGURED TO
OPERATE IN A CONTAMINATED ENVIRONMENT**

TECHNICAL REPORT

**11 September 1991
Revised
27 November 1991**

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**PRELIMINARY ASSESSMENT
FOR
THEATER MISSILE DEFENSE (TMD)
GROUND BASED RADAR (GBR)**

TECHNICAL REPORT

8 October 1991

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**"QUICKLOOK" ASSESSMENT
OF THE
ELECTRONIC FIGHTING VEHICLE SYSTEM
(EFVS)**

TECHNICAL REPORT

9 April 1992

**BY
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