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REPORT ON RESULTS OF
CONCEPT FORMULATION ACTIVITIES FOR
AN ARMED AIRCRAFT QUALIFICATION RANGE
SCORING SYSTEM

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Del Mar Engineering Laboratories and
Booz-Allen Applied Research Inc.
Los Angeles, California
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April 1970

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STUDY, ARNED AIRCRAFT QUALIFICATION RANGE SCORING SYSTEM

ABSTRACT

This study determined the technical feasibility and optimum design analysis for an Armed Aircraft Qualification Range Scoring System in accordance with Concept Formulation outlined in AMCR 70-30 and system requirements outlined in a Small Development Requirement (SDR).

After an intensive review and analysis of the SDR Requirements had been completed, a detailed investigation was conducted of all available "OFF-THE-SHELF" scoring systems. A "Trade-Off" analysis was made of the characteristics of each of these systems versus the requirements outlined for the optimum scoring system developed by the revised SDR. A cost effectiveness effort was completed, an Operational Specification was written, and a Concept Formulation Report was prepared. The report concluded that an off-the-shelf scoring system using acoustic sensing principles be further developed to meet the functional requirements of the optimum system in order to satisfy armed aircraft gunnery scoring requirements of the 1970 to 1975 time frame.
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This report describes the concept formulation work performed under NAVTRADEVCHN Contract N61339-69-C-0178 with Del Mar Engineering Laboratories and Booz-Allen Applied Research, Inc. The purpose of the study was to provide the technical, economic, and military basis for the decision to initiate engineering system development for a helicopter gunship scoring range.

The basic objectives of the study were to (1) analyze the requirements of the DA approved Small Development Requirement (SDR), (2) examine existing scoring systems in light of the SDR, and (3) propose a hardware system, requiring little research and development, to meet the requirements. The ultimate goal is a reliable, dependable, and versatile scoring system that will provide instant hit information to the attacking helicopter pilot trainee and instructor pilot. The system must perform acceptable regardless of attack angle and azimuth, type of armament selected, and type of target engaged.

The study has revealed that the technology is not sufficiently at hand to meet all of the SDR requirements. The most difficult problem areas to solve are discriminating between the different types of rounds hitting a target simultaneously, and providing a detection system that does not restrict the attack angle and is not susceptible to damage from armament fired into the target area.

Two approaches seem logical at this time: (1) reevaluate the SDR to determine the minimum essential requirements, thereby enabling existing technology to satisfactorily meet the reduced requirements or (2) embark on a research and development effort to ascertain if there is any approach that will meet the existing requirements.

KENNETH W. PETERSON
Project Engineer
Naval Training Device Center

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.
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A requirement exists for an Armed Aircraft Qualification Range Scoring System which will permit the recording of hits and near-misses on ground targets at a central location remote from a firing area. Numerous attempts by industry, both domestic and foreign, have been made to meet this need. None have fulfilled all the requirements of the optimum scoring system. This study has investigated all known scoring systems, applied those components to the optimum system needs and recommends development or augmentation of existing hardware and methods of application to provide a scoring system adequate to accomplish its goals without need for invention or scientific advances. In consonance with policy, prior to initiating work on system development, this study was directed to insure that the following system prerequisites had been met.

1. **PREREQUISITE 1**
   Engineering rather than experimental effort is required and the technology needed is sufficiently in hand.

2. **PREREQUISITE 2**
   The mission and performance envelopes are defined.

3. **PREREQUISITE 3**
   The best technical approaches have been selected.

4. **PREREQUISITE 4**
   A thorough trade-off analysis has been made.

5. **PREREQUISITE 5**
   The cost-effectiveness of the proposed system has been determined to be favorable in relationship to the cost-effectiveness of competing items on a DOD-wide basis.

6. **PREREQUISITE 6**
   The cost and schedule estimates are credible and acceptable.

The Study Tasks were developed so that all necessary prerequisite requirements were fulfilled.
The objective of the study is to determine the technical feasibility as well as the economic and military considerations for the development of an Armed Aircraft Qualification Range Scoring System. This system should accurately provide both hit and miss data to an airborne gunner trainee immediately following his training exercise. This timely information would allow corrective action to be taken before his next firing pass. Information needed to improve his gunnery techniques is vector data, i.e. over-short-left or right. In selecting systems and scoring hardware, only state-of-the-art hardware and techniques should be used with little or no invention or scientific advances required.

B. Definition of the Problem

"A Study Outline for Armed Aircraft Qualification Range Scoring System", NTDC-371-105, Project 191, dated 16 February 1963 and an "Approved Small Development Requirement (SDR) for an Armed Aircraft Qualification Range Scoring System" was provided as program guidance. These documents and AMCR 70-30 are included as Appendix A to this report.
SECTION III

METHOD OF PROCEDURE

A. GENERAL

In order to produce a properly validated specification for an Armed Aircraft Qualification Range Scoring System, eight specific tasks were undertaken. These tasks were accomplished in such a manner that all the necessary information would be assembled to meet the prerequisite requirements of ANCR 70-33.

1. Task #1 - Review and analyze the Small Development Requirement.
2. Task #2 - Develop system functional analysis and requirements allocation.
3. Task #3 - Identify, analyze and develop technical summary of applicable off-the-shelf systems and state-of-the-art technology.
4. Task #4 - Conduct trade-off studies of hardware identified in Task #3.
5. Task #5 - Define recommended system with consideration for maximum modular concept integration; and preparation of performance specification, cost estimates and schedules.
6. Task #6 - Identify subsystem and/or hardware areas where future development is required to optimize the recommended off-the-shelf system.
7. Task #7 - Prepare concept formulation study report.
8. Task #8 - Conduct technical reporting conferences.

B. TASK #1 - REVIEW AND ANALYZE THE SMALL DEVELOPMENT REQUIREMENT

This task involved the review and understanding of the Small Development Requirement (SDR). To accomplish this, field visits were made to numerous Army installations, and conferences with senior Army aviators intimately involved in both individual and unit gunnery training programs were conducted.

The SDR was analyzed to define the essential and desirable operational characteristics of the Qualification Range Scoring System, not only in the light of scoring systems themselves, but also as the system is related to weapons systems. Specific comparisons were drawn between stated SDR requirements and those arising from aircraft armament subsystems, Government field activities, and equipment manufacturers. In this effort, we drew not only on past experience with the stated SDR parameters, but also on the results of day-to-day contact with currently operational scoring systems.
The system is to be used with targets presenting real-time projectile impact information to observers located at a point remote from the range itself. The resulting technique will replace the current practice of counting holes in a target panel, which is not only tedious and wasteful of manpower, but also ineffectual in terms of psychological impact on the attacking pilot, because of the time lapse between his firing pass and the determination of his results. It is apparent that a real-time score display (hits and misses) results in accelerated pilot gunnery training programs and qualification exercises, with a corresponding increase in range efficiency and personnel utilization. This concept should manifest itself in a higher level of gunner proficiency.

During the unit training phase the SDR recognizes that an acceptable range must present a realistic situation to the attacking pilot, with respect both to the targets themselves and to their environment. The targets must appear real in their representation of personnel, vehicles and equipment, with their appearance not compromised by the presence of scoring equipment. All system elements must be light in weight and readily portable to facilitate rearrangement of the tactical situation on a given range, or a change in locale, possibly to a different range altogether. The range equipment must be operable both day and night under typical world-wide climatic and terrain conditions, with little or no target site preparation or equipment re-calibration required.

The scoring system recommended must be compatible with contemporary weaponry such as gun-propelled projectiles from 5.56mm through 30mm, 40mm grenades and 2.75" to 6" rockets, primarily inert rounds. Rates of fire up to 24,000 rounds per minute can be expected. With airborne armament systems now including a variety of weapons on a given aircraft, the impact detection system must change its response parameters in a minimum of time to score the various projectile types which may be fired during any one mission. No scoring technique should be selected which will prohibit scoring of foreseeable future air-to-ground weapon system - the scoring system must never restrict the ability to train.

In individual and unit gunnery qualification roles, the scoring system need present only a summary of hits and misses. However, during training programs leading to qualification, it is necessary to provide vector (quadrant) information in addition to hit/miss data. The SDR recognizes that, in either role, a high level of accuracy must be demonstrable so that the pilots undergoing training or qualification will accept the results displayed, thereby enhancing their progress toward combat readiness.

Preliminary evaluation studies were conducted to define system approaches, the level of present state-of-the-art, and the risk involved in establishment of any required development activity. The emphasis of this evaluation is to interpret the feasibility of the operational characteristic identified in the SDR, and to assist in planning implementation of the other study tasks.

Attached as Appendix D is the resulting statement of understanding of the SDR, a list of installations and personnel contacted and work sheets which were prepared from information gained. At the completion of this task, a Technical Reporting Conference (TRC) was conducted and the results and findings discussed.
C. **TASK #2 DEVELOP SYSTEM FUNCTIONAL ANALYSIS AND REQUIREMENTS ALLOCATION**

A system's functions are the various operations which are expected of the system or any of its parts to perform in order to satisfy the defined mission. The system's design results in hardware which satisfactorily performs these functions considering maximum personnel safety and the expected range of environmental conditions. An initial step in the system engineering technique consisted of the formulation of a functional analysis of the system. This functional description was a prerequisite in developing, interpreting and providing standards for design of the hardware and its interfaces.

Functional aspects to be identified within the functional analysis include (a) a description of the functions, (b) the sequence of their occurrences, (c) the logical arrangement between these functions, (d) their hierarchy.

The Small Development Requirements were assigned to each appropriate defined function. This effort translated the functions into design requirements; and, in addition, provided guidelines for evaluating the degree of acceptability in the trade-off analysis of the existing hardware (Task #4) and hardware development (Task #6).

Attached as Appendix C is the completed Functional Analysis for the Optimum Armed Aircraft Qualification Range Scoring System.

D. **TASK #3 IDENTIFY, ANALYZE AND DEVELOP TECHNICAL SUMMARY OF APPLICABLE OFF-THE-SHELF SITES AND STATE-OF-THE-ART TECHNOLOGY**

All promising scoring systems were investigated to determine their applicability in satisfying the demands of the Small Development Requirement; that is, whether they are suitable to be used as the basis for elements in the idealized system as outlined. This determination was accomplished by a careful parametric analysis of each technique as substantiated by field experience, manufacturer's specifications, or basic system analysis where required.

It is apparent from system considerations that three areas of investigation exist which were studies more or less independently of each other. These are the hit detection technique itself (at the target site), the data transmission link and the display elements. The study program for each of these areas is discussed below:

1. **HIT DETECTION**

The study was limited to currently available non-cooperative (passive) hit-detection methods so that standard combat weapons and projectiles can be used on the range. The study was further limited to those techniques which have been reduced to hardware, preferably production hardware, form. Within these limitation, the following techniques were studied to determine their suitability as the hit-detection element of the idealized system:
a. Doppler Radar 

b. Pulse Radar 

c. Acoustic 

(1) Amplitude 

(2) Time-of-arrival differential 

d. Hit-Count Panels 

(1) Electrically conductive 

(2) Mechanically excited. 

2. DISPLAY 

With the entire purpose of range exercises being the immediate presentation of desired information to cognizant personnel, it is evident that the display method recommended is an extremely important element of the ideal system. The study investigated various displays from simple hit counting to sophisticated presentation of actual miss-distances, both scalar and vectorial, which may demand some form of recording or computer analysis as a part of the data reduction process. 

The following display (and recording) techniques were studied: 

a. Hit counting 

b. Miss-distance presentation 

(1) Round-by-round 

(2) Mean Point of Impact (MPI) 

c. Miss-direction presentation 

(1) Quadrant 

(2) Clock 

d. Recording Techniques. 

Each analysis gave due consideration to human factors in order that the information displayed will be readily grasped for timely communication to the attacking trainee pilot. Of special significance was the capability of the technique under study to accommodate the high fire rate required by the SDR. 

3. DATA TRANSMISSION LINK 

A significant portion of the proposed study was devoted to an investigation of data transmission links between the range itself and the display sites. The systems investigated included, but were not necessarily
limited to, hard-wire links; Fm telemetry, either digital or in PECM format; \( X/M \) telemetry. Of special importance in this phase of the study were considerations of range portability, system reliability, immunity from spurious responses, availability of r-f frequencies, and compatibility with IRIG specifications.

Attached as Appendix D is the Technical Analysis of the "Off-the-Shelf" candidate systems that were investigated and a listing of technical data that were received.

**E. TASK #4 CONTACT TRADE-OFF STUDIES OF HARDWARE IDENTIFIED IN TASK #3**

The objective of this task was to validate the candidate Armed Aircraft Qualification Range Scoring System from the hardware identified in Task #3, with respect to the functional requirements specified in Task #2.

A trade-off matrix was prepared which listed the optimum system's functional requirements as well as the functional characteristics of each candidate system developed during Task #3. Each system's essential function was ranked and graded as follows: a value of "3" was given when the candidate system component met the requirement; a value of "2" was given when the candidate system component only partially met the requirement; a value of "1" was assigned when candidate system component did not meet the requirement except to a minor degree and "0" value was assigned when candidate system component did not satisfy any part of the optimum system's functional requirement. Upon completion of the grading, each functional characteristic was weighted in accordance with established hierarchy of importance determined in Task #2. Three levels of importance were used and the following weights were applied.

1. Level 1 (Sensing Scoring & Displaying) 50%
2. Level 2 (MPI for Miss-distance, r & \( \phi \)) 25%
3. Level 3 (Data Transmission & Miscellaneous) 25%

Thus the rating value multiplied by the level of importance yielded the weighted score for each candidate system.

An attempt was made to arrive at a composite system comprising the best subsystem from the candidates, however, this effort was dropped when it became apparent that interfaces were completely incompatible.

It is also concluded that no one system, currently available, will completely satisfy the true functional requirement.

Attached as Appendix E is the Trade-Off Analysis, the work sheets used, and a ranking table of all candidate systems considered.
This task consisted of three parts; the definition of the recommended optimum scoring system, the development and preparation of a performance specification for the optimum scoring system and the cost effectiveness of the recommended system. A complete system definition and the resulting proposed performance specification 371-112A, Specification for Armed Aircraft Qualification Range Scoring System has been provided. This specification was prepared in accordance with Level III, under MIL-T-23991 and Chapter 5, DSM 41203-M.

A true cost effectiveness study for this system could not be achieved due to the lack of necessary information, both operational and vendor supplied, however, a cost model was constructed. This model and other rational is provided in Appendix F.

The purpose of this effort was to determine the amount and type of development engineering effort and an estimated cost to update all candidate "off-the-shelf" scoring systems to meet the idealized system's functional requirements.

In study Tasks 3 and 4 it was ascertained that each of the candidate "off-the-shelf" scoring systems were functionally inadequate and none met all the requirements of the idealized system specification.

To develop a method of estimating additional development and estimated production costs for candidate systems without attempting to forecast individual company development costs, a standardized method of cost estimating was used. Details of this effort are found in Appendix "m".

This Concept Formulation Study Report summarizes the results of the eight study tasks and meets the requirements of NAVTRADENEW-STD-104D, paragraph 5.1.4, final report, as applicable. The study report fulfilled the six prerequisites specified in NAVTRADENEW 70-30 and covered all of the requirements specified in the Study Outline 371-106, 16 February 1963.

Three Technical Reporting Conferences were conducted, the First on 23 May 1969 at the Naval Training Device Center, Orlando, Florida; the Second on 17 July 1969 at Del Mar Engineering Laboratories, Los Angeles, California and the final one on 23, 24 September 1969 at Del Mar Engineering Laboratories. Included as Appendix G are the agendas and summary report for each conference.
SECTION IV
RESULTS

A. GENERAL

The study revealed that deficiencies currently exist in four major areas pertinent to Armed Aircraft Gunnery Training Scoring:

1. Proficiency criteria for gunnery qualification is non-existent.

2. Developmental Engineering is required to modify the Candidate Scoring System found to be most effective to meet all functional, environmental and operational requirements of the Optimum Range Scoring System.

3. Candidate Scoring Systems, in an "off-the-shelf" category, do not meet all functional requirements of the idealized scoring system.

4. Operational and system costs of present scoring methods and systems have not been defined adequately enough for a thorough cost effectiveness effort to be completed herein.

B. PROFICIENCY CRITERIA

True Qualification Standards criteria has not been established for the individual training of gunnery students except for gunnery flight instructor pilots. Subjective scoring is accomplished by Gunnery Instructor Pilots using visual and judgment techniques. Standards for evaluating unit gunnery proficiency and accuracy have not been developed. Army Training Tests (ATT) do not include objective scoring of units in gunnery subjects. The lack of these criteria and standards make the task of determining the true effectiveness of an optimum scoring system difficult.

C. DEVELOPMENTAL ENGINEERING

An investigation was conducted to determine the effort and cost of up-dating each candidate "off-the-shelf" system to meet the idealized system's functional requirements. The methodology and results of this effort are shown in Appendix "H".

D. FUNCTIONAL REQUIREMENTS

The functional analysis performed in Tass's 2 and 4 revealed that candidate systems ranked in the following order: Approach 7, 8, 9, 14, 16, 3, 12, 13, 5, 1, 15, 2, 6, 10 and finally 11. Approach 7 rated highest, meeting 43% of the optimum system's requirements, and Approach 11 rated the lowest, meeting only 20%. The functional and technical analysis are furnished as Appendices C and D respectively. Deficiencies common to all candidates include; scoring rate - too low, scoring radius - too small, no method of determining mean point of impact and no vector or quadrant information provided.
E. COST EFFECTIVENESS

Cost data for present day scoring methods and systems are either unclear or unavailable. Total number of aircraft hours utilized, quantities of ordnance expended, and support effort necessary to "qualify" a gunnery student have not been determined. Candidate Scoring System manufacturers have provided only "first" cost figures; mortality rates for down-range sub-systems have not been estimated; operational support costs have not been calculated; estimated logistics costs have not been determined. Lacking these data a true cost effectiveness analysis cannot be completed. However, a cost effectiveness model was constructed. This formula was applied to eligible candidate systems for cost and economic considerations and the resultant rankings are as follows: Approach 8, 14, 13, 7, 9, 15, and 4.

Approach 8 was determined to be most cost/effective with a relative value of $10.34 while Approach 4 was the least cost/effective with a relative value of $33.75. Certain candidates were eliminated from consideration due to lack of adequate price and cost information or where excessive development effort was obvious. Appendix F provides details of the cost/effectiveness effort.
A. GENERAL

The study tasks enumerated in Section I have been prioritized to incorporate all data and information necessary for compliance with prerequisite requirements of AMCR 70-30.

1. PREREQUISITE 1

Information necessary for compliance with this prerequisite was obtained during the completion of Tasks 2, 3, 5 and 6. Task 2 developed a functional analysis of the system in conjunction with the SDR; Task 3 investigated all known scoring systems, and state-of-art technology; Task 5 defined the ultimate system required including cost-effectiveness evaluation and Task 6 identified and estimated the development effort required to optimize the recommended off-the-shelf system. Data resulting from these tasks indicate that engineering rather than experimental effort is required and technology needed is sufficiently in hand to develop the idealized scoring system.

2. PREREQUISITE 2

The Task 2 analysis defined the mission and performance envelopes for the idealized scoring system, thereby meeting the prerequisite requirements.

3. PREREQUISITE 3 & 4

Trade-off studies of candidate systems conducted under Task 4 and the review of state-of-the-art technology completed during Task 3, has insured that the best technical approach has been selected. Additionally, the complete functional comparison of all candidate systems has resulted in the selection of the best qualified off-the-shelf system which might be modified and improved, with minimal effort, to meet specification requirements.

4. PREREQUISITE 5

A cost/effectiveness model was prepared in Task 5, and applied to each candidate system. Lack of up-to-date factual information on present-day operation and maintenance costs and the limited price data furnished by candidate-system manufacturers prohibited the preparation of a more comprehensive analysis. However, estimates and weighting factors were used to provide an effective cost analysis.

5. PREREQUISITE 6

During Tasks 5 and 6 it was determined that cost estimates and time estimates were accurate and realistic within the imposed boundary conditions. These estimates include system development, testing, evaluation, acquisition, operation and maintenance costs and time.
SECTION VI

CONCLUSIONS

A. GENERAL

From the results of investigations and data compiled during the course of the study, it was concluded that acoustic sensing techniques offered the best technical approach to meet air-to-ground armament scoring system requirements. It is also apparent that a trade-off must be made to ensure that all military and economic aspects of the idealized scoring system are considered. The results of functional adequacy and cost/effectiveness as discussed in Section IV are shown below:

<table>
<thead>
<tr>
<th>Functional Adequacy Ranking</th>
<th>Percent Functional</th>
<th>Cost Effectiveness Ranking</th>
<th>C-E Value</th>
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<tr>
<td>Approach # 7</td>
<td>43%</td>
<td>Approach # 8</td>
<td>$10.34</td>
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<td>8</td>
<td>41%</td>
<td>14</td>
<td>12.06</td>
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<td>9</td>
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<td>4</td>
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<td>15</td>
<td>16.96</td>
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<tr>
<td>15</td>
<td>22%</td>
<td>4</td>
<td>33.75</td>
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The candidate systems which rank first, second and third in functional adequacy (Approaches 7, 8 and 9) were reviewed with candidate systems which rank first, second and third in cost/effectiveness (Approaches 8, 14, and 13) to provide a final basis for systems selection. In functional adequacy, insignificant differences existed between the leading three candidates (3%), while in the cost/effectiveness area a significant difference is apparent. It should also be noted, at this point, that approaches 13 and 14 represent systems manufactured by foreign companies. If "Buy-America" policies are to be considered, resulting in elimination of two more candidates, the cost effectiveness value differential is quite significant (approximately 25%). It is concluded, therefore, that the candidate system represented by Approach Number 8 is the most acceptable, off-the-shelf scoring system in consideration of technical feasibility, economic and military requirements, and the development requirement.

B. MODIFIED DEVELOPMENT TECH/COST CYCLE

It is further concluded that, although technically feasible and within the state-of-the-art, it may be relatively costly and time consuming to
develop a scoring capability for all projectile types (inert, HE, subsonic and supersonic projectiles) and, particularly, to develop the means to score simultaneous, multiple-type projectiles on the same target. This consideration is applicable to all candidate systems.
SECTION VII
RECOMMENDATIONS

A. GENERAL

Following the conclusions reached in Section VI, it is recommended that engineering development of this optimum scoring system be initiated, utilizing NTDC Specification 371-112A as a basis.

B. QUALIFICATION CRITERIA

It is further recommended that, concurrent with the engineering development process, qualification standards be established for gunnery proficiency ratings, based on the use of instrumented scoring systems.

C. MODIFIED DEVELOPMENT TIME/COST CYCLE

It is recommended that consideration be given to modification or deletion of the requirements to score all projectile types and to score multiple-type projectiles simultaneously on the same target.

D. SCORING SYSTEM UTILIZATION STUDY

It is also recommended that a study of the methods for best utilization of scoring systems as an aid to gunnery training be conducted. Human factors related to utilization of the scoring system as a training aid should receive the greatest emphasis. Publication of a guide for scoring systems users would be an end item for such a study.
REFERENCES

(1) **Patent:**

(2) **Patent:**

(3) **Patent:**

(4) **Program of Instruction:**
United States Army Aviation School. POI for 2C-F13 OH-6 Transition/Gunnery IP Qualification Course; Fort Rucker, Alabama; U. S. Army, 1967.

(5) **Program of Instruction:**

(6) **Program of Instruction:**
United States Army Aviation School. POI for 2C-1961-A/2C-06ZB-A Officer/Warrant Officer Rotary Wing Qualification Course (Reserve Component/Allied). Fort Rucker, Alabama; U. S. Army, 1969.

(7) **Program of Instruction:**
United States Army Aviation School. POI for 2C-1961-D/2C-06ZB-D Officer/Warrant Officer Rotary Wing Qualification Course (Active Army). Fort Rucker, Alabama; U. S. Army, 1968.

(8) **Program of Instruction:**

(9) **Program of Instruction:**
(10) Program of Instruction:

(11) Program of Instruction:

(12) Program of Instruction:

(13) Program of Instruction:

(14) Program of Instruction:

(15) Program of Instruction:

(16) Specification:

(17) Specification:

(18) Report:
(19) Report:

(20) Report:
Aeronic Ltd. Acoustic AS-100 Miss Distance Indicator. Stockholm, Sweden, Air Target Ltd., 1964.

(21) Report:

(22) Report:

(23) Report:

(24) Report:

(25) Report:

(26) Report:

(27) Report:

(28) Report:
(29) Report:

(30) Report:

(31) Report:

(32) Report:

(33) Report:
SIFENA. Miss-Distance Acoustic Detector (SIFENA Model 12B). Societe Francaise D'Equipements Pour La Navigation Aeriennne, Beauilly, France.

(34) Report:

(35) Report:

(36) Report:

(37) Report:

(38) Report:
(39) Report:


(40) Report:


(41) Report:


(42) Report:


(43) Report:


(44) Manual:


(45) Manual:


(46) Manual:


(47) Manual:


(48) Manual:

(49) Manual:
    Headquarters, Dept. of the Army. Divisional Armored and Air Cavalry

(50) Manual:
    U. S. Army Aviation School. Reference Data for Army Aviation in the

(51) Manual:
    U. S. Army Aviation School. Volumes 1 and 2 FM1-40 Attack Helicopter

(52) Manual:

(53) Manual:
    U. S. Defense Department. Standardization Policies, Procedures and

(54) Report:
    Normal Case Considering Angle of Attack. Boo, Allen Applied Research,
NAVY NAVY 69-C-0178-1

16 February 1968
Project 1968

NAVAL PROBLEM SOLUTION CENTER
GREASE, FLORIDA

STUDY OUTLINE FOR
ARMED AIRCRAFT QUALIFICATION GAUGE SYSTEM
CONCEPT FORMULATION

PREPARED BY:

APPROVED BY:

Project Engineer

Department
STUDY OUTLINE FOR

ARMED AIRCRAFT QUALIFICATION RANGE SYSTEM
CONCEPT FORMULATION

1. SCOPE

1.1 This study outline establishes the requirements for a study to
determine the technical feasibility, economic, and military considerations
for preparation to initiate development of the Armed Aircraft Qualification
Range System. The study shall include a survey of the technological state-
of-the-art hit and near miss detection, and data acquisition and interpre-
tation.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of
invitation for bids or request for proposal form a part of this specification
to the extent specified herein:

STANDARDS

Military

MIL-STD-461 Electrical Interference Characteristics Requirements for Equipment

MIL-STD-470 Maintainability Program Requirements (For Systems and Equipment)

MIL-STD-471 Maintainability Demonstration Reliability Tests Exponential Distribution

MIL-STD-785 Requirements for Reliability Program (For Systems and Equipment)
Naval Training Device Center (NAVTRADCEN)

NAVTRADCEN-STD-164 Standard for Preparation of Technical Reports

PUBLICATIONS

U. S. Army Materiel Command

Regulation 70-30 Concept Formulation, Prerequisites to Initiating Engineering or Operational Systems Development Effort

Approved Small Development Requirement (SDR) for an Armed Aircraft Qualification Range System.

(Copies of specifications, standards, drawings and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the Contracting Officer.)

3. REQUIREMENTS

3.1 Background - Army Materiel Command Regulation (AMCR) 70-30 outlines the concept formulation prerequisites that must be analyzed and evaluated prior to initiating development of an operational system. The approved SDR for Armed Aircraft Qualification Range System outlines the proposed system and its capabilities required to fulfill the Army Aviation School air-to-ground ordnance training program.

3.2 Study outline. - This study shall determine the technical feasibility and acceptability of the concept formulation outlined in AMCR 70-30 and the system requirements as outlined in the SDR. Design analysis, comparison and recommendation shall be supported by appropriate rationale and data. The concept formulation shall consist of the 6 AMCR 70-30 prerequisites plus all included, but not be limited to, the following items and analysis:

2.2.1 Prerequisites. - Primarily, engineering rather than experimental effort is required in the definition of the concept development system and components, the studies of the system and components for the Armed Aircraft Qualification Range System design. The study shall evaluate a representative development for the Armed Aircraft Qualification Range System which will require system-level system design, and the identification of subsystems and components in the sense of critical subsystems which will not be underfunded or selected in the sense. This study shall include, but not be limited to, analysis of the following items.
371-106

(a) Various hit detection scoring techniques, components, and systems for supersonic and subsonic projectiles of various calibers. This shall include the operational parameters as well as compatibility with the requirements of the site. Particular attention is directed to the determination of the "near miss" projectile impact point capability.

(b) Various means of interfacing the hit detection system and components with the central display unit. The interface design shall consider hit signal data conversion, timing function, data transfer from target areas to the control center, and central display unit for displaying data from target areas throughout the range system.

3.2. Prerequisite 2 - The mission and performance envelopes are defined. Trainer performance and operating characteristics shall be analyzed and outlined in this section. These shall include, but not be limited to, the following items:

(a) Limitation on angle or entry of projectiles into the target detection zone.

(b) Clearly defined maintainability and reliability outline which complies with the concepts of MIL-STD-470, MIL-STD-471, and MIL-STD-785.

(c) Physical size, shape, and weight of individual system components, including containers for transport, to comply with requirements for high transportability.

(d) Radio frequencies and output power of the system data link to conform to FCC regulations and availability of frequency bands.

(e) Power requirements of the system, and power sources recommended to satisfy these requirements.

(f) Limitations on hit detection rate and accuracy for single projectiles as well as simultaneous burst hits of various types of projectiles.

(g) Feasibility of detection and scoring of both subsonic and supersonic projectiles, with any one method or concept, shall be supported by quantitative basis. Should a single method be incapable of accomplishing the desired results, the minimum number and types of system concepts or methods necessary shall be indicated.
(a) Inly defined electromagnetic interference characteristics in accordance with the concepts of MIL-STD-460.

(b) Extent to which flying objects generated by "war-fires" projection will be a problem.

3.2.3 Prerequisites. The two technical approaches have been selected. The two technical approaches shall include an analysis of present design of airborne detection and data transmission system as compared with the Armed Aircraft Qualification Range System technical approaches. The study reports shall stipulate why certain approaches are not recommended and why other approaches were selected.

3.2.4 Prerequisite 4. A thorough trade-off analysis has been made. The trade-off analysis shall also include all trade-off studies performed in preliminary design configurations. These studies shall include, but not be limited to, performance, economics, trainer efficiency, reliability and maintainability concepts.

3.2.5 Prerequisite 5. The cost effectiveness of the proposed trainer has been examined to be favorable in comparison with the cost effectiveness of the training trainer and a satisfactory trainer. The cost effectiveness shall be oriented to achieve the potential savings attainable through the use of the Armed Aircraft Qualification Range System in lieu of the techniques now utilized in other training and research methods. Considerations shall be given to the quantity of students, training proficiency requirements, and projection of future requirements and costs. The cost effectiveness analysis shall include generating cost estimates of the trainer such as reliability, maintainability, and utilization over the effective life of the trainer.

3.2.6 Prerequisite 6. The cost and schedule estimates are credible and acceptable. Complete estimate documentation, and cost information with supporting hardware and material estimates shall be provided. The estimate shall include design and manufacture of the Armed Aircraft Qualification Range System within the fiscal year 68--70 period.

3.3 Execution. The end product shall consist of a complete technical report in accordance with the final report requirements of NAWTRDEVCEN 69-C-0179-1.

3.4 Data and reference materials. Except for the applicable documents of paragraph 3.1, all data and reference materials shall be attached to the contract. Such data shall include the detection design and operational characteristics, magnetic characteristics, cost, military utilization and other pertinent information.

3.5 Security, theft, and damage. The end product shall be unclassified.

4. QUALITY ASSURANCE PROVISIONS

4.1 The end product will be maintained.

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be subject to review and approval, in writing, by the Contracting Officer. Review will include determination of compliance with the requirements of this study outline and applicable specifications.

5. PREPARATION FOR DELIVERY

5.1 The concept formulation data shall be prepared for delivery in accordance with NAVTRADEVCEN STD 104 and the Contract Schedule.

6. NOTES

6.1 Intended Use - The Concept Formulation Study will provide technical feasibility, economic considerations, and best technical approach toward development of a hardware prototype, Armad Aircraft Qualification Range System.
STUDY OUTLINE FOR
ARID AIRCRAFT QUALIFICATION RANGE SYSTEM
CONCEPT FORMULATION

Prepared by: [Signature]
Project Engineer

Approved by: [Signature]
Head, Land Warfare Department
NAVYDEVEN 69-C-0178-1

AMENDMENT - 1
9 July 1968
Project 196

NAVAL TRAINING DEVICE CENTER
ORLANDO, FLORIDA

STUDY OUTLINE FOR
ARMED AIRCRAFT QUALIFICATION RANGE SYSTEM
CONCEPT FORMULATION

This amendment forms a part of and shall be attached to Study Outline 371-156, dated 16 February 1968.

On the cover page: Add the word "Scoring" between the words "Range" and "System".

Page 1, in the Title: Add the word "Scoring" between the words "Range" and "System".

Page 1, paragraph 1.1: In line 4, add the word "Scoring" between the words "Range" and "System".

Page 7, paragraph 3.2: In line 4, add the word "Scoring" between the words "Range" and "System".

Page 2, paragraph 3.2.1: In line 4 and line 6, add the word "Scoring" between the words "Range" and "System".

Page 3, paragraph 3.2.1(a): Delete the words "near miss".

Page 3, paragraph 3.2: Change paragraph identification to read "3.2.2".

Page 3, newly identified 3.2.2(a): In line 1, add the words "Quantitatively expressed" between the words "outline" and "which".

Page 4, newly identified paragraph 3.2.2: Add "(j) Probability of an actual hit not being detected or recorded".

Page 4, paragraph 3.2.3: Delete in its entirety and substitute in lieu thereof: "3.2 Approach... The best technical approach has been selected... The Technical Approach which best satisfies the requirements of the work shall be presented. This approach shall be based upon the best data on all factors considered in the other preconditions. The above report shall indicate why other approaches are not recommended and why the proposed approach was selected."
Page 4, paragraph 3.2.5: In line 5, add the word "Scoring" between the words "Range" and "System".

Page 4, paragraph 3.2.6: In line 5, add the word "Scoring" between the words "Range" and "System".

Page 5, paragraph 3.3: In line 2, insert the words "that satisfies the requirements of AGCA 70-30 and its six prerequisites and is" between the words "enough" and "in".

Page 5, paragraph 6.1: In line 4, add the word "Scoring" between the words "Range" and "System".
DEPARTMENT OF THE ARMY APPROVED SMALL DEVELOPMENT REQUIREMENT
(SDR) FOR AN ARMED AIRCRAFT QUALIFICATION RANGE SYSTEM

1. Purpose and Operational Characteristics: A requirement exists for a range system which will permit the recording of hits on ground targets at a central location remote from a firing area used by U.S. Army armed aircraft. This system will be used in the training of aircraft crews, maintaining proficiency of trained crews, and associated applications. As the projectiles used in the training and proficiency roles will be primarily of an inert nature, a means for scoring near misses will be required in order to determine adjustments needed to improve accuracy.

a. (Essential) Targets used must realistically represent personnel, combat and tactical vehicles and crew-served ground weapons appropriate to the terrain and environment in which installed.

b. (Essential) The system must be adaptable to the simulation of various field tactical situations.

c. (Essential) Targets, hit count measurement and transmission devices and a hit count and register central display unit must be included as a part of the system.

d. (Essential) All components of the range system must be portable in nature and easily assembled and disassembled.

e. (Essential) The range system must be capable of operation through an area 2000 meters in width and 6000 meters in length, down to a minimum of 400 meters in width and 2500 meters in length.

f. (Essential) The range system must be capable of day and night operations under intermediate climatic conditions as outlined in Change 1, AR 705-15. Kits will be provided, if required, for use in cold, hot-dry climates.

g. (Essential) The range system must acquire and record scoring (hit and near miss) data on the following armament subsystems:

1. (Essential) 7.62 machineguns.

2. (Essential) 50 caliber machineguns.

3. (Essential) Rockets and missiles (2.75 to 6").

4. (Essential) 40mm grenade launchers.

5. (Essential) 20mm and 30mm automatic gun.

h. (Essential) The system must be capable of scoring a single machinegun or multiple machineguns with rates of fire up to 6000 rpm or a single firing run and combinations of those subsystems outlined in g above, on consecutive, but separate firing runs.
1. (Desired) The system must be capable of recording the combinations of the different weapons outlined in g above in a single firing run.

J. (Essential) The system must be capable of recording the distances of their terminal projectile positions from the target centers up to miss distances of 50 meters (recording of the azimuths and elevations desired if development time and cost is not excessive). Miss distance recordings of 0 to 15 meters must be within ±2 percent accuracy; for distances between 15 and 30 meters, accuracy must be within ±10 percent. If the desired azimuth and elevation recording is not achieved, target hits will be scored for small targets only and zone scoring is not achieved, target hits will be scored for small targets only and zone scoring will be used for all targets.

k. (Essential) The range system must be capable of collecting and recording data from each individual target and up to a minimum of six targets simultaneously.

l. (Desired) The range system must be capable of collecting and recording data simultaneously from ten targets.

m. (Essential) Targets and any associated instrumentation must:

1) Be easy to install with little or no site preparation.

2) Be portable by medium helicopter sling load to facilitate rearrangement of target arrays.

3) Be realistic in appearance.

4) Simple to repair and capable of individual component of module replacement.

5) Require minimum maintenance as outlined in paragraph 5.

6) Require no excessive calibration prior to operation.

7) The hit count and register central display unit must have a self-contained lighting capability for effective night operations.

n. (Essential) The system must be capable of storage and transit under the conditions outlined in AR 705-15 (i.e., Army aircraft).

o. (Essential) The system must be adaptable to various types of terrain, i.e., desert, mountain, and jungle (see para 2f).

p. (Desired) The system must be capable of prolonged periods of inactivity while exposed to the local environmental climate (not to exceed 30 days), without requiring extensive preparation prior to activation.

q. (Essential) The command/control system must be adaptable to the electrical power available in CONUS and overseas or be capable of operation utilizing standard US Army generators.
r. (Essential) If batteries are used as power source for target arrays, they must be capable of 24-hour operation prior to recharge.

s. (Essential) The range system must be simple to establish, operate, and require a minimum or organizational maintenance (see para 5.)

t. (Essential) The system should have an expansion capability so as to accommodate future developed aerial weapons and platforms, e.g., Advanced Aerial Fire Support System.

u. (Essential) The hit count and register central display unit should be capable of being mounted in the back of a standard US Army 3/4-ton vehicle or 3/4-ton trailer (1/4-ton truck or 1/4-ton trailer desired).

v. (Essential) The system will have a minimum acceptable mean-time between failure of twenty hours under relatively heavy usage conditions.

2. Supporting Justification and Data:

a. Reasons for Requirement:

(1) As the helicopter is employed as an aerial platform for a variety of weapons systems, a formal program for the initial training and/or qualification of armed aircraft crews is required. Training programs must develop and maintain skills in target acquisition; identification, neutralization, and destruction. This new equipment will greatly reduce the time now required to train individual aviators in air-to-ground gunnery techniques. Substantial savings will result in ammunition expended, helicopter flight time reduced and overall student training efficiency increased.

(2) Current ranges used for this helicopter gunnery training utilize old ground-to-ground scoring techniques which require that scoring be accomplished by a "shoot and count holes" procedure or in-flight observation. The former is time-consuming and requires the range to be closed while personnel are in the firing areas; the latter scoring method is inaccurate as it provides only general hit or miss data. There presently no means to count and locate relative to the target those projectiles which are near misses. This information is necessary in order to properly assess the effectiveness of the fire. Overall, the present type of scoring operation is inefficient, time consuming, and expensive. The training time lost, to include the down-time of the helicopter, is excessive and wasteful. The new proposed range system will eliminate all of these disadvantages now found in current range scoring training programs of instruction.

(3) A range system is required by US Army Aviation School and other commands with armed aircraft which will have the capability of accurately detecting target hits and near misses and displaying these data at a central location. These range systems will be authorized in Department of the Army Tables of Allowance (DA 23) of Army Aviation Training Centers in Continental United States and overseas, and will be utilized in the training of Army armed aircraft crews in order to:
(a) Provide for a more efficient utilization of personnel and aircraft involved.

(b) Expedite and improve the quality of initial crew training in armed aircraft.

(c) Improve the method of analyzing the armed aircraft crew proficiency (annual qualification).

(d) Improve all current scoring methods.

(e) Improve current range operating efficiency.

(4) Maintenance Concept. Organizational maintenance personnel should be able to accomplish the majority of the maintenance of this system on site. Such organizational maintenance should be restricted to minor, readily accomplished repairs, so that it will not interfere with the training program. Mechanisms requiring repair beyond the scope of organizational maintenance should be removed on site and evacuated through normal maintenance channels to the appropriate Direct, General or Depot maintenance facility. It is expected that a minimal training program for organizational maintenance personnel on the electronics portion of this device will be required. Maintenance functions will be accomplished by military personnel of MOS series 383 (Electronic Instrument Repairman) or equivalent DA civilian personnel. The maintenance required (all categories) for the Range System will not exceed one hour for each ten hours of training under normal circumstances. One hour of maintenance for twenty hours of training is desired.
Naval Ordnance Test Station

Subject: Contract DA-AC-69-C-0174, USA Material Command, 70-35, Summary of

Page: (a) Letter 1st Mar-21, signed on 8 April 1965

Inc.: (1) Requisition 70-36

Enclosed herewith publication requested in reference (a).

Capt J. H. Scott, Commanding Officer

[Signature]
RESEARCH AND DEVELOPMENT

CONTRACT FORMATION- PROGRESS IN INITIATING ENGINEERING
ON OPERATIONAL SYSTEMS DEVELOPMENT REPORT

Paragraph

1. Purpose... This regulation sets forth requirements that must be met prior to submitting a request to U.S. Army Material Command (AMC) for approval to enter a project into engineering or operational systems development.

2. Scope... This regulation applies to:

a. Headquarters, AMC; AMC major subordinate commands; project managers; and separate installations and activities reporting directly to headquarters, AMC, and performing research and development functions.

b. Research, development, test, and evaluation (RDE) projects funded in the AMC system program that are proposed for engineering development. CDRER category civil or operational systems development (RMD) category.

3. Definitions... Subject matter covers the activities and procedures necessary to carry out engineering or operational systems development. These activities include the development, testing, and evaluation of technical concepts and their implications on advanced development status. Together with the 31 program offices, they provide the technical...
ecological and military bases for the decision to initiate development of an operational system. Concept formulation begins early enough to include all activities that can be recognized as directly leading to, or supporting, the project to be qualified and approved for engineering or operational systems development. It does with the ASC Technical Committee action establishing the project. Its relationship to other activities in the research and development cycle is shown schematically in Figure 1.

b. Concept definition (formerly referred to as project definition phase) is the first step in engineering or operational systems development and immediately precedes initial development. It is a formal step during which preliminary design and engineering are verified or accomplished and first contract and component planning are performed. AR 73-2 specifies that all new (or major modification of existing) equipment or operational systems developments estimated to require cumulative R&D funds in excess of $50 million, or estimated to require production procurement of equipment and missiles, Army (PMAC) and Military Construction, Army (OBM), not related to research and development (R&D) in excess of $10 million will include a contract definition period unless waived in writing by Headquarters, Department of the Army. Below these thresholds, contract definition may be required by Headquarters, DA, or the Headquarters, ASC, and may be reconsidered by commanders of commodity commands or project managers, if circumstances warrant.

**SCHEMATIC RELATIONSHIP OF CONCEPT FORMULATION TO RESEARCH AND DEVELOPMENT CYCLE**

<table>
<thead>
<tr>
<th>R&amp;D Category</th>
<th>Development Effect</th>
<th>Operational System Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploratory</td>
<td>Advanced Engineering or Operational System Development (6.2-1, 6.3-1)</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>Contract Formulation</td>
<td>Competition</td>
</tr>
</tbody>
</table>

**Decision:**
- Decision: To grant conditional approval to later proceed, engineering or operational systems development.
- Decision: To deny conditional approval.

**Note:** In cases where contract definition is not required, the two decision points will combine and a single decision will be made to approve entry into engineering or operational systems development.

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**Figure 1.**
a. Full development. The period of contract effort substantial enough to provide test data, for the principal equipment or system to be built, and equipment, or system, or some major portion thereof, has been completed or is continuing to be completed. It begins with the award of the principal contract(s) for equipment or system or support hardware development effort, or initiation of comparable development effort or phase when development and testing activity is no longer significant, usually with classification as an added category type in accordance with 50 F.R. 20.

4. Approval to initiate unit in engineering or operational systems development is a decision that will be based on: (a) System objectives will be met; (b) the concept formulation effort provided the request for the project has met all certain requirements; (c) the requirements, as appropriate, to enter into engineering or operational systems development, specified in AS 70.4.1 are listed in paragraph 5 and elaborated upon in appendix 1. Although concept formulation normally provides concept definition, these prerequisites are equally applicable to all hardware free for system projects. Regardless of whether contract definition is required.

5. Development of a realistic material requirement (QMR) and the appendix 1 (see AR 70.5-8) is a process not normally conducted in the breadth and depth indicated for concept formulation. For this reason, the qualitative material requirement (QMR) or small development requirement (QMR), includes several distinct processes. The first step is that after all aspects of the system and techniques are fully considered, the resulting product will provide adequate military utilities for the research's expectation any of the other alternatives. Therefore, the QMR and SDR must be backed up by the results of the concept formulation effort.

6. Project formulation. In accordance with paragraph 4, before any report is due to its committee, QMR and SDR, for approval to initiate work in engineering or operational systems development, the project concerned, in addition to project written QMR or SDR, must have met the following prerequisites:

a. Full development. Primarily, engineering, rather than experiment, effort is required and the technology needed is sufficiently in hand.

b. Project formulation. The mission and performance envelopes are defined...
HAVITRADEVCS 69-C-0178-1

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d. Pragmatism - The best technology approach has been chosen.

e. Integrity - A thorough trade-off analysis has been made.

f. Pragmatism - The cost effectiveness of the proposed approach has been determined to be favorable in relationship to the cost effectiveness of competing things on a department of defense (DoD) wide basis.

g. Pragmatism - Cost and schedule estimates are credible and acceptable.

6. Depth of accomplishment. The prerequisites listed in paragraph 5 are to be satisfied before a project can be considered properly prepared for entry into engineering or operational system development. However, for compliance to below threshold for a potentially contract definition (para. 3.0), certain criteria for those of low total cost, it is realized that the relative payoff of satisfying the depth criteria of the prerequisites or aspects of these (for example, the relative extent of effort) are relative not just the order of the project and effort from other lower cost or higher priority projects. Therefore, it is expected that the amount of effort required on the accomplishment of these prerequisites and the depth of the accomplishment will be in proportion to what the project deserves, in consideration of the dollar value and the importance of the project.

7. Validation of technical significance. There is no readout of a method for determining the extent to which the prerequisites stipulated in paragraph 5 have been accomplished. The necessary proof that the prerequisites have been met may be contained in one document or in several documents, but should be presented in a single package. For example, a research outline organizing this evidence, to facilitate review and approval, is contained in appendix C. The detailed technical development plan under the PR part 1.09 (Research and Technology Memo) should make reference to these documents and the detailed TP also should include summaries of these contents, as indicated in RQ 705 3.

b. The regulation should not be construed to require that the requirements of other local devices in the system be any more than the course of previous experience for managing on-going systems development. Thus, I will provide with the six prerequisites of paragraph 3 in mind. Let's discuss the intent of the regulation and its purpose as stated in the regulation and directive WV 10-25, AY 705-5, 1963-11-5, and attached items. The one exception should provide the basic data and

additional information within the scope of this regulation. These should be in line with the data documentation used to meet other
requirements of a written submission, he used to satisfy one or more of the project titles in paragraph 3. For clarity, after complying with this regulation, there should be very little additional effort required to meet the objectives of the independent reviews for technical and engineering characteristics (ANC 70-39).

c. For projects exceeding the thresholds of paragraph 3, the proof of project task accomplishment should accompany the request. Once the responsible commodity element or project is sent to headquarters, ANC, and from headquarters, ANC, to headquarters, ANC to approve entry into contract definition. For those projects below the thresholds of paragraph 3, the proof of accomplishment must be submitted and approved in accordance with 2 below, prior to requesting ANC Technical Committee action to establish the project in accordance with ANC 70-39.

d. Paragraph 5, ANC 70-4, sets forth the principle of stratification regarding the level of authority for decisions required during full-scale development. One of the thresholds specified in ANC 70-5 is also applicable to the approval of the concept formulation results as follows:

(1) For projects or tasks below $50 million estimated combined R&D and PPA funding and which do not exceed the thresholds of paragraph 3, the commander will assure himself that the requirements of paragraph 5 have been satisfied and the project is no longer ready to enter engineering or operational system development. An initial analysis of the supporting material will be forwarded to the Executive Officer, ANC, ATTJ, ANC, concurrently with the request for ANC Technical Committee action.

(2) For projects or tasks above $10 million estimated combined R&D and PPA funding, documented evidence shows the facts and reasoning leading to the conclusion that the requirements of paragraph 5 have been satisfied, will be forwarded to the Executive Officer, ANC, ATTJ, ANC, prior to the request for ANC Technical Committee action.

(3) For projects that are project-similar and that do not exceed the thresholds of paragraph 3, the commander will assure himself that the requirements of paragraph 5 have been satisfied and the project is no longer ready to enter engineering or operational system development. An initial analysis of the supporting material will be sent to the Secretary, ANC, or Deputy Commanding General, ANC, after a review by the Director of Research and Development, ANC, and prior to the request for ANC Technical Committee action.
These projects that exceed the thresholds for mandatory contract decision will be projected in accordance with AK 70-17. In the exercise of a project's readiness to enter engineering or operational systems development will be made by the Commanding General, ASC, or Deputy Commanding General, ASC, after review by the Director of Research and Development, Headquarters, ASC.

8. Project Review. a. The Director of Research and Development, Headquarters, ASC, has ASC staff responsibility for assuring that the prerequisites specified in this regulation have been satisfactorily accomplished for each project or task exceeding the threshold of paragraph 7(7), prior to approval to initiate effort in engineering or operational systems development.

b. Director and chiefs of separate staff offices, Headquarters, ASC, are responsible, within their functional areas, for providing all necessary assistance in meeting the requirements specified in this regulation.

c. In the case of field projects, on overseas bases, the commander of the installation or project reporting to the ASC, is responsible for assuring that the prerequisites listed in paragraph 5, are satisfied for those projects, or portions of projects, for which he is responsible, prior to submitting requests for initiation of effort in engineering or operational systems development to Headquarters, ASC.

9. Implementation. a. The prerequisites listed in paragraph 5 must be fulfilled for all projects or tasks which:

1) Are approaching, but not approved, for engineering or operational systems development.

2) Have been directed for project initiation by Headquarters, ASC, but which have not been established as projects by technical committee action in accordance with AK's 700-20 and 700-9.

3) Have been approved for engineering or operational systems development, but for which the required cost estimates (RCE) have not been forwarded to Headquarters, ASC, for approval.

b. Further action to satisfy the prerequisites for entry into engineering or operational system development, unless otherwise directed by Headquarters, ASC, need not be made for:

1) Projects already approved for engineering or operational systems development and for which the RCE has been submitted to Headquarters, ASC (SP 35), for approval.
(2) A project already in engineering or operational systems development.

10. Every PIR, in the judgment of the commander of a commodity program or project manager, it appears to be in the best interests of the Government to waive all or a portion of the requirements of this regulation, a request for the waiver may be submitted to headquarters, ASC, for review and approval. The request must state specifically which requirements are to be waived and give reasons therefor.

11. References. a. AR 11-27, 70-17, 70-20, 70-5, 70-6, 705-12, and 705-27.

b. ASCR 70-5, 70-28, 70-6.

Appendix I

DISCUSSION OF PRELIMINARIES

Section I. Introduction

Approved as a project to enter engineering or operational systems development depends very much on how well the six prerequisites discussed in paragraphs 4 through 8, this appendix, have been accomplished during the concept formulation period. The results of meeting these prerequisites may produce a high degree of confidence that technology will permit a desirable development schedule that fits, and the project will result in greater military capability for the resources expended than the alternatives could offer. For it is true that each of the six prerequisites is specifically addressed in the concept formulation period preceding engineering or operational system development. the following discussion is offered as guidance. The statutory provisions of this regulation are contained in paragraphs 4 through 10 above; guidance contained in this appendix is permissive.

Section II. Discussions

1. Preliminary. In order to properly engineer and develop a project, the following are basic to the project and system design. The project and system development and testing schedule shall not preclude the various phases of the project and system design. The project and system development and testing schedule shall not preclude the various phases of the project and system design. The project and system development and testing schedule shall not preclude the various phases of the project and system design. The project and system development and testing schedule shall not preclude the various phases of the project and system design. The project and system development and testing schedule shall not preclude the various phases of the project and system design.

a. This prerequisite does not mean that a system must be limited to an assembly of off-the-shelf components, however, it does mean that when components or "building blocks" do not already exist, the technology...
It is not the case that, in order to provide the system initially designed, the enterprise must meet one or more that the technology required to design and develop a system is available. It is certain that the enterprise under normal laboratory conditions must have shown the capability to do that and not the equipment.

Further, any projections based upon these quantitative results must be made on the productivity of building that but not exceeding that during engineering or operational systems development.

b. It is not the case that, in order to do this productively, the technology being developed should be utilized where the system becomes obsolete even before it is produced. It is intended that components required for the system be available at least only in development to use, that it is expected to come, that fully by extrapolating the existing technology within the timeframe of the system development. It is intended that development development (with, category 6.21) is completed prior to system (6.21) operational systems (6.21) development; although some research and development effort (6.21) can be carried into the engineering or operational systems development phase provided that it will be completed in time to meet the requirements of an acceptable development schedule.

c. The key criterion, then, is to determine how much of a risk, and hence in what, is the level of confidence that the development will be successful, that is, successful in terms of operational effectiveness, cost, and time.

2. For: design and performance envelopes are defined, the model of the planned system or equipment usually include such detailed factors as size, weight, reliability, success performance characteristics, such as air flow profiles, range, speed, payload, altitude, fuel consumption, lethality, accuracy, reliability, maintainability, and other appropriate test item or system under any condition. Although, the concept of performance envelope is that it is a set of design and performance envelopes, arrived at after comparison of several analyses, to be a little bit more appropriate or to get a system under any condition. Although, the design and performance envelopes can be changed after concept definition, or prior to full-scale development, upon valid indication that they cannot be met within acceptable costs, can easily be accomplished at cost, or are more than required. The optimum amount of performance envelopes should be identified through the use of the cost effectiveness test as levels calculated to support the tradeoff analysis required by progress and the cost-effectiveness requirements required by present use.

3. It is not the case that the levels of performance envelopes are defined.
The net result of this report is the identification of the detailed information and the logical alternatives for selecting the most effective weapon system. Conceptual analyses and the product, conducted, will provide the海军 through the alternative weapon and program costs. All of these factors are related to system approaches and implementation requiring operational, technical, economic, cost, and performance trade-offs. Analysis of the projections and the alternative weapon systems will be applied in either or both, or one of the discussions which would be presented here. For the sake of eliminating duplications, the treatment of these procedures is presented in two phases for the purpose of weapon systems.

b. From the point of view of the analysis of the requirements of the system, there are three major factors to be determined in the evaluation of the system approaches: weapon effects, cost, and operational requirements. The system approaches for the weapon systems should be compared with existing operational requirements for the weapon systems for meeting the operational requirement.

c. In order to determine if an analysis of the weapon system can be made, the relationship of the system to the operational requirements of the weapon system must be determined. The weapon system approach can be concerned with the operational effectiveness of the weapon system. The weapon system approach can be concerned with the operational effectiveness of the weapon system.

In a weapon system, the weapon system is divided into two categories: the weapon system and the operational effectiveness. The weapon system is divided into two categories: the weapon system and the operational effectiveness. The weapon system is divided into two categories: the weapon system and the operational effectiveness. The weapon system is divided into two categories: the weapon system and the operational effectiveness.
b. Cost-effectiveness studies, as well as trade-off analyses, where possible, should be based on the cost available estimate of the total cost of acquisition and ownership for the total system.

(1) The total system cost should include design and test, production, operation, and maintenance costs of the system itself, as well as all related costs, such as personnel training and training copy of facilities, maintenance and repair support facilities, logistics, and support, as well as supporting spares, support facilities, etc., and the design, development of processes that would be funded as a result of the total of the proposed system should be included from the total cost.

(2) Further, organizations should be used in the context of the complete operation in which the supporting work may form a part. For example, to capture the costs of the system, costs required not only for the maintenance effectiveness of the total system but also costs of the time, power, the mobile and fixed launching facilities and the detection, and the control equipment, and the support and repair facilities, while it is not necessary to request all these costs accurately, a program should be presented of the two activities and their relative increase and costs related to the background of the complete operation in which they will be used.

c. Operational effectiveness, likewise, should be more inclusive than the cost, which usually first comes to mind. In addition to these factors, such as speed, payload, accuracy, etc., such factors as reliability, survivability, and logistics should also be considered.

d. To be effective, both trade-off and cost-effectiveness analyses must be conducted in an objective manner and they should be viewed as tools for the decision maker and should be presented to alleviate instead of to present a biased case. It should be pointed out that both the trade-off and the cost-effectiveness analysis, although very important, are not precise tools, but should, for decisions must be considered with other factors in other contexts.

6. Progiatan. The cost and schedule estimates of systems should include, along with accuracy and cost estimates for development, testing, evaluation, logistics, and maintaining the system, costs for support, and costs for development, and research are due to the development costs of the required support, components, and other facility, and should be consistent with the schedule cost reduction data.

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1. Purpose. The suggestions contained in this appendix are intended as assistance in normalizing and presenting the documentation evidence that the concept formulation effort has satisfied the war-prerequisites for entering engineering or operational system development (see para 3, part 2). It is not intended as a strict or limiting exercise of imagination and ingenuity in preparing a clear, logical, easily followed answer the proof that a project is, in fact, ready to enter engineering development. However, regardless of how the supporting material is presented, it should be done while keeping in mind the problem of those who must review and act on the evidence presented.

2. The outline. Figures 2 and 3 are outlines of one method of presentation. It is important, whether or not the suggested outline is used, to address each prerequisite individually and to reference each significant supporting document. It is necessary for actually including a specific document will depend upon how well its contents are already known, how many copies are in circulation, and how available a copy may be to the headquarters to take the review.

a. Although there may be a number of reports, studies, summaries, analyses, and other documents required to report the concept formulation work, they should all be included in a single package. The package should be introduced and summarized by a cover paper as outlined in figure 7.

b. Each prerequisite may be addressed in a separate section of the concept formulation package. If the volume of material dictates, a subvolume. For each prerequisite, the pertinent portions of the supporting documents should be summarized even though the documents themselves may be included.
(A letter format may be used)

1. An introduction (purpose of report, how report is organized, indication of details of effort to satisfy pre-requisites, etc.).

2. Description of the system (what it is intended to do, through what it is intended to achieve, parameters and control, performance characteristics, etc.) and the program (e.g., CR, DRA, and CUA) used to achieve this or system being replaced, replacing items or systems, etc.).

3. Requirements and limitations affecting results and conclusions reached in... (e.g., reliability requirements, input parameters and input variability, adequacy of need, requirement to accelerate development, etc.).

4. Evaluation of alternative (existing or otherwise) possibilities of accomplishing the objective, qualitative and quantitative evaluation of... (e.g., with appropriate references made to supporting data and...).
The first task to be accomplished in this Concept Formulation Study for an Armed Aircraft Qualification Range Scoring System is the completion of a review and analysis of the pertinent Small Development Requirement (SDR) (see Task 2, Ph Report No. 27, 17 September 1969). To initiate this review and analysis, specific comparisons have to be made between status SDR requirements and those current requirements arising from the latest helicopter armament subsystems, aviation practical gunnery training methods, etc. To determine these comparisons and to underline the validity of comparison results, conferences were held with representatives of various aerial gunnery training facilities/installations. (See Appendix A and Appendix B). These conferences provided the most current information on Army aviation gunnery training, including equipment, techniques of training and scope of instruction. With this information, requirements stated in the SDR could be converted to provide the breadth and depth necessary for the Concept Formulation Study (see Paragraph 4.3 - ACR 70 - 55).

Information derived from the conferences conclusively established that individual (or basic) gunnery training programs and unit (tactical) gunnery training programs often employ different practical instructional methods and, in fact, aim at different levels of proficiency as training objectives. It was necessary to investigate and identify these variances in order to reference them to appropriate sections of the SDR. This results in arriving at a comprehensive, current statement of the need as related to scoring hardware. When coupled to weapon characteristics and aircraft performance envelopes in the 1967-70 era, the scoring system performance criteria can be defined.

So that the aforementioned variances may be more readily identified, each parameter of the proposed Small Development Requirement for an Armed Aircraft Qualification Range Scoring System is reported here as it appears in the SDR. Following each "A parameter is a clarification and expansion of that parameter, if appropriate, as derived from the conferences and discussions conducted with current, responsible representatives of aerial gunnery training facilities and organizations in the U.S. Army."

Clarifying parameters are identified by enclosure within vertical bars on either side of the parameter.

1. Range and Operational Characteristics: A requirement exists for a range to be established at a central site and a number of smaller, local ranges. This range will be utilized for the actual range operations of the armed aircrafts and will only be utilized for the actual range operations of the armed aircraft. The range will be used for the purpose of training in the weapon's efficiency and the reliability of the weapon system, a range for maintenance of armament will be required in order to determine adjustments needed to improve accuracy.
1. **Purpose and Functional Characteristics:** The purpose of the Naval Aircrew Gunnery Training Aid (NAVTRA 69-G-0179-1) is to provide a practical means by which projectile-effect data can be recorded and presented, from which individual, aircrew, and collective-unit training status can be objectively assessed and developed. This is expected to result in an increase in overall training efficiency and effectiveness. Such a requirement demands a scoring system be utilized in conjunction with naval aircraft gunnery training. The scoring system will provide a remote real-time display of projectile "hit" data and/or projectile "killed" data relative to the ground target(s), and will permit recording of such data at a location remote from the target or weapons range area. The system will be used in the training of individual pilot/navigator and crew member personnel, and in the training of naval aircraft units and crews thereof, both in qualification training and testing, and in annual proficiency testing. The scoring system must be capable of functioning with both explosive and inert ordnance of types and sizes currently being utilized, or projected for utilization in the 1969-1975 timeframe.

   a. **(Essential) Targets must realistically represent personnel, combat and tactical vehicles and crew-served ground weapons appropriate to the terrain and environment in which installed.**
      
      a. It is essential that realistic, representative tactical targets be employed during those phases of unit training which incorporate gunnery tactics (i.e., target acquisition, target identification, weapon ingress and egress routes, ordnance selection, damage assessment, etc.). For individual basic gunnery ("marksmanship") qualification phases of training, however, simple and readily discernible aiming points are desired in lieu of realistic tactical targets.
   
   b. **(Essential) The system must be adaptable to the simulation of various field tactical situations.**
      
      b. The scoring system must be adaptable both to a simulated tactical environment for unit tactical training and to a basic gunnery "marksmanship" training environment.
   
   c. **(Essential) Targets, hit count measurement and transmission devices and a hit count and register central display unit must be included as a part of the system.**
      
      c. The system will consist of the following major components:
         
         - Target (tactical targets and/or simple aiming point targets, depending upon training application)
- Sensor ("hit" sensors and/or "miss" sensors)
- Data Transmitter (via radio, wire, etc.)
- Data Receiver (via radio, wire, etc.)
- Scoring Display
- Recorder (manual or automatic)

d. (Essential) All components of the range system will be portable in nature and easily assembled and disassembled.

d. It is essential that all major components of the scoring system be portable and incorporate sectional (targets) and modular construction methods.

e. (Essential) The range system must be capable of operation through an area 2000 meters in width and 6000 meters in length, down to a minimum of 400 meters in width and 2500 meters in length.

e. It is essential that the scoring system be capable of operation through an area of 30,000 meters in width and 30,000 meters in length (tactical unit training) down to a minimum area of 400 meters in width and 2500 meters in length (individual qualification).

Aircraft performance, weapons systems and type-training desired are considerations which influenced the determination of optimum range size.

f. (Essential) The range system must be capable of day and night operations under intermediate climatic conditions as outlined in Change 1, AK-705-15. Kits will be provided, if required, for use in cold-hot-dry climates.

g. (Essential) The range system must acquire and record scoring (hit and near miss) data on the following armament subsystems:

(1) (Essential) 7.62mm machineguns.
(2) (Essential) 50 caliber machineguns
(3) (Essential) Rockets and missiles (2.75 to 6")
(4) (Essential) 40mm grenade launchers
(5) (Essential) 20mm and 30mm automatic gun.

h. (Essential) The system must be capable of scoring a single machinegun or multiple machineguns with rates of fire up to 6000 rpm on a single firing run and combinations of those subsystems outlined in g. above, on consecutive, but separate firing runs.
1. (Desired) The system must be capable of recording the combinations of the different weapons outlined in Paragraph 1.g., above in a single firing run.

(1) The system must be capable of scoring inert and HE ammunition delivered by the armament subsystems listed in Paragraph 1.g., above.

(2) Each scoring system must be capable of sensing target hits and near-misses at impact rates not less than those indicated below for each type weapon:

<table>
<thead>
<tr>
<th>SIZE</th>
<th>TYPE</th>
<th>IMPACT RATES (MAX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5cm</td>
<td>Machine gun (MG)</td>
<td>24,000</td>
</tr>
<tr>
<td>7.62mm</td>
<td>Machine gun (MG)</td>
<td>24,000</td>
</tr>
<tr>
<td>12.7mm</td>
<td>Machine gun (MG)</td>
<td>6,000</td>
</tr>
<tr>
<td>20mm</td>
<td>Automatic cannon (AC)</td>
<td>6,000</td>
</tr>
<tr>
<td>30mm</td>
<td>Automatic cannon (AC)</td>
<td>6,000</td>
</tr>
<tr>
<td>40mm</td>
<td>Grenade launcher (GL)</td>
<td>400</td>
</tr>
<tr>
<td>2.75 in.</td>
<td>Folding-fin aerial rocket (FFAR)</td>
<td>12 per sec.</td>
</tr>
<tr>
<td>5 inch</td>
<td>Aerial rocket (AR)</td>
<td>2 per sec</td>
</tr>
<tr>
<td>5 inch</td>
<td>Wire-guided missile (WGM)</td>
<td>2</td>
</tr>
</tbody>
</table>

Cyclic rate of fire and simultaneous multiple weapons usage are the primary consideration determining system response.

(3) For basic gunnery ("marksmanship") qualification, the system must score only one of the size/type weapons listed in Paragraph 1.g., (3), above, on a single firing run. The system must provide scoring data from all on-range targets/aiming points, attacked sequentially in a single firing run.

(4) For crew/fire team/aviation unit tactical gunnery training, the system must score the weapon size/type mixes indicated below, and must be capable of providing scoring data on at least two targets attacked simultaneously by an aircraft in a single firing run. (Tactical gunnery training will require scoring the weapons of as many as two attack aircraft, each firing any of the weapon mixes indicated below, simultaneously against a single target.)
<table>
<thead>
<tr>
<th>NUMBER</th>
<th>CARR</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to four</td>
<td>5.56mm</td>
<td>Machine Gun</td>
</tr>
<tr>
<td>or four</td>
<td>7.62mm</td>
<td>Machine Gun or M-134</td>
</tr>
<tr>
<td>or two</td>
<td>12.62mm (50 cal)</td>
<td>Machine Gun</td>
</tr>
<tr>
<td>or two</td>
<td>20mm</td>
<td>Automatic Cannon</td>
</tr>
<tr>
<td>or two</td>
<td>30mm</td>
<td>Automatic Cannon</td>
</tr>
</tbody>
</table>

- OR -

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>CARR</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to four</td>
<td>5.56mm MG</td>
<td>2.75&quot; FFAR</td>
</tr>
<tr>
<td>or</td>
<td>7.62mm MG</td>
<td></td>
</tr>
<tr>
<td>or</td>
<td>12.62mm MG</td>
<td>40mm Grenade</td>
</tr>
<tr>
<td>or</td>
<td>20mm AC</td>
<td>5&quot; Wire Guided Missile</td>
</tr>
<tr>
<td>or</td>
<td>30mm AC</td>
<td>6&quot; Wire Guided Missile</td>
</tr>
</tbody>
</table>

j. (Essential) The system must be capable of recording the distances of terminal projectile positions from the target centers up to miss distances of 30 meters (recording of the azimuths and elevations desired if development time and cost is not excessive). Miss distance recordings of 0 to 15 meters must be within ±2 percent accuracy; for distances between 15 and 30 meters, accuracy must be within ±10 percent. If the desired azimuth and elevation recording is not achieved, target hits will be scored for small targets only and zone scoring will be used for all targets.

j. (1) The weapons listed in Paragraph 1.4, above, can be classified as either point weapons or area weapons. Only the 5" wire guided missile (1-42 sub-system) and the TOW missile are classified as point weapons, with the remaining weapons classified as area weapons. It is desired that area weapons fire be scored in terms of projectile ground impact within a circular horizontal plane on the ground centered on the target. It is desired that point weapons fire be
scored in terms of a projectile hit, excluding a rocket hit, or the physical qualities of the target; further, point weapons fire miss-information is desired in terms of projectile passage through an extended vertical target plane which is terminated at the ground, and through a horizontal target plane lying on the ground between the weapon and the target and terminating at the target.

(2) It is essential that the scoring system furnish vector scoring data (i.e. indicate an intersection of a projectile trajectory with the target or a nonphysical extension of the target, and provide a measurement of the direction and distance from the point of aim to the point of intersection). This is particularly important during those phases of gunnery training when inert grenade, rocket and/or missile ammunition is utilized.

(3) Vector score (direction and distance relative to a target/aiming point) can be expressed in polar coordinates (r, $\theta$) within the scoring planes discussed in Paragraph 1. (1) and (2), above. Polar coordinates provide specific impact location information relative to a reference point (target/aiming point), the format in which this information is presented is easily interpreted and understood; direction ($\theta$) and distance (r) can be expressed as falling within pre-defined areas or zones.

(4) The following table indicates the effective miss-distance of machine gun, automatic cannon and HE rocket/missile projectiles (area weapons). It is readily apparent that effective miss-distance increases as the size of the projectile increases. Thus the pre-defined scoring zones from 1. (3), above, should be remotely adjustable, during the basic gunnery qualification (carrots-anaht) training phase only, if a score of effective fire is to be furnished.

<table>
<thead>
<tr>
<th>SIZE</th>
<th>TYPE</th>
<th>EFFECTIVE MISS-DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.56mm</td>
<td>MG</td>
<td>5</td>
</tr>
<tr>
<td>7.62mm</td>
<td>MG</td>
<td>5</td>
</tr>
<tr>
<td>12.6mm</td>
<td>MG</td>
<td>10</td>
</tr>
<tr>
<td>20mm</td>
<td>AC</td>
<td>10</td>
</tr>
<tr>
<td>30mm</td>
<td>AC</td>
<td>10</td>
</tr>
<tr>
<td>40mm</td>
<td>GL</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
</tr>
</tbody>
</table>
The scoring system should be capable of scoring projectiles impacting at radial miss-distances of up to 54 meters within the scoring plane; it is essential that projectiles impacting at radial miss-distances of up to 15 meters be scored (2.75" FPAR - 10 lb. warhead).

The scoring system must sense those projectiles which impact within the scoring plane to an accuracy of 95% ± 5%. The projectiles sensed must be correctly located within the pre-defined distance/direction (r = Δ) zone(s) in which they impact, to an accuracy of 95% ± 5%. These accuracies must be maintained throughout all sensing/scoring exercises; any deviation from these accuracy requirements during any single firing run/pass is unacceptable.

The range system must be capable of collecting and recording data from each individual target and up to a minimum of six targets simultaneously.

The range system must be capable of collecting and recording data simultaneously from ten targets.

An individual scoring system, major components of which are listed in Paragraph l.c., above, must be capable of operating in conjunction with a minimum of five additional scoring systems on the gunnery range (six systems, total). On some tactical unit aerial gunnery training ranges, it may be desirable to place and operate up to ten scoring systems on the range. However, at no time will more than two targets on the range, and their associated scoring systems, be required to sense and score simultaneously.

Targets and any associated instrumentation must:

1. Be easy to install with little or no site preparation.
2. Be portable by medium helicopter' sling load to facilitate rearrangement of target arrays.
3. Be realistic in appearance.
4. Simple to repair and capable of individual component or module replacement.
(5) Require minimum maintenance as outlined in Paragraph 5.

(6) Require no excessive calibration prior to operation.

(7) The hit count and register central display unit must have a self-contained lighting capability for effective night operations.

m. It is essential that:

- aiming points, utilized during basic aerial gunnery (marksmanship) qualification training, must be simple, easily discernible and relatively invulnerable to catastrophic damage by weapons fire.

- tactical targets, utilized during unit (aircrew, fire-team, etc.) tactical training, must be realistic representations of combat targets, providing a means of acquisition/identification through all attack azimuths up to 360-degrees. Tactical targets must be easy to emplace on-range, must be portable by utility helicopter to facilitate replacement or rearrangement of target locations.

- all scoring components, including targets/aiming points, must be easy to install with little or no site preparation, require minimum maintenance (as outlined in Paragraph 4, below), require little or no calibration prior to operation (should operate without calibration for at least 125 hours utilization). A means must be provided at the remote central scoring center to alert operator personnel to system malfunction and to identify system malfunction. The scoring display unit must include a self-contained lighting capability for effective night operations.

n. (Essential) The system must be capable of storage and transit under the conditions outlined in AR 705-15 (i.e., Army aircraft).

o. (Essential) The system must be adaptable to various types of terrain, i.e., desert, mountain, and jungle (see Paragraph 2.f.).

p. (Desired) The system must be capable of prolonged periods of inactivity while exposed to the local environmental climate (not to exceed 30 days), without requiring extensive preparation prior to activation.

q. (Essential) The command/control system must be adaptable to the electrical power available in CONUS and overseas or be capable of operation utilizing standard U.S. Army generators.

r. (Essential) If batteries are used as power source for target arrays, they must be capable of 24-hour operation prior to recharge.
a. (Essential) The range system must be simple to establish, operate, and require a minimum of organizational maintenance (see Paragraph 5.).

b. (Essential) The system should have an expansion capability so as to accommodate future developed aerial weapons and platforms, e.g., Advanced Aerial Fire Support System.

c. (1) The system must provide a scoring capability which will support individual qualification training and unit tactical training in the Model AH-56A (Advanced Aerial Fire Support System). To effectively score weapons systems of the AH-56A, and to incorporate into gunnery training the full capability of these weapons systems, it is essential that the scoring system be capable of operation at variable attack azimuths through 360-degrees.

(2) The scoring data receiver/display unit, located at a site remote from the target range, should provide a means to interface with an external automatic data recorder. This capability permits permanent logging of student, crew and/or unit gunnery performance data and subsequent monitoring or analyses of qualification criteria.

d. (Essential) The hit count and register central display unit should be capable of being mounted in the back of a standard U.S. Army 3/4-ton vehicle or 3/4-ton trailer (1/4-ton truck or 1/4-ton trailer desired).

e. (Essential) The system will have a minimum acceptable mean-time-between-failure of twenty hours under relatively heavy usage conditions.

f. The scoring system, not including targets/aiming points, must provide a minimum mean-time-between-failure (MTBF) of 1200 hours, and a maximum mean-time-to-repair (MTTR) of 30 minutes. The MTBF does not consider component failures caused directly by weapons fire damage.

2. Supporting Justification and Data:

a. Reasons for Requirement:

(1) As the helicopter is employed as an aerial platform for a variety of weapons systems, a formal program for the initial training and/or qualification of armed aircraft crews is required. Training programs must develop and maintain skills in target acquisition, identification, neutralization, and destruction. This new equipment will greatly reduce the time now required to train individual aviators in air-to-ground gunnery techniques. Substantial savings will result in a reduction expected, helicopter flight time reduced and overall student training efficiency increased.

(2) Current ranges used for this helicopter gunnery training utilize old ground-to-ground scoring techniques which require that scoring be accomplished by a "shoot and count holes" procedure or in-flight observation. The former is time-consuming and requires the range to be closed while personnel
(3) A range system is required by U.S. Army Aviation School and other commands with armed aircraft which will have the capability of accurately detecting target hits and near misses and displaying these data at a central location. These range systems will be authorized in Department of the Army Tables of Allowance (TA 232) of Army Aviation Training Centers in Continental United States and overseas, and will be utilized in the training of Army armed aircraft crews in order to:

(a) Provide for a more efficient utilization of personnel and aircraft involved.

(b) Expedite and improve the quality of initial crew training in armed aircraft.

(c) Improve the method of analyzing the armed aircraft crew proficiency (annual qualification).

(d) Improve all current scoring methods.

(e) Improve current range operating efficiency.

(4) Maintenance Concept. Organizational maintenance personnel should be able to accomplish the majority of the maintenance of this system on site. Such organizational maintenance should be restricted to minor, readily accomplished repairs, so that it will not interfere with the training program. Mechanisms requiring repair beyond the scope of organizational maintenance should be removed on site and evacuated through normal maintenance channels to the appropriate Direct, General or Depot maintenance facility. It is expected that a minimal training program for organizational maintenance personnel on the electronics portion of this device will be required. Maintenance functions will be accomplished by military personnel of MOS series 353 (Electronic Instrument Repairman) or equivalent DA civilian personnel. The maintenance required (all categories) for the Range System will not exceed one hour for each ten hours of training under normal circumstances. One hour of maintenance for twenty hours of training is desired.
DATA ANALYZE
APV'S AIRCRAFT QUALIFICATION RANGE SCORING SYSTEM

CONTRACT NO: N61339-69-C-0172-1

DATA ANALYSIS

1. Range Characteristics
2. Scoring Characteristics
3. Data Display
4. Data Transmission
5. Training Use
6. Miscellaneous
<table>
<thead>
<tr>
<th>ITEM</th>
<th>FORT MACARTHUR</th>
<th>FORT BENNING</th>
<th>SCHOOL</th>
<th>HMMWV</th>
<th>CDC</th>
<th>MCT</th>
<th>MINIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1 Range Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4000m X 2500m</td>
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<td></td>
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<td></td>
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### Remarks

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**REMARKS**

- Only when smart missiles used with point fire weapon (R.F.), vector is desired.

Pt. Rocker/Pt. Stewart

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**Legend:**
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- **Desired**
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**Remarks**

75/76
| ITEM | FORT MACPHERSON | FORT BENNING | SCHOOL | HAMPTON C | CDC | STE 
|------|----------------|--------------|--------|------------|-----|------
| 2-6 Mixed Weapon Scoring | | | | | | 
| Yes | X | X | | | | 
| Sequential/Simultaneous | Sin | Sin | Seq | | | 
| If Sequential, Time Between Employment | | | | | | 
| Different Targets Simultaneously | X | X | X | | | 
| 2-7 Power Supply | | | | | | 
| Commercial | X | X | | | | 
| Generator | X | X | | | | 
| Battery | X | X | | | | 
| Most economical Other maintainable | | | | | | 
| 2-8 Accuracy | | | | | | 
| 0-15M ± 2% | X | 100% | 90% | 100 | | 
| 15-30M ± 10% | X | 100% | | | | 
| Implications or Individual Round Scoring Accuracy | | | | | |
### RANGE SCORING SYSTEM

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**Remarks**

On sequential scoring, time between target engagements can be 1 second.

((Ft. Rucker/Steinert) Although scoring accuracy should be 90-95%, the most important requirement is one of repeatable performance bias, from student to student.)
## Scoring Plane

### Referenced Vertically
- Point of Reference Above Ground
- Point of Reference at Ground

### Referenced Horizontally
- Point of Reference Above Ground
- Point of Reference at Ground

## Lethality Criteria for Determination of Hit/Miss for Ordnance from 2.75"

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Minimum range is 300 to 500 meters in all cases.

Maximum range is the same as either maximum effective range of weapon or range limits, whichever is least.
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REMARKS

- 35° 15°
- 15° 60°
- 20° 80°
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See notes.
(RmKRO) - "Extremely desirable to provide scoring data to firing student immediately, whether by read-out onboard aircraft or immediate communication."
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- **School - No requirement to score**
- Familiarization training.

- **Pt. Stewart does not conduct door-gunner training.**
## DATA SHEET
**ARMED AIRCRAFT QUALIFICATION RANGE SCORING**

**CONTRACT NO.: N61339-69-C-0178**

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**Contract NjO.:** 73139-69-6-0178

**AAC:** HEARST BIBLE SCHOOLS/HRSC/RQ CDC/STEWART

- **2 Air.**
- **01 Air.**
- **01 Other**
- **01**

**Note:**
- All components, including down range, must provide minimum life (vulnerability) of 125 hours.
- Essential, no down range calibration within 125 hour limit - Desire self-test feature by operator & display.
- Maximum down range calibration is monthly.
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Remarks:
- Electronic component.
- Min range, must reliability of 100.
- Duration within test feature by.
- On is monthly.

93/94
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**Data Sheet**

**Armed Aircraft Qualification Range Scor**

**Contract No.:** 461239-69-C-0178

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95/96
NAVTELEGRAM 69-C-0178-1

FOLLOWING MILITARY INSTALLATIONS WERE VISITED

LOCATION: 3rd U.S. Army - Headquarters
            Ft. McPherson, Atlanta, Georgia
Date: Monday, 21 April 1969

LOCATION: 10th Aviation Group
            Fort Benning, Georgia
Date: Tuesday, 22 April 1969

LOCATION: U.S. Army Aviation School
            Ft. Rucker (Ft. Stewart Representatives)
Date: Wednesday, 23 April 1969

LOCATION: Headquarters, Continental Army Command (CINARC)
            Ft. Monroe, Virginia
Date: Thursday, 24 April 1969

28 Personnel
**FIELD TRIP CONFERENCE**  
(Attendees)

**LOCATION:** 3rd U.S. Army - Headquarters  
Pt. McPherson - Atlanta, Georgia  
**DATE:** Monday, 21 April 1959

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<td>BAARINC</td>
<td>Project Scientist</td>
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<td>Wally Brondstatter</td>
<td>Civ</td>
<td>DMEL</td>
<td>Program Manager</td>
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<tr>
<td>William D. Proctor</td>
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<td>Chief, Aviation DIVN &amp; AVN Officer 3rd Army</td>
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<td>Lauren S. Davis</td>
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<td>GCS - O &amp; T (AVN)</td>
<td>Chief, AVN Tng. Ops. &amp; Plans Brach</td>
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# NAVTRADEVCTR 69-C-0178-1

**CONCEPT FORMULATION STUDY:**

(AIRCRAFT QUALIFICATION RANGE ESCAPE SYSTEM)

Ref: Contract 61339-69-C-0178

**FIELD TRIP CONFERENCE**

(Attendees)

**LOCATION:** 50th Security Group
St. Mary's, Georgia

**DATE:** September 1971

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99
# RAVTRADECN 69-C-0178-1

## Concept for Evaluation Study

(Air Force Aircraft Qualification Range Scoring System)

Ref: Contract D1339-69-C-0178

### Field Trip Conference

(Attendees)

**U.S. Army Aviation School**

**Location:** Ft. Mustle (Lt. General's Representatives)

**Date:** Wednesday, 2 April 1970

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Page 100
CONCEPT FORMULATION STUDY:
(AIRCRAFT QUALIFICATION RANGE SENSING SYSTEM)  
Ref: Contract NS1332-69-C-0172

FIELD TRIP CONFERENCE  
(Attendees)

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<td>Intg., Ops, Eng. Officer</td>
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DATE: 4/25/69  
LOCATION: Continental Air Terminal (CI)
APPENDIX C
FUNCTIONAL ANALYSIS

1. INTRODUCTION

1.1 How the Task 2 Study is Organized

The functional formulation task starts with a statement defining what task the range scoring system is expected to perform in support of the overall Army Armed Aircraft Military Mission. This becomes the statement of requirement leading to a description of the operational function the system is required to perform. A system description, in engineering terms, derived from system function will be prepared (Tasks 3, 4, 5, 6, and 7). Tradeoff studies of "off-the-shelf hardware" will be conducted to determine how well a selected configuration combination matches the needed system requirement. Finally, a recommended best technical approach statement will be prepared. This may include a recommended program for a hardware development if it becomes apparent that currently available equipment will not suffice.
Throughout the study attention will be continually directed toward:

- Feasibility
- Mission effectiveness
- Cost of ownership
- Cost effectiveness
- Availability
- Reliability and maintenance

1.2 Study Rationale

Provide a specification for a range scoring system that most closely matches the requirement in all respects. Over-design of hardware is to be avoided in all cases to preclude purchase of overpriced, over-complicated hardware. Inadequate design is likewise to be avoided to obviate inadequate performance.

1.2.1 Background

In order to satisfy the foregoing, it was first necessary to establish what task the range scoring system is expected to perform for the user. The SDR analysis has been completed and user agencies have been contacted to ascertain the training requirements by training phase. Results of this combined analysis, starting with the mission objective of armed aircraft gunnery training programs, are stated in the succeeding paragraphs.
2. **MISSION (OBJECTIVE)**

U.S. Army armed aircraft individual familiarization and qualification training, unit qualification and tactical training using simulated targets and gunnery scoring methods.

3. **FUNCTION**

When the mission is broken down into first level functions, two significant categories emerge: (1) individual familiarization and qualification; (2) unit qualification and tactical training. The two functions are mutually dependent.

Figure 1 shows the overall armed aircraft gunnery training mission broken down into training functions.

3.1 **Individual Training**

Figure 2 shows the individual training requirements broken down to scoring systems functions.
Overall Training Mission
Requirements and Function

- INDIVIDUAL QUALIFICATION
  - INDIVIDUAL FAMILIARIZATION
  - UNIT TACTICAL TRAINING (INCLUDES POTENTIAL FOR MULTIPLE FIRE TEAMS)

- PERFORMANCE PARAMETERS
  - SPEED/RANGE
  - TYPE OF AIM
  - FIRING AZIMUTH AND ELEV.
  - WEAPON SEQUENCE
  - FIRING

- AIRCRAFT + ARMAMENT

- TRAINING MISSION

- TRAINING FUNCTION

- REQUIREMENTS
FIGURE 2
Individual Training Requirements and Scoring System Function

ELEMENTS
- RANGE SIZE & LAYOUT
- TRAINING CRITERIA
- PROFICIENCY RATING CRITERIA

INDIVIDUAL TRAINING REQUIREMENT
(a) FAMILIARIZATION
(b) QUALIFICATION

GUNNERY SCORING SYSTEM FUNCTION
- TRANSMISSION OF DATA
- DISPLAYING OF SCORE
- RECORDING OF DATA
3.1.1 Familiarization

Objective: to familiarize the individual with the aircraft ordnance under in-flight conditions. Both day and night operations are included. The student is schooled to get the "feel" of the aircraft and its armament in a live ammunition firing situation. Primary grading is on his performance in following prescribed operating procedures, and safety criteria. Equipment malfunction (both simulated and real) is included, and improvisation techniques are graded.

An aiming point is provided; however, the student is not expected to provide accurate fire during this phase.

3.1.1.1 Method of Scoring

We concur with the Training Command's conclusion, as stated in Department of the Army Publication 1-40, that the instructor pilot scoring by manual notation will suffice during this phase of training.

3.1.2 Qualification

Objective: to develop the student's proficiency in placing accurate fire on the target. Both day and night operations are included. Primary grading should be on his ordnance delivery proficiency and accuracy.

3.1.2.1 Method of Scoring

An accurate measure of qualification level per student can be established when standards are well defined and tests become independent of individual interpretation.

Following gunnery familiarization training and starting with the qualification phase for Individual Training, the scoring task becomes more stringent, demanding precise assessment of target kill potential. A machine scoring system is essential during this phase of training in order to establish a uniform method of proficiency rating not open to individual interpretation.
3.1.2.2 Targets

A most important criteria is establishment of target standardization. The targets provided for individual qualification should be point of aim, semi-fixed, multiple target complexes on a typical firing range. Figures 3, 4, 5, and 6 describe circular and elliptical fire dispersion patterns. Reference Appendix IV for target dimensions and layout.

3.1.2.3 Armament

- Rapid fire (6,000 rounds per minute) machine guns - 7.62 mm, 5.56 mm.
- 50 caliber machine guns
- Rockets and missiles (2.75 to 6 in)
- 40 mm grenade launcher
- 20 mm and 30 mm automatic guns

Inert rounds as well as HE and tracer will be employed during the training phase.

All ordnance except the TOW and M-22 (wire-guided) missiles are classified as "area weapons." TOW and M-22 are "point of impact weapons."

3.1.2.4 Scoring

The scoring system sector coverage from the target forward direction has been stated as being ± 45° in azimuth and 0° to 30° vertical elevation.

Accuracy of projectile or burst count (for rapid fire weapons) should be 95% ± 5%.

Calculations for elliptical patterns are contained in Appendix I.
Figure 4
Projection of Trajectory Normal
Dispersion onto Ground Plane

141-2-144R3, "Hit Probabilities in the Elliptical Normal Case Considering Angle of Attack," June,
1963.
Figure 5
Estimated Hit Zone for
7.62 mm Machinegun

U.S. Army Aviation School, Fort Rucker,
Alabama, April, 1953.
Over, short, left, or right to locate mean point of impact "miss location" is the coverage required in the horizontal plane at ground level for area weapons; "Point" type weapons require the same coverage in the vertical plane. Only hits within the pre-defined target zone must be scored (counted). Misses in "over/short"-"left/right" zones need not be scored. (See Appendix IV.)

3.1.2.5 Scoring Sensor(s)

The sensor(s) installed at the target site must be capable of responding to a rate of fire 6,000 rounds per minute. The rate of information transmission to display and recording instruments can be as low as a rate determined by dividing two times the shortest burst duration a gunner is able to fire (human reaction time) into a unit of elapsed time; i.e., 1 sec/0.25 = 4 per sec.

3.1.2.6 Data Transmission and Display

Human factors engineering studies indicate the fastest response to perform this function is in the order of 1/4 second. Therefore, the information data rate of 10 words per second for each target will suffice. (See Appendix II, Scoring Rate.)

Scoring and miss data may be transmitted via buried hard-wire cable or wireless telemetry from targets to display units in the control tower. Each target should be displayed individually. Individual target data need to be transmitted via wireless telemetry to the firing aircraft where the instructor pilot can select and display the target being engaged, if it is within the capability or physical limitations of the aircraft. Maximum delay time between projectile impact and display is 250 milliseconds (as requested by Training Commands).

3.1.2.7 Recording

Scoring of ordnance by type and by firing aircraft for interweave aircraft firing runs by four aircraft in a race track pattern is possible on
each range must accompany the scoring records. This may be accomplished by various means such as a voice or tone index that identifies firing aircraft, target engaged, run number, and ordnance used.

Automatic recording of scoring data is virtually essential due to the large volume of data to be handled plus the need for precise measurement of student gunnery proficiency during the qualification phase.

3.1.2.8 Power

Power for instrumentation at the target site may be supplied via underground cable along with a hard-wire telemetry cable. (Note: Training Commands are opposed to batteries.)

3.2 Unit Training

Figure 7 shows the unit training requirements broken down to scoring systems functions.

3.2.1 Unit Tactical Training

For unit tactical training the basic scoring equipment functional and performance requirements for individual qualification can be used if additional capabilities are added. These are:

1. Increase sensor coverage from 90° azimuth to 360°. (Provided the range can accommodate an uncontrolled approach up to 360°.) (Figure 3)

2. Provide wireless telemetry from target with a range of 30,000 meters.
(3) Provide self contained air transportable scoring system, including power source, Reference Appendix IV.

(4) Increase scoring rate (system wide) to 24,000 rpm.

(5) Provide scoring for simultaneous fire with mixed weapon fire from single or multiple aircraft, in addition to automatic sorting of firing A/C.

3.2.2 Unit Qualification and Multiple Team Fire

Unit qualification and multiple unit firing does not require additional scoring capability beyond that required in Individual Training.

3.3 Sequence of Occurrence and Conceptual Flow Diagram

Figure 9 describes the sequence of information flow.

Figures 10 and 11 show samples of the next lower level flow diagram and the associated data rate.

4. RELIABILITY

Reliability is of paramount importance to successful employment of any scoring system. If confidence in reliable performance is low, the entire gunnery mission will suffer; therefore, reliability becomes a key consideration in systems cost effectiveness. The burden of any added expense incurred by slowing down gunnery training due to poor reliability must be charged to the system.
FIGURE 9
Sequence of Occurrence

- ON-BOARD DISPLAY
- RECORDING
- INFORMATION RETRIEVAL
- RELAY TO AIRCRAFT
- DISPLAYING
- DATA TRANSMISSION
- SENSING
- TARGETING FUNCTION

*SCORE HIT COUNT
* IN-ZONE EFFECT
* SECTOR IMPACT DATA
Reliability of the candidate equipment will be analyzed during Task 4 to determine performance conformity to MIL-STD 785. A further requirement requested by user agencies is 1200 hours mean time between failure for the entire system. All components downrange, (in the vicinity of the target), must provide unattended service, including vulnerability, of at least 120 hours range operation time.

5. **MAINTAINABILITY**

Ideally, a system should require no maintenance; however, in real systems this becomes virtually an impossibility. The maintenance effort required must be kept as low, simple, and as infrequent as possible.

Modular construction where system major components may be replaced quickly and easily has been employed successfully in many cases. Modular construction is included as part of the scoring systems study.

A maintainability plan should accompany the system during the hardware design conceptual phase.

Upon delivery and installation of any scoring system, a maintainability demonstration should be required. A maintenance training syllabus should also be included as part of the deliverable end product.
Maintainability of the candidate equipment will be analyzed during Table 4 to determine adherence to MIL-STD-470 and -471. In addition, the user agencies require a maximum time of 30 minutes for maintenance or replacement of all downrange equipment. Level of skill required to maintain, "trouble shoot," and replace damaged or defective subsystems is limited to standards of field organizational maintenance personnel. Major repairs or maintenance will be accomplished at a general or depot maintenance facility.

6. SCORING SYSTEM "TRADE-OFF" OF REQUIREMENTS

Figure 12 describes the system functions in order of importance, Level 1 being the most important. The most important functions are to sense hits, score hits versus rounds expended, provide an aiming point, and to display these data at the range central control station and in the aircraft for the benefit of the instructor pilots.

The next most important function is to provide miss distance information by 1 and 3 zones.

Data transform, transmission methods, and recording for post-operative review are considered as lower level since these parameters, although important, do not constitute the fundamental function of range scoring.
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<thead>
<tr>
<th>Level 1</th>
<th>Sensing hits</th>
<th>Scoring</th>
<th>Displaying</th>
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<table>
<thead>
<tr>
<th>Level 2</th>
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<table>
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<th>Data transmission</th>
<th>Data recording</th>
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<td>• Sorting of ordnance</td>
<td>• Rate</td>
<td>• Information storage and retrieval</td>
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<tr>
<td></td>
<td>• Sorting of firing A/C</td>
<td>• Method</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Format</td>
<td></td>
</tr>
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</table>
APPENDIX I

PROBLEM STATEMENT

In general, if \( f(X, Y) \) represents the probability density for random ground impacts for a given weapon type, and if \( f(X, Y) \) can be transformed into the probability density \( h(r, \phi) \) in polar coordinates, then the probability of an impact occurring in a circle of radius \( r_o \) is given by the expression

\[
P(r_o) = \int_0^{2\pi} \int_0^{r_o} g(r, \phi) \, dr \, d\phi.
\]  

(1)

In a true exterior ballistics problem, the weapon rarely impacts with the ground at a \( 90^\circ \) angle. Therefore, it seems reasonable to assume that the distribution about the expected trajectory may be elliptical normal, where the probability density is given by

\[
f(x, y) = \frac{1}{2\pi} \frac{1}{\sqrt{2\xi ^2 + 2\eta ^2}} \exp \left( -\frac{\xi^2 + \eta^2}{2\xi ^2 + 2\eta ^2} \right).
\]  

(2)
Here, $X$ is measured in the range direction, $Y$ in the deflection direction, and $u_x = u_y = 0$. The angle of impact, $\theta$, is now defined by the tangent to the trajectory at the point of impact. Furthermore, $\sigma_x$ and $\sigma_y$ should be dependent in some sense upon the trajectory length, but independent of each other.

The problem then becomes one of mapping the probability density $f(X, Y)$ onto the ground plane, transforming the new function to polar coordinates, and then integrating over circles of various radii.

**PROBLEM SOLUTION**

The ground impact probability density is obtained by letting

$$X = u \sin \theta$$

and

$$Y = v.$$  \hspace{1cm} (3)

The probability density for $u$ and $v$ then becomes

$$g(u, v) = \frac{\sin \theta}{2 \pi x \sigma_x \cdot y} e^{- \frac{u^2 \sin^2 \theta}{2 \sigma_x^2} - \frac{v^2}{2 \sigma_y^2}}.$$ \hspace{1cm} (4)
it is seen that \( y(u, v) \) is also an elliptical normal distribution in \( u \) and \( v \) with

\[
\sigma_u^2 = \left( \frac{u}{\sin \theta} \right)^2
\]

and

\[
\sigma_v^2 = \sigma_y^2.
\]  

(5)

The usual transformation to polar coordinates,

\[
r \sin \phi = v/\sigma_v
\]

and

\[
r \cos \phi = u/\sigma_u
\]  

(6)

yields the resulting probability distribution of impacts on the ground as

\[
h(r, \phi) = \frac{r}{2\pi} e^{-r^2/2}.
\]  

(7)

It is desired to integrate the function \( h(r, \phi) \) over circles of various radii and for selected values of \( k = \tan \theta \). The detailed numerical integration procedures appear in another paper. Reference BAARINC "Hit Probabilities in the Elliptical Normal Case Considering Angle of Impact, Part II: Theoretical Considerations," report to U.S. Naval Weapons Laboratory, Dahlgren, Virginia, June 1963.
APPENDIX II

1. **Rapid Scoring Rate**

Maximum scoring rate may be limited to the human factor reaction time of the gunner. A gunner under the most favorable environment with fast reflexes cannot be expected to react (fire the weapon in the shortest burst possible) faster than approximately 1/4 second. Therefore, for rapid fire weapons (greater than 500 rpm) single projectile scoring may not be required. (Example: 6000 rpm, 1/4 second burst = \( \frac{6000 \times 0.25}{60} \) or 25 shells fired; [240 rpm].)

**Statistically, the probability of hit (S/N) for 95 percent confidence level is 14%.** If four gunners are firing at a single target during unit training, each at an individual rate of 240 rounds/minute (rpm), then:

\[
4 \times 240 \times 0.44 = 522.4 \text{ hits/minute}.
\]

Scoring count accuracy = 95% ± 5%.

\[
\frac{522.4}{0.90} = 574 \text{ rpm maximum rate, (100% ± 10%) or } \frac{1}{0.90} = 110\% \text{ for worst case.}
\]
2. CONCLUSION

An arbitrary maximum scoring rate per target of 600 per minute with a command accuracy of 95% ± 5% may suffice, provided an individual round history is not required at the display site.
1. DISCUSSION OF DESTRUCTIVE
   FIRE IN A TARGET AREA

   Using a hypothetical model for purposes establishing downrange
   equipment (targets and sensors etc.), maximum destructive fire over a
   120-hour range operating time at eight hrs/day is as follows:

   (1) Stated survivability: 120 hours unattended performance.

   (2) Predicted target hits are based on the performance
       envelope of the Advanced Aerial Fire Support System
       (AAFSS).

   (3) Other considerations:
       (a) Four (4) aircraft firing in racetrack pattern
       (b) Two flights each per day for five days
       (c) Duration of each flight - airborne for three hours
       (d) Firing run time - 1-1/2 hours per flight
       (e) Time per lap - 10 minutes
       (f) Six (6) targets per range (two point plus four area).

   (4) AAFSS armament total maximum rounds per flight and two
       flights per day in two different configurations (same
       aircraft).
### Morning Flight Inventory (assumed)

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<th>Weapon Type</th>
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### Afternoon Flight Inventory (assumed)

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### Total Rounds Carried - Five (5) Days of Flight

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<td>2,010</td>
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<td>780</td>
</tr>
<tr>
<td></td>
<td>152</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

16,522 x 5 = 82,760 total rounds fired per week per aircraft

Point 2 x 5 = 10 total rounds fired per week per aircraft
120 hours total = 3 weeks
3 hits/day x 5 days/week.

Total Rounds/Number of Targets

Weapon Type
Area \[ \frac{82,760 \times 4 \times 3 \times 0.6^2}{4} = 124,140 \text{ hits (120 hrs)} \]
Point \[ \frac{10 \times 4 \times 3 \times 0.7^2}{2} = 42 \text{ hits (120 hrs)} \]

By providing separate targets for point and area weapons, it should be possible to enhance target survivability.

Following this argument to its logical conclusion suggests that some measure of ordnance sorting is automatic since one type target is used for "point" weapons, the projectile is all being supersonic; and, another type target is used for "area" weapons consisting of both supersonic and subsonic projectiles.

* For purposes of estimating, a 50 percent hit probability for all area weapons rounds fired is assumed. Actual experience suggests a hit probability of less than 10 percent; however, this can be expected to improve through the use of machine-scoring systems in artillery training. A 70 percent hit probability is assumed for point weapons.

** Assumes uniform density over the entire target area.
APPENDIX IV

DISCUSSION OF VERTICAL AND HORIZONTAL TARGET ZONE DIMENSIONS

1. POINT WEAPONS ZONE DIMENSIONS

The solution of vertical target zone size is relatively simple. A circular target area comprising the cone of fire circular normal dispersion is usually considered a target "hit" zone. All rounds passing within an impact area have to be sensed and scored.

Rounds which pass the target at any greater radial distance are classified as misses. Since target criteria for direction of miss is limited to "over", "under", "left", or "right", it is only necessary to provide instrumentation that will sense the miss in quadrants. The target zone may be arbitrarily reduced in size and shaped to conform to a realistic silhouette for some phases of training.

Probably the best solution for Individual Training would be to restrict the radial distance (starting at target center) to some arbitrary value which approximately duplicates a realistic target size.

For Unit Training on "point" weapons, the most desirable solution would be to construct the "hit zone" in the same configuration as real targets (tanks, vehicles, etc.). Any departure will result in
establishing an unrealistic target; i.e., either rounds that would normally be hits would be classified as misses, or rounds that are actually misses would be counted as hits. The degree of discrepancy depends on the relationship of real target geometrical boundaries deviation from a circle.

2. **AREA WEAPONS ZONE DIMENSIONS**

The horizontal target zone for area weapons is a difficult problem since the shape is elliptical due to the plane change from circular cone of fire to horizontal impact zone. The width and length of the elliptical "beaten zone" are both variables, depending principally on gun-to-target range, attack angle, and stability of the firing platform.

**Three solutions are possible:**

1. **Construct an elliptical target** at ground level to sense and count impacts within the target geometry; or

2. **Use an offset vertical circular sensing zone system** and count the rounds passing through this zone area; or

3. **Choose an arbitrary shape similar to the unit training realistic targets**, modified for ease of installation, replacement, etc.

The problem of providing a continuously changing target beaten zone is very complex, requiring equipment sophistication well beyond that needed for gunnery training. (1)
Use of the offset vertical aiming zone requires a continuously changing dimension of sensor-to-aiming point and a coupled plane change from near-vertical to near-horizontal orientation. (2)

Since proficiency rating is a hit percentile against the norm for classes of students, it is not necessary to score every round that would impact in the beaten zone for given angles of attack and range. It is only necessary to score on the percentage of hits to rounds expended, student versus student; therefore, the size and shape of scoring area become arbitrary. The target shape in the horizontal plane should be similar to that encountered in unit training, modified in dimension to conform to an easily handled size. (3)

A circular target will generally meet these requirements with the added advantage of closely relating to explosive warhead effective burst radii (circular).

Once a target shape and dimension is chosen it should not be altered; otherwise the proficiency rating standards will become obsolete and invalid. It is necessary to count all rounds that hit within this area. It is not essential to locate a mean point of impact within the "hit" area. Conversely, it is essential to locate the mean point of impact outside this envelope. (It has been stated that mean point of impact by clock position and zone is required for misses.) If two zone depths are to be
cluded, each should be one-half the maximum radial miss distance equipment sensitivity limits minus the "hit" zone radius from target center; however, analysis of the purpose and use of the information derived on "hit area" suggests that "miss" scoring by quadrant instead of clock position, will suffice.

The miss zone sector becomes four pie-shaped wedges 45 degrees wide, starting at the exterior limits of the hit zone.

3. CONCLUSION

For individual training, separation of point and area weapons targets into two separate targets would be the simplest solution; all other considerations being equal.

For unit training, a natural separation does occur, because ordnance is applied for target type. (Example: Vehicles—point weapons and personnel—area weapons.)

Point Weapon Targets for General Unit Training

Hit zone - circular arbitrary size approximates "real" target size; plus miss scoring in four quadrants.
Area Weapon Target Dimensions - Individual Training

Hit zone - circular or some other arbitrary shape. Dimension chosen on the basis of convenience of target erection, etc.

Miss zone - sectored: Four quadrants ("over, short, left, or right").

Horizontal Target Dimensions - Unit Training

Same as Individual Training.
TECHNICAL DATA

BA-1  MIL-T-10043921C
      Contract No.1339-69-C-0178

BA-2  MANUAL 4120.3-M
      Standardization Policies, Procedures & Instructions

BA-3  NAVFTR TR-573
      Cooperative Doppler Scoring System Study

BA-4  NAVWEPS RPT 6674
      Design for a Laser Rangefinder

BA-5  BRL HOP No. 1409
      A Microwave Modulation Telemetering

BA-6  AF MANUAL 50-13
      Weapons Ranges

BA-7  TECH. MR-10 11-55
      Transducer Techniques for Measuring the Effect of
      Small-Arms Noise on Hearing

BA-8  TC 1-22
      Rotary Wing A/C Gunner Armament Sub-System, Helicopter,
      7.62mm Machinegun (M-6 Series) Quad Gun

BA-9  NAVTRADECN STD 115
      Environmental Testing of Training Devices Designed for
      Use in Field Exercises & Installation on Military Vehicles

BA-10  AMC REGULATION NO. 70-30
       Research & Development-Concept Formulation—Prerequisites
       to Initiating Engineering or Operational System Develop-
       ment Effort

BA-11  AD NO. 465235
       Acoustic Amplification in III-V
       Compounds (Second Interim Report)

BA-12  AD NO. 465234
       Acoustic Amplification in III-V
       Compounds (First Interim Report)

BA-13  AD-245-555
       Electronic Control & Guidance Division Report or Experimental
       Investigation of a Miss-Distance Indicator Using Radioactivc
       Techniques

BA-14  AD-413-231
       Instrument Operations on Test Department Ranges
| BA-15 | Feasibility Study of Stabilizing the Line of Sight of an Automatic Miss Distance Indicator for Tanks |
| BA-16 | ST 1-100-1 Reference Data for Army Aviation in the Field Army |
| BA-17 | FM 17-36 Divisional Armor and Air Cavalry Units |
| BA-18 | TM9-8920-210-14 Targets, Target Material, and Training Course Layouts |
| BA-19 | TOE 1-111T (Test) Special Army Training Test 1-111 (TOE 1-111T) |
| BA-20 | TOE 1-111T (Program) Special Army Training Program 1-111 (TOE 1-111T) |
| BA-21 | FM 1-40 Attack Helicopter Gunnery (Illustrations) |
| BA-22 | FM 1-40 Attack Helicopter Gunnery (Text) Volume 1 of 2 |
| BA-23 | FM 1-40 Attack Helicopter Gunnery (Text) Volume 2 of 2 |
| BA-24 | AD 465 673 Propagation of Sound in Air-A Bibliography with Abstracts |
| BA-25 | Gunnery Instructor Pilot Handbook |
| BA-26 | 67-285-40 UH-1 LP Gunnery Qualification Course |
| BA-27 | 9-68 Program of Instruction for OH-58 Transition/Gunnery IP Qualification Course |
| BA-28 | 4-68 2C-715 Program of Instruction for AH-1G (Navy Cobra) Pilot Transition/Gunnery Course |
| BA-29 | 5-68 2C-714 Program of Instruction for AH-1G (Navy Cobra) Instructor Pilot (Transition/Gunnery) Qualification Course |
| BA-30 | J-69 2C-719 Program of Instruction for UH-1 Pilot Transition Course (Navy) |
FAVTRAD/VCEN 69-C-0178-1

BA-31  7-68  630-67120
Program of Instruction for UH-1 Repair Course

BA-32  2-69  2C-F9
Program of Instruction for (Wire Guided Missile) M22 Gunnery Qualification Course

BA-33  1-69  2C-1931-C/2C-0622-B
Program of Instruction for Officer/Warrant Officer Rotary Wing Aviator Course

BA-34  2-69  2C-1931-D/2C-0622-B
Program of Instruction for Officer/Warrant Officer Rotary Wing Qualification Course (Active Army)

BA-35  3-69  2C-1931-A/2C-0622-A
Program of Instruction for Officer/Warrant Officer Rotary Wing Qualification Course (Reserve Component/Allied)

BA-36  2-69  2C-F3
Program of Instruction for UH-1 (Iroquois) Instructor Pilot (Transition/Gunnery) Qualification Course

BA-37  12-68  2C-F13
OH-6 Transition/Gunnery IP Qualification Course

BA-38  LOH-IP
Gunnery Qualification Course
Flight Syllabus & Standardization Guide

BA-39  3,160,415
Strafing Target Using Schlieren Effect

BA-40  3,147,335
Optical Miss-Distance Indicator

BA-41  3,201,791
Near Miss-Distance Scoring System Using Doppler Effect
This Electromagnetic Pulse-Doppler Scoring System was designed primarily for use with airborne targets and has been produced for the U.S. Army and Air Force. Although the scoring principles used in this system could satisfy a number of the functional requirements of the Armed Aircraft Qualification Range Scoring system, limitations in the following areas have been defined:

- **Scoring Radius**: Limited to 50 feet
- **Accuracy**: Adequate only with large caliber weapons
  - Two square feet radar cross section or more
- **Caliber/Type Weapon**: No capability with 5.56 or 7.62mm
- **Vector**: No vector information provided
- **Data Display**: No real-time hit, miss and vector data displayed
- **Malfunction/Damage Alarm**: None

See Worksheet "A"
This system which is under development for the U.S. Army is designed to sense misses of projectiles from flechette to 40mm in size and the point-of-impact for 40mm grenades surrounding a personnel type target. Application of this system to the functional requirements of the Armed Aircraft Qualification Range Scoring System leaves deficiencies in the following general areas:

Scoring Radius: Limited to 20 meters
Accuracy: Unstated (developmental system)
Caliber/Type Weapons: Limited to projectiles 5.56 to 40mm
Data Display: No real time display of hit-miss or vector data
Vector: No vector data provided
Malfunction/Damage Alarm: None

See Worksheet "A"
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<th>Model</th>
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<td>(USA)</td>
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<td>Pulse-Doppler</td>
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** Primarily Air-to-Air and/or Ground-to-Air.**
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**Radio**
- 9/5 ZC 2.75 Zone
- Vector
- HE - Inert
- Subsonic

**HE**
- 100 Cal.
- 2.75 Zone
- HE - Inert
- Subsonic

**Zones**
- 2.75 Zone
- 100 Cal.

**Radio**
- 9/5 ZC
- Vector
- HE - Inert
- Subsonic

**HE**
- 100 Cal.
- 2.75 Zone
- HE - Inert
- Subsonic
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<th>1710-1850 MHz</th>
<th>30,000 RPM</th>
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<th>Intermediate Climatic Zone</th>
<th>ARMY A/C</th>
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<th>1/4 T Truck</th>
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<td>FREQUENCY BAND</td>
<td>TRANSMISSION RANGE</td>
<td>DATA DISPLAY</td>
<td>DATA RECORDING CAPABILITY</td>
<td>ENVIRONMENTAL CHARACTERISTICS</td>
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<td>(USA)</td>
<td>.5W</td>
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<td>TM &quot;S&quot; band</td>
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<td>Not stated</td>
<td>Computer</td>
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<td></td>
<td>15 + miles</td>
<td>inputs</td>
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<td>TTY</td>
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<td>UNIT A/C</td>
<td>Aiming Pt and 3-D Tactical</td>
<td>0° to 80°</td>
<td>360° Unit</td>
<td>Minimum</td>
<td>Minimum</td>
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<td>3/4 T Truck</td>
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<td>Tactical</td>
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<td>PORTABILITY</td>
<td>MTBF</td>
<td>TARGET TYPE</td>
<td>DIVE ANGLE</td>
<td>AP ROACH</td>
<td>VULNERABILITY</td>
<td>TARGET SITE</td>
<td>DISPLAY SITE</td>
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<td>EQUIP. WT.</td>
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<td>Aerial directional</td>
<td>Omni-directional</td>
<td>Antennas</td>
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<td>1200</td>
<td>tow target bunker</td>
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<td>1200+</td>
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<td>A Antennas</td>
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<td>Remaining target site equipment protected</td>
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<td></td>
<td>10#</td>
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<td>SYSTEM MANUFACTURER</td>
<td>POWER TARGET SITE</td>
<td>110VAC</td>
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<td>Sub-sonic</td>
<td>Super-sonic</td>
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<td>24-32VDC</td>
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<td>500/5000</td>
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<tr>
<td>(USA)</td>
<td>60Hz</td>
<td>Doppler</td>
<td>ft/sec</td>
<td>Lots of 20</td>
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**Technical Summary**

**The -Shield" Scoring Systems**

**Qualification Range Scoring Systems**

(Work Sheet)

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Worksheet "A"
(Cont'd)
TECHNICAL ANALYSIS
OF
MISS DISTANCE ACOUSTIC DETECTOR
SFENA MODEL MAE 12B

This acoustic (amplitude) system was designed primarily for use with
aerial targets and has been in use by the French Air Force and Army
for several years. The principles of operation and scoring methods
used are adaptable to the Armed Aircraft Qualification Range Scoring
System but in many regards are not compatible with its functional
requirements. The major diversions are as follows:

Scoring Rate: Not stated

Scoring Radius: Limited to 4.5 meters

Accuracy: Not stated

Caliber/Type Weapon: Used with 50 caliber and 30mm only
(supe-onic)

Vector: No vector information provided

Number of Targets per System: Limited to 1 target per
system

Simultaneous Multiple Type Weapons: Limited to 1 type
of weapon

See Worksheet "B"
This electromagnetic scoring system was designed for use with a single personnel type target. It is based on the pulsed doppler radar principle, amplitude intensity. This system's characteristics, when applied to the functional requirements of the Armed Aircraft Qualification Range Scoring System are inconsistent in many respects. Major inconsistencies are as follows:

- **Scoring Radius**: Limited to 4 meters
- **Caliber/Type Weapons**: Limited to 5.56mm to 50 caliber
- **Zone/Vector**: No vector data provided
- **Horizontal/Vertical Plane**: Half hemisphere only each plane
- **Data Display**: No special display for real time readout
- **Approach Azimuth**: 0 - 180°
- **Malfunction/Damage Alarm**: None
- **MTBF**: 100 hours

See Worksheet "B"
This electromagnetic scoring system is designed for air-to-ground strafing use. It is based on the pulsed doppler radar principle, amplitude intensity. When applied to the functional requirements of the Armed Aircraft Qualification Range Scoring System, some significant diversions are observed and follow:

- **Scoring Radius**: Limited to 20 feet
- **Caliber/Type Weapons**: 7.62mm to 40mm only
- **Zone/Vector**: Single Zone/no vector
- **Vertical/Horizontal Plane**: Vertical only (point weapons)
- **Ammo Characteristics**: Inert only
- **Data Trans Range**: 1 mile
- **Dive Angle**: Limited to between 5° and 15°
- **Approach Azimuth**: 15° - 0° - 15°
- **Vulnerability**: Due to bulk of sensing hardware, down range equipment must be protected.
- **Malfunction/Damage Alarm**: None

See Worksheet "B"
This electromagnetic scoring system was designed for use in either an air-to-air or a ground-to-air application. It gives continuous miss distance scale data and is based on the pulsed doppler correlation radar principle using pseudo-random coded phase reversal modulation techniques. Primary intended use is with missiles having a reasonably large radar cross section. The characteristics of this system when correlated with the functional requirements of the Armed Aircraft Qualification Range Scoring System reveals that some essential qualities are lacking, namely:

Scoring Rate: Approximately 860 RPM

Caliber/Type Weapon: Only missiles with 2 square feet radar reflectivity

Zone/Vector: No zone, no vector data

Malfunction/Damage Alarm: None

MTBF: 100 hours

See Worksheet "B"
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<tr>
<th>FUNCTIONAL REQUIREMENT</th>
<th>SYSTEM MANUFACTURER</th>
<th>TYPE</th>
<th>MODEL</th>
<th>STATUS</th>
<th>&quot;Off-the-Shelf&quot;</th>
<th>RATE</th>
<th>RADIUS</th>
<th>ACCURACY</th>
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<td>SFENA (France)</td>
<td>Acoustic (Amplitude)</td>
<td>SFENA</td>
<td>Production</td>
<td>24,000 RPM</td>
<td>0-5%</td>
<td>95 ± 5%</td>
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<td></td>
<td></td>
<td></td>
<td>MAE 12B</td>
<td></td>
<td></td>
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<td>2.8-4.5M</td>
<td>Not stated</td>
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<td>Sanders (USA)</td>
<td>Electromagnetic (Amplitude Intensity)</td>
<td>Rascal S</td>
<td>Production</td>
<td>20,000 RPM 20 Ft.</td>
<td>± 12</td>
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<tr>
<td></td>
<td></td>
<td>Pulsed Doppler PW 10ns X-Band</td>
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<td></td>
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<td>Electromagnetic (Amplitude Intensity)</td>
<td>Rascal-AP</td>
<td>Production</td>
<td>20,000 RPM 2 &amp; 4W</td>
<td>± 2W</td>
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<td>Pulsed Doppler 8 ns L-Band</td>
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<td></td>
<td></td>
<td>Electromagnetic</td>
<td>Rascal-M</td>
<td>Production</td>
<td>Continuous Miss Distance 0-275 Ft</td>
<td>±2.5'</td>
<td>115'</td>
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<td>Pulsed Doppler 10ns L-Band</td>
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<td>Amplitude Intensity</td>
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<td></td>
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** Primarily Air-to-Air and/or Ground-to-Air.**

*** Used primarily w/personnel type target.**
# Critical Summary

**Tiefl Scope Systems Identification Range Scoring System**

<table>
<thead>
<tr>
<th>Weert Sheet</th>
<th>7.62mm</th>
<th>40mm</th>
<th>20mm Tow</th>
<th>Zone</th>
<th>Vector</th>
<th>Vertical &amp; Horizontal Plane</th>
<th>HE-Inert &amp; Sub-sonic</th>
<th>Supersonic</th>
<th>Up to</th>
<th>Yes</th>
<th>Radio - UT Wire - IT</th>
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<tr>
<td>Not stated</td>
<td>50 cal</td>
<td>30 mm</td>
<td>2' Zone</td>
<td>Sphere</td>
<td>Super-sonic</td>
<td>1</td>
<td>No</td>
<td>TM</td>
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<td>± 12&quot;</td>
<td>7.62 to 40 mm (inert)</td>
<td>1 Zone</td>
<td>Vertical (Plane)</td>
<td>Super &amp; Sub-sonic + HE</td>
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<td>Yes</td>
<td>Coax Cable or FM/PM TM</td>
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<tr>
<td>± 2M</td>
<td>5.56mm to 90 cal</td>
<td>2 &amp; 4M Zones</td>
<td>Half Hemisphere</td>
<td>Sub &amp; Supersonic rounds</td>
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<td>Yes</td>
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<tr>
<td>±22.5'@115'</td>
<td>Missiles</td>
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<td></td>
<td>Sub &amp; Supersonic rounds</td>
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<td>FM/PM POM</td>
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<tr>
<td>±5'@115'</td>
<td>w/2 sq ft. Radar Reflect at 275'</td>
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Worksheet "B"
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<td>TRANSMISSION RANGE</td>
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<td>4 digit</td>
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<td>Zone</td>
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<td>1/4 T Truc</td>
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*** Used primarily w/personnel type target.
### Technical Summary

**ARMS® Scoring Systems**

**Qualification Range Scoring System**

**Worksheet**

<table>
<thead>
<tr>
<th>Network-</th>
<th>ARMY A/C</th>
<th>1200 Hrs.</th>
<th>Aiming Pt &amp; 3-D Tactical</th>
<th>0° to 90°</th>
<th>45° Individ</th>
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<td>MTBF</td>
<td>Target Type</td>
<td>Dive Angle</td>
<td>Approach Azimuth</td>
<td>Vulnerability</td>
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<td>Display Site Equip. Wt.</td>
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<td>Fixed</td>
<td>1300</td>
<td>Panel</td>
<td>5 to 15°</td>
<td>15°-0°-15°</td>
<td>Must be bunkered</td>
<td>33#</td>
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<tr>
<td>(Bulls Eye)</td>
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<td>Fixed</td>
<td>100</td>
<td>Personnel</td>
<td>0 - 90°</td>
<td>0 - 180°</td>
<td>Must be protected</td>
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<td>Fixed</td>
<td>100</td>
<td>Drone aerial targets</td>
<td>All</td>
<td>0 - 360°</td>
<td>TM &amp; Antennas</td>
<td>27.5#</td>
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Worksheet "B" (Cont'd)

163/164
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<th>SYSTEM MANUFACTURER</th>
<th>FUNCTIONAL REQUIREMENT</th>
<th>24 Hrs. of Operation</th>
<th>110VAC Comm'l. or Generator</th>
<th>Minimum</th>
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<th>Super-sonic</th>
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<td>220VAC</td>
<td>50 Hz</td>
<td>Generator</td>
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<td>Sanders (USA)</td>
<td>+28VDC</td>
<td>115VAC</td>
<td>GunScope</td>
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<td>15 - 17 K</td>
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<tr>
<td></td>
<td>110VAC 60Hz</td>
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</tr>
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<td></td>
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<td>OR DAMAGE</td>
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Worksheet "B"  
(Cont'd)
NAVTRADVECO 69-C-0178-1

TECHNICAL ANALYSIS

OF

-ACOUSTIC & VIBRATION SCORING SYSTEM DA-2

DEL MAR ENGINEERING LABORATORIES

This scoring system was designed to collect both hit and miss distance data from personnel type targets when fired on with small arms (5.56mm, 7.62mm and flechette) and to collect zones miss data when fired on by 40mm grenades.

- Scoring Rate: 12,000 RPM-Hit, 6000 RPM-Miss, 500 RPM-Grenade
- Scoring Radius: 0 - 2 meters
- Caliber/Type Weapon: Small arms & 40mm Grenade
- Transmission Range: 10,000 feet
- Data Display: Computer inputs
- MTEF: 500 hours
- Attack Azimuth: Hit count panel: 0° - 60°
  All others: 360°
- Malfunction/Damage Alarm: None

See Worksheet "C"
This acoustic (amplitude) scoring system is in wide use by U.S. Navy and Air Force as an air-to-ground strafing/gunnery trainer. When comparing the operational characteristics of this system to the functional requirements of the Armed Aircraft Qualification Range Scoring System, the following inadequacies have been noted:

- **Scoring Rate:** Presently limited to 10,000 RPM
- **Scoring Radius:** Presently limited to 15 meters
- **Zone/Vector:** No multiple zone - no vector data
- **No. of Targets per System:** Limited to 1 f/simultaneous scoring
- **Simultaneous Multiple Type Weapons:** One caliber/type at a time
- **MTBF:** 700 hours
- **Data Recording:** No provisions for

See Worksheet "C"
TECHNICAL ANALYSIS

OF

ACOUSTIC SCORING SYSTEM, MODEL DA-3/E

DEL MAR ENGINEERING LABORATORIES

This fixed acoustic (amplitude) scoring system is in use at helicopter gunnery training schools of the U.S. Army. A comparison of the operational characteristics of this system with the functional requirements of the Armed Aircraft Qualification Range Scoring System reveals that it meets all requirements except the following:

- **Scoring Rate:** Up to 6,000 RPM
- **Transmission Range:** Up to 10,000 (Wire)
- **Data Display:** No vector
- **MTBF:** 700 hours
- **Zone/Vector:** Partial vector (Combination of 2 or more sensors)

See Worksheet "C"
NAVTRAD/NINC 69-C-0178-1

TECHNICAL ANALYSIS

OF

ACOUSTIC SCORING SYSTEM, MODEL DA-3/A

DEL MAR ENGINEERING LABORATORIES

This acoustic (amplitude) scoring system used by the U.S. Army for weapons system evaluation and possible training mission application. It was designed primarily for air-to-ground (helicopter) gunnery scorings. When comparing the operating characteristics of this system with the functional requirements of the Armed Aircraft Qualification Range Scoring System, limitations have been defined in the following areas:

Scoring Rate: 6,000 RPM

Zone & Vector: No vector, information data

Simultaneous Multi-Weapon: One type ammo at a time

MTBF: 700 hours

Malfunction/Damage Alarm: None

See Worksheet "C"
<table>
<thead>
<tr>
<th>FUNCTIONAL REQUIREMENT</th>
<th>SYSTEM MANUFACTURER</th>
<th>TYPE</th>
<th>MODEL</th>
<th>STATUS</th>
<th>RATE</th>
<th>RADIUS</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Off-the-Shelf&quot;</td>
<td>Del Mar Engineering</td>
<td>Acoustic</td>
<td>DA-3F*</td>
<td>Production</td>
<td>24,000 RPM</td>
<td>0-54M</td>
<td>95 ± 5 %</td>
</tr>
<tr>
<td></td>
<td>Laboratories (USA)</td>
<td>(Amplitude)</td>
<td>(3H18C)</td>
<td></td>
<td>10,000 RPM</td>
<td>Adjustable 1.5 to 15m Increments of 5 ft.</td>
<td>&gt; 95%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acoustic</td>
<td>DA-3E*</td>
<td>Production</td>
<td>6,000 RPM</td>
<td>5-50 meters</td>
<td>&gt; 95%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Amplitude) (3H18B)</td>
<td></td>
<td></td>
<td>4-20mm</td>
<td>4-15 meters Acoustically</td>
<td>&gt; 95%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acoustic</td>
<td>DA-3A</td>
<td>Pre-production</td>
<td>6,000 RPM</td>
<td>3-250 ft. (5-zone)</td>
<td>&gt; 95%</td>
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<td></td>
<td></td>
<td>(Amplitude)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>Piezo-electronic Sensor &amp; Acoustic Amp</td>
<td>DA-2</td>
<td>Production</td>
<td>12,000 RPM</td>
<td>Personnel Panel Hit</td>
<td>&gt; 98%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6,000 RPM</td>
<td>4 Zones of Miss &amp; 2 Miss at 120°</td>
<td>&gt; 95%</td>
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<tr>
<td></td>
<td></td>
<td>1 Zone Acoustic Grenades</td>
<td></td>
<td></td>
<td>300 RPM</td>
<td>1 Zone 5 Meters</td>
<td>&gt; 90%</td>
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</table>

* Has cable and/or sensor fault detection.
<table>
<thead>
<tr>
<th>ACCURACY</th>
<th>CALIBER/TYPE</th>
<th>ZONE/VECTOR</th>
<th>SENSITIVE AREA</th>
<th>CHARACTERISTICS</th>
<th>SCORING</th>
<th>HE-INERT</th>
<th>Sub-sonic</th>
<th>Supersonic</th>
<th>Up to</th>
<th>Yes</th>
<th>Radio-UT</th>
<th>Wire - IT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 95%</td>
<td>5.56 to 155mm inert</td>
<td>1-Zone</td>
<td>Radial Plane</td>
<td>90° Vert to horizontal</td>
<td>8</td>
<td>No</td>
<td>Active</td>
<td>Targets one</td>
<td>Single RF</td>
<td>Channel in a sequential firing mode</td>
<td></td>
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<tr>
<td>95%</td>
<td>5.56 to 70mm HE inert - HE</td>
<td>3 Zone on HE</td>
<td>Radial Plane</td>
<td>90° Vert to horizontal</td>
<td>3</td>
<td>No</td>
<td>Wire</td>
<td>(Comax)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>95%</td>
<td>5.56 to 155mm HE Inert - Supersonic</td>
<td>5-Zone &amp; Scalar dis- tance in feet</td>
<td>Radial Plane</td>
<td>90° Vert to super- sonic flight path</td>
<td>8</td>
<td>No</td>
<td>Same as DA-3F above</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 98%</td>
<td>All</td>
<td>Both</td>
<td>Panel</td>
<td>Hit Panel limited by computer increments</td>
<td>Wire</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>&gt; 98%</td>
<td>Small Arms</td>
<td>Radial Plane</td>
<td>0 - 2 meters</td>
<td>Input typical</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 90%</td>
<td>40mm HE Grenades</td>
<td>1 Zone</td>
<td></td>
<td>No</td>
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Worksheet C
<table>
<thead>
<tr>
<th>FUNCTIONAL REQUIREMENT</th>
<th>FREQUENCY BAND</th>
<th>TRANSMISSION RANGE</th>
<th>DISPLAY</th>
<th>RECORDING</th>
<th>ENVIRONMENTAL CHARACTERISTICS</th>
<th>PORTABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1710 - 1850 MHz</td>
<td>30,000 ft</td>
<td>3 digit</td>
<td>No</td>
<td>Full</td>
<td>MIL</td>
<td>Transporta</td>
</tr>
<tr>
<td>Del Mar Engineering</td>
<td>1710 - 1850 MHz</td>
<td>5 miles</td>
<td>NIXI</td>
<td>MIL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratories (USA)</td>
<td>Furnished w/4 select-able frequencies</td>
<td>220-240 MHz</td>
<td>5 miles</td>
<td>NIXI (Miss Provisions: Distance to tenths of ft. Available)</td>
<td></td>
<td>Transportable</td>
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</table>
### Technical Summary

#### Self Scoring Systems

<table>
<thead>
<tr>
<th>Army A/C</th>
<th>PORTABILITY</th>
<th>MTBF</th>
<th>Target Type</th>
<th>Diver Angle</th>
<th>Approach Azimuth</th>
<th>Vulnerability</th>
<th>Target Site Equipment Wt.</th>
<th>Display Equipment Wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 T Truck</td>
<td>Transportable</td>
<td>700 hrs.</td>
<td>All</td>
<td>0-90°</td>
<td>360°</td>
<td>Sensor only</td>
<td>30#</td>
<td>45#</td>
</tr>
<tr>
<td>1/4 T Truck</td>
<td>Fixed</td>
<td>700 hrs.</td>
<td>All</td>
<td>0-90°</td>
<td>360°</td>
<td>Sensor only</td>
<td>1#</td>
<td>45#</td>
</tr>
<tr>
<td></td>
<td>Transportable (Approx)</td>
<td>700 hrs.</td>
<td>All</td>
<td>0-90°</td>
<td>360°</td>
<td>Sensor only</td>
<td>30#</td>
<td>50#</td>
</tr>
<tr>
<td></td>
<td>Fixed (Approx)</td>
<td>500 hrs.</td>
<td>Personnel &amp; Panel Type</td>
<td>0-60° &amp; 0-90°</td>
<td>± 60° Hit &amp; Target &amp; Sensors</td>
<td>300#</td>
<td>Various Computer Peripherals</td>
<td></td>
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</table>

Worksheet C (Cont'd)

173/174
<table>
<thead>
<tr>
<th>FUNCTIONAL REQUIREMENT</th>
<th>24 Hrs. of Operation</th>
<th>110VAC</th>
<th>Minimum</th>
<th>Sub-sonic</th>
<th>N/A</th>
<th>Required</th>
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<tbody>
<tr>
<td>SYSTEM MANUFACTURER</td>
<td>POWER TARGET SITE</td>
<td>POWER DISPLAY SITE</td>
<td>SYSTEM SUPPORT EQUIPMENT</td>
<td>PROJECTILE VELOCITY</td>
<td>COST</td>
<td>MALFUNCTION OR DAMAGE ALARM</td>
</tr>
<tr>
<td>Del Mar Engineering</td>
<td>30 VDC Nicad Batt.</td>
<td>115VAC</td>
<td>Test Calibrator</td>
<td></td>
<td></td>
<td>$25,000</td>
</tr>
<tr>
<td>Laboratories (USA)</td>
<td>6 watts 24 hrs. @ + 25°C</td>
<td>60 W</td>
<td>Battery Charger</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>(100 watts) Test Calibrator</td>
<td></td>
<td></td>
<td>$20,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>115VAC</td>
<td></td>
<td></td>
<td>Less cable</td>
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<tr>
<td></td>
<td>30V DC 6 watts Nicad</td>
<td>115VAC</td>
<td>Test Calibrator</td>
<td></td>
<td></td>
<td>$50,000</td>
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<tr>
<td></td>
<td>6 watts 115VAC Battery Charger</td>
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<td></td>
<td>1220V 60 110V 60 Test Calibrator</td>
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<td>Igt &amp; Gun Test Set</td>
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- **Technical Off-the-Shelf Armed Aircraft Qualification Project**
- **Work Package**
<table>
<thead>
<tr>
<th>REQUIRED</th>
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<tbody>
<tr>
<td>MALFUNCTION OR DAMAGE ALARM</td>
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<p>| | | | | | | | | | |</p>
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</tbody>
</table>

Worksheet C (Cont'd)
This hit panel type scoring system was designed primarily for use on tank gunnery ranges in both a stationary and mobile configurations. Comparing the characteristics and capabilities of this system to the functional requirements of the Armed Aircraft Qualification Range Scoring System, it is evident that the following areas are not fulfilled:

- **Scoring Rate:** 60 RPM
- **Scoring Radius:** Dependent on panel size
- **Zone/Vector:** Neither is furnished
- **Data Transmission:** Wire
- **Data Display:** None
- **Dive Angle:** 0° - 60°
- **Approach Azimuth:** ± 60°
- **Malfunction/Damage Alarm:** None

See Worksheet "D"
NAVTRADEVNEC 69-C-0178-1

TECHNICAL ANALYSIS
OF
HIT PANEL SCORING SYSTEM, MODEL HT-14
SAAB AKTIEBOLAG (SWEDEN)

This hit panel type scoring system was designed for use by strafing aircraft during individual training. A comparison of this system's characteristics with the functional requirements of the Armed Aircraft Qualification Range Scoring System results in the following discrepancies:

- Scoring Rate: 9,000 RPM
- Caliber/Type Weapon: 7.62 - 40mm
- Zone/Vector: No zone, no vector
- Scoring Radius: 20 feet
- Data Transmission Range: 1000m (Wire)
- Data Recording: No provisions
- Portability: Fixed
- Dive Angle: 10° - 30°
- Approach Azimuth: ± 30
- Malfunction/Damage Alarm: None

See Worksheet "D"
This acoustic (amplitude) scoring system was designed for use with aerial targets. A comparison of this system’s characteristics with the functional requirements of the Armed Aircraft Qualification Range Scoring System results in the following discrepancies:

- **Scoring Rate:** Up to 9,000 RPM
- **Zone/Vector:** No vector data obtained
- **Simultaneous Multiple Weapons:** One type/caliber weapon at a time
- **MTBF:** Not stated
- **Malfunction/Damage Alarm:** None

See Worksheet “D”
This acoustic (amplitude) scoring system was designed for use with aerial targets. As in all acoustic (amplitude) scoring systems, a number of the requirements can be satisfied, but when the system's characteristics are compared to the functional requirements of the Armed Aircraft Qualification Range Scoring System, the following limitations are apparent:

- **Scoring Rate:** 2,000 RPM
- **Scoring Radius:** 2 - 20M
- **Accuracy:** 90%
- **Zone/Vector:** 12 zones - 4 sector under development
- **Scoring Charts:** Supersonic only (No HE or subsonic)
- **MTBF:** Not stated
- **Malfunction/Damage Alarm:** None
- **Number of Targets per System:** Limited to 1 target per system
- **Simultaneous Multiple Type Weapons:** Limited to 1 type of weapon

See Worksheet "D"
This fixed acoustic scoring system was designed for air-to-ground gunnery scoring using the amplitude principle. It has been used by the French Air Force in aerial gunnery training. When comparing the characteristics of this system to the functional requirements of the Armed Aircraft Qualification Range Scoring System, the following essential elements are,

- **Scoring Rate**: 8,000 RPM
- **Scoring Radius**: 10m
- **Zone/Vector**: No vector data furnished
- **Type/Caliber**: Up to 30mm
- **Simultaneous Multiple Type Weapons**: One caliber at a time
- **Data Transmission**: Wire only, no TM
- **Attack Azimuth**: $\pm 20^\circ$
- **Dive Angle**: $10 \pm 5^\circ$
- **Malfunction/Damage Alarm**: None
- **Number of Targets per System**: Limited to 1 target
- **Data Recording**: No provisions

See Worksheet "D"
<table>
<thead>
<tr>
<th>System Manufacturer</th>
<th>Type</th>
<th>Model</th>
<th>Status</th>
<th>Rate</th>
<th>Radius</th>
<th>Accuracy</th>
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</thead>
<tbody>
<tr>
<td>Del Mar Engineering (USA)</td>
<td>Vibration</td>
<td>X3A109/1</td>
<td>Production</td>
<td>60 RPM</td>
<td>Panel</td>
<td>95% for 30 to 200 rockets f per sq.ft. area</td>
</tr>
<tr>
<td></td>
<td>Sens. Target</td>
<td></td>
<td></td>
<td></td>
<td>7.5 x 7.5</td>
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</tr>
<tr>
<td>SAAB Aktiebolaget (Sweden)</td>
<td>Hit Panel</td>
<td>HT-14</td>
<td>Production</td>
<td>9,000 RPM</td>
<td>20 x 11</td>
<td>94 - 96%</td>
</tr>
<tr>
<td></td>
<td>(Piezo Elec</td>
<td>Sensor)</td>
<td></td>
<td></td>
<td>5 + 4 Panels</td>
<td>each w/sensor</td>
</tr>
<tr>
<td></td>
<td>Acoustic</td>
<td>ET-23</td>
<td>Production</td>
<td>Up to 9,000 RPM</td>
<td>1-1/2&quot; to 30&quot;</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>(Amplitude)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Production</td>
<td>2,000 RPM</td>
<td>2 to 20 M</td>
<td>80 - 90%</td>
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<td>Air Target Ltd.</td>
<td>Acoustic</td>
<td>AS-100</td>
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<tr>
<td>Aeronic AB (Sweden)</td>
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<td></td>
<td>Production</td>
<td>8,000 RPM</td>
<td>0-34-7.62</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0-10M 30mm</td>
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<tr>
<td>SPHMA (France)</td>
<td>Acoustic</td>
<td>MAE SPHMA</td>
<td>Production</td>
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</tr>
<tr>
<td></td>
<td>(Amplitude)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90%</td>
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</table>

** Primarily Air-to-Air and/or Ground-to-Air.
<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Caliber/Type</th>
<th>Zone/Area</th>
<th>Sensitive Area</th>
<th>Characteristics</th>
<th>Number of Targets</th>
<th>Simultaneous Multiple Type Weapons</th>
<th>Data Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>90% for SA</td>
<td>556 to 8</td>
<td>7.5 x 7.5'</td>
<td>Hit Panel</td>
<td>8</td>
<td>Yes</td>
<td>Wire</td>
<td></td>
</tr>
<tr>
<td>90% for large rocket distribution</td>
<td>155 mm Separate Panels or Personnel</td>
<td>Target</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1' 90% - 99%</td>
<td>7.62 - 40mm</td>
<td>1-Zone Panel Area</td>
<td>Pre Amplifier Adjusted for 1 or 2 different calibers</td>
<td>No</td>
<td>(20 conductor) Wire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td>7.62mm to 76mm Inert</td>
<td>Zone Radial Plane 3 Zone</td>
<td>Adjustable (2 HF Frequencies)</td>
<td>No</td>
<td>Radio</td>
<td></td>
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</tr>
<tr>
<td>90%</td>
<td>7.62mm to no limit</td>
<td>Both Radial Plane Supersonic</td>
<td>Projectile</td>
<td>No</td>
<td>TM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td>7.62mm 30mm higher</td>
<td>1-Zone Radial Plane</td>
<td>No</td>
<td>Direct Burial Cable</td>
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Worksheet "D"
## TECHNICAL SUPP

"OFF-THE-SHELF" SCORE

ARMED AIRCRAFT QUALIFICATION

(WORK SHEET)

<table>
<thead>
<tr>
<th>FUNCTIONAL REQUIREMENT</th>
<th>1710 - 1890 MHz</th>
<th>30,000 ft</th>
<th>Hit, Miss &amp; Vector</th>
<th>Yes</th>
<th>Intermediate Climatic Zone</th>
<th>3/4 T True</th>
<th>1/4 T True</th>
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</thead>
<tbody>
<tr>
<td>SYSTEM MANUFACTURER</td>
<td>FREQUENCY BAND</td>
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Worksheet "D" (Cont'd)
TRADE-OFF ANALYSIS

1. TASK IV

The objective of Task IV is to evaluate and validate candidate hardware systems applicable to the requirements for the Armed Aircraft Qualification Range Scoring System.

The selection of hardware is accomplished by relating hardware functional performance and design features in matrix form on the summary trade-off sheets prepared from data derived from Tasks I, II, and III.

During Step 1 the essential parameters functional and design requirements are entered under "nomenclature" on the summaries. These data resulted from the analysis of Task II wherein the system functional requirements were established, independent of available equipment considerations.

Step 2 identifies criticality of candidate systems hardware parameters and each is listed in descriptive form opposite the functional requirements.
Step 3 is the evaluation phase of this task. It is the initial step in evaluating systems effectiveness (part of the cost/effectiveness analysis). In Step 3, the term Functional Operational Adequacy ($F_o$) is introduced.

**Functional Operational Adequacy**

Functional Operational Adequacy ($F_o$) is defined as the difference between Functional Requirement ($F_r$) and Systems Functional Capability ($F_c$). (i.e., a system whose functional adequacy exactly matches the requirement is neither over-designed, nor under-designed.)

In order to provide the most accurate appraisal and to minimize influencing bias, the candidates were broken down into major subsystems functional descriptions.

In arriving at $F_o$, each major subsystem is evaluated separately using the trade-off summary sheets. Comparative rankings are graded using the schedule:

- 3 = Meets requirement
- 2 = Partially meets requirement or partially over-designed
- 1 = Does not meet requirement or grossly over-designed
- 0 = Does not meet requirements in any respect.
Ratings for each subsystem are calculated on total points scored/total points achievable. Weighting of individual subsystems will follow the established hierarchy of importance.

**Level 1** = 50 percent (sensing, scoring, displaying)

**Level 2** = 25 percent (mean point of impact for miss + $r$ and $g$

**Level 3** = 25 percent (data transform, data transmission, targeting, recorder output features)

Thus, rating value $\times$ level of importance = weighted score. The total Score $F_o$ is the sum of the subsystems weighted scores during the projected systems life cycle in years $\left( \sum_{n=1}^{y} \right)$.

Figures E-1 through E-3 are the completed trade-off summary sheets.
TRADE-OFF WORK SHEETS

The following pages contain the trade-off work sheets with critical parameters, functional and technical design requirements entered. Accompanying each work sheet is a short summary statement amplifying the most significant parameter entries. Targets and recorders are excluded in the rankings primarily because these equipment are not normally supplied as part of the basic scoring systems hardware inventory. These items are included in the trade-off work sheet descriptive section for two reasons: (1) for completeness of description, and (2) because of their impact on the functional interfaces with each system.

1. TARGETS - INDIVIDUAL TRAINING

It is essential in Individual Training to provide a well-defined aiming point for two types of weapons. "Point" weapons require a vertical aiming point at some distance "d" above ground level. The "area" weapons require a horizontal aiming point at ground level with an arbitrary "point" area. The angle of attack may range from 0° to 30° elevation with the weapon platform and ± 45° sensitivity in the firing vector.
Targets for Individual Training comprise a complex made up of both types. Up to six (6) target complexes should be provided on each gunnery range.

The target site is semi-permanent, prepared in advance. Target repair or replacement time is limited to 30 minutes. Each target should provide survivability of 120 hours of unattended performance. It is estimated that the point weapon target will sustain approximately 42 "hits" for each 120 hours of range operation time; and that the area weapon target can sustain up to 124,000 hits in each 120 hours of operation if the target area is large (~1500 meters$^2$) and the gunnery is exceptionally accurate (50 percent "hits"). Total "hits" are primarily a function of target area and gunner accuracy.

1.2 TARGETS - UNIT TRAINING

It is essential that the targets for Unit Training be realistic, simulating combat and tactical vehicles, crew-served ground weapons, and personnel. Up to 10 targets per range may be employed. The scoring system for unit training targets must provide coverage for 360° in azimuth and 0° to 80° dive angle.

Targets must be air transportable for either repair/replacement or relocation to any one of up to 20 previously prepared sites.
Target repair or replacement time is limited to 30 minutes.

The target complex must be self-contained, including power.

Modular construction is essential for maintenance and repair.

Each target should provide a survivability of 120 hours unattended performance, including survival from ordnance fire.

1.3 SENSING - INDIVIDUAL AND UNIT TRAINING

Sensors and associated electronics located at the target complex must be capable of 120 hours of range operation including survivability from ordnance fire.

For Individual Training the required sensitive region is ±45° in a direction facing the firing weapon, and 0° to 80° elevation above the ground. Sensor coverage for Unit Training encompasses 360° in azimuth and dive angle from 0° to 80° elevation. Point weapon sensing is:

1. "Target" zone hit count (scoring)

2. Over/short, left/right zone coverage for misses and direction information.

Area weapons fire is sensed in the horizontal plane referenced to an aiming point (see Appendix IV). Therefore, an arbitrary area within the beaten zone must be sensed and scored. Misses occurring...
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outside the zone must be detected, the mean point of impact automatically determined, and data derived for zone and over/short or left/right zone.

Maximum sensing rate is 24,000 rounds per minute (both subsonic and supersonic, inert and high explosive projectiles).

Maximum range of sensitivity from target center is three times the maximum effective fire radius of ordnance being fired.

Sensors must be compatible with target power systems.

1.4 DATA CONVERSION SYSTEM

Must be able to accept raw data from sensors and convert to hit count (score) plus r and s information on misses. This function is first order data reduction for transmission to the balance of the system.

Converters must be extremely stable, contributing less than one-tenth percent error to the scoring system. Data rate input is up to 400 bits per second.

1.5 DATA TRANSMISSION (Target to Control)

Data transmission system should be essentially noise-free with an accuracy of at least 99.9 percent.

201/202
<table>
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- **Approach 2:** SBR 65, 0.3, 75, 50, 30, 20, 15, 10, 5, 2
- **Approach 3:** SBR 65, 0.3, 75, 50, 30, 20, 15, 10, 5, 2
- **Approach 4:** SBR 65, 0.3, 75, 50, 30, 20, 15, 10, 5, 2
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<td>AIR PARK-ET</td>
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<td>A-150</td>
<td>MAE-14</td>
<td>MAE-14</td>
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<td>Distance in Degrees</td>
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</tr>
<tr>
<td>Height</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16</td>
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</table>
It must have linear response over the operating range and be capable of transmitting all data at a rate commensurate with the balance of the scoring system.

The system needs to be essentially maintenance-free (MTBF 1200 hours).

Minimum cross-talk between channels is essential.

It is desirable that the transmission system require zero calibration. It must present a proper impedance match for input and output interfaces.

Note:

1. If data conversion is provided at the target site the information rate per function drops from a maximum of 400 hits per second to 10 bytes per second (see data conversion) (a separate trade-off analysis may be performed to compare transmission with conversion versus transmission without).

2. For individual training the using Training Command suggests a buried hard-wire power and data link.

3. For Unit Training it is concluded that wireless transmission is required because of the need for single package portability for relocation.

Range: 50,000 meters.
A continuous display of the data and operational status of each target is required in the range control center.

The display system requires a built-in scoring (hit count) register and visual display of these data. Data should be stored until reset is activated. Manual reset functions after each target engagement should be incorporated. In addition, $r$ and $s$ information on target misses must be displayed. The format must be easily read, requiring no interpretation on the part of the operator.

The display system needs to be easy to operate. It should be of modular construction and be easy to maintain by field organizational maintenance personnel.

The display function should also incorporate the buffer function of converting sensor-derived information to hit count plus zone and sector information for score recording and for remote display units if required.

The display system should incorporate system test and calibration features. Equipment should be operable from either 60 cycle 110 volt or 24 volt direct current track power (commercial power or mobile in order to achieve the greatest flexibility).
<table>
<thead>
<tr>
<th>APPROACH 11</th>
<th>APPROACH 12</th>
<th>APPROACH 13</th>
<th>APPROACH 14</th>
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</thead>
<tbody>
<tr>
<td>DEL MAR</td>
<td>SAAB 109</td>
<td>SAAB 109</td>
<td>AIR TARGET</td>
<td>SPNA 14</td>
<td>JOANEL</td>
</tr>
<tr>
<td>NLA 109</td>
<td>HT-14</td>
<td>HT-21</td>
<td>AS-100</td>
<td>MAE 14</td>
<td></td>
</tr>
</tbody>
</table>

- No display: No output to user, no display or target warning.
- Yes - targets 1-8: Yes, targets 1-8.
- Yes: Modular construction.
- Displays hits, 2-digit: Displays hits, 2-digit.
- Displays hits on 2-digit counters: Displays hits on 2-digit counters.
- Displays hits on 2-digit counter: Displays hits.
- Not displayed: Not displayed.
- No provisions: No provisions.
- Yes, not provided: Yes, not provided.
- Yes, not provided: System go signal.
<table>
<thead>
<tr>
<th>APPROACH 1 - SENA</th>
<th>APPROACH 15 - JOSELI</th>
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<th>Comparative Rankings</th>
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<td></td>
<td></td>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16</td>
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<tr>
<td>Display Hits</td>
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<td></td>
<td>9 0 1 2 0 0 2 2 2 0 0 2 2 2 2 2</td>
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**Notes:**
- W - 110 V AC or 110 V DC
- No - None
- 12 - 12 volt battery
- 00 - No damage alarm
- 01 - Low battery alarm
- 02 - Low battery alarm
- 03 - No damage alarm
- 04 - No damage alarm

*Comparison Table*
It may be desirable to incorporate multiple target displays in a single unit. This should be considered in the trade-off analysis.

For automatic weapons, only the mean point of impact is required for establishing the direction and zone location reference point on target misses. This becomes an averaged value over some discrete interval of time. One-tenth second has been arbitrarily chosen (less than one-half shortest burst duration for rapid fire weapons). The display-buffer unit should contribute less than 0.1 percent error to the scoring system.

1.7 DATA TRANSMISSION TO FIRING AIRCRAFT

Target data information transmission to firing aircraft is only required for individual qualification training and proficiency rating.

Information on all targets on the range should be transmitted to firing aircraft during individual qualification training.

If data conversion and reduction is performed by ground equipment the band-pass requirement is greatly reduced. Example: assuming 10 bytes/second for \( x - x' \) data and 10 bytes, second for \( y - y' \) plus total bit count \( \approx 20 \) bytes per second for each target \( x \) targets \( \approx 120 \) bytes/second. A 240 Hz band pass would be more than ample.
The data transmission system should be kept as simple as possible and utilize equipment common to the aircraft as possible. Example - use one channel of existing communications equipment.

1.6 DISPLAYING IN AIRCRAFT

The displaying of target information on a selective basis in the aircraft for the benefit of the instructor pilot is essential during individual qualification. This comprises both score- and target miss-type information.

The requirement for display capability is limited to one target at a time (target engaged). Therefore the instructor pilot should be able to select any one of the six targets on the range.

The aircraft display unit should be kept as simple as possible and require no modification to the aircraft. The display must be readable under all lighting conditions normally encountered during aircraft operation.

In view of the limitations for modification to Army aircraft, the on-board display system will have to be a self-contained, self-powered unit issued to an instructor pilot for the training mission. Weight should be five pounds or less. Package size and shape should be easily operated and carried (hand-held).
1.9 RECORDING

Only the scoring data (hits) from each target need to be recorded. Some means for aircraft identification, firing run number, and target being engaged need to accompany the record for post-operational evaluation.

2.0 SCORE

Individual scores are based on the following schedule:

In production = 3 points
Pre-production = 2 points
Developmental = 1 point

Closest approach to:

24,000 rpm = 3 points
16,000 rpm = 2 points
8,000 rpm = 1 point

Closest approach in range to:

54 m = 3 points
36 m = 2 points
18 m = 1 point
Closest accuracy to

- 95 percent = 3 points
- 85 percent = 2 points
- 80 percent or less = 1 point

Projectile sensing:

- All = 3 points
- Two-thirds = 2 points
- One-half or less = 1 point

Zone/vector sensing:

- Zone plus vector = 3 points
- Vector only = 1 point
- Zone only = 1 point

Multiple fire:

- Mixed with sorting = 3 points
- Mixed - no sorting = 2 points
- One type only = 1 point
Range in meters (FT):  

- 20,000 to 30,000 m = 3 points  
- 10,000 to 20,000 m = 2 points  
- 10,000 m or less    = 1 point  

All other categories are based on subjective judgment of how near the requirement is fulfilled.

2.1 RANKING $F_o$

In arriving at a total score the telemetry to the aircraft and display in the aircraft are included in the rankings. No single "off-the-shelf" hardware system includes these features. These deficiencies are factored into the total score for each candidate system in order to establish the value of $F_o$ relative to an optimized system that satisfies all requirements. Eighteen points are added to the sensing/displaying score potential (50 percent weight factor) for the aircraft display rating. Parameters considered are: hit display, miss display, target identification, ease of operation, power, and portability, each worth three points.

In a similar manner, data transmission to the aircraft is included in the total potential score (25 percent weight factor). Parameters considered are: transmission means and range; added points are six.
Table 1 is a tabulation of the weighted scores ($R_o$) resulting from evaluation and comparison of "off-the-shelf" hardware systems with the optimized requirement (Task II). The most significant value is the highest percentage.
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<td>.30</td>
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</table>
System References 3, 4, 7, 8, 9, 12, 13, 14, and 16 and 17.

It can be concluded that the highest ranking system only meets 43 percent of the actual functional requirements.

As the cost/effectiveness analysis proceeds, it is expected that the most acceptable system or systems will be more clearly indicated.
The objective is to define a recommended system with full consideration for concept integration, performance, and cost estimate. Required is a cost effectiveness evaluation of all candidates compared to an optimized set of requirements.

**COST/EFFECTIVENESS**

Cost/effectiveness analysis is normally defined as Life Cycle Costs in dollars, normalized for each of the candidate systems, divided by the effectiveness of a system, a qualitative assessment expressed in numerical terms.

LCC includes cost of all elements pertaining to acquisition and use of candidate systems. Examples are development costs, system costs in production, installation costs, maintenance costs, training costs of personnel to be able to operate and maintain the system(s), logistics costs including system spares, utilization costs accumulated for support of the weaponry training program such as aircraft operating.
To construct a complete costs analysis of candidate scoring systems would require answers in the following specific parameters:

(1) Discounted life-cycle cost
(2) Discount factor applied from base year
Number of years over which costs are accumulated
Number of years life for each system
Development cost of the system
Initial investment cost of candidates
Cost of operation (annual) for each system
Cost of spares
Number of military officers receiving training and average salaries plus allowances
Number of aviation instructors required to conduct initial training on systems
Duration of initial training session
Number of students per class
Number of classes per instructor
Number of depot personnel requiring training
Average salary plus allowances of depot personnel
Estimate of time required to reach a prescribed level of training without system
Estimate of time required to reach a prescribed level of training with candidates by candidate
Estimate of R&D required to improve system to meet requirements
Estimate of cost of ultimate system (in production)
Estimate of annual savings in manpower through use of ultimate system
Estimate of cost of spares in ultimate system
(22) Cost of aircraft operation/training period
(23) Cost of expendables/training period
(24) Cost of range operation per hour or per year
(25) Etc.

Answers to many of the questions on cost are not readily available and are beyond the scope of this contract to develop.

Therefore, the cost model will be constructed as follows. The candidate system normalized cost analysis in dollars will be constrained to cost per system in production ($N_p$) + development cost (if applicable) ($N_d$) + estimated annual maintenance cost ($N_m$) + estimated cost of installation ($N_i$) + estimated annual operating costs ($N_o$) for

$$Y \sum_{N=1}^{Y}$$

**Effectiveness**

Effectiveness is a figure of merit usually derived from a qualitative analysis expressed in numerical terms. Normally, a mathematical model is used for rating and ranking candidate systems. The model is constructed using identified critical parameters. In application, the end product achieved through intended use of scoring systems or methods is a level of proficiency ($P_o$) achieved by an individual.
student graded against a form times the number of student(s) trained during the lifetime of the system for all candidate systems.

\[ \text{Eff} = P_o N \]  

(2)

The absolute value of \( P_o \) is currently poorly defined. Unit proficiency is likewise poorly defined and measured using current methods.

Some other method for evaluating "effectiveness" had to be determined during the course of this study. (For purposes of evaluation the proficiency term \( P_o \) is assumed to be uniform "student-for-student" and "unit-for-unit" at end of qualification regardless of the scoring system or method used.

The term \( N \) is also substituted.

Effectiveness for purposes of evaluation during this study will consider only \( F_o, A_o, U_o \).

Functional operation adequacy \( F_o \) has been previously defined.

Operational availability, \( A_o \) is defined as:

\[ A_o = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR} + \text{MLDT}} \]  

(3)
\[ \text{MTBF} = \text{Mean time between failures} \]
\[ \text{MTTR} = \text{Mean time to repair} \]
\[ \text{MLDT} = \text{Mean logistics downtime} \]

The utilization factor \( U_o \) for the systems, is the yearly hours of use divided by annual range operating time in hours:

\[
U_o = \frac{S_o}{R_o}
\]  \hspace{1cm} (4)

where

\[ S_o = \text{Estimated systems operational hours of use (potential)} \]
\[ R_o = \text{Total range operational time (range availability)} \]

The measure of effectiveness can now be expressed as:

\[
\text{Eff} = F_o A_o U_o
\]  \hspace{1cm} (5)

**SUBSTITUTED COST/EFFECTIVENESS MODEL**

\[
C/E = \sum_{N=1}^{Y} \left( \frac{N_o + N_i + N_f + N_l + Y}{F_o A_o U_o} \right)
\]  \hspace{1cm} (6)
The lowest figure of C/E will have the highest figure of merit. In addition to the Cost/Effectiveness Analysis, completion of Task V will include preparation of a performance specification, cost estimates, and schedule base on utilization of "off-the-shelf" hardware.

Table 1 derived from Appendix J cost estimates provides a summary of estimated dollar values for the cost model:

\[
Y = \sum_{N=1}^{N} (N_d + N_p + N_i + N_o + N_n)
\]

where \( y = 10 \) years for all systems. (Note: During analysis of systems costs in Appendix J candidates 1, 2, 3, 5, 6, 10, 11, 12, and 16 were eliminated.) Normalized values referenced to $1,00 are tabulated in the bottom column of Table 1.

Table 2 provides values of \( A_0 \) for each candidate based on Equation (3). The term MTTR was redefined to Mean Time To Restore instead of the classical Mean Time To Repair, since it is meaningless to estimate repair on systems that have virtually no history of extended operational use. Conversely, it is reasonable to estimate restoration time for the same systems. A basic assumption in establishing values of \( A_0 \) is that all failed modules replaced will not be repaired. (The cost of parts (modules) replaced as included in the cost analysis.)
<table>
<thead>
<tr>
<th>Candidates</th>
<th>No. 4</th>
<th>No. 7</th>
<th>No. 8</th>
<th>No. 9</th>
<th>No. 13</th>
<th>No. 14</th>
<th>No. 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development Cost ($N_d)^#</td>
<td>840,000</td>
<td>705,000</td>
<td>530,000</td>
<td>960,000</td>
<td>255,000</td>
<td>425,000</td>
<td>830,000</td>
</tr>
<tr>
<td>Production Cost ($N_p)^#</td>
<td>58,000</td>
<td>60,250</td>
<td>49,000</td>
<td>78,000</td>
<td>19,500</td>
<td>32,250</td>
<td>56,500</td>
</tr>
<tr>
<td>Installation Cost ($N_i)^#</td>
<td>3,500</td>
<td>250</td>
<td>5,750</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>5,750</td>
</tr>
<tr>
<td>Annual Operating Cost ($N_o)^#</td>
<td>8,000</td>
<td>8,000</td>
<td>8,000</td>
<td>8,000</td>
<td>8,000</td>
<td>8,000</td>
<td>8,000</td>
</tr>
<tr>
<td>Annual Maintenance Cost ($N_m)^#</td>
<td>4,800</td>
<td>2,400</td>
<td>2,000</td>
<td>2,400</td>
<td>2,400</td>
<td>2,400</td>
<td>2,400</td>
</tr>
<tr>
<td>Estimated Cost Totals</td>
<td>80,950</td>
<td>42,000</td>
<td>39,275</td>
<td>46,825</td>
<td>31,600</td>
<td>35,000</td>
<td>42,425</td>
</tr>
<tr>
<td>Normalized Value</td>
<td>$8.10</td>
<td>$4.20</td>
<td>$3.93</td>
<td>$4.68</td>
<td>$3.16</td>
<td>$3.50</td>
<td>$4.24</td>
</tr>
</tbody>
</table>

# Derived from Appendix B.
* Includes spares.
<table>
<thead>
<tr>
<th>Candidates</th>
<th>MTBF(1) Hours</th>
<th>MTTR(2) Hours</th>
<th>MLDT(3) Man-hours/Year</th>
<th>Total</th>
<th>One failure each 120 hours</th>
<th>Mean time to replace. Assumes 25 failures per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4</td>
<td>1200</td>
<td>52</td>
<td>26</td>
<td>1278</td>
<td>.94</td>
<td>.99</td>
</tr>
<tr>
<td>No. 7</td>
<td>1200</td>
<td>13</td>
<td>0</td>
<td>1239</td>
<td>.94</td>
<td>.99</td>
</tr>
<tr>
<td>No. 8</td>
<td>1200</td>
<td>13</td>
<td>26</td>
<td>1225</td>
<td>.94</td>
<td>.99</td>
</tr>
<tr>
<td>No. 9</td>
<td>1200</td>
<td>13</td>
<td>26</td>
<td>1239</td>
<td>.94</td>
<td>.99</td>
</tr>
<tr>
<td>No. 10</td>
<td>1200</td>
<td>13</td>
<td>26</td>
<td>1225</td>
<td>.94</td>
<td>.99</td>
</tr>
<tr>
<td>No. 13</td>
<td>1200</td>
<td>13</td>
<td>26</td>
<td>1239</td>
<td>.94</td>
<td>.99</td>
</tr>
<tr>
<td>No. 14</td>
<td>1200</td>
<td>13</td>
<td>26</td>
<td>1239</td>
<td>.94</td>
<td>.99</td>
</tr>
<tr>
<td>No. 15</td>
<td>1200</td>
<td>13</td>
<td>26</td>
<td>1239</td>
<td>.94</td>
<td>.99</td>
</tr>
</tbody>
</table>
The utilization factor, $U_0$, (Equation (4)) for each remaining candidate is shown in Table 3. Annual hours of useful service for each candidate are calculated based on total range time less the estimated time to start up and shut down the scoring system.

The yearly range operating time (3220 hours) assumes 5 days per week, 14 hours per day in two shifts, and 50 weeks per year less 250 hours for contingencies (lost time due to range operational problems).

Table 4 summarizes the cost/effectiveness model,

$$C/E = \sum_{N=1}^{N=10} \left( \frac{\text{Normalized Cost}}{F_0 \cdot A_o \cdot U_o} \right)$$

for candidates 4, 7, 8, 9, 13, 14, and 15. The lowest "dollar" value is the most cost/effective system.
### Table 3
Utilization Analysis

<table>
<thead>
<tr>
<th>Candidates</th>
<th>No. 4</th>
<th>No. 7</th>
<th>No. 8</th>
<th>No. 9</th>
<th>No. 13</th>
<th>No. 14</th>
<th>No. 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Hours of Useful Service (assumes no failures) ($S_o$)</td>
<td>2600</td>
<td>2800</td>
<td>3000</td>
<td>2800</td>
<td>2800</td>
<td>2800</td>
<td>3000</td>
</tr>
<tr>
<td>Annual Range Operating Time (14 hours/day - 5 days/week - 50 weeks/year) ($R_o$)</td>
<td>3220</td>
<td>3220</td>
<td>3220</td>
<td>3220</td>
<td>3220</td>
<td>3220</td>
<td>3220</td>
</tr>
</tbody>
</table>

\[ U_o = \frac{S_o}{R_o} \]

<p>|   | .75 | .83 | .93 | .88 | .88 | .88 | .93 |</p>
<table>
<thead>
<tr>
<th>Candidates</th>
<th>No. 4</th>
<th>No. 7</th>
<th>No. 8</th>
<th>No. 9</th>
<th>No. 13</th>
<th>No. 14</th>
<th>No. 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_0$</td>
<td>.34</td>
<td>.43</td>
<td>.41</td>
<td>.40</td>
<td>.35</td>
<td>.38</td>
<td>.28</td>
</tr>
<tr>
<td>From Table 1 - Appendix E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_0$</td>
<td>.94</td>
<td>.86</td>
<td>.99</td>
<td>.86</td>
<td>.86</td>
<td>.86</td>
<td>.93</td>
</tr>
<tr>
<td>From Table 2 - Appendix G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$U_0$</td>
<td>.75</td>
<td>.88</td>
<td>.93</td>
<td>.88</td>
<td>.88</td>
<td>.88</td>
<td>.92</td>
</tr>
<tr>
<td>From Table 3 - Appendix G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost (normalized)</td>
<td>$8.10$</td>
<td>$4.20$</td>
<td>$3.93$</td>
<td>$4.68$</td>
<td>$3.16$</td>
<td>$3.50$</td>
<td>$4.24$</td>
</tr>
<tr>
<td>From Table 1 - Appendix G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product of</td>
<td>$F_0 \cdot A_0 \cdot U_0$</td>
<td>.24</td>
<td>.32</td>
<td>.38</td>
<td>.50</td>
<td>.26</td>
<td>.29</td>
</tr>
<tr>
<td>$C/E = \frac{\text{Normalized Cost}}{F_0 \cdot A_0 \cdot U_0}$</td>
<td>$33.75$</td>
<td>$13.12$</td>
<td>$10.34$</td>
<td>$15.60$</td>
<td>$12.16$</td>
<td>$12.06$</td>
<td>$15.96$</td>
</tr>
</tbody>
</table>
CONCLUSION

1. Candidate 8 at $10.34 is the best choice with candidate 14 at $12.06 following in second place. The separation between these two candidates is quite significant.

2. The effectiveness of candidate 8, currently configured, meets about 38 percent of the optimum systems effectiveness requirements. (Average : 29 percent.)

3. Selection of a system based on the combination of earliest capability and best cost/effic vein would place the order of preference:

   - Candidate 8 = best choice
   - Candidate 14 = second best choice
   - Candidate 13 = third best choice
I PROGRAM PLAN

Purpose of the Study

Tasks to be Accomplished

Program Schedule

II ACCOMPLISHMENTS DURING THE REPORT PERIOD

A. Requests for Technical Data from All Known Scoring System Manufacturers

B. Requests for Technical Document and Studies Relative to Scoring Systems

C. Field Visits to Military Installations

D. Completion of SDR Review (Task 1)

E. Started Preliminary Functional Analysis and Requirement Allocation Effort (Task 2)

F. Started Preliminary Identification, Analysis and Development of Applicable Off-the-Shelf Systems and State-of-Art Technology (Task 3)
III  PROBLEM AREAS

A. Anticipate Problem in Obtaining In-Depth Information From Equipment/Component Manufacturers (Including Cost Ranges)

B. Input Data for Cost Effectiveness

IV  WORK TO BE ACCOMPLISHED BEFORE NEXT TECHNICAL REPORTING CONFERENCE

A. Complete Tasks 2 and 3

B. Initiate Task 4

V  WORK STATUS

Approximately 28% of work effort has been accomplished.
To: Department of the Navy
Naval Training Device Center
Orlando, Florida 32813

Attention: Mr. K. W. Peterson, Code 371
Project Engineer
Army Participation Group

Reference: Contract N61339-69-C-0178,
Armed Aircraft Qualification Range Scoring
System Study

Subject: First Technical Reporting Conference
23 May 1969

1. The first Technical Reporting Conference for the Armed Aircraft
Qualification Range Scoring System Study was conducted at the Naval
Training Device Center, Orlando, Florida, on 23 May 1969. The following
personnel were in attendance:

Mr. Paul S. Walker - Army Participation Group, NTDC Code 381
Mr. K. W. Peterson - Project Engineer, NTDC Code 371
Mr. Art Drucker - Contracting Officer, NTDC Code 1532
** Lt.Col. Frank Miller - Army Participation Group, NTDC Code 381
Lt.Col. D.J. Falczyński - DCSOPS-AVH, USCOMARC
Mr. John P. Ford - Booz-Allen Applied Research, Los Angeles
Mr. Wally Brondstatter - Del Mar Engineering Labs., Los Angeles

** partial participation
To: Navyal Training Device Center
Orlando, Florida

Attention: Mr. K. W. Peterson, Code 371

2. Transmitted herewith, in triplicate, are copies of the conference agenda and all information and back up material discussed. It is understood that this volume (in triplicate) is acceptable to VTDC and will serve as both the minutes of the conference and constitute the report for the First Technical Reporting Period. The major portion of the conference was devoted to a review of the Contractor's approach to the problem and his accomplishments to date. It was concluded that this effort is being performed in a satisfactory manner and in accordance with the contract schedule.

3. It is estimated that Tasks 2 and 3 will be completed, and Task 4 started, by mid-July. It is therefore recommended that the Second Technical Reporting Conference be scheduled for the week starting 14 July 1969.

DEL MAR ENGINEERING LABORATORIES

R. E. Denney

Enc: As noted
I PURPOSE AND REVIEW

II DESCRIPTION OF TASK #2 AND #3

III PROGRAM SCHEDULE

IV ACCOMPLISHMENTS DURING THE REPORT PERIOD
A. Analysis of System Functions - Task #2
B. Translation of Functions into Design Requirements - Task #2
C. Review of Documents, Studies, ATT, ATP, etc.
D. Review of Technical Data from Known Scoring System Manufacturers - Task #3
E. Analysis of Scoring Systems - Task #3
   (Hardware in Comparison to Functional Requirements)
F. Initiate Task #4

V PROBLEM AREAS
A. Input Data f/Cost Effectiveness
B. Lack of Information from Some System Manufacturers
VI WORK TO BE ACCOMPLISHED BEFORE NEXT TRG

A. Complete Task #4
B. Initiate Task #5 & #7

VII WORK STATUS

Approximately 40% of the study effort has been accomplished with same percentage of man/hour expenditure.
To: Department of the Navy  
Naval Training Device Center  
Orlando, Florida 32813

Attention: Mr. K. W. Peterson, Code 371  
Project Engineer  
Army Participation Group

Reference: Contract N61339-69-C-0178  
(Armed Aircraft Qualification Range  
Scoring System Study)

Subject: Second Technical Reporting Conference, (TRC)  
17 July 1969

1. The Second Technical Reporting Conference for the Armed Aircraft  
Qualification Range Scoring System Study was conducted at Los Angeles,  
California on 17 July 1969. The following personnel were in attendance:

   Mr. Paul S. Walker  
   Army Participation Group, NTDC Code 381

   Mr. K. W. Peterson  
   Project Engineer, NTDC Code 371

   Mr. John P. Ford  
   Booz-Allen Applied Research, Los Angeles

   Mr. Art Sullivan  
   Booz-Allen Applied Research, Los Angeles

   Mr. Wally Brondstatter  
   Del Mar Engineering Labs., Los Angeles

   Mr. John M. Hammond  
   Del Mar Engineering Labs., Los Angeles

2. Attached as Enclosure 1 is the Technical Reporting Conference  
Agenda covering topics which were discussed, and insert data for updating  
the TRC Manual. Item I of the Agenda covered the purpose of the conference  
and a review of what had been accomplished prior to the first TRC.  
Item II consisted of a description of Study Tasks #2 and #3, while Item  
III was a review of the program schedule. It was pointed out during this  
discussion that the program was on schedule, and that tasks were being
completed as planned. Item IV of the Agenda, "Accomplishments During the Report Period," was divided into six sub-items. Sub-items A and B concerned Task #2; sub-items C and D concerned the review of technical data and "off-the-shelf" scoring systems (Task #3); sub-item E was an analysis of "off-the-shelf" systems and a comparison of these systems to the optimum system's functional characteristics as determined in Task #2; sub-item F concerned work being done on Task #2.

3. During the discussion of Task #2 accomplishments, it was agreed that the contractor's development of functional requirements for the system was correct and that the results appeared adequate. A detailed write up of accomplishments for this task is furnished herewith and should be included as Tab VIII of the TRC Manual.

4. Discussions concerning the review of technical documents, ATPs, ATTs, etc., revealed that all technical information requested has been received and that no problem area exists. However, it was reported by the Contractor that information requested from manufacturers concerning "off-the-shelf" scoring systems, generally was incomplete, and that several manufacturers had not responded to the request for system specifications. The contractor informed Government representatives that a "second request" letter had been transmitted to these manufacturers. A copy of this letter is provided and should be included with Tab 1 of the TRC Manual.

5. In conjunction with the review of "off-the-shelf" scoring system specifications, mentioned above, an analysis was made of each system in terms of the functional characteristics of the Armed Aircraft Qualification Range Scoring System. Work sheets and summaries prepared in conjunction with the review are furnished herewith for insertion as Tab IX to the TRC Manual. These worksheets and summaries will be used during the execution of Task #4.

6. The status of Task #4 accomplishments was discussed and the work reviewed. Details are furnished on Pages 23 through 45, Tab VIII of the TRC Manual.

7. Anticipated problem areas were discussed. These are: 1) cost effectiveness trade-offs and the lack of good information on level of proficiency on which to base a measure of performance; 2) a good definition of operational effectiveness of training and; 3) complete information on "off-the-shelf" hardware (vendor-supplied information). It was agreed that the contractor would make assumptions on performance and proficiency for the purpose of completing the cost effectiveness modeling. The basis for the assumptions are to be described in order to provide a measure of confidence level on accuracy of the estimates. When better information becomes available.
The Contractor will continue to attempt acquisition of more information from vendors on "off-the-shelf" hardware throughout the study program, up until conclusion of Task #4.

8. No exception to current program direction or results was taken by Government representatives. It was agreed to accept the Contractor's recommendations for

1. Separating the point weapon targets from area weapon targets during Individual Training.

2. Compression of maximum data rate for display, from rate of five (up to 24,000 RPM) to 1/4 second for reduced scoring rate.

3. Change of horizontal scoring plane (area weapons) from clock to quadrant and the reduction of 2 miss zones to 1 for over, short, left, or right, the latter for consistency with the vertical scoring plane (point weapon) requirement.

9. It was agreed that the Third Technical Reporting Conference would be held during the last week of August 1969, the date and place to be mutually agreed upon. The Contractor stated that by that time, Task #4 would be complete and that Tasks #5 and #7 would be well under way.

10. It was stated by the Contractor that it is estimated that the study is approximately 40% complete and that approximately 50% of the authorized man/hour effort had been expended.

11. This report is furnished to comply with the requirements set forth in Section "C", Item 2.d. of the referenced contract.

DEL MAR ENGINEERING LABORATORIES

R. E. Denney
Administrative Assistant
SECOND TECHNICAL REPORTING CONFERENCE (TRC)
17 JULY 1969
DEL MAR ENGINEERING LABORATORIES AND
BOOZ-ALLEN APPLIED RESEARCH INC.
LOS ANGELES, CALIFORNIA

ARMED AIRCRAFT QUALIFICATION RANGE
SCORING SYSTEM

CONTRACT N 61339-69-C-0178
DATED 24 APRIL 1969
DEL MAR ENGINEERING LABORATORIES
BOOZ-ALLEN APPLIED RESEARCH INC.
AGENDA
SECOND TECHNICAL REPORTING CONFERENCE
17 JULY 1969

I. PURPOSE & REVIEW

II. DESCRIPTION & TASKS 2 & 3

III. PROGRAM SCHEDULE

IV. ACCOMPLISHMENTS DURING THE REPORT PERIOD
   A. Analysis of System Functions, Task 2.
   B. Translation of Functions into Design Requirements, Task 2.
   C. Review of Technical Data from Known Scoring System, Task 3.
   D. Analysis of Scoring System, Task 3.
   (Hardware in comparison to functional requirements)
   E. Review of Documents, Studies, ATT, ATP, etc.
   F. Initiate Task 3

V. PROBLEM AREAS
   A. Input Data & Cost Effectiveness
   B. Lack of Information from Some System Manufacturers

VI. WORK TO BE ACCOMPLISHED BEFORE NEXT TRC
   A. Complete Task 3
   B. Initiate Task 5 & 7

VII. WORK STATUS
    Approximately 40% of the study effort has been accomplished with same percentage of man/hour expenditure.
PURPOSE

The purpose of the study is to establish the requirements and to determine technical feasibility, economic and military considerations for the development of an ARMED AIRCRAFT QUALIFICATION SCORING SYSTEM.

The study will result in the preparation of a CONCEPT FORMULATION REPORT and a SYSTEM PERFORMANCE SPECIFICATION.
PROGRAM TASKS

1. SDR Review and updating.
2. System functional analysis.
4. 'Trade-off' studies of hardware.
5. Prepare recommended scoring system performance specifications.
6. Determine future development requirements (if any).
7. Prepare CONCEPT FORMULATION REPORT.
TASK-2

OBJECTIVE:

Develop System Functional Analysis & Requirements Allocation

MAJOR AREAS TO BE CONSIDERED:

Hierarchy of Importance. Operational Requirements. Functional Constraints
TASK 3

OBJECTIVE:

Identify, analyze and develop Technical Summary of 'Off-the-Shelf' systems and 'State-of-Art' technology. (Joint Task - DM/BAAR Inc)

The three major areas to be considered are:

Hit Detection
Data Transmission
Display (Information Retrieval)
PROGRAM SCHEDULE

TASK 1
TASK 2
TASK 3
TASK 4
TASK 5
TASK 6
TASK 7
TASK 8

\[
\begin{array}{cccccc}
\text{MONTHS} \\
1 & 2 & 3 & 4 & 5 \\
\end{array}
\]

\[
\begin{array}{cccccc}
\Delta TRC \\
\end{array}
\]
TASK 2 Starts with

- Statement of Requirement developed in TASK 1 (SOP)
  Leads to

- Operational Function of the System
OVERALL TRAINING MISSION REQUIREMENTS - FUNCTION

PERFORMANCE
PARAMETERS

- SPEED/ RANGE
- FIRE SUPPORT
- OPTIMUM GUESS
- FEED ELEVATION
- SEARCH/ SEQUENCE FIRING

REQUIREMENTS

- TRAINING MISSION

- TRAINING FUNCTION

- INDIVIDUAL QUALIFICATION
- UNIT TACTICAL TRAINING
- UNIT QUALIFICATION
  (Includes Potential for multiple fire teams)
UNIT TRAINING

REQUIREMENT

UNIT TRAINING
  a. TACTICAL
  b. QUALIFICATION & MULTIPLE FIRETEAMS

GUNNERY SCORING SYSTEM FUNCTION

- TARGETING & SENSING
- TRANSMISSION OF DATA
- SCORING
- DISPLAYING OF SCORE
- SCORE RECORDING

ELEMENTS

- RANGE SIZE & LAYOUT
- TRAINING CRITERIA
- PROFICIENCY CRITERIA
<table>
<thead>
<tr>
<th>Preprocessing</th>
<th>Format</th>
<th>Transformation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>Data</td>
<td>Data</td>
</tr>
<tr>
<td>Retrieval</td>
<td>Methods</td>
<td>Scoring A/2</td>
</tr>
<tr>
<td>Retrieval</td>
<td>Data</td>
<td>Scoring of</td>
</tr>
<tr>
<td>Data</td>
<td>Transforms</td>
<td>Scoring of</td>
</tr>
<tr>
<td>Data</td>
<td></td>
<td>Data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MISS DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$ BR ZONE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Displaying</th>
<th>Scoring</th>
<th>Sensing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aiming point</td>
<td>Rounds fired</td>
<td>Hits versus</td>
</tr>
</tbody>
</table>

**SCORING SYSTEM**

**SCORING SYSTEM**
WORK ACCOMPLISHED during TASK 2

CRITICAL PARAMETERS & FUNCTIONAL DESIGN REQUIREMENTS have been established for each SUB SYSTEM:

- TARGETS
- SENSING
- DATA CONVERSION
- DATA TRANSMISSION
- DISPLAY
- RECORDING
TARGET RAJEVERS

- Assumes a point-of-aim ± 45° forward direction + ground impact (area) for individual training.
- Assumes a simulated realistic target up to 360° for point weapons + 360° ground impact for area weapons for unit training.
- Assumes 0° to 80° dive angle for all targets.
TARGET PROBLEM

VERTICAL PLANE

VERTICAL TARGET

VERTICAL TARGET
AIMING POINT

HORIZONTAL
PLANE

HORIZONTAL
TARGET

IMPACT POINT
BY ZONE + CLOCK (θ, τ)

HORIZONTAL TARGET
(GROUND LEVEL)

ELEVATION ANGLE

PROJECTILE TRACK

VERTICAL DISTANCE
ABOVE
GROUND LEVEL
**TARGETS** for **INDIVIDUAL** and **UNIT** training

<table>
<thead>
<tr>
<th>POINT TYPE</th>
<th>ORDNANCE SELECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>REALISTIC</td>
<td>POINT WEAPONS → WEAPONS etc</td>
</tr>
<tr>
<td></td>
<td>AREA WEAPONS → PERSONNEL etc</td>
</tr>
</tbody>
</table>

**INDIVIDUAL** / POINT OF AIM

- POINT WEAPONS → VERTICAL PLANE
- AREA WEAPONS → HORIZONTAL PLANE

**RECOMMEND** SEPARATION of POINT and AREA WEAPON TARGETS for INDIVIDUAL TRAINING as well as UNIT TRAINING

- **4** AREA WEAPON AIMING POINT TARGETS +
- **2** POINT WEAPON AIMING POINT TARGETS per RANGE (IT)
SENSING PLANE + AREA

REQUESTED

1. POINT WEAPONS  HIT AREA + OVER-SHORT; L-R
2. AREA WEAPONS  HIT AREA + CLOCK; MPI + 2 ZONES

EXTENDED

1. POINT WEAPONS  VERTICAL PLANE; HIT AREA + OVER-SHORT; L-R
2. AREA WEAPONS  HORIZONTAL PLANE; HIT AREA + OVER-SHORT; L-R
SYSTEM INFORMATION RATE

ARMAMENT RPM MAX

SENSING MAX RATE

GUNNER REACTION TIME

DISPLAY RATE

——— up to 24,000 RPM

——— up to max ordnance rate

——— 0.250 sec or longer

——— 0.120 sec or longer (usual reaction time 0.500 sec)

2) SLOWEST INFORMATION RATE IN SYSTEM

3) FASTEST SINGLE FUNCTION/DISPLAY RATE FOR USABLE INFORMATION (Faster displays will be integrated by observer)
EXAMPLE OF A CONCEPTUAL INFORMATION FLOW DIAGRAM
EXAMPLE OF AN ALTERNATE FLOW DIAGRAM

SENSOR

RELAY TO
A/C
A/C DISPLAY

LOGIC NETWORK

DISPLAY

RECORDER

265° to 315°

X(θ)

315° to 45°

X(θ)

45° to 135°

X(θ)

135° to 225°

X(θ)

225° to 315°

X(θ)

HIT COUNT

RESET
REVIEW OF DOCUMENTS AND PERTINANT INFORMATION.

REVIEW OF MANUFACTURERS SPECIFICATIONS.

ANALYSIS OF EACH SYSTEM VS AAQRSS REQUIREMENTS (TAB IX)
COST EFFECTIVENESS - DUE TO LACK OF A PRECISE METHOD FOR MEASUREMENT OF PROFICIENCY CURRENT UNIT TRAINING IN THE U.S. PROVIDES VERY LITTLE TO MEASURE EFFECTIVENESS AGAINST LACK OF INFORMATION FROM SOME SYSTEM MANUFACTURERS
IDENTIFIED CRITERIA TO BE USED IN COST EFFECTIVENESS ANALYSIS

- SPEED & ACCURACY OF SCORING SYSTEMS & METHODS; CURRENT & PROJECTED VS INITIAL & CONTINUUM INVESTMENTS.
- REDUCTION IN RANGE PERSONNEL & SERVICES REQUIRED FOR SCORING.
- PROJECTED REDUCTION IN TIME & MATERIAL CONSUMED IN ANNUAL OR PERIODIC UNIT REQUALIFICATION.
- TIME & COST OF TRAINING INDIVIDUALS & UNITS TO PRESCRIBED LEVELS OF PROFICIENCY.
II  ACCOMPLISHMENTS DURING THE REPORT PERIOD
   A. Completion of Task 4 (Trade-Off Summaries)
   B. Initiation of Task 5 (Draft Performance Specification)
   C. Initiation of Task 7 (Draft Concept Formulation Report)

III  PROBLEM AREAS
   A. Input Data for Cost Effectiveness
   B. Lack of Information for Some System Manufacturers

IV  WORK YET TO BE ACCOMPLISHED
   Complete Tasks 5, 6, & 7

V  WORK STATUS
   Approximately 75% of the Study Effort has been accomplished.
To: Department of the Navy
Naval Training Device Center
Orlando, Florida 32813

Attention: Mr. K. W. Peterson, Code 371
Project Engineer
Army Participation Group

Reference: Contract N0179-69-C-0178
(Armed Aircraft Qualification Range Scoring System Study)

Subject: Third Technical Reporting Conference, (TRC)
23 - 24 September 1969

1. The third Technical Reporting Conference for the Armed Aircraft Qualification Range Scoring System Study was conducted at the Contractor's facility at Los Angeles, California, on 23 24 September 1969. The following personnel were in attendance:

   Mr. Paul S. Walker  Army Participation Group, NTDC Code 321
   Mr. K. W. Peterson  Project Engineer, NTDC Code 371
   Captain Robert N. Franklin  U. S. Army Armor School, Weapons
                               Dept. Fort Knox, Kentucky
   Mr. John P. Ford  Booz-Allen Applied Research, Los Angeles
   Mr. Wally Zundtatter  Del Mar Engineering Labs., Los Angeles
   Mr. John M. Hammond  Del Mar Engineering Labs., Los Angeles
   Mr. O. B. Lolbaugh  Del Mar Engineering Labs., Los Angeles

2. Attached as Enclosure 1 is the Technical Reporting Conference Agenda covering topics which were discussed. The initial portion of the conference consisted of a presentation by the Contractor of all agenda items. Following this, Government representatives reviewed and prepared informal questions on all data prepared by the Contractor during the report period. The final portion of the conference included a review of the Government representatives'
3. Included herewith as Enclosure 2 is a summary of the Contractor's Task 4 activities and accomplishments. It was concluded that the Contractor's efforts and methods used in the scoring system trade-off analysis were acceptable, and that the results assigned each of the sixteen candidate hard ware systems were appropriate to essential functional system requirements. The system awarded the highest score meets less than 50% of the essential requirements for an idealized range scoring system.

4. A draft specification for the idealized range scoring system was presented by the Contractor (Task 5). The specification includes all the essential functional scoring system requirements which were developed during Tasks 1 and 2. Government representatives expressed satisfaction with the scope, content, and format of the draft specification, suggesting, however, that a more specific delineation of system characteristics be incorporated. The Contractor agreed to incorporate the suggestions made during the critique portion of the conference. A copy of the draft specification is attached herewith as Enclosure 3. The preparation of a cost effectiveness study is required to complete Task 5. Since neither operational nor specific hardware acquisition cost data is available, a cost model was constructed and presented at the conference. It was agreed that this model should be used in the Contractor's cost effectiveness effort. This model and other rationale is provided as Enclosure 4.

5. The Contractor initiated work on Task 7 ("The Concept Formulation Report"), during the report period, but this obviously cannot be finalized until all study tasks are completed. A copy of this draft report is furnished herewith as Enclosure 5. It was mutually agreed that Ncrc would not furnish a "Foreword" to this report and consequently will be omitted by the Contractor.
6. It was reported by the Contractor that the problems reported during the Second Technical Reporting Conference still exist, namely, lack of data for a complete cost-effectiveness effort and lack of complete information from scoring system manufacturers. It was also reported by the Contractor that approximately 75% of the study effort was complete. Work yet to be accomplished includes completion of Tasks 5, 6, and 7.

7. This report is furnished to comply with the requirements set forth in Section "C", Item 2d of the reference contract; submittal of this report satisfies completion of Item 2 of the reference contract.

DEL MAR ENGINEERING LABORATORIES

R. E. Denney
Administrative Assistant

Enclosures: As Noted
DEVELOPMENTAL ENGINEERING

1. PURPOSE. The purpose of this report is to determine the amount and type of developmental engineering effort and an estimated cost to update all candidate "off-the-shelf" storing systems to meet the identified system's functional requirements. This determination is limited to state-of-the-art technology and the development will not require invention or scientific advances to achieve.

2. Condt. In study tasks 3 and 4 it was ascertained that each of the candidate "off-the-shelf" storing systems were functionally inadequate and none met all the requirements of the finalized system specification. Attached in Tables 2 through 17 are individual developmental estimates for each candidate system showing elapsed development time and cost of the effort required to evaluate each approach as well as estimated recurring maintenance and operations expenses.

3. Cost Estimation Methodology. To develop a method of estimating additional cost, and unadjusted production costs for candidate systems without attempting to forecast individual company development costs, a standardized method of cost estimating was used.

A new percentage figure was derived for each candidate system by taking the weighted score for each system less the points for the airborne data link, and cost recovery capabilities, as these would have to be developed by each candidate system manufacturer.

A development ratio factor was then generated by using the inverse square of the percentage figure.

All candidates who had a new percentage figure of below 50% were eliminated on the basis of excessive development, this also tended to eliminate unsuitable systems.

Development ratio factors then ranged from a low of 1.4 to a high of 2.7.

A times factor of 20 is the ratio of production to development cost, based on previous hardware development experience.

Development costs were then estimated as:

Existing production costs times 20 times development ratio factor.

Production costs were then estimated as:

Development cost + original production cost.

Table 1 shows cost estimation data generated during cost estimating effort.

Development costs were amortized over 20 systems for 10 years for the final estimates.
Candidate 3 was not included in the cost estimates due to lack of any pricing data.

Candidates 12 and 15 were eliminated on the basis that a pure hit panel system would be unsuitable for development due to the large scoring areas involved, and replacement costs.
<table>
<thead>
<tr>
<th>Candidate No.</th>
<th>Modified Weighted Score</th>
<th>Modified %</th>
<th>Development Ratio</th>
<th>Existing Production Costs</th>
<th>Development Costs</th>
<th>Estimated Production Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>40/77</td>
<td>52</td>
<td>2.63</td>
<td>$16,000</td>
<td>$540,000</td>
<td>$58,000</td>
</tr>
<tr>
<td>7</td>
<td>61/77</td>
<td>79</td>
<td>1.41</td>
<td>$25,000</td>
<td>$705,000</td>
<td>$60,250</td>
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<tr>
<td>8</td>
<td>60/77</td>
<td>78</td>
<td>1.45</td>
<td>$20,000</td>
<td>$580,000</td>
<td>$49,000</td>
</tr>
<tr>
<td>9</td>
<td>56/77</td>
<td>73</td>
<td>1.59</td>
<td>$30,000</td>
<td>$560,000</td>
<td>$78,000</td>
</tr>
<tr>
<td>13</td>
<td>50/77</td>
<td>65</td>
<td>1.93</td>
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<td>$255,000</td>
<td>$19,500</td>
</tr>
<tr>
<td>14</td>
<td>51/77</td>
<td>66</td>
<td>1.85</td>
<td>$11,000</td>
<td>$250,000</td>
<td>$32,250</td>
</tr>
<tr>
<td>15</td>
<td>39/77</td>
<td>59</td>
<td>2.73</td>
<td>$15,000</td>
<td>$830,000</td>
<td>$56,500</td>
</tr>
</tbody>
</table>

COST ESTIMATING DATA

TABLE 1
This Electromagnetic Pulse-Doppler Scoring System was designed primarily for use with aircraft targets and has been produced for the U. S. Army and Air Force. Although the scoring principles used in this system could satisfy a number of the functional requirements of the Armed Aircraft Qualification Range Scoring System, limitations in the following areas have been defined:

- Scoring Radius: Limited to 50 feet
- Accuracy: Adequate only with large caliber weapons
  - Two square feet radar cross section or more
- Caliber/Type Weapon: No capability with 5.56 or 7.62mm
- Vector: No vector information provided
- Data Display: No real-time-hits, misses and vector data displayed
- Malfunction/Damage Alarm: None

<table>
<thead>
<tr>
<th>Development Cost Estimate</th>
<th>$ N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elapsed Development Time</td>
<td>_______ Months</td>
</tr>
<tr>
<td>Exceptions: None</td>
<td></td>
</tr>
<tr>
<td>Note: Eliminated as candidate due to low functional performance.</td>
<td></td>
</tr>
<tr>
<td>System life cycle</td>
<td>N/A years</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ITEM</th>
<th>ESTIMATES</th>
<th>COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
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<td></td>
</tr>
<tr>
<td>Installation</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Annual Maintenance</td>
<td>N/A</td>
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</tr>
<tr>
<td>Annual Operation</td>
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<td></td>
</tr>
<tr>
<td>Annual Spares</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 2
This system which is under development for the U. S. Army is designed to
simulate hits of projectiles from flechettes to 40mm in size and the point-
of-impact for 40mm grenades surrounding a personnel type target. Application
of this system to the functional requirements of the Armed Aircraft Qualification
Range Scoring System leaves deficiencies in the following general areas:

- **Scoring Radius:** Limited to 20 meters
- **Accuracy:** Unstated (developmental system)
- **Caliber/Type Weapons:** Limited to projectiles 5.56 to 40mm
- **Data Display:** No real time display of hit-miss or vector data
- **Vector:** No vector data provided
- **Malfunction/Damage Alarm:** None

<table>
<thead>
<tr>
<th>Development Cost Estimate</th>
<th>$ N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elapsed Development Time</td>
<td>_____ Months</td>
</tr>
<tr>
<td>Exceptions</td>
<td>None</td>
</tr>
</tbody>
</table>

Note: Eliminated as candidate due to low functional performance and lack of cost information.

System Life Cycle: N/A Years
This acoustic (amplitude) system was designed primarily for use with aerial targets and has been in use by the French Air Force and Army for several years. The principles of operation and scoring methods used are adaptable to the Armed Aircraft Qualification Range Scoring System but in many regards are not compatible with its functional requirements. The major diversions are as follows:

- **Scoring Rate:** Not stated
- **Scoring Radius:** Limited to 4.5m
- **Accuracy:** Not stated
- **Caliber/Type Weapon:** Used with 50 caliber and 30mm only (supersonic)
- **Vector:** No vector information provided
- **Number of Targets per System:** Limited to 1 target per system
- **Simultaneous Multiple Type Weapons:** Limited to 1 type of weapons

<table>
<thead>
<tr>
<th>Development Cost Estimate</th>
<th>$ N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elapsed Development Time</td>
<td>N/A Months</td>
</tr>
<tr>
<td>Exceptions: None</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Eliminated as candidate due to low functional performance and lack of cost data.

**System Life Cycle** N/A Years

**TABLE 4**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>N/A</td>
</tr>
<tr>
<td>Installation</td>
<td>N/A</td>
</tr>
<tr>
<td>Annual Maintenance</td>
<td>N/A</td>
</tr>
<tr>
<td>Annual Operation</td>
<td>N/A</td>
</tr>
<tr>
<td>Annual Spares</td>
<td>N/A</td>
</tr>
</tbody>
</table>
This electromagnetic scoring system is designed for air-to-ground strafing use. It is based on the pulsed doppler radar principle, 6-cubic intensity, then applied to the functional requirements of the Armored Aircraft Qualification Range Scoring System, some significant divergences are observed and follow:

Scoring Radius: Limited to 20 feet
Caliber/Type Weapons: 7.62mm to 40mm only
Zone/Vector: Single Zone/no vector
Vert/Horiz Plane: Vertical only (point weapons)
Ammo Characteristics: Inert only
Data Trans Range: 1 mile
Dive Angle: Limited to between 5° and 15°
Approach Azimuth: 15° - 0° - 15°
Vulnerability: Due to bulk of sensing hardware, down range equipment must be protected.
Malfunction/Status Alarm: None

Development Cost Estimate $840,000.00
Elapsed Development Time Est. 27 Months
Exceptions: None
System Life Cycle 10 Years

TABLE 5

<table>
<thead>
<tr>
<th>Item</th>
<th>1971</th>
<th>1972</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>$38,000.00</td>
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<tr>
<td>Installation</td>
<td>$3,500.00</td>
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</tr>
<tr>
<td>Annual Maintenance</td>
<td>$4,500.00</td>
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<tr>
<td>Annual Operation</td>
<td>$8,000.00</td>
<td></td>
</tr>
<tr>
<td>Annual Spares</td>
<td>$7,500.00</td>
<td></td>
</tr>
</tbody>
</table>
This electromagnetic scoring system was designed for use with a single personnel type target. It is based on the pulsed doppler radar principle, amplitude intensity. This system's characteristics, when applied to the functional requirements of the Armed Aircraft Qualification Range Scoring System are inconsistent in many respects. Major inconsistencies are as follows:

Scoring Radius: Limited to 4 meters
Caliber/Type Weapons: Limited to 5.56mm to 50 caliber
Zone vector: No vector data provided
Horizontal/Vertical Plane: Half hemisphere only each plane
Data Display: No special display for real time readout
Approach Azimuth: 0° - 180°
Malfunction/Damage Alarm: None
MTBF: 100 hours

Development Cost Estimate $ N/A
Elapsed Development Time N/A Months
Exceptions: None
Note: Eliminated as candidate due to low functional performance.
System Life Cycle N/A Years

<table>
<thead>
<tr>
<th>ITEM</th>
<th>ESTIMATES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COST</td>
</tr>
<tr>
<td>Production</td>
<td>N/A</td>
</tr>
<tr>
<td>Installation</td>
<td>N/A</td>
</tr>
<tr>
<td>Annual Maintenance</td>
<td>N/A</td>
</tr>
<tr>
<td>Annual Operation</td>
<td>N/A</td>
</tr>
<tr>
<td>Annual Spares</td>
<td>N/A</td>
</tr>
</tbody>
</table>

TABLE 6

284
This electromagnetic scoring system was designed for use in either an air-to-air or a ground-to-air application. It gives continuous missed distance scale data and is based on the pulsed doppler correlation radar principle using pseudo-random coded phase reversal modulation techniques. Primary intended use is with missiles having a reasonable large radar cross section. The characteristics of this system when correlated with the functional requirements of the Armed Aircraft Qualification Range Scoring System reveals that some essential qualities are lacking, namely:

- Scoring Rate: Approximately 860 RPM
- Caliber/Type Weapon: Only missiles with 2 square feet radar reflectivity
- Zone/Vector: No zone, no vector data
- Malfunction/Damage Alarm: None
- MTBF: 100 hours

### TABLE 7

<table>
<thead>
<tr>
<th>Development Cost Estimate</th>
<th>$ N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elapsed Development Time</td>
<td>N/A Months</td>
</tr>
<tr>
<td>Exceptions: None</td>
<td></td>
</tr>
<tr>
<td>Note: Eliminated as candidate due to low functional performance.</td>
<td></td>
</tr>
<tr>
<td>System Life Cycle</td>
<td>N/A Years</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>ITEM</th>
<th>ESTIMATES</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>RPM</td>
</tr>
<tr>
<td>Production</td>
<td>N/A</td>
</tr>
<tr>
<td>Installation</td>
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<td>Annual Maintenance</td>
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<td>Annual Operation</td>
<td>N/A</td>
</tr>
<tr>
<td>Annual Spares</td>
<td>N/A</td>
</tr>
</tbody>
</table>

285
This acoustic (amplitude) scoring system is in wide use by U. S. Navy and Air Force as an air-to-ground strafing/gunfire trainer. When comparing the operational characteristics of this system to the functional requirements of the Armed Aircraft Qualification Range Scoring System, the following inadequacies have been noted:

Scoring Rate: Presently limited to 10,000 RPM
Scoring Radius: Presently limited to 150
Zone/Vector: No multiple zone - no vector data
No. of Targets per System: Limited to 1 f/simultaneous scoring
Simultaneous Multiple Type Weapons: One caliber/type at a time

MTEF: 700 hours
Data Recording: No provision for

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Cost Estimate</th>
</tr>
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<tbody>
<tr>
<td>Production</td>
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<tr>
<td>Installation</td>
<td>250</td>
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<td>Annual Maintenance</td>
<td>2,400</td>
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<tr>
<td>Annual Operation</td>
<td>8,000</td>
</tr>
<tr>
<td>Annual Spares</td>
<td>22,025</td>
</tr>
</tbody>
</table>

Development Cost Estimate: $705,000
Elapsed Development Time: 12 Months
Exceptions: None
System Life Cycle: 10 Years

TABLE 8

286
This fixed acoustic (amplitude) scoring system is in use at helicopter training school of the U.S. Army for air-to-ground gunnery qualification. A comparison of the operational characteristics of this system with the functional requirements of the Armed Aircraft Qualification Range Scoring System reveals that it meets all requirements except the following:

- **Scoring Rate:** Up to 6000 RPM
- **Transmission Range:** Up to 10,000M (wire)
- **Data Display:** No vector
- **MTBF:** 700 hours
- **Zone/Vector:** Partial vector (Combination of 2 or more sensors)

**Development Cost Estimate** $590,000

**Elapsed Development Time** 12-1/2 Months

**Exceptions:** None

**System Life Cycle** 10 Years

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Production</td>
<td>$49,000</td>
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<tr>
<td>Annual Maintenance</td>
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<td>8,000</td>
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<tr>
<td>Annual Spares</td>
<td>20,900</td>
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</tbody>
</table>

**TABLE 9**
This acoustic (amplitude) scoring system used by the U. S. Army for weapons system evaluation and possible training mission application. It was designed primarily for air-to-ground (helicopter) gunery scoring. When comparing the operational characteristics of this system with the functional requirements of the Armed Aircraft Qualification Range Scoring System, limitations have been defined in the following areas:

Scoring Rate: 6000 RPM

Zone & Vector: No vector information data

Simultaneous Multi-Weapon: One type ammo at a time

MTBF: 700 hours

Malfunction/Damage Alarm: None

<table>
<thead>
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<th>Development Cost Estimate</th>
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<tbody>
<tr>
<td>Elapsed Development Time</td>
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<tr>
<td>Exceptions: None</td>
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</tr>
<tr>
<td>System Life Cycle</td>
<td>10 Years</td>
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</tbody>
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<tr>
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<td>Annual Maintenance</td>
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<tr>
<td>Annual Operation</td>
</tr>
<tr>
<td>Annual Spares</td>
</tr>
</tbody>
</table>

TABLE 10
This scoring system was designed to collect both hit and miss distance data from personnel type targets when fired on with small arms (9.56mm, 7.62mm and Minette) and to collect zones miss data when fired on by 40mm grenades.

**Scoring Rate:** 12,000 RPM-Hit, 6000 RPM-Miss, 500 RPM-Grenade

**Scoring Radius:** 0 - 2 meters

**Caliber/Type Weapon:** Small arms & 40mm Grenade

**Transmission Range:** 10,000 feet

**Data Display:** Computer inputs

**MTBF:** 500 hours

**Attack Azimuth:** Hit count panel: 0° - 60°

**All others:** 360°

**Malfunction/Damage Alarm:** None

---

**Development Cost Estimate:** $ \text{N/A}

**Elapsed Development Time:** \text{N/A} Months

**Exceptions:** None

**Note:** Eliminated as candidate due to low functional performance and lack of accurate cost information.

**System Life Cycle:** \text{N/A} Years

---

**TABLE 11**
NAVTRADIVICN 69-C-0178-1

COST WORKSHEET

APPROACH NO. 11

HIT SENSITIVE PANEL TARGET SYSTEM, X34109/1

DEL MAR ENGINEERING LABORATORIES

This hit panel type scoring system was designed primarily for use on track targets ranging in both a stationary and mobile configurations. Comparing the characteristics and capabilities of this system to the functional requirements of the Armed Aircraft Qualification Range Scoring System, it is evident that the following areas are not fulfilled:

- Scoring Rate: 60 RPM
- Scoring Radius: Dependent on panel size
- Zone/Vector: Neither is furnished
- Data Transmission: Wire
- Data Display: None
- Dive Angle: 0 - 60°
- Approach Azimuth: ± 60°
- Malfunction/Damage Alarm: None

Development Cost Estimate $ N/A

Elapsed Development Time N/A Months

Exceptions: None

Note: Eliminated as candidate due to low functional performance and lack of production cost information.

System Life Cycle N/A Years

---

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<th>ITEM</th>
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<tbody>
<tr>
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<td>Annual Spares</td>
<td>N/A</td>
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</table>

TABLE 12

290
This hit panel type scoring system was designed for use by strafing aircraft during individual training. A comparison of this system's characteristics with the functional requirements of the Armed Aircraft Qualification Range Scoring System results in the following discrepancies:

- **Scoring Rate**: 9000 RPM
- **Caliber/Type Weapon**: 7.62 - 40mm
- **Zone/Vecto**: No zone, no vector
- **Scoring Radius**: 20 feet
- **Data Transmission Range**: 1000 (Wire)
- **Data Recording**: No provisions
- **Portability**: Fixed
- **Dive Angle**: 10° - 30°
- **Approach Azimuth**: ± 30°
- **Malfunction/Leakage Alarm**: None

| Development Cost Estimate | $ \text{N/A} $
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<tbody>
<tr>
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<tr>
<td>Annual Spares</td>
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TABLE 13

291
ACOUSTIC (AMPLITUDE) SCORING SYSTEM, MODEL BT-23
SAAB-LULOW (SWEDEN)

This acoustic (amplitude) scoring system was designed for use with acoustical targets. A comparison of this system's characteristics with the functional requirements of the Armed Aircraft Qualification Range Scoring System results in the following discrepancies:

- Scoring Rate: Up to 9000 RPM
- Zone/Vector: No vector data obtained
- Simultaneous Multiple Weapons: One type/caliber weapon at a time
- MTBF: Not stated
- Malfunction/Damage Alarm: None

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</tr>
<tr>
<td>Annual Operation</td>
</tr>
<tr>
<td>Annual Spares</td>
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</tbody>
</table>

**TABLE 14**
This acoustic (amplitude) scoring system was designed for use with aerial targets. As in all acoustic (amplitude) scoring systems, a number of the requirements can be satisfied, but when the system's characteristics are compared to the functional requirements of the Armed Aircraft Qualification Range Scoring System, the following limitations are apparent:

Scoring Rate: 2000 RPM
Scoring Radius: 2 - 20M
Accuracy: < 90%
Zone/Vector: 12 zones - 4 sector under development
Scoring Charts: Supersonic only (no HE or subsonic)
MTBF: Not stated
Malfunction/Damage Alarm: None
No. of Targets per System: Limited to 1 target per system
Simultaneous Multiple Type Weapons: Limited to 1 type of weapon

Development Cost Estimate $425,000
Elapsed Development Time Est. 22 Months
Exceptions: None
System Life Cycle 10 Years

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TABLE 15
293
This fixed acoustic scoring system was designed for air-to-ground gunnery scoring using the amplitude principle. It has been used by the French Air Force in aerial gunnery training. When comparing the characteristics of this system to the functional requirements of the Armed Aircraft Qualification Range Scoring System, the following essential elements are:

- **Scoring Rate**: 8000 RPM
- **Scoring Radius**: 100m
- **Zone/Vector**: No vector data furnished
- **Type/Caliber**: Up to 30mm
- **Simultaneous Multiple Type Weapons**: One caliber at a time
- **Data Transmission**: Wire only, no TM
- **Attack Azimuth**: ± 20°
- **Dive Angle**: 10 ± 5°
- **Malfunction/Damage Alarm**: None
- **No. of Targets per System**: Limited to 1 target
- **Data Recording**: No provisions

### Table 16

<table>
<thead>
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<th>Item</th>
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<td>Development Cost Estimate</td>
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<tr>
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</table>

- **Development Cost Estimate**: $830,000
- **Elapsed Development Time**: Est. 33 months
- **Exceptions**: None
- **System Life Cycle**: 10 Years
This fixed hit scoring system was designed to be used in training tank 
munition techniques for the U. S. Army. When comparing the characteristics 
of this system to the functional requirements of the Armed Aircraft Qualifi-
cation Range Scoring System, the following limitations are apparent:

- **Scoring Rate:** 10,000 RPM
- **Scoring Radius:** Limited to panel size
- **Zone/Vector:** None provided
- **Data Transmission:** 149/150 MHz TM
- **Display:** No vector or miss
- **Malfunction/Target Alarm:** None
- **Miss Data:** None

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<td>Elapsed Development Time</td>
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<td>System Life Cycle</td>
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**TABLE 17**

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<td>Annual Operation</td>
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</tr>
<tr>
<td>Annual Spares</td>
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<td></td>
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295
| Requirements had been completed, a detailed investigation was conducted of all available "OFF-THE-SHELF" scoring systems. A "Trade-Off" analysis was made of the characteristics of each of these systems versus the requirements outlined for the optimum scoring system developed by the USN's EDR. A cost-effectiveness effort was completed, an Operational Specification was written, and the Concept Formulation Report was prepared. The report concluded that an "off-the-shelf" scoring system using acoustic sensing principles be further developed to meet the functional requirements of the optimum system in order to satisfy armament scoring requirements of the 1970 to 1975 time frame.

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This study determined the technical feasibility and optimum design analysis for an Armed Aircraft Qualification Range Scoring System in accordance with Concept Formulation outlined in AMCR 70-10 and system requirements outlined in a Small Development Requirement (SDR).

After an intensive review and analysis of the SDR Requirements had been completed, a detailed investigation was conducted of all available "OFF-THE-SHELF" scoring systems. A "Trade-Off" analysis was made of the characteristics of each of these systems versus the requirements outlined for the optimum scoring system developed by the revised SDR. A cost-effectiveness effort was completed, an Operation Specification was written, and a Concept Formulation Report was prepared. The report concluded that an off-the-shelf scoring system using acoustic sensing principles be further developed to meet the functional requirements of the optimum system in order to satisfy armed aircraft gunnery scoring requirements of the 1970 to 1975 time frame.
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REPORT ON RESULTS OF CONCEPT FORMULATION ACTIVITIES FOR AN ARMED AIRCRAFT QUALIFICATION RANGE SCORING SYSTEM

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Developmental Engineering

Functional Requirements

Cost Effectiveness

Trade-Off of Off-the-shelf Hardware

Best Available Copy