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ABSTRACT

The methods for evaluating Air Force engineering proposals are well established. However, at times, the rating a proposal receives is arbitrarily and/or subjectively determined. The method proposed in this study will yield a systematically determined rating for each proposal.

In this thesis, a multi-attribute evaluation methodology is developed based on the Analytical Hierarchy Process to prioritize proposals. The methods are applied to two different stages of the Air Force laboratory procurement process: the first stage is the resource allocation phase where division-level management decides which projects will be funded; the second stage is proposal evaluation, where the project engineer evaluates proposals sent in by defense contractors.

The methodology used in both stages follows a two step process: first, data on preferences among the various attributes is gathered through the use of pairwise comparisons and a questionnaire; second, the pairwise comparison data are used to determine the relative weights of all the attributes.

The hierarchies in both stages of this study were developed using attributes that have been used in previous resource allocation and proposal evaluation cases. The hierarchies were then used to determine the "best" projects to fund in the resource allocation stage, or proposals in the proposal evaluation stage.

The results of this study led us to the conclusion that a multi-attribute evaluation methodology based on the analytical hierarchy process can be readily applied to both stages of the procurement process studied and provide an objective, systematic means for prioritizing projects and proposals.

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A MULTI-ATTRIBUTE EVALUATION MODEL FOR AIR FORCE ENGINEERING PROJECTS

By

Captain Robert Jon Keppler

A Thesis Submitted in

Partial Fulfillment of the

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Umesh Saxena 5/6/92

Umesh K. Saxena, Major Professor Date

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MULTI-ATTRIBUTE EVALUATION MODEL FOR AIR FORCE ENGINEERING PROJECTS

By

Captain Robert Jon Keppler

The University of Wisconsin-Milwaukee, 1993

Under the Supervision of Professor Umesh K. Saxena

ABSTRACT

The methods for evaluating Air Force engineering proposals are well established. However, at times, the rating a proposal receives is arbitrarily and/or subjectively determined. The method proposed in this study will yield a systematically determined rating for each proposal.

In this thesis, a multi-attribute evaluation methodology is developed based on the Analytical Hierarchy Process to prioritize proposals. The methods are applied to two different stages of the Air Force laboratory procurement process: the first stage is the resource allocation phase where division-level management decides which projects will

be funded; the second stage is proposal evaluation, where the project engineer evaluates proposals sent in by defense contractors.

In the resource allocation stage, a total of twenty-five attributes was used, and in the proposal evaluation stage twenty-three attributes were used. The methodology used in both stages follows a two step process: first, data on preferences among the various attributes is gathered through the use of pairwise comparisons and a questionnaire; second, the pairwise comparison data are used to determine the relative weights of all the attributes. The weights are used to rank the projects/proposals.

The hierarchies in both stages of this study were developed using attributes that have been used in previous resource allocation and proposal evaluation cases. The hierarchies were then used to determine the "best" projects to fund in the resource allocation stage, or proposals in the proposal evaluation stage, using actual laboratory procurement cases.

The results of this study led us to the conclusion that a multi-attribute evaluation methodology based on the analytical hierarcy process can be readily applied to both stages of the procurement process studied and provide an objective, systematic means for prioritizing projects and proposals.

Umesh Saxena 8/6/93

Umesh K. Saxena, Major Professor Date

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I. INTRODUCTION

"At the very least, 10 percent of the $76 billion that the government now spends each year on research should be redirected from the Pentagon's research budget to civil efforts." President Bill Clinton.

1.1. Background

Even before Mr Clinton committed these words to paper in his 1992 Presidential Campaign literature entitled *Technology: The Engine of Economic Growth*, the defense budget, and hence the money available for defense related research, has been steadily falling since the peak of the Reagan build-up. In fact, with the Fiscal 1993 budget, for the eighth consecutive year, the Pentagon's spending power will decline (Green, 1992). Now, with Bill Clinton's election, exactly how far the defense budget will tumble is unknown.

With the demise of the Soviet Union and the end of the cold war, the perceived need for the military has diminished. Congress appears determined to continuously slash defense and spend the "peace dividend" on other programs in their respective districts.

Future defense budgets will continue to decline. By 1997, it is estimated that US defense spending as a percentage of Gross National Product and of the federal budget, will be lower than its post- World War II levels (Canan, 1992 and Auster, 1993). The chart in Figure 1.1.1 shows where the defense budget will absorb the cuts; notice that Research and development will drop by 23.8 percent. (Auster, 1993)

FIGURE 1.1.1.

Outlay Reductions 1988-97

Budget Category	Dollar Drop	Percent Drop
Military procurement	$46 billion	46.0
Military personnel	25 billion	28.4
Operations and maintenance	19 billion	19.8
Research and development	10 billion	23.8
Military construction	1 billion	9.1
Total	**$101 billion**	

One important lesson of the Persian Gulf War was that high technology weapon systems can become significant force multipliers, and more importantly, can save the lives of American forces. Therefore, it is imperative that US forces continue to develop the most technologically advanced systems in the world, in spite of these budget cuts.

To maintain technological superiority in the days of austere budgets, procurement and research and development (R & D) organizations will have to become even more efficient than they already are. One method being discussed in Washington to accomplish this is to emphasize prototyping weapons. In an Air Force magazine article, former Deputy Secretary of Defense Donald Atwood had this to say about the situation, "Production rates will be considerably less than in the past and below the capacity of industry to produce. It is vitally important to push the research and development of innovative new technology." Thus, research and prototyping take on added significance. (Auster, 1992)

1.2. Purpose of Study

The purpose of this study is to illustrate how a multiattribute evaluation model based on the Analytical Hierarchy Process can be used for resource allocation and proposal evaluation in Air Force R & D organizations. Where appropriate, key attributes applicable to exploratory and advanced development research in both the resource allocation and proposal evaluation processes will be identified. The attributes and hierarchies developed in this study are unique to the organization examined. The specific objectives of the study are to:

a. Establish an objective resource allocation procedure;

b. Develop an universally acceptable methodology for proposal evaluation;

c. Assign a quantified numerical output to identify resource allocation priority and individual proposal merit; and

d. Compare and contrast the present methods with the proposed ones.

1.3. Significance of the Study

Project engineers and program managers in Air Force R & D organizations are directly involved in the allocation of large sums of money entrusted to them by the American people. This money will be used to accomplish objectives set forth by the highest elected officials in the land, those designated as being vital to the defense of the United States. Many of the programs will have important long-term implications to the nation. (Laboratory Program Managers Guide, 1985)

The proper evaluation of research proposals and subsequent selection of a contractor to conduct the research plays an important role in the management of military technology. With the defense budget continuously shrinking, and with the present push towards prototyping systems, the appropriate selection of contractors to perform R & D takes on added significance.

1.4 Organization of the Study

This study is divided into five sections. The first section introduces the thesis and provides background highlighting the need for formal, scientific procedures to allocate resources and perform proposal evaluations in Air

Force R & D organizations. The second section contains an examination of the present processes and a literature review, it outlines descriptions of the present process for allocating resources in the Electronic Warfare Division of the Avionics Directorate at Wright Patterson Air Force Base, Ohio and generally accepted procedures for evaluating R & D proposals. Also in the second section is a review of related research work. A detailed discussion of the proposed method is presented in the Section Three. Included in this section is the development of the hierarchies for projects and proposals, the construction of questionnaires to gather information, the development of priority weights, and the formulation of the resource allocation and proposal evaluation methods. The methodology was applied to existing resource allocation and proposal evaluation data, and the results of these tests are presented in the Section Four. Detailed discussion of the outcomes and calculations are also included in this section. The fifth section contains additional discussions and conclusions along with recommendations for future work.

II. EXAMINATION OF EXISTING PROCESS AND LITERATURE REVIEW

There are already methods in existence for resource allocation and proposal evaluation in the organization studied. To better understand how the proposed methods can be applied, it will be beneficial to briefly discuss the methods presently used; therefore, an explanation of the organization and the present processes is presented here.

An extensive review of literature revealed that different organizations in the Department of Defense (DOD) are examining ways to utilize multiattribute decision models in the project and source selection processes. Results of some of these studies are presented in this section.

2.1. Existing Laboratory Procurement Process

The following paragraphs will describe the procurement process used in the Avionics Directorate's Electronic Warfare Division at the time of the study. A brief explanation of the organizational structure and how the division receives its budget is presented.

2.1.1. Organizational Structure

The Electronic Warfare Division is part of the Avionics Directorate at Wright Patterson Air Force Base near Dayton, Ohio. Figure 2.1.1. shows the division's position in the directorate's hierarchy.

FIGURE 2.1.1.

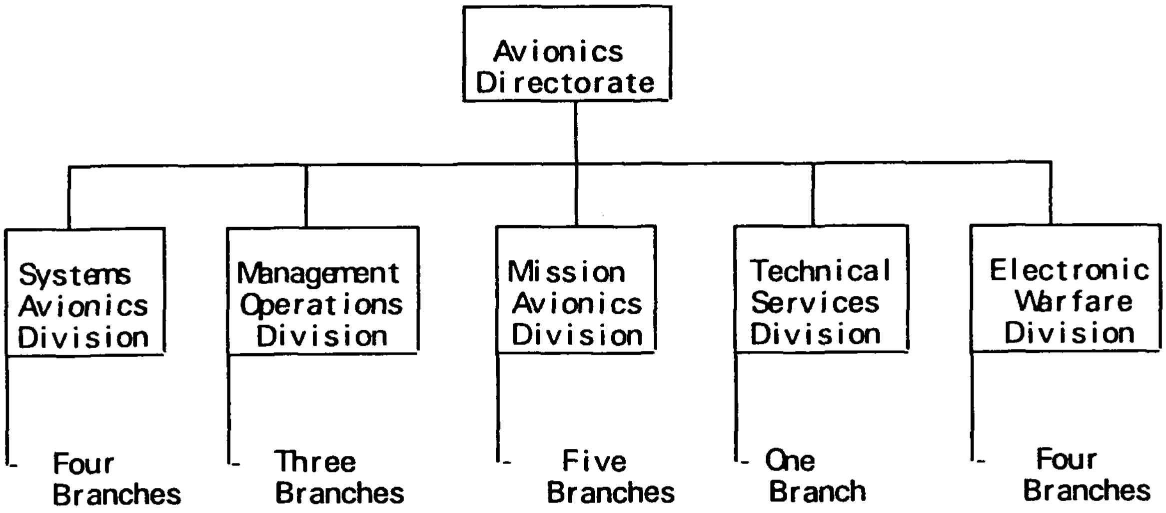
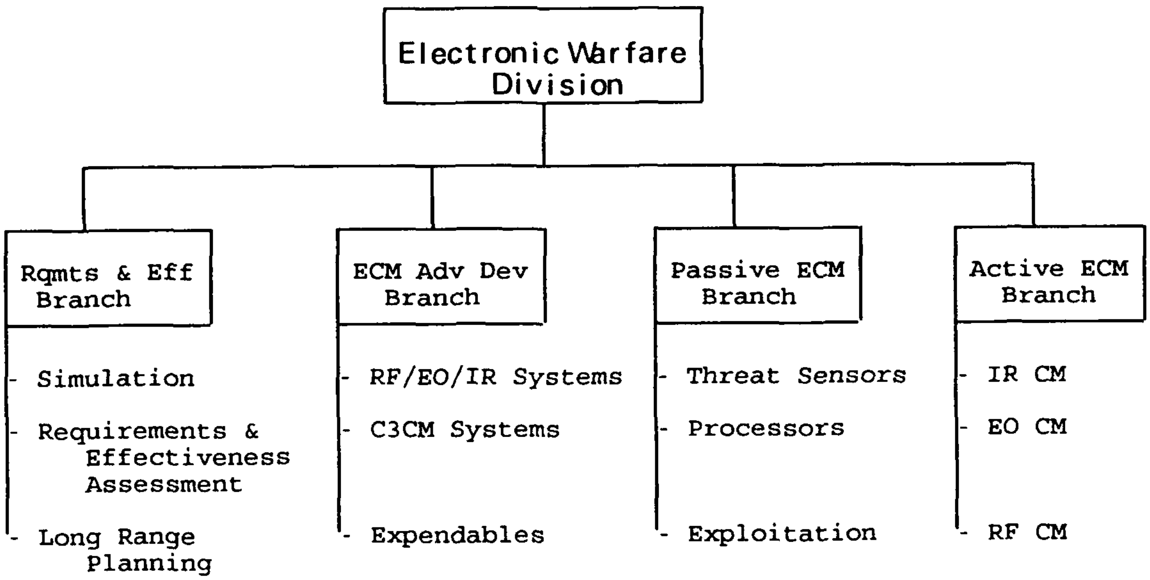


FIGURE 2.1.2.



As can be seen in Figure 2.1.2., the division is comprised of four branches; the Requirements and Effectiveness Evaluation Branch, the Electronic Countermeasures Advanced Development Branch, the Passive Electronic Countermeasures Branch, and the Active Electronic Countermeasures Branch. Each of these branches will have several groups underneath them.

The division conducts basic, exploratory, and advanced development research in electronic warfare techniques and technologies. Research and development is conducted both in-house and through defense contractors. Areas of research include but are not limited to: radio frequency (RF), electro-optical(EO), and infrared (IR) electronic warfare techniques and systems; electronic warfare sensors, receivers, and transmitters; and foreign threat systems and capabilities. Figure 2.1.2. also provides a brief sample of some of the technologies being worked by each branch.

2.1.2. Resource Allocation Process

The budget the division uses to fund new programs is a part of the overall annual defense budget. Describing the in-depth process of how money is allocated to the division through the DOD Biennial Planning and Budgeting System is beyond the scope of this study; however a brief description will prove beneficial. The budgetary process is highlighted in Figure 2.1.3.

FIGURE 2.1.3.

Agency	Activity
CONGRESS	AUTHORIZES AND APPROPRIATES
PRESIDENT	SIGNS APPROPRIATION
TREASURY	ISSUES WARRANT TO ESTABLISH AIR FORCE FUNDING PROGRAM
OFFICE OF MANAGEMENT AND BUDGET	APPORTIONS
USAF	ALLOCATES
AIR FORCE MATERIEL COMMAND	ALLOTS
LABORATORIES	INITIATES

SOURCE: Laboratory Program Managers Guide, Part II

In general, the Electronic Warfare Division receives money from three sources: 1) the program element (PE) in the overall DOD budget for Avionics, 2) the PE for Electronic Warfare Technology, and 3) outside users. The dollars from the Avionics PE funds exploratory development research, while the money from the Electronic Warfare PE is applied to advanced development projects. The funds from outside users are applied to special projects on an as needed basis.

Each year, after the President signs the budget, the division will know how much money they have from the PEs described above. The money owed on previously funded programs in the given fiscal year is subtracted from the money allocated through the PEs, this gives the amount of money that is available to fund new programs.

To determine which new programs will be funded, the division convenes the Resource Allocation Committee (RAC) each January. The RAC is made up of the Division Chief, the Technical Director for the division, and the four Branch Chiefs. Project engineers from the groups will brief their ideas for new programs to the RAC.

For each program briefed to the RAC, each member is given a rating sheet that contains a brief program description, funding information on the program, and space for the evaluators ratings of the program against various criteria.

FIGURE 2.1.4.

NEED:

Generally Applicable - critical	8
Limited Applicability - critical	4
Generally Applicable - non-critical	2
Limited Applicability - non-critical	1

TECHNICAL APPROACH:

Well Defined	8
Promising	4
Some Potential	2

INNOVATION:

High Pay-Off Approach to New Area	8
Novel Approach to Old Area	4
Some New Ideas	2
Routine	1

ALTERNATIVES:

None	8
Others - But This is Better	4
Several of Equal Value	2
Many Others - Some Better	1

ADDITIONAL:

Follow-on From Successful Program	1
Joint Program	1
Can be Done In-House	1
Supports Existing or Future Programs	1
Supports Forecast II	1

FIGURE 2.1.5.

	Evaluator							
Program	**1**	**2**	**3**	**4**	**5**	**6**	**7**	Rank
1	1	1	16	8	3	6	1	5.1
2	3	2	9	6	10	4	4	5.4
3	12	3	5	9	4	3	3	5.6
4	3	11	1	4	12	-	-	6.2
5	9	17	2	1	2	8	9	6.9
6	6	13	7	5	16	2	2	7.3
7	11	5	11	3	7	-	-	7.4
8	6	7	12	10	1	9	8	7.6
9	13	4	3	16	9	1	-	7.7
10	9	10	13	2	15	5	6	8.6
11	9	9	8	11	8	7	11	9.0
12	17	15	4	7	6	-	7	9.3
13	6	6	15	17	13	-	3	10.0
14	16	12	6	12	5	-	-	10.2
15	10	16	10	14	11	-	-	12.2
16	16	8	17	13	14	10	10	12.6
17	14	14	14	15	17	-	5	13.2

An evaluator will use the criteria and weights in Figure 2.1.4 to determine his "total" score for an analysis program. After all programs are presented and similarly scored, the evaluator will rank the projects in ascending order from one through the number of projects briefed, where one means this is the best program in the evaluators eyes, two is the second best, etc. The individual rankings given by each RAC member for a given program are then averaged to give the program its final score. All the programs are then arranged in ascending order according to their final score, money is allocated to the programs with the highest final scores until all available money for the given fiscal year has been allotted. The rankings given by each member are averaged to remove any bias (positive or negative) the RAC member may have toward a program. The results of a recent analysis RAC are presented in Figure 2.1.5.

2.1.3. Request for Proposal Process

Once a project engineer is notified that his new program idea will be funded, he begins preparing a purchase request package (PRP). The PRP forms the basis of the solicitation and award phase of the procurement process. This package authorizes the procurement office to solicit proposals for the award of R & D contracts, and describes the technical requirement and other information to administer and control the remainder of the procurement process. This package contains many things including the Statement of Work, which thoroughly describes the research effort and prescribes what is expected of prospective contractors, and the evaluation factors and criteria that will be applied to the contractor's proposals. The evaluation factors and criteria will communicate to potential offerors the important considerations which will be used in the evaluation of proposals. (AFR 70-30, par 17b)

Through various methods, a list of possible sources for the research is obtained. Those contractors on the list will receive a formal Request for Proposal, which will contain the Statement of Work and evaluation criteria. Those contractors who elect to will send their proposals to the Air Force contracting office for the requesting R & D organization. The proposals will be forwarded to the responsible project engineer for technical evaluation.

2.1.4. Technical Evaluation Process

Technical evaluation of proposals in Air Force R & D organizations is accomplished in accordance with policies and procedures set forth in Air Force Regulation (AFR) 70-30 and WRDC Regulation 70-5. These evaluations are performed by a team of evaluators, with the project engineer serving as Team Chief.

The proposals are rated against the criteria established by the evaluation team and sent to the prospective contractors in the Request for Proposal package. AFR 70-30 describes the requirements for the evaluation criteria:

> Specific criteria relate to program or project characteristics. The specific criteria are divided into appropriate technical and (or) management evaluation areas. Areas of specific criteria are evaluated in a matrix fashion against assessment criteria. Examples of specific criteria might include technical, logistics, manufacturing, operational utility, design approach, readiness and support, test and management. These areas are further subdivided into items, factors, and in some instances, subfactors. The lowest level of subdivision depends on the complexity of the area being evaluated. (AFR 70-30)

These official guidelines for the evaluation criteria are consistent with the establishment of a hierarchy for proposal evaluation in this study using AHP.

The technical team will rate each proposal against the lowest level criteria as either Exceptional, Acceptable, Marginal, or Unacceptable. Except for the rating Unacceptable, each rating can have a (+) or (-) associated with it indicating there is a high, middle, and low range for each rating. The definitions for these ratings are contained in AFR 70-30, and are presented in Table 2.1.1.

The technical team is required to prepare a written report that documents the results of the evaluation of the proposals against the standards. The report is sent to the contracting office and becomes the basis for negotiations between the Air Force and the contractors.

TABLE 2.1.1.

Rating	Definition
Exceptional	Exceeds specified performance or capability in a beneficial way to the Air Force; and has high probability of satisfying the requirement; and has no significant weakness
Acceptable	Meets evaluation standards; and has good probability of satisfying the requirement; and any weaknesses can be readily corrected
Marginal	Fails to meet minimum evaluation standards; and has low probability of satisfying the requirement; and has significant deficiencies but correctable
Unacceptable	Fails to meet a minimum requirement; and deficiency requires major revision to the proposal to make it correct

The evaluation report will contain an overall rating for each contractor's proposal. Additionally, the report will include a discussion of the acceptable proposals considering each of the evaluation criteria with a narrative describing how the offeror met the criteria. If any proposal is found to be unacceptable, this must be fully documented in the report.

2.2. Review of Related Work

Much has been written about the advantages and disadvantages of the application of the Analytical Hierarchy Process (AHP). It is not within the scope of this study to discuss the arguments (either for or against) related to AHP's application. Therefore, the literature review focused on applications of AHP in the research and development (R & D) and source selection environments.

Section 2.1 above described how the existing processes for resource allocation and proposal evaluation work; the literature review concentrated on alternatives to these procedures. It was discovered that various multiattribute decision techniques have been examined by others in DOD to see how they may be utilized in various stages of the procurement process. The results of some of the representative analyses will be described in this section.

2.2.1. Decision Analysis in Source Selection

Two professors at the United States Air Force Academy, Lieutenant Colonel Vernon E. Francis and Captain Jeffrey S. Stonebraker investigated the application of formal decision analysis methods to the selection of the "best" contractor for defense system acquisition (Francis and Stonebraker, 1991). They examined Multiattribute Utility Theory (MAUT) and the AHP to determine how they could be applied to source selection in an Air Force system program office.

Additionally, they described the source selection process and both MAUT and AHP, as well as apply them both to an actual air Force source selection case study. Because this study focuses on the AHP, only their findings related to it will be discussed.

With current source selection procedures in systems acquisition, evaluation criteria are broken down into areas and areas are further subdivided into items, factors, and subfactors (AFR 70-30). The authors found that these elements map directly into a hierarchical model for use in AHP. In their study, they used the application of AHP found in the software package EXPERT CHOICE to aid in analysis of the source selection problem.

Because current procurement directives prohibit the direct comparison of competing contractors' proposals, an absolute system of measurement had to be developed. These gentlemen created an interesting absolute measurement system that will be described in detail and applied later in this study.

They also investigated ways to make the application of AHP to source selection more consistent with established procedures so that evaluators and decision makers would not have to learn a drastically different method. They did this by translating the numerical ratings produced by AHP into the color ratings used in the present evaluation system.

In their study of the application of AHP to source selection, they arrived at the following conclusion:

> It is the conclusion of this research that formal decision analysis should be used to improve the source selection process. In particular, decision analysis would assist evaluators in structuring this important problem, ascertaining the criteria upon which the decision should be based, deriving weights for these criteria, and evaluating contractor proposals against these criteria. Moreover, decision analysis would facilitate a more logical and consistent synthesis of judgements into a final ranking of contractor proposals. (Francis and Stonebraker, 1991)

2.2.2. Decision Models for Army R & D Project Selection

Given the recent changes in the international strategic environment and the resulting congressional emphasis on applied research short of production, US Army Captain Tod Jordan examined methods for applying multicriteria decision models to the Army's R & D project selection process (Jordan, 1992). He examines the AHP, MAUT, Goal Programming, and Graphical Techniques, presenting a description of each and a summary of their strengths and weaknesses.

After a description of the Army R & D Investment strategy, the author describes basic decision theory concepts and presents an introduction to analytic decision models. He then describes each of the multicriteria decision models, again, only research related to AHP will be described here.

In his description of AHP, Jordan states, "This technique is quite possibly the most important for quantifying qualitative expert opinion and judgment for decision support, at least in terms of its ease of use, its parallel to actual decision making processes, and its broad applicability." (Jordan, 1992). Sentiments similar to these were also expressed by the previous authors.

Captain Jordan presents an example of AHP that has for its top-level mandate Enhance Warfighting. The objectives that make up the next level of the hierarchy are Minimize Cost, Minimize Risk, Maximize Benefit, Maximize Capability, and Maximize Availability. Under this level would be the alternatives.

From this example of AHP and the other techniques described, Jordan concludes:

> For the Army research and development project selection problem, MCDM hold a great deal of promise. With increased pressure from Congress for the Department of Defense to assure America's technological defense superiority in the face of dramatically reduced defense spending, there will be increased scrutiny and accountability for the Army's R&D resource commitment

decisions. Multicriteria decision models offer a means to develop logically supportable solutions to this issue. (Jordan, 1992)

III. RESEARCH METHODOLOGY

As stated previously, the purpose of this study is to formulate a procedure to evaluate and prioritize programs and projects in the resource allocation and proposal evaluation stages of the procurement process in an Air Force research and development laboratory. The Analytical Hierarchy Process (AHP) developed by Saaty (Saaty, 1982) will be used in both stages. The first step in AHP is to determine the appropriate attributes and subattributes for both stages of the procurement process. The next step in the process is to classify the attributes into functional hierarchies. The final step of the process is to develop questionnaires for determining the relative importance of attributes which are then used in calculating the ranking and weighting of the attributes and subattributes.

3.1. Hierarchy for Projects and Proposals

Functional hierarchies can be used to break down complex systems into their constituent parts according to their essential relationships (Saaty, 1982). In this study, functional hierarchies were developed for evaluating projects before the Resource Allocation Committee (RAC) in the resource allocation stage, and for evaluating contractor proposals in the proposal evaluation stage. For the resource allocation hierarchy, the attributes identified are Need, Technical Approach, Innovation, Alternatives, and

Additional. The attributes identified for the proposal evaluation hierarchy are Understanding the Problem, Soundness of Approach, Compliance with Requirements, and Special Technical Factors.

> Because a hierarchy represents a model of how the brain analyzes complexity, the hierarchy must be flexible enough to deal with that complexity. The levels of hierarchy interconnect like layers of cell tissue to form an organic whole that serves a certain function. A spiraling effect is noticeable when we move from the focus expanding the hierarchy to the level of simple elements (Saaty, 1982).

To further define the main attributes in the resource allocation and proposal evaluation hierarchies, a second level of subattributes was added. The hierarchy diagrams for the resource allocation and proposal evaluation stages can be seen in Figure 3.1.1. and Figure 3.1.2. respectively.

In this study, appropriate attributes were established during an interview with the Director of the Electronic Warfare Division. These attributes have been used in the Division for several years. The attributes and subattributes used for the proposal evaluation stage are similar to those which are currently used for evaluating a research and development effort presently under contract. These were obtained during an interview with a division project engineer. Definitions for all attributes and subattributes is in contained Appendix A.

To see how to view the hierarchies, examine Figure 3.1.1, the hierarchy for resource allocation. On the first level, one of the attributes is Need. The subattributes under Need are Generally Critical, Limited Critical, Generally Non-Critical, and Limited Non-Critical, these define the second level of the hierarchy. The final level deals with the project alternatives before the Resource Allocation Committee (RAC).

Hierarchy for Resource Allocation

First level: Need, Technical Approach, Innovation, Alternatives, and Additional.

Second Level:

Need: Generally Critical, Limited Critical, Generally Non-Critical, Limited Non-Critical.

Technical Approach: Project Definition, Practicality, Feasibility.

Innovation: High Payoff Approach, Novel Approach, Some New Ideas, Routine.

Alternatives: None, Others/This Better, Several Equal, Many/Some Better.

Additional: Follow-On Program, Joint Program, In-House, Supports Other Programs, Supports Forecast II.

Third Level: Project 1, Project 2, Project 3

FIGURE 3.1.1

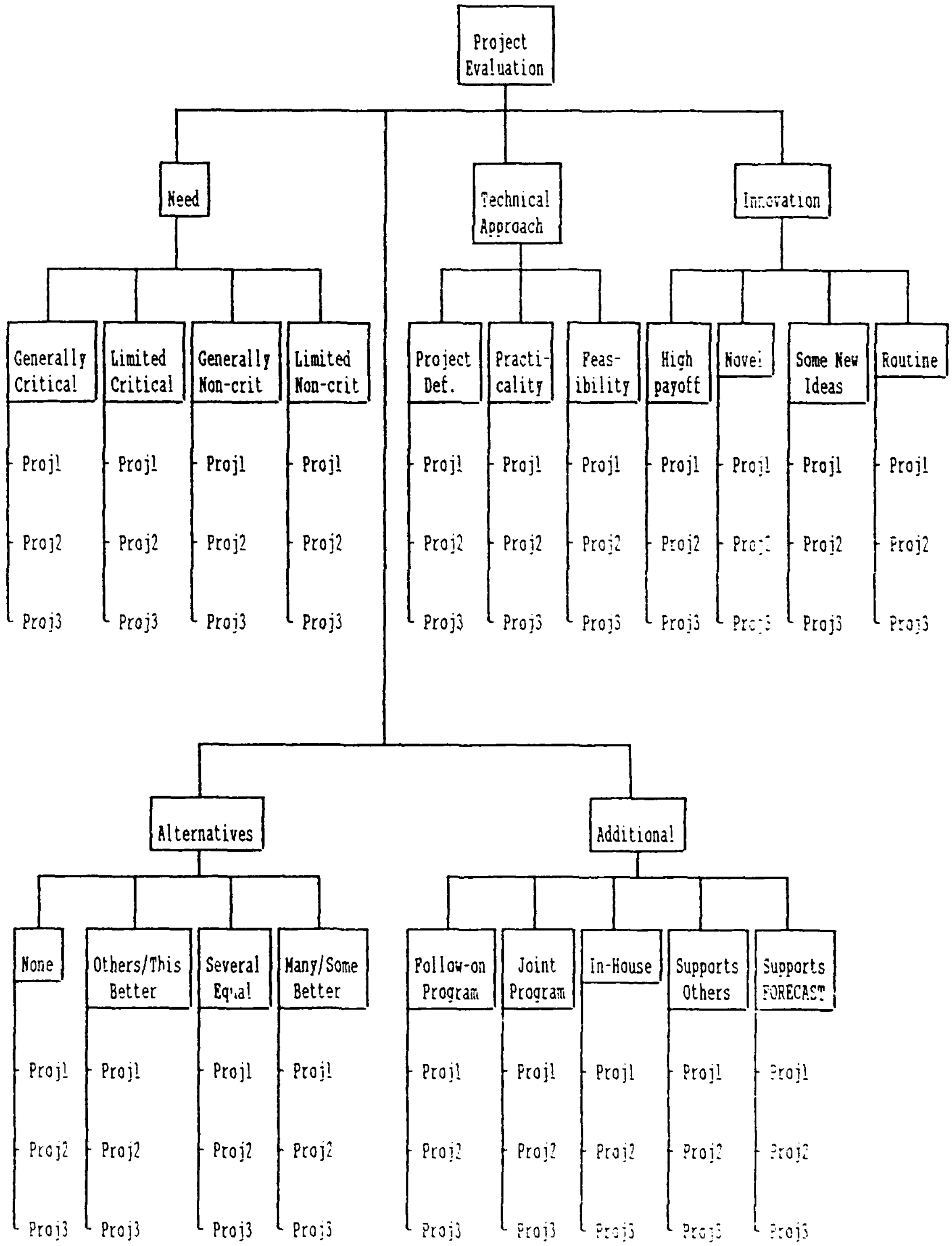
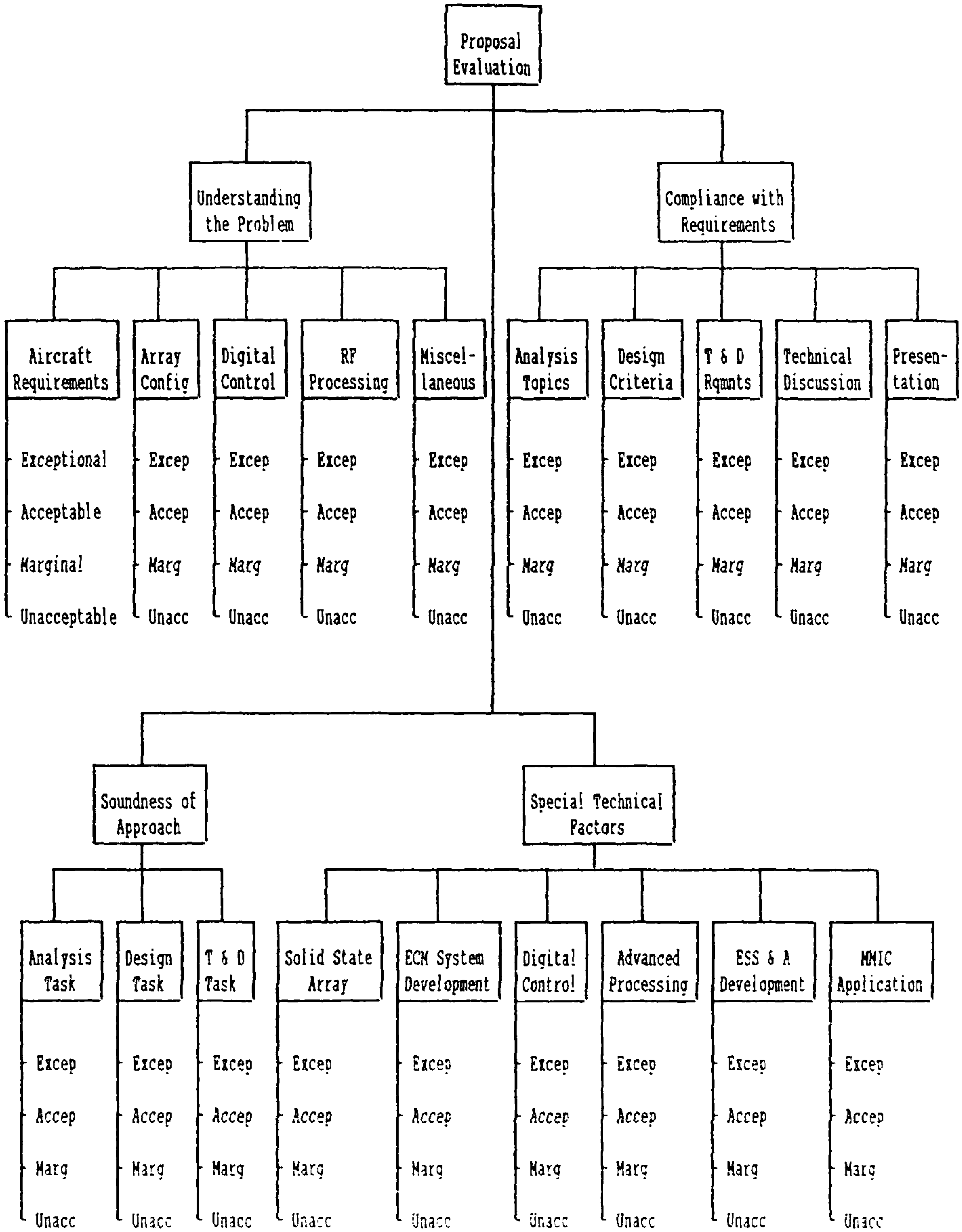

Project Evaluation
Need
Technical Approach
Innovation
Generally Critical
Limited Critical
Generally Non-crit
Limited Non-crit
Project Def.
Practi-cality
Feas-ibility
High payoff
Novel
Some New Ideas
Routine
Proj1
Proj2
Proj3
Alternatives
Additional
None
Others/This Better
Several Equal
Many/Some Better
Follow-on Program
Joint Program
In-House
Supports Others
Supports FORECAST

FIGURE 3.1.2.


Proposal Evaluation
Understanding the Problem
Compliance with Requirements
Aircraft Requirements
Array Config
Digital Control
RF Processing
Miscel- laneous
Analysis Topics
Design Criteria
T & D Rqmnts
Technical Discussion
Presen- tation
Exceptional
Acceptable
Marginal
Unacceptable
Excep
Accep
Marg
Unacc
Soundness of Approach
Special Technical Factors
Analysis Task
Design Task
T & D Task
Solid State Array
ECM System Development
Digital Control
Advanced Processing
ESS & A Development
MMIC Application

Hierarchy for Proposal Evaluation

First Level: Understanding the Problem, Soundness of Approach, Compliance with Requirements, Special Technical Factors.

Second Level:

Understanding the Problem: Aircraft Platform Requirements, Array Antenna Configuration Trade-Offs, Processing and Control, Signal Processing and Switching, Miscellaneous.

Soundness of Approach: Analysis, Design, Testing and Demonstration (T & D).

Compliance with Requirements: Address Minimum Analysis Topics, Meet Minimum, Design Criteria, Meet Minimum T & D requirements, No Restatement, Presentation.

Special Technical Factors: Design of Solid State Arrays, ECM System Development, Digital Controller Development, Advanced Processing Investigation, Embedded System Software, MMIC Device Application.

Third Level (proposal ratings): Exceptional, Acceptable, Marginal, and Unacceptable.

3.2. Procedure for Data Collection

Recall, one of the objectives of this study was to develop an easy to use procedure to evaluate and prioritize projects brought before the RAC and proposals sent in by defense contractors. A two step methodology has been developed through the use of AHP to institute a procedure, recognizing the individual differences among R & D organization's resource allocation and project engineer's proposal evaluation priorities. In step one, data on the preferences among different attributes is collected, this is done using pairwise comparisons. Pairwise comparisons are accomplished by comparing two attributes within a given level of the hierarchy and rating them with respect to each other on a scale of 1 to 9. The scale reflects the degree of importance between the two attributes. The relative weights of the attributes are determined in the second step using the pairwise comparison data of step one. The weights are then used to determine the scores for each project or proposal.

In his development of AHP, Saaty states:

> Humans have the ability to perceive relationships among the things they observe, to compare pairs of similar things against certain criteria, and to discriminate between members of a pair by judging the intensity of their preference for one over the other. Then they synthesize their judgements -- through imagination or, with the AHP, through a new logical process -- and gain a better understanding of the whole system. (Saaty 1982)

This provides the basis for the use of pairwise comparisons in determining the relative importance of all the attributes and subattributes in the two previously described hierarchies.

The hierarchies described earlier for resource allocation and proposal evaluation were used to develop questionnaires for evaluating the relative importance of the attributes and subattributes. For example, a questionnaire was developed to ascertain the importance of Need in the resource allocation hierarchy. The respondent was given a questionnaire with a complete set of instructions for its completion. His preferences were indicated by placing a check mark under the appropriate number of the scale on either the right or left side of the table, depending upon which attribute was preferred. A copy of the questionnaires and their instructions is included in Appendix C. Basically, the questionnaire requires the respondent to determine two things: 1) which attribute/subattribute is more important, and 2) by how much.

3.2.1. Resource Allocation Stage

To show how this process can be applied to the resource allocation stage, a simulated RAC was established. Personnel included on this committee were the Division Chief/Director, Director of Analysis Projects for the division, and three project engineers who have extensive experience with the RAC. Normally, the RAC would consist of the Division Chief, the Division Technical Director, and all the Branch Chiefs.

Each of these individuals was given a questionnaire, complete with instructions, and asked to carefully fill out the tables. Their responses were used to calculate a final score for each project, this procedure will be described in detail in the following sections.

3.2.2. Proposal Evaluation Stage

Application of the process to the proposal evaluation stage was accomplished by examining a research and development effort that is presently under contract. The model was applied using the actual criteria that were used to evaluate proposals sent in response to this effort. Because of the security classification and sensitive nature of some of the proposals sent in by defense contractors, the project engineer asked that the real proposals not be used in this evaluation.

The project engineer for the R & D effort used in this study was furnished with the instructions and questionnaire for evaluating technical proposals found in Appendix D. His responses were used to evaluate and prioritize three fictitious proposals. Again, this procedure will be described in detail in the following sections.

3.3. Calculation of Priority Weights

The procedure for calculating the priority weights is the same for both the resource allocation and proposal evaluation stages in this study. Different weights are assigned to the attributes by translating the data from a given comparison table to a preference matrix. The eigen values of the preference matrix then become the weights for each attribute.

An approximate method is used to determine the eigen values of the preference matrix. With the approximate method, the weights are calculated by summing each column of the preference matrix individually and dividing each element of the column by the sum. Next find the mean for each row of the matrix, this becomes the weight (approximate eigen value) for that row. A computer spreadsheet has been developed to calculate the approximate eigen values.

The above procedure is best illustrated through an example. The proposal evaluation comparison Table 3.3.1 was completed by a project engineer in the division studied.

Previously it was shown that there are four main attributes in the proposal evaluation hierarchy, the initial step is the formation of a four-by-four matrix; this is known as the preference matrix, and in this case, has 16 entries. Notice that the diagonal of the matrix consists of all 1s, this is because each criteria is compared with itself. In translating the comparisons table to a matrix, first determine whether the row is more important or the column is more important. With respect to proposal evaluation, if the row is more important, the value from the comparisons table is copied into this entry. Conversely, if the column is more important, the reciprocal of the value from the comparisons table is copied into this entry. A preference matrix based on the Table 3.3.1 (the comparisons table for proposal evaluation) is shown in Table 3.3.2.

TABLE 3.3.1.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
UNDERSTANDING																			SOUNDNESS
UNDERSTANDING																			COMPLIANCE
UNDERSTANDING																			SPECIAL FACTORS
SOUNDNESS																			COMPLIANCE
SOUNDNESS																			SPECIAL FACTORS
COMPLIANCE																			SPECIAL FACTORS

TABLE 3.3.2.

PROPOSAL EVALUATION	UP	SA	CR	STF
Understanding the Problem (UP)	1	3	6	5
Soundness of Approach (SA)	1/3	1	5	4
Compliance with Requirements (CR)	1/6	1/5	1	1/2
Special Technical Factors (STF)	1/5	1/4	2	1

TABLE 3.3.3.

	Priority Weight
Understanding the Problem	0.54
Soundness of Approach	0.29
Compliance with Requirements	0.07
Special Technical Factors	0.10
Total	1.00

3.4. Calculation of Project/Proposal Scores

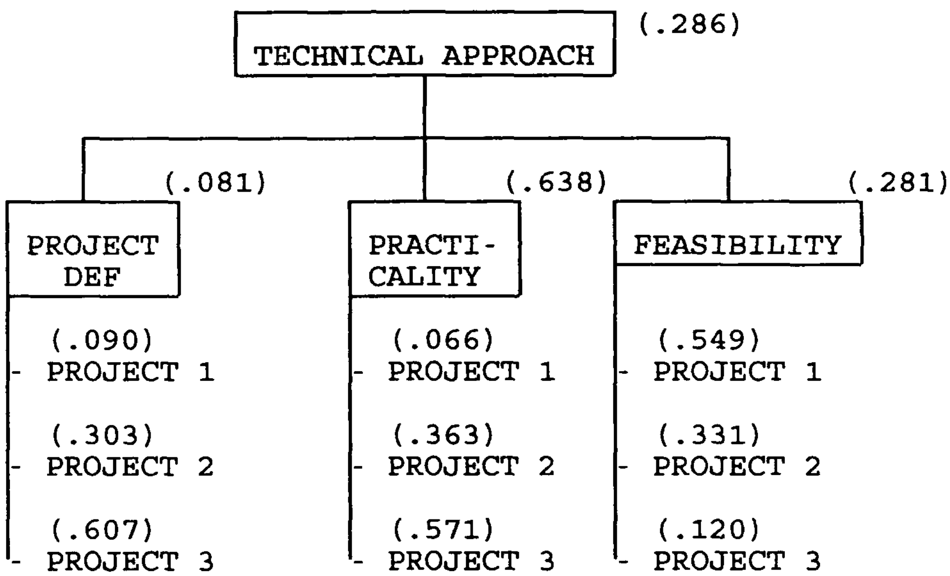
After the pairwise comparisons are completed at all levels of the hierarchies and the weights established from the preference matrices, a single score of the overall performance of each alternative can be calculated.

3.4.1. Resource Allocation Project Scores

The final ranking of projects brought before the RAC is derived by using a combination of methods from the existing process and methods used in AHP.

Again, a brief example will be useful in illustrating the methodology for calculating the project score. Figure 3.4.1. shows one level of the resource allocation hierarchy along with the weights calculated using the method of the previous section. The score for an alternative is determined by the sum of products of the value of the attribute and its weight. The interim score calculated in this example is only for Technical Approach, similarly scores would be calculated for the other attributes at level 1 (Need, Innovation, Alternatives, and Additional). The interim scores would then be summed across the hierarchy for all alternatives to determine their final scores.

FIGURE 3.4.1.



Project 1 = .286[.081(.090)+.638(.066)+.281(.549)]

= .058

similarly for Project 2, we have

Project 2 = .286[.081(.303)+.638(.363)+.281(.120)]

= .100

finally, for Project 3, we have

Project 3 = .286[.081(.607)+.638(.571)+.281(.120)]

= .128

This would provide an interim score at Technical Approach, similar interim scores would be calculated at the other level one attributes and summed to determine the final score for each project.

$$\text{Final Score}_{\text{Project 1}} = \text{Score at Need} + \text{Score at Technical of Approach} + \text{Score at Innovation} + \text{Score at Alternatives} + \text{Score at Additional}$$

This process is called "folding back the tree."

It was noted in Section Two that in the resource allocation process, several committee members evaluate the projects and their individual responses must be aggregated. To accomplish this aggregation in this study, a method similar to that used in the existing process will be applied.

Final scores for each project will be calculated for each evaluator. Based on the final scores, the projects will be rank ordered for each committee member, for example, the committee chairman may have the projects ranked as follows: project three ranked one, project one ranked two, and project two ranked three. The interim rankings for each evaluator would then be averaged to determine the final rankings.

3.4.2. Proposal Evaluation Scores

Because procurement regulations prohibit the direct comparison of contractors on a numerical scale (AFR 70-30, par 30d.), we cannot use pairwise comparisons to compare the contractors. Thus an absolute method of evaluating the proposals needed to be adopted in the model.

The absolute ratings used to evaluate the proposals are exceptional, acceptable, marginal, and unacceptable. These are the ratings specified in the regulation governing technical evaluations of proposals in the organization studied (WRDC Regulation 70-5). Each rating could have a plus (+) or minus (-) associated with it, i.e., a rating of 'exceptional +' is possible.

The method applied here is based on the one proposed by Francis and Stonebraker. In their application of AHP to source selection, they used color coded ratings which would correspond to the four ratings used in this study.

> For each criterion at the lowest level of the hierarchy, pairwise comparisons were initially employed to determine the relative importance of the colors with respect to each of these criteria. This permits item specific meanings for the color ratings. (Francis and Stonebraker, 1991)

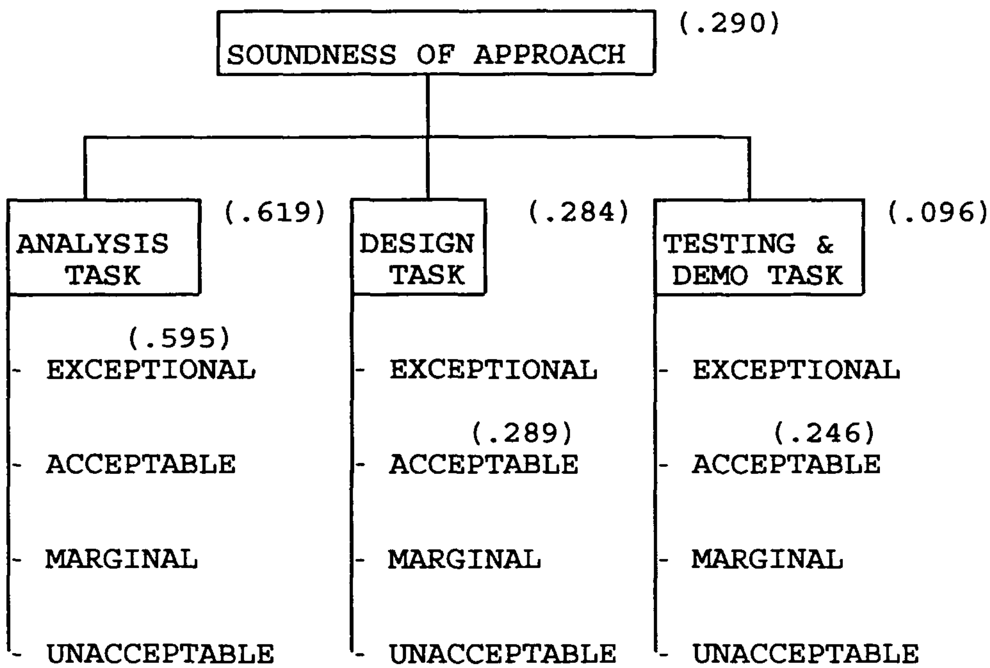
To visualize what they mean by item specific meanings for the ratings, consider this example, the relative importance of unacceptable and exceptional will probably be different when rating Aircraft Platform Requirements versus Presentation.

The last section of the proposal evaluation questionnaire contains comparison tables for the four ratings considering the lowest level criteria in the proposal evaluation hierarchy. Also contained in this section are tables to evaluate each proposal independently against the criteria (see Appendix C). Notice that each of the three proposals could possibly receive the same rating.

The final score the proposal receives is calculated as follows: the rating the proposal receives for a given criterion is assigned the weight for that rating (weights determined from the pairwise comparisons), this is done for all the criteria in the lowest level of the hierarchy; the remainder of the calculation is the same "folding back the tree" process found in the previous section.

Here, a brief example will be useful in illustrating the methodology for calculating the final score. Figure 3.4.2. shows one level of the proposal evaluation hierarchy along with the weights calculated using the method of the Section 3.3. Assume the proposal being evaluated was rated exceptional for Analysis Task, and acceptable for both Design Task and Testing and Demonstration Task. The interim score at Soundness of Approach would be 0.150. The final score for the project would be the sum of the interim scores at Understanding the Problem, Soundness of Approach, Compliance with Requirements, and Special Technical Factors.

FIGURE 3.4.2.



Interim score at Soundness of Approach = .290[.595(.691)+ .289(.284)+.246(.096)] = .150

To be consistent with present procurement procedures, the final score must be translated to an overall rating of exceptional, acceptable, marginal, or unacceptable.

Again, Francis and Stonebraker provide guidance for making this translation:

In our application to the case study, we investigated ways to translate the numerical "composite priorities" provided by the AHP back into a traditional color rating. This makes the application of AHP to source selection consistent with established procedures. Moreover, the AHP methodology is almost totally "hidden" from the users, giving the appearance that they are "conducting business as usual." It should be emphasized that

1. all of the advantages of applying the AHP are retained,

2. source selection proceeds as specified in existing regulations, directives and policies, and

3. evaluators and decision makers are not confronted with changing to and learning a dramatically different method. (Francis and Stonebraker, 1991)

The actual translation of the final scores into the ratings they prescribed is done as follows :

1. For the attributes being evaluated, set all evaluations to exceptional. Note the resultant final score. This becomes the upper limit for exceptional.
2. Set all evaluations to acceptable. Note the resultant final score.
3. The average of the final scores obtained in steps 1 and 2 is the lower limit of the exceptional range and the upper limit of the acceptable range.
4. Repeat steps 1 through 3 for acceptable and marginal.

The following table provides hypothetical results using the above procedure.

TABLE 3.4.1.

Evaluations all set to:	Resultant final score	Average	Rating Code Range
Exceptional	0.54		0.430 - 0.540
		0.430	
Acceptable	0.32		0.235 - 0.429
		0.235	
Marginal	0.15		0.095 - 0.234
		0.095	
Unacceptable	0.04		

The extreme points for each rating range could then be used for the plus and minus designations. Assume proposal one receives a final score of 0.440, thus its rating would then be exceptional.

IV. PERFORMANCE EVALUATION

The model and application procedures developed in this study were used in two stages of the procurement process in an Air Force research and development laboratory: the resource allocation stage and the proposal evaluation stage. In the resource allocation stage, the method for prioritizing projects was briefed (and questionnaires provided) to five members of the division studied, these individuals comprised the Resource Allocation Committee (RAC) used in the study. Typically, the RAC would be made up of the Division Chief, Division Technical Director, and the four Branch Chiefs. The results provided by the RAC members will be analyzed and the projects ranked according to the procedure outlined in the previous section. To demonstrate how the method can be applied in the proposal evaluation stage, a project engineer in the division was asked to complete the questionnaire. The criteria/ attributes used in both stages of the study were provided by the division and have been previously used in practice. Actual names and addresses of the respondents in this study have been withheld for confidentiality reasons.

With the resource allocation stage of the study, a pairwise comparison of the attributes and the projects in the resource allocation hierarchy was completed by each member of the RAC using the questionnaire in Appendix C.

Similarly, the project engineer completed a pairwise comparison of the attributes and ratings for proposals in the project evaluation hierarchy using the questionnaire in Appendix D. The proposals were then evaluated against the lowest level criteria in the proposal evaluation hierarchy using the evaluation tables in the last part of Appendix D.

The data were analyzed by the procedure outlined in Section Three. The results of both of these analyses are fully discussed in the following sections.

4.1.1. Resource Allocation Stage

There were five people from the division who completed questionnaires for this stage of the process. Each respondent's results will be analyzed separately and summarized in the following pages.

Recall, the attributes identified at the first level of the resource allocation hierarchy are: Need, Technical Approach, Innovation, Alternatives, and Additional. The preference matrices for each evaluator considering these level-one attributes is presented in Table 4.1.1. The priority weights (PW) shown are the approximate eigenvalues of the comparison matrix.

Looking at Table 4.1.1, it is seen that all evaluators agree that Need is the most important attribute. This is to be expected, why spend scarce research and development dollars on something that is not needed. Moreover, all evaluators, except evaluator five, agree that Technical Approach is second, and Additional is third.

TABLE 4.1.1.

Project Evaluation	Need	TA	ADD	ALT	IN	PW
Need	1	2	4	4	4	.412
Technical Approach (TA)	1/2	1	5	4	3	.308
Additional (ADD)	1/4	1/5	1	1	1/2	.076
Alternatives (ALT)	1/4	1/4	1	1	1/2	.079
Innovation (IN)	1/4	1/3	2	2	1	.126
Project Evaluation	Need	TA	ADD	ALT	IN	PW
Need	1	1	5	5	3	.358
Technical Approach (TA)	1	1	5	5	2	.329
Additional (ADD)	1/5	1/5	1	1	1/2	.087
Alternatives (ALT)	1/5	1/5	1	1	1/2	.087
Innovation (IN)	1/3	1/2	2	2	1	.140
Project Evaluation	Need	TA	ADD	ALT	IN	PW
Need	1	2	7	5	2	.430
Technical Approach (TA)	1/2	1	5	2	2	.253
Additional (ADD)	1/7	1/5	1	1/2	1/2	.059
Alternatives (ALT)	1/5	1/2	2	1	1	.116
Innovation (IN)	1/2	1/2	2	1	1	.142

TABLE 4.1.1 Continued

Project Evaluation	Need	TA	ADD	ALT	IN	PW
Need	1	5	3	3	5	.400
Technical Approach (TA)	1/5	1	7	5	6	.286
Additional (ADD)	1/3	1/7	1	5	1/5	.105
Alternatives (ALT)	1/3	1/5	1/5	1	1/5	.055
Innovation (IN)	1/5	1/6	5	5	1	.155
Project Evaluation	Need	TA	ADD	ALT	IN	PW
Need	1	1	2	3	4	.323
Technical Approach (TA)	1	1	2	4	3	.326
Additional (ADD)	1/2	1/2	1	1	1	.133
Alternatives (ALT)	1/3	1/4	1	1	2	.124
Innovation (IN)	1/4	1/3	1	1/2	1	.095

For brevity, preference matrices for the second and third levels of the resource allocation hierarchy for each evaluator are not included here; however, the results of the analysis of the preference matrices for each evaluator are summarized in the tables that follow.

The summary of the comparison of subattributes under Need: Generally Critical, Limited Critical, Generally Non-Critical, and Limited Non-Critical is shown in Table 4.1.2. The elements in the table are the priority weights calculated for each evaluator.

TABLE 4.1.2.

	Evaluator				
NEED	1	2	3	4	5
Generally Critical	.585	.622	.578	.533	.553
Limited Critical	.228	.218	.270	.252	.205
Generally Non-Crit	.136	.117	.081	.159	.186
Limited Non-Crit	.051	.043	.071	.056	.056

The second-level attributes identified to further define Technical Approach are: Project definition, Practicality and Feasibility. The priority weights calculated for each of the five evaluators are shown below in Table 4.1.3.

TABLE 4.1.3.

	Evaluator				
TECHNICAL APPROACH	1	2	3	4	5
Project Definition	.321	.259	.525	.081	.400
Practicality	.225	.171	.142	.638	.400
Feasibility	.454	.570	.334	.281	.200

High Payoff Approach, Novel Approach, Some New Ideas, and Routine are the second-level subattributes under Innovation. The priority weights calculated for each of the five evaluators are shown in below in Table 4.1.4.

TABLE 4.1.4.

	Evaluator				
INNOVATION	1	2	3	4	5
High Payoff Approach	.601	.618	.529	.684	.454
Novel Approach	.235	.246	.244	.164	.191
Some New Ideas	.114	.091	.183	.110	.191
Routine	.050	.045	.045	.042	.163

The subattributes identified under the level-one attribute Alternatives are: None, Others/This Better, Several Equal, Many/Some Better. The priority weights calculated for each evaluator are shown below in Table 4.1.5.

TABLE 4.1.5.

	Evaluator				
ALTERNATIVES	1	2	3	4	5
None	.641	.571	.625	.675	.591
Others/This Better	.198	.228	.234	.105	.245
Several Equal	.096	.127	.106	.115	.064
Many/Some Better	.064	.073	.035	.105	.101

The final level-one attribute is Additional, the subattributes under this are: Follow-On, Joint Program, In-House, Supports Others, Supports Forecast II. The priority weights calculated for each evaluator are shown in Table 4.1.6.

Once all of the priority weights are calculated for all of the attributes and subattributes, the weights the proposals receive considering each of the subattributes need to be calculated for each evaluator. The results of this analysis are summarized in Table 4.1.7.

The resource allocation hierarchies complete with weights for all evaluators are presented in Figures 4.1.1. through 4.1.5. respectively.

TABLE 4.1.6.

	Evaluator				
ADDITIONAL	1	2	3	4	5
Follow-On	.222	.337	.489	.052	.169
Joint Program	.267	.203	.122	.488	.144
In-House	.144	.112	.243	.137	.144
Supports Others	.244	.269	.094	.201	.255
Supports Forecast II	.122	.079	.051	.122	.288

TABLE 4.1.7.

		Evaluator				
SUBATTRIBUTE	PROPOSAL	1	2	3	4	5
Generally Critical	1	.701	.467	.056	.065	.263
	2	.234	.467	.242	.259	.288
	3	.065	.067	.702	.675	.448
Limited Critical	1	.703	.455	.056	.067	.198
	2	.222	.455	.242	.467	.490
	3	.075	.090	.702	.467	.312
Generally Non-Critical	1	.525	.429	.056	.315	.333
	2	.334	.429	.263	.204	.333
	3	.142	.143	.681	.481	.333
Limited Non-Critical	1	.765	.429	.055	.714	.333
	2	.197	.429	.227	.143	.333
	3	.070	.143	.717	.143	.333
Project Definition	1	.725	.122	.078	.090	.233
	2	.200	.230	.234	.303	.367
	3	.075	.648	.688	.607	.400
Practicality	1	.717	.633	.333	.066	.333
	2	.218	.260	.333	.363	.333
	3	.065	.106	.333	.571	.333
Feasibility	1	.717	.455	.117	.549	.264
	2	.218	.455	.538	.331	.329
	3	.065	.090	.345	.120	.407

TABLE 4.1.7. Continued

		Evaluator				
SUBATTRIBUTE	PROPOSAL	1	2	3	4	5
High Pay-off	1	.668	.648	.052	.071	.218
	2	.257	.230	.632	.206	.348
	3	.075	.122	.316	.723	.434
Novel Approach	1	.607	.778	.052	.140	.172
	2	.303	.111	.579	.574	.350
	3	.090	.111	.368	.286	.478
Some New Ideas	1	.638	.600	.052	.140	.225
	2	.273	.200	.579	.286	.454
	3	.089	.200	.368	.574	.321
Routine	1	.694	.333	.808	.090	.537
	2	.231	.333	.074	.303	.268
	3	.075	.333	.118	.607	.195
None	1	.600	.600	.061	.333	.333
	2	.200	.200	.723	.333	.333
	3	.200	.200	.216	.333	.333
Others/This Better	1	.600	.600	.052	.333	.407
	2	.200	.200	.685	.333	.329
	3	.200	.200	.263	.333	.264
Several Equal	1	.537	.537	.090	.138	.333
	2	.268	.268	.556	.239	.333
	3	.195	.195	.354	.623	.333

TABLE 4.1.7. Continued

		Evaluator				
SUBATTRIBUTE	PROPOSAL	1	2	3	4	5
Many/Some Better	1	.333	.333	.667	.140	.524
	2	.333	.333	.167	.286	.304
	3	.333	.333	.167	.574	.172
Follow-On Program	1	.590	.655	.750	.600	.411
	2	.145	.158	.125	.200	.328
	3	.266	.187	.125	.200	.261
Joint Program	1	.443	.443	.333	.333	.333
	2	.387	.387	.333	.333	.333
	3	.170	.170	.333	.333	.333
In-House	1	.333	.333	.333	.686	.417
	2	.333	.333	.333	.211	.231
	3	.333	.333	.333	.102	.352
Supports Others	1	.333	.333	.333	.089	.235
	2	.333	.333	.333	.658	.325
	3	.333	.333	.333	.253	.440
Supports FORECAST II	1	.333	.333	.333	.138	.250
	2	.333	.333	.333	.239	.500
	3	.333	.333	.333	.623	.250

FIGURE 4.1.1

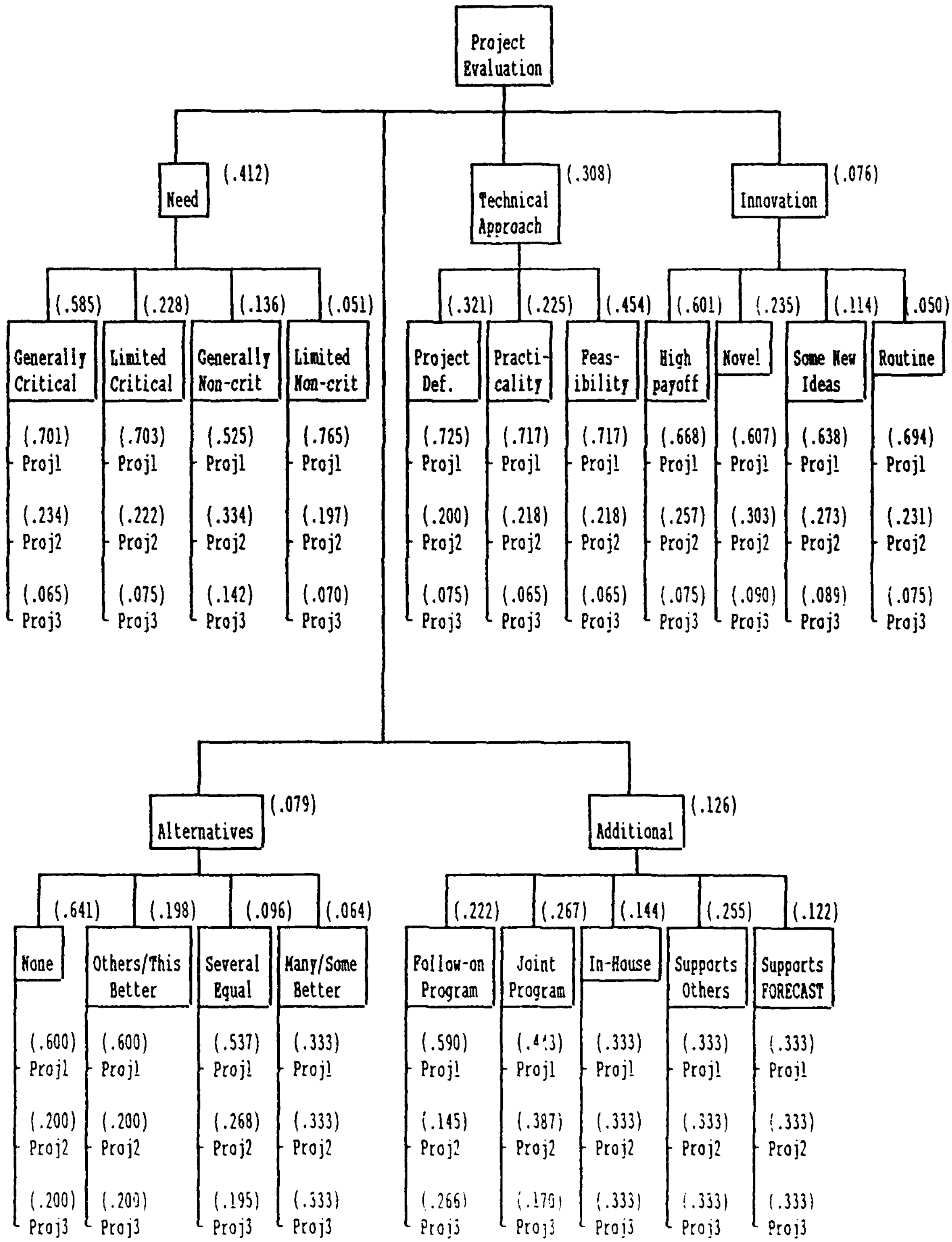

Project Evaluation
Need (.412)
Technical Approach (.308)
Innovation (.076)
Alternatives (.079)
Additional (.126)
(.585) Generally Critical
(.701) Proj1
(.234) Proj2
(.065) Proj3
(.228) Limited Critical
(.703) Proj1
(.222) Proj2
(.075) Proj3
(.136) Generally Non-crit
(.525) Proj1
(.334) Proj2
(.142) Proj3
(.051) Limited Non-crit
(.765) Proj1
(.197) Proj2
(.070) Proj3
(.321) Project Def.
(.725) Proj1
(.200) Proj2
(.075) Proj3
(.225) Practi-cality
(.717) Proj1
(.218) Proj2
(.065) Proj3
(.454) Feas-ibility
(.717) Proj1
(.218) Proj2
(.065) Proj3
(.601) High payoff
(.668) Proj1
(.257) Proj2
(.075) Proj3
(.235) Novel
(.607) Proj1
(.303) Proj2
(.090) Proj3
(.114) Some New Ideas
(.638) Proj1
(.273) Proj2
(.089) Proj3
(.050) Routine
(.694) Proj1
(.231) Proj2
(.075) Proj3
(.641) None
(.600) Proj1
(.200) Proj2
(.200) Proj3
(.198) Others/This Better
(.600) Proj1
(.200) Proj2
(.200) Proj3
(.096) Several Equal
(.537) Proj1
(.268) Proj2
(.195) Proj3
(.064) Many/Some Better
(.333) Proj1
(.333) Proj2
(.333) Proj3
(.222) Follow-on Program
(.590) Proj1
(.145) Proj2
(.266) Proj3
(.267) Joint Program
(.443) Proj1
(.387) Proj2
(.170) Proj3
(.144) In-House
(.333) Proj1
(.333) Proj2
(.333) Proj3
(.255) Supports Others
(.333) Proj1
(.333) Proj2
(.333) Proj3
(.122) Supports FORECAST
(.333) Proj1
(.333) Proj2
(.333) Proj3

FIGURE 4.1.2

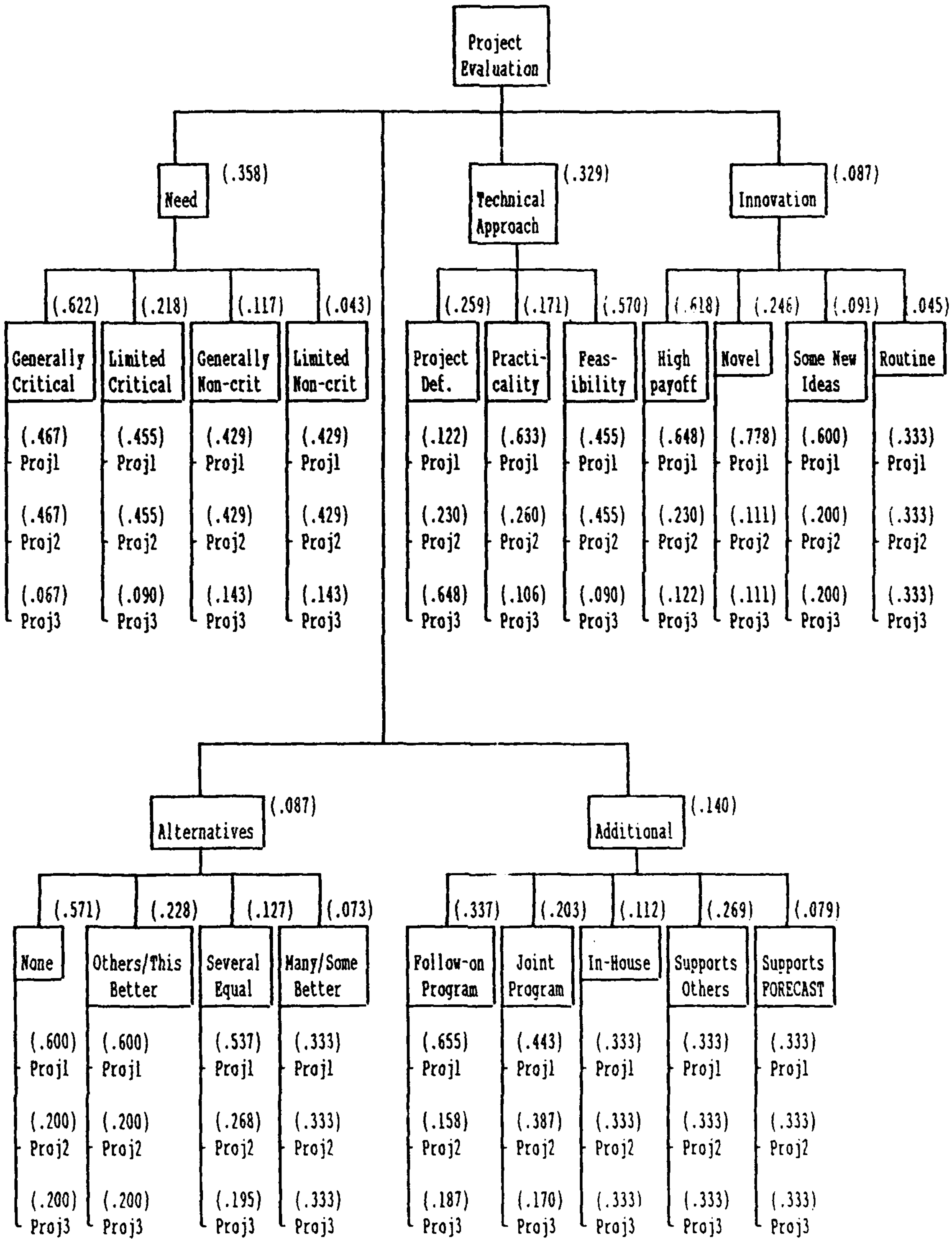

Project Evaluation
Need (.358)
Technical Approach (.329)
Innovation (.087)
Alternatives (.087)
Additional (.140)
(.622) Generally Critical (.467) Proj1 (.467) Proj2 (.067) Proj3
(.218) Limited Critical (.455) Proj1 (.455) Proj2 (.090) Proj3
(.117) Generally Non-crit (.429) Proj1 (.429) Proj2 (.143) Proj3
(.043) Limited Non-crit (.429) Proj1 (.429) Proj2 (.143) Proj3
(.259) Project Def. (.122) Proj1 (.230) Proj2 (.648) Proj3
(.171) Practi-cality (.633) Proj1 (.260) Proj2 (.106) Proj3
(.570) Feas-ibility (.455) Proj1 (.455) Proj2 (.090) Proj3
(.618) High payoff (.648) Proj1 (.230) Proj2 (.122) Proj3
(.246) Novel (.778) Proj1 (.111) Proj2 (.111) Proj3
(.091) Some New Ideas (.600) Proj1 (.200) Proj2 (.200) Proj3
(.045) Routine (.333) Proj1 (.333) Proj2 (.333) Proj3
(.571) None (.600) Proj1 (.200) Proj2 (.200) Proj3
(.228) Others/This Better (.600) Proj1 (.200) Proj2 (.200) Proj3
(.127) Several Equal (.537) Proj1 (.268) Proj2 (.195) Proj3
(.073) Many/Some Better (.333) Proj1 (.333) Proj2 (.333) Proj3
(.337) Follow-on Program (.655) Proj1 (.158) Proj2 (.187) Proj3
(.203) Joint Program (.443) Proj1 (.387) Proj2 (.170) Proj3
(.112) In-House (.333) Proj1 (.333) Proj2 (.333) Proj3
(.269) Supports Others (.333) Proj1 (.333) Proj2 (.333) Proj3
(.079) Supports FORECAST (.333) Proj1 (.333) Proj2 (.333) Proj3

FIGURE 4.1.3

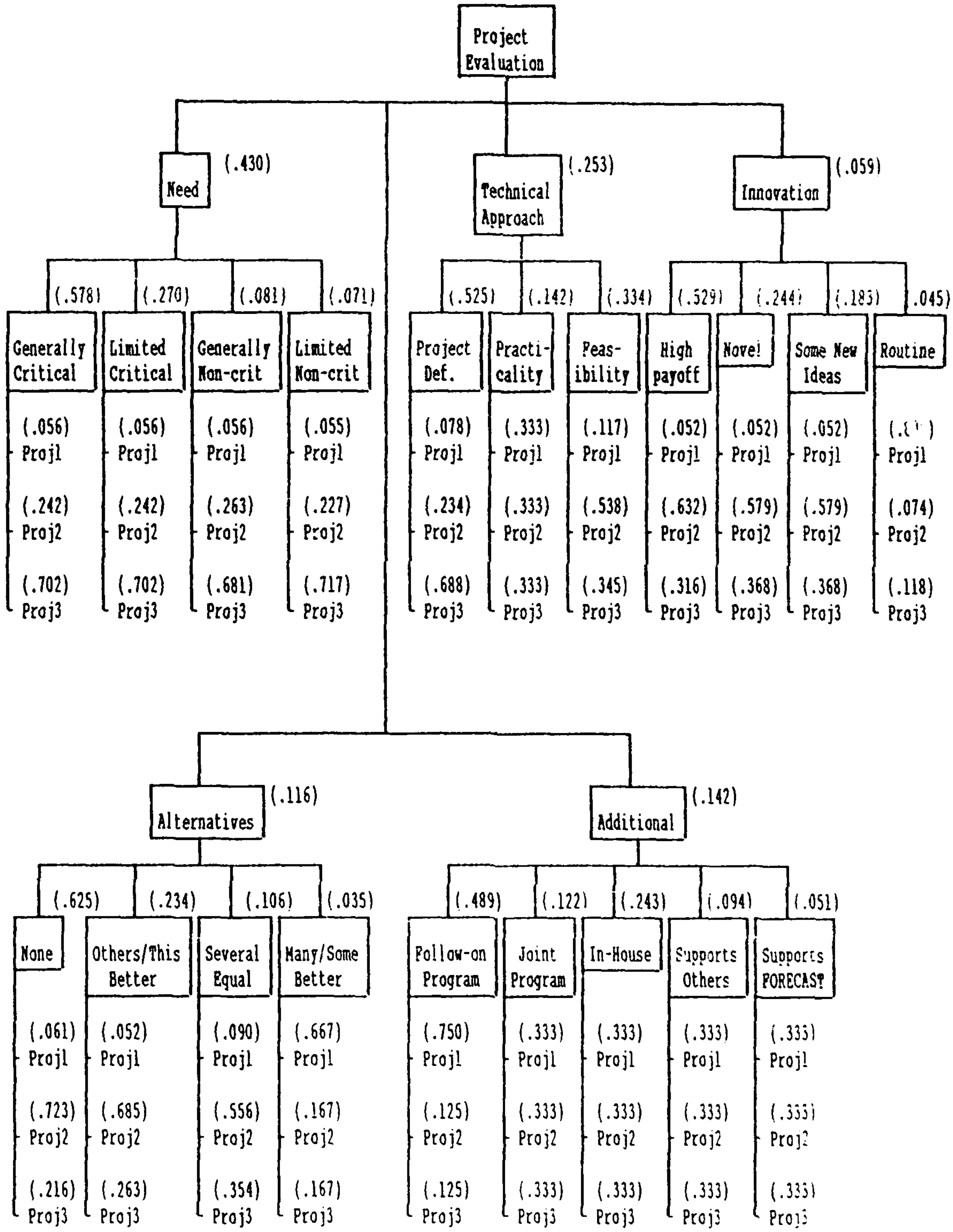

Project Evaluation
Need (.430)
Technical Approach (.253)
Innovation (.059)
Alternatives (.116)
Additional (.142)
(.578) Generally Critical
(.270) Limited Critical
(.081) Generally Non-crit
(.071) Limited Non-crit
(.056) Proj1 (.242) Proj2 (.702) Proj3
(.056) Proj1 (.242) Proj2 (.702) Proj3
(.056) Proj1 (.263) Proj2 (.681) Proj3
(.055) Proj1 (.227) Proj2 (.717) Proj3
(.525) Project Def.
(.142) Practi-cality
(.334) Feas-ibility
(.078) Proj1 (.234) Proj2 (.688) Proj3
(.333) Proj1 (.333) Proj2 (.333) Proj3
(.117) Proj1 (.538) Proj2 (.345) Proj3
(.529) High payoff
(.244) Novel
(.183) Some New Ideas
.045) Routine
(.052) Proj1 (.632) Proj2 (.316) Proj3
(.052) Proj1 (.579) Proj2 (.368) Proj3
(.052) Proj1 (.579) Proj2 (.368) Proj3
Proj1 (.074) Proj2 (.118) Proj3
(.625) None
(.234) Others/This Better
(.106) Several Equal
(.035) Many/Some Better
(.061) Proj1 (.723) Proj2 (.216) Proj3
(.052) Proj1 (.685) Proj2 (.263) Proj3
(.090) Proj1 (.556) Proj2 (.354) Proj3
(.667) Proj1 (.167) Proj2 (.167) Proj3
(.489) Follow-on Program
(.122) Joint Program
(.243) In-House
(.094) Supports Others
(.051) Supports FORECAST
(.750) Proj1 (.125) Proj2 (.125) Proj3
(.333) Proj1 (.333) Proj2 (.333) Proj3
(.333) Proj1 (.333) Proj2 (.333) Proj3
(.333) Proj1 (.333) Proj2 (.333) Proj3
(.333) Proj1 (.333) Proj2 (.333) Proj3

FIGURE 4.1.4

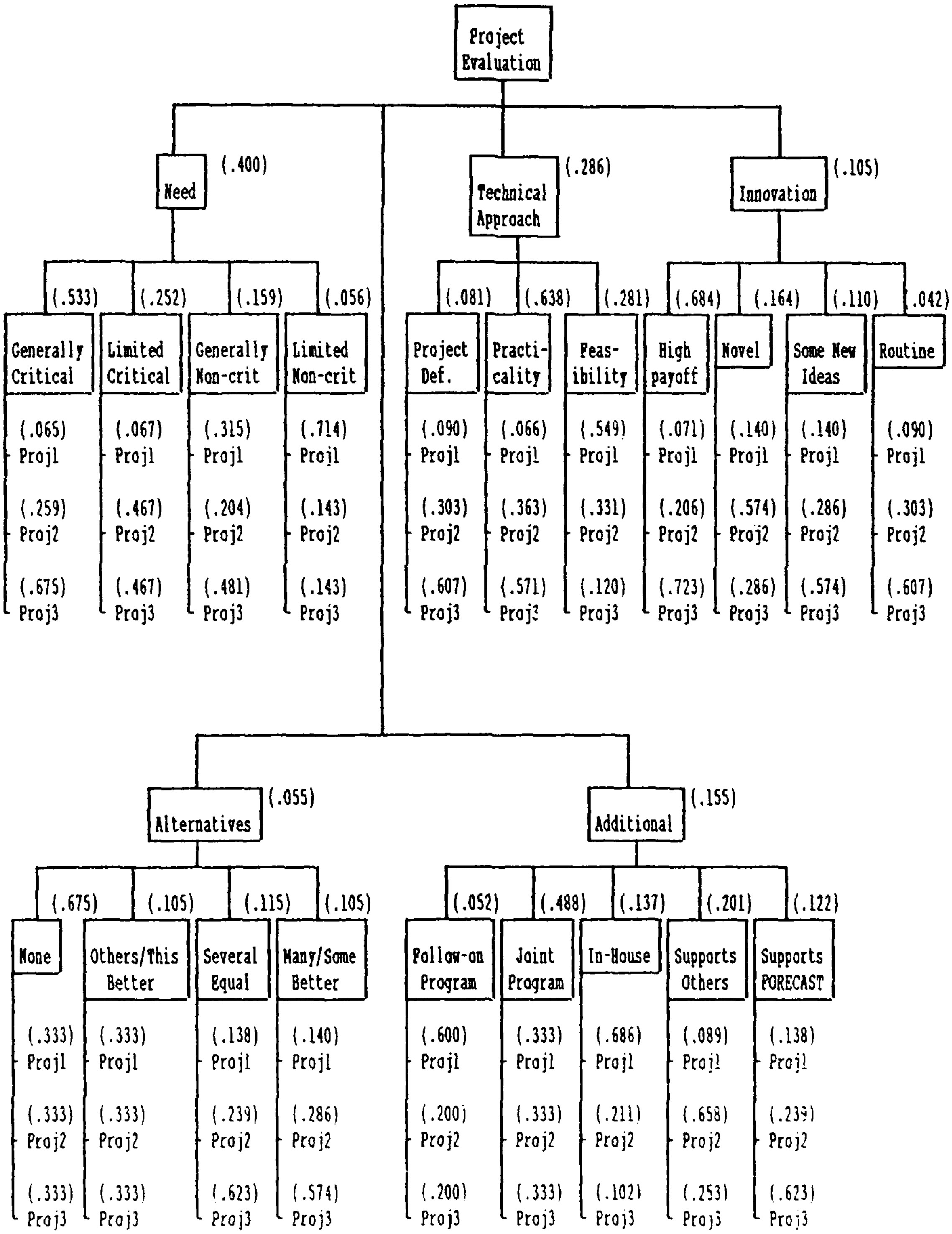
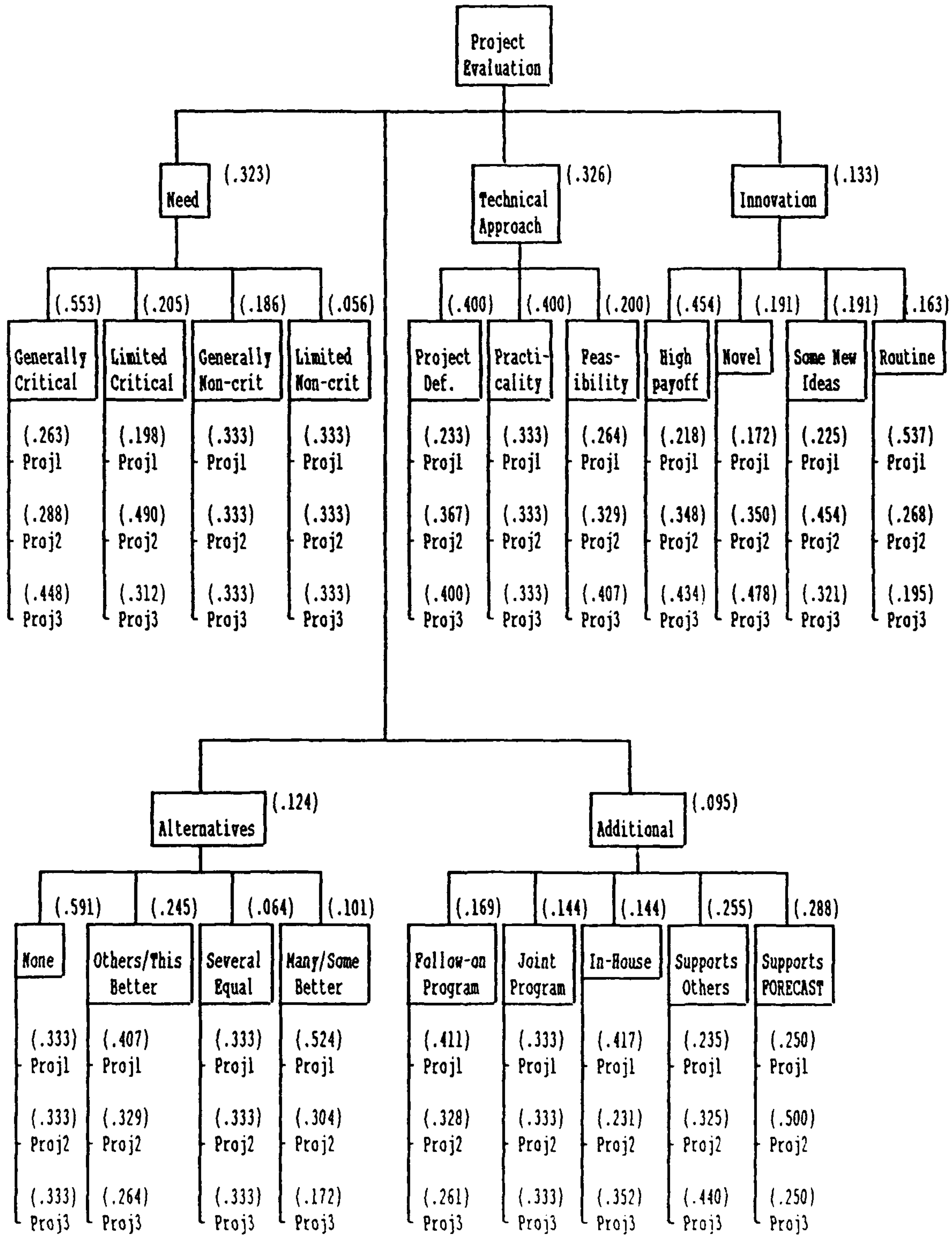

Project Evaluation
Need (.400)
Technical Approach (.286)
Innovation (.105)
Alternatives (.055)
Additional (.155)
(.533) Generally Critical (.065) Proj1 (.259) Proj2 (.675) Proj3
(.252) Limited Critical (.067) Proj1 (.467) Proj2 (.467) Proj3
(.159) Generally Non-crit (.315) Proj1 (.204) Proj2 (.481) Proj3
(.056) Limited Non-crit (.714) Proj1 (.143) Proj2 (.143) Proj3
(.081) Project Def. (.090) Proj1 (.303) Proj2 (.607) Proj3
(.638) Practi-cality (.066) Proj1 (.363) Proj2 (.571) Proj3
(.281) Feas-ibility (.549) Proj1 (.331) Proj2 (.120) Proj3
(.684) High payoff (.071) Proj1 (.206) Proj2 (.723) Proj3
(.164) Novel (.140) Proj1 (.574) Proj2 (.286) Proj3
(.110) Some New Ideas (.140) Proj1 (.286) Proj2 (.574) Proj3
.042) Routine (.090) Proj1 (.303) Proj2 (.607) Proj3
(.675) None (.333) Proj1 (.333) Proj2 (.333) Proj3
(.105) Others/This Better (.333) Proj1 (.333) Proj2 (.333) Proj3
(.115) Several Equal (.138) Proj1 (.239) Proj2 (.623) Proj3
(.105) Many/Some Better (.140) Proj1 (.286) Proj2 (.574) Proj3
(.052) Follow-on Program (.600) Proj1 (.200) Proj2 (.200) Proj3
(.488) Joint Program (.333) Proj1 (.333) Proj2 (.333) Proj3
(.137) In-House (.686) Proj1 (.211) Proj2 (.102) Proj3
(.201) Supports Others (.089) Proj1 (.658) Proj2 (.253) Proj3
(.122) Supports FORECAST (.138) Proj1 (.239) Proj2 (.623) Proj3

FIGURE 4.1.5


Project Evaluation
Need (.323)
Technical Approach (.326)
Innovation (.133)
Alternatives (.124)
Additional (.095)
(.553) Generally Critical
(.205) Limited Critical
(.186) Generally Non-crit
(.056) Limited Non-crit
(.400) Project Def.
(.400) Practi-cality
(.200) Feas-ibility
(.454) High payoff
(.191) Novel
(.191) Some New Ideas
.163) Routine
(.263) Proj1 (.288) Proj2 (.448) Proj3
(.198) Proj1 (.490) Proj2 (.312) Proj3
(.333) Proj1 (.333) Proj2 (.333) Proj3
(.333) Proj1 (.333) Proj2 (.333) Proj3
(.233) Proj1 (.367) Proj2 (.400) Proj3
(.333) Proj1 (.333) Proj2 (.333) Proj3
(.264) Proj1 (.329) Proj2 (.407) Proj3
(.218) Proj1 (.348) Proj2 (.434) Proj3
(.172) Proj1 (.350) Proj2 (.478) Proj3
(.225) Proj1 (.454) Proj2 (.321) Proj3
(.537) Proj1 (.268) Proj2 (.195) Proj3
(.591) None
(.245) Others/This Better
(.064) Several Equal
(.101) Many/Some Better
(.169) Follow-on Program
(.144) Joint Program
(.144) In-House
(.255) Supports Others
(.288) Supports FORECAST
(.333) Proj1 (.333) Proj2 (.333) Proj3
(.407) Proj1 (.329) Proj2 (.264) Proj3
(.333) Proj1 (.333) Proj2 (.333) Proj3
(.524) Proj1 (.304) Proj2 (.172) Proj3
(.411) Proj1 (.328) Proj2 (.261) Proj3
(.333) Proj1 (.333) Proj2 (.333) Proj3
(.417) Proj1 (.231) Proj2 (.352) Proj3
(.235) Proj1 (.325) Proj2 (.440) Proj3
(.250) Proj1 (.500) Proj2 (.250) Proj3

With the hierarchies for each evaluator completed, the projects can be ranked (for each evaluator) according to the final score calculated for each project using the method outlined in Section Three. Table 4.1.8 provides the final score given each project by each evaluator, and also the rank order of the projects for a given evaluator. For example, if the rank order is 3 2 1, this means the final scores indicate Project 1 is ranked 3, Project 2 is ranked 2, and Project 3 is ranked 1 for the given evaluator.

TABLE 4.1.8.

	Project					
Evaluator	1	2	3	Rank Order		
1	.651	.247	.111	1	2	3
2	.468	.361	.173	1	2	3
3	.147	.340	.515	3	2	1
4	.191	.320	.490	3	2	1
5	.287	.346	.339	3	1	2

Recall from Section Three, the overall ranking of the projects is obtained by averaging the rankings obtained for each evaluator. Using the results found in Table 4.1.8, the overall ranking for the three proposals was calculated and the results presented in Table 4.1.9.

TABLE 4.1.9.

	Evaluator					Overall Rank
Project	1	2	3	4	5	
2	2	2	2	2	1	1.8
3	3	3	1	1	2	2.0
1	1	1	3	3	3	2.2

The results of this analysis show that Project Two has the lowest 'overall rank', thus it is the top ranked project. Project Three is the next highest ranked, and Project One is the lowest ranked according to analysis of the evaluators questionnaires.

In this study, three projects were used to illustrate how AHP can be use to rank projects brought before the RAC. In an actual application of the procedure, there will likely be several more projects that need to be evaluated; however, the same simple steps will be followed to determine their overall ranking. With the overall ranking and knowledge of how much money is available to fund new efforts, a funding line can be drawn with all projects above the line being funded.

4.1.2. Proposal Evaluation Stage

A project engineer from the division was recruited to complete the questionnaire for this stage of the process. In a meeting held in August 1992, this individual provided the criteria/attributes that were used in this study. As previously stated, this is the same criteria that was actually used to evaluate proposals sent in response to a request for proposal prepared by the project engineer.

The results of the analysis of the project engineer's responses is contained in the following pages. As with the previous stage, the priority weights in the following tables were calculated as prescribed in Section Three.

The attributes identified at the first level of the proposal evaluation hierarchy are: Understanding the Problem, Soundness of Approach, Compliance with Requirements, and Special Technical Factors. The preference matrix for the level-one attributes is presented in Table 4.2.1.

Examining this preference matrix, it can be noted that Understanding the Problem is the highest rated attribute, next is Soundness of Approach, followed by Special Technical Factors, and finally Compliance with Requirements. These weights are as anticipated; because the contractor is expected to comply with the requirements set forth in the request for proposal, it follows that Compliance with Requirements should be the lowest rated attribute.

TABLE 4.2.1.

PROPOSAL EVALUATION	UP	SA	CR	STF	PW
Understanding the Problem (UP)	1	3	6	5	.542
Soundness of Approach (SA)	1/3	1	5	4	.290
Compliance with Requirements (CR)	1/6	1/5	1	1/2	.066
Special Technical Factors (STF)	1/5	1/4	2	1	.103

The preference matrix for the subattributes Aircraft Requirements, Array Configuration, Digital Control, RF Processing, and Miscellaneous found under Understanding the Problem is shown in Table 4.2.2.

TABLE 4.2.2.

UNDERSTANDING (UP)	AR	AC	DC	RF	MC	PW
Aircraft Requirements (AR)	1	1/2	1/2	1/2	1	.122
Array Configuration (AC)	2	1	1	2	3	.297
Digital Control (DC)	2	1	1	2	3	.297
RF Processing (RF)	2	1/2	1/2	1	2	.183
Miscellaneous (MC)	1	1/3	1/3	1/2	1	.102

Looking at Table 4.2.2, Array Configuration and Digital Control are of equal importance, followed by RF Processing, Aircraft requirements, and Miscellaneous, respectively. This is to be expected considering the criteria applies to the development of an electronic countermeasures antenna controller.

Table 4.2.3 shows the preference matrix for the subattributes found under Soundness of Approach, namely, Analysis Task, Design Task, and Testing and Demonstration (T & D) task.

TABLE 4.2.3.

SOUNDNESS OF APPROACH	AT	DT	TD	PW
Analysis Task (AT)	1	3	5	.619
Design Task (DT)	1/3	1	4	.284
T & D Task (TD)	1/5	1/4	1	.096

As indicated in Table 4.2.3, Analysis task is considered the most important attribute under Soundness of Approach, followed by Design Task and T & D Task.

The third attribute in the first level of the proposal evaluation hierarchy is Compliance with Requirements. Its subattributes are Analysis Topics, Design Criteria, T & D Requirements, Technical Discussion, and Presentation. The preference matrix can be seen in Table 4.2.4.

As expected, Presentation is not as important as the other subattributes under Compliance with Requirements. The contractor is expected to submit a neat, grammatically correct proposal. Consistent with the weights for the previous attribute, Analysis Topics is again considered more important than Design Criteria, followed by T & D Requirements and Technical Discussion.

TABLE 4.2.4.

COMPLIANCE	AT	DC	TR	TD	PR	PW
Analysis Topics (AT)	1	3	5	3	7	.456
Design Criteria (DC)	1/3	1	3	2	6	.235
T & D Requirements (TR)	1/5	1/3	1	2	6	.154
Technical Discussion (TD)	1/3	1/2	1/2	1	3	.114
Presentation (PR)	1/7	1/6	1/6	1/3	1	.041

The final set of subattributes in the hierarchy is under Special Technical Factors, these being Solid State Array Design, ECM System Development, Digital Control, Advanced Processing, Embedded System Software and Algorithm (ESS & A) Development, and MMIC Application. The preference matrix for these subattributes is displayed in Table 4.2.5.

Examining the priority weights in Table 4.2.5, it is noted that the weights for these subattributes consistent with what can be expected for an antenna controller development effort. Solid State Array Design carries the most weight, followed by MMIC Application, Digital Control and software development considerations.

TABLE 4.2.5

SPECIAL TECHNICAL FACTORS	SS	ECM	DC	AP	ESS	MA	PW
Solid State Array Design (SS)	1	2	2	2	2	2	.291
ECM System Development (ECM)	1/2	1	1/2	1/2	2	1/2	.122
Digital Control (DC)	1/2	2	1	1	1	1	.151
Advanced Processing (AP)	1/2	2	1	1	1/2	1/2	.128
ESS & A Development (ESS)	1/2	1/2	1	2	1	1	.145
MMIC Application (MA)	1/3	2	1	2	1	1	.163

The next thing to be done in this stage is to determine the item specific weights for the proposal ratings Exceptional, Acceptable, Marginal, and Unacceptable.

The preference matrix in Table 4.2.6 illustrates the method for arriving at priority weights for the proposal ratings when considering the second level subattributes. Immediately following Table 4.2.6 in Table 4.2.7 is a summary of the remaining preference matrices for the item specific proposal ratings. The entries in the table under the four ratings (Exceptional, Acceptable, Marginal, and

Unacceptable) are the priority weights for the given subattributes.

TABLE 4.2.6.

AIRCRAFT REQUIREMENTS	EX	AC	MG	UA	PW
Exceptional (EX)	1	2	4	8	.485
Acceptable (AC)	1/2	1	4	8	.344
Marginal (MG)	1/4	1/4	1	4	.126
Unacceptable (UA)	1/8	1/8	1/4	1	.045

TABLE 4.2.7.

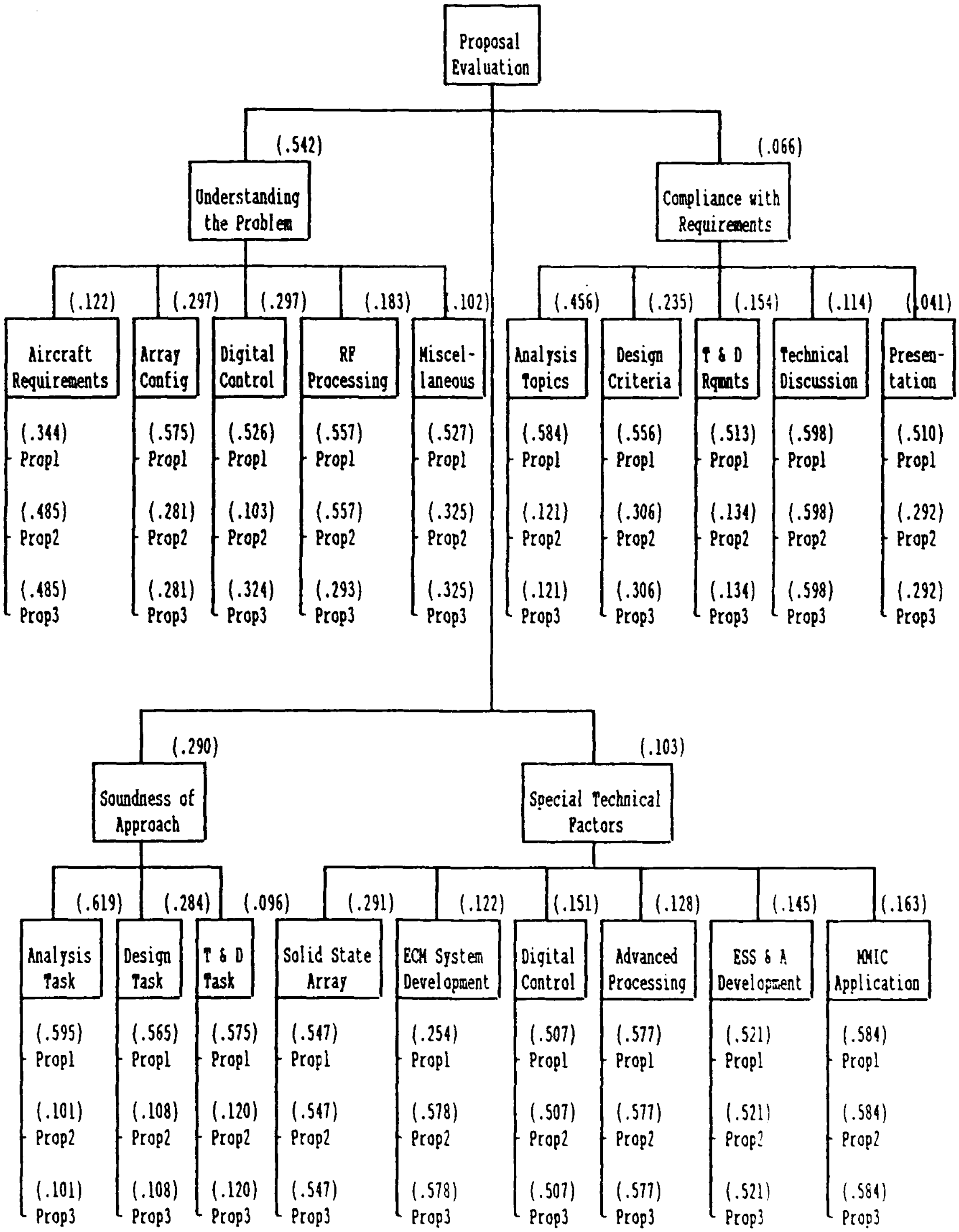
	Proposal Rating			
SUBATTRIBUTE	EX	AC	MG	UA
Aircraft Requirements	.485	.344	.126	.045
Array Configuration	.575	.281	.103	.039
Digital Control	.526	.324	.103	.049
RF Processing	.557	.293	.097	.040
Miscellaneous	.527	.325	.110	.042
Analysis Task	.595	.260	.101	.040
Design Task	.565	.289	.108	.042
T & D Task	.575	.246	.120	.064
Analysis Topics	.584	.241	.121	.051
Design Criteria	.556	.306	.093	.043
T & D Requirements	.513	.305	.134	.052
Technical Discussion	.598	.264	.091	.043

TABLE 4.2.7. Continued

	Proposal Rating			
SUBATTRIBUTE	EX	AC	MG	UA
Presentation	.510	.292	.146	.057
SS Array Design	.547	.272	.119	.054
ECM System Development	.578	.254	.118	.045
Digital Controller Dev	.507	.328	.120	.046
Advanced Processing Inv	.577	.281	.096	.047
ESS & A Development	.521	.326	.099	.056
MMIC Device Application	.584	.258	.108	.048

Using the data in all of the above tables, the proposal evaluation hierarchy, complete with priority weights, is reconstructed in Figure 4.2.1. This hierarchy is not all that is required to calculate the final scores for each of the proposals. With procurement regulations prohibiting the direct comparison of different contractor's proposals, an absolute measurement system had to be developed. The method adopted in this study discussed in Section Three was developed by Francis and Stonebraker (Francis and Stonebraker, 1991). Recall that with this method, each proposal is rated against each of the second level subattributes, then each proposal is assigned the priority weight for the rating it receives. The final score is then calculated by 'folding back the tree' as described in Section Three.

FIGURE 4.2.1.


Proposal Evaluation
(.542)
Understanding the Problem
(.066)
Compliance with Requirements
(.122)
Aircraft Requirements
(.344) Prop1
(.485) Prop2
(.485) Prop3
(.297)
Array Config
(.575) Prop1
(.281) Prop2
(.281) Prop3
(.297)
Digital Control
(.526) Prop1
(.103) Prop2
(.324) Prop3
(.183)
RF Processing
(.557) Prop1
(.557) Prop2
(.293) Prop3
(.102)
Miscel-laneous
(.527) Prop1
(.325) Prop2
(.325) Prop3
(.456)
Analysis Topics
(.584) Prop1
(.121) Prop2
(.121) Prop3
(.235)
Design Criteria
(.556) Prop1
(.306) Prop2
(.306) Prop3
(.154)
T & D Rqmnts
(.513) Prop1
(.134) Prop2
(.134) Prop3
(.114)
Technical Discussion
(.598) Prop1
(.598) Prop2
(.598) Prop3
(.041)
Presen-tation
(.510) Prop1
(.292) Prop2
(.292) Prop3
(.290)
Soundness of Approach
(.103)
Special Technical Factors
(.619)
Analysis Task
(.595) Prop1
(.101) Prop2
(.101) Prop3
(.284)
Design Task
(.565) Prop1
(.108) Prop2
(.108) Prop3
(.096)
T & D Task
(.575) Prop1
(.120) Prop2
(.120) Prop3
(.291)
Solid State Array
(.547) Prop1
(.547) Prop2
(.547) Prop3
(.122)
ECM System Development
(.254) Prop1
(.578) Prop2
(.578) Prop3
(.151)
Digital Control
(.507) Prop1
(.507) Prop2
(.507) Prop3
(.128)
Advanced Processing
(.577) Prop1
(.577) Prop2
(.577) Prop3
(.145)
ESS & A Development
(.521) Prop1
(.521) Prop2
(.521) Prop3
(.163)
MMIC Application
(.584) Prop1
(.584) Prop2
(.584) Prop3

The tables that follow give the results of this absolute measurement of the three proposals. Table 4.2.8 gives the ratings each proposal received against the second level subattributes, and Table 4.2.9 shows how the final scores will map into an overall rating for the proposals.

TABLE 4.2.8.

		Proposal Rating			
FACTOR	PROPOSAL	EX	AC	MG	UA
Aircraft Requirements	1		x		
	2	x			
	3	x			
Array Configuration	1	x			
	2		x		
	3		x		
Digital Control	1	x			
	2			x	
	3		x		
RF Processing	1	x			
	2	x			
	3		x		
Miscellaneous	1	x			
	2		x		
	3		x		

TABLE 4.2.8. Continued

		Proposal Rating			
FACTOR	PROPOSAL	EX	AC	MG	UA
Analysis Task	1	x			
	2			x	
	3			x	
Design Task	1	x			
	2			x	
	3			x	
T & D Task	1	x			
	2			x	
	3			x	
Analysis Topics	1	x			
	2			x	
	3			x	
Design Criteria	1	x			
	2		x		
	3		x		
T & D Requirements	1	x			
	2			x	
	3			x	
Technical Discussion	1	x			
	2	x			
	3	x			

TABLE 4.2.8. Continued

		Proposal Rating			
FACTOR	PROPOSAL	EX	AC	MG	UA
Presentation	1	x			
	2		x		
	3		x		
SS Array Design	1	x			
	2	x			
	3	x			
ECM System Development	1		x		
	2	x			
	3	x			
Digital Controller Dev	1	x			
	2	x			
	3	x			
Advanced Processing Inv	1	x			
	2	x			
	3	x			
ESS & A Development	1	x			
	2	x			
	3	x			
MMIC Device Application	1	x			
	2	x			
	3	x			

TABLE 4.2.9.

Evaluations all set to:	Resultant final score	Average	Rating Code Range
Exceptional	.557		.557 - .424
		.424	
Acceptable	.291		.199 - .423
		.199	
Marginal	.106		.075 - .198
		.075	
Unacceptable	.043		

The final score for proposal 1 is given by:

Proposal 1 = .542[.344(.122)+.575(.297)+.526(.297)+.557(.183)+.527(.102)] +
.290[.595(.619)+.565(.284)+.575(.096)] +
.066[.584(.456)+.556(.235)+.513(.154)+.598(.114)+.510(.041)] +
.103[.547(.291)+.254(.122)+.507(.151)+.577(.128)+.521(.145)+.584(.163)]
= .543

The final score for proposal 2 is given by:

Proposal 2 = .542[.485(.122)+.281(.297)+.103(.297)+.557(.183)+.325(.102)] +
.290[.101(.619)+.108(.284)+.120(.096)] +
.066[.121(.456)+.306(.235)+.134(.154)+.598(.114)+.292(.[illegible])] +
.103[.547(.291)+.578(.122)+.507(.151)+.577(.128)+.521(.1[illegible].163)]
= .269

The final score for proposal 3 is given by:

Proposal 3 = .542[.485(.122)+.281(.297)+.324(.297)+.293(.183)+.325(.102)] +
.290[.101(.619)+.108(.284)+.120(.096)] +
.066[.121(.456)+.306(.235)+.134(.154)+.598(.114)+.292(.041)] +
.103[.547(.291)+.578(.122)+.507(.151)+.577(.128)+.521(.145)+.584(.163)]
= .278

Thus, the proposals would receive the following ratings:

Proposal 1 = Exceptional

Proposal 2 = Acceptable

Proposal 3 = Acceptable

V. CONCLUSIONS

5.1. Conclusions

This study examined a new approach to resource allocation and proposal evaluation in an Air Force Research and Development (R & D) organization. A method for prioritizing potential new-start programs using pairwise comparison of related attributes and the programs was developed. These techniques, along with an absolute rating system, were also applied to technical proposal evaluations with very good results. In both cases, the rank ordering of projects and proposals is developed in a highly systematic fashion. The methodologies developed are based on the Analytical Hierarchy Process (AHP) and seem to offer an effective way to handle the resource allocation and proposal evaluation problems. These methods were designed primarily for use in R & D organizations, and are very easily implemented. Some conclusions as a result of this study are:

1. The AHP can be easily applied to resource allocation and proposal evaluation and provides an objective, systematic, and easily defensible means of prioritizing projects and proposals.

2. The present guidelines for establishing proposal evaluation criteria prescribed in current procurement regulations are consistent with the development of a hierarchical model.

3. Translating the final numerical proposal scores into the existing ratings, exceptional, acceptable, marginal, and unacceptable makes this method consistent with established procedures. This translation can also be applied to the level one attributes Understanding the Problem, Soundness of Approach, Compliance with requirements, and Special Technical Factors, if required.

4. Sensitivity analysis can be performed on the results to provide greater insight, and answer all types of "what if" questions.

5. The inclusion of an absolute measurement system in the proposal evaluation stage eliminates the need to directly compare the contractors using pairwise comparisons.

5.2. Future Work

To be consistent with present proposal evaluation procedures, the final scores obtained for the proposals were mapped into the present ratings. Work needs to be done to develop a theoretically sound method for performing this mapping.

With project evaluation in the resource allocation stage, the managers who evaluate the projects are generally pressed for time; therefore, it is important to further simplify the instruction booklet and the project evaluation questionnaire.

The attributes used in the resource allocation hierarchy are the same as those used in the present process and may not be fully independent. It would be interesting to see if totally independent attributes can be developed.

Finally, the AHP has already been used in commercially available software packages; however these are not geared toward Air Force R & D. Thus, it would be very useful if these methods could be incorporated into a user friendly computer software package for use in these organizations.

REFERENCES

Air Force Regulation 70-30, "Streamlined Source Selection Procedures," April 1988.

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Appendices

Appendix A

Explanation of Attributes Used in this Study

EXPLANATION OF ATTRIBUTES USED IN THIS STUDY

RESOURCE ALLOCATION EVALUATION HIERARCHY:

ADDITIONAL - Additional factors generally accepted as being important to a project. The following subattributes were considered important in this study: follow-on program, joint program, in-house, supports other programs, supports forecast II.

ALTERNATIVES - This refers to the fact that there may be more than one alternative to solve an individual need. The following subattributes were considered important in this study: none, others - this better, several equal, many - some better.

FEASIBILITY - A measure of whether the project will solve the given problem and whether management will be receptive of the solution.

FOLLOW-ON - This refers to whether or not the proposed project is a follow-on from a successful program.

GENERALLY APPLICABLE - CRITICAL - The proposed project is generally applicable to a variety of critical threats.

GENERALLY APPLICABLE - NON-CRITICAL - The proposed project is generally applicable to a variety of non-critical threats.

HIGH PAYOFF - The proposed project offers a high payoff approach to a new area.

IN-HOUSE - If resources and manpower are available, the project can be done in-house.

INNOVATION - This refers to the uniqueness of the approach proposed by the project engineer. The following subattributes were considered important in this study: high payoff approach, novel approach, some new ideas, routine.

JOINT PROGRAM - The proposed project will be done in conjunction with,or with assistance from, the other military services.

LIMITED CRITICAL - The proposed project has limited applicability to critical threats.

LIMITED NON-CRITICAL - The proposed project has limited applicability to non-critical threats.

MANY/SOME - Many other programs were proposed and some were better.

NEED - This refers to the stated or perceived need for the proposed project. The following subattributes were considered important in this study: generally critical, limited critical, generally non-critical, limited non-critical.

NONE - This is the only program proposed to meet the given need.

NOVEL APPROACH - The proposed project offers a novel approach to an old area.

OTHERS/THIS BETTER - Similar programs were proposed to meet the given need, but this is the better project.

PRACTICALITY - Are the funds/manpower/resources available to achieve the program goal.

PROJECT DEFINITION - This is a measure of how well the engineer defines the problem and how the problem will be solved.

ROUTINE - This refers to whether the proposed project is routine and offers no new ideas.

SEVERAL/EQUAL - Several programs were proposed and they are all roughly equal.

SOME NEW IDEAS - This refers to whether the proposed project offers some new ideas.

SUPPORTS FORECAST II - The proposed project supports FORECAST II.

SUPPORTS OTHERS - The proposed effort supports existing or future programs.

TECHNICAL APPROACH - This relates to the approach the project engineer proposes to meet the need/requirement. The following subattributes were considered important in this study: project definition, practicality, feasibility.

PROPOSAL EVALUATION HIERARCHY:

ADVANCED PROCESSING INVESTIGATION - The contractor must have corporate experience and individual experience in advanced real time processing.

AIRCRAFT REQUIREMENTS - Includes aircraft, aircraft subsystem, and environment requirements.

ANALYSIS TASK - the plan for performing analysis, extracting important data, performing trade-offs, evaluating data, and interpreting results.

ANALYSIS TOPICS - The proposed effort must address minimum analysis topics unless otherwise justified in the proposal.

ARRAY CONFIGURATION TRADE-OFFS - Includes affects aperture technologies have on placement and design of the antenna array.

COMPLIANCE WITH REQUIREMENTS - The contractor shall comply with the requirements of the Statement of Work and the Request for Proposal. The following subattributes were considered important in this study: analysis topics, design criteria, testing and demonstration requirements, technical discussion, and presentation.

DESIGN CRITERIA - The proposed effort will meet minimum design criteria unless otherwise justified in the proposal.

DESIGN TASK - The contractor must show a plan for creating a top-level design of a control system and associated RF switching and array configuration.

DIGITAL CONTROL - Short for processing and digital control of high speed, real-time RF applications.

DIGITAL CONTROLLER DEVELOPMENT - The contractor must show corporate and individual experience in digital control and control system development.

ECM SYSTEM DEVELOPMENT - The contractor must have individual and corporate experience in ECM systems.

EMBEDDED SYSTEM SOFTWARE AND ALGORITHM (ESS & A) DEVELOPMENT - Must haze corporate and individual experience in signal processing algorithm development and software development.

MISCELLANEOUS - Miscellaneous device technology, power and heat distribution issues. Also includes logistics and manufacturing technologies.

MMIC APPLICATION - The contractor must have individual and corporate experience in MMIC device application.

PRESENTATION - Proposals must be neat, organized, readable, understandable, and grammatically correct.

RF PROCESSING - Includes knowledge of current technologies and general RF system design.

SOLID STATE (SS) ARRAY DESIGN - The contractor must have corporate and individual experience technology and design of solid state arrays.

SOUNDNESS OF APPROACH - The contractors will be evaluated on the soundness of their approach towards providing a solution to the problem. The following subattributes were considered important in this study: analysis task, design task, and testing and demonstration task.

SPECIAL TECHNICAL FACTORS - The contractor will be evaluated on experience and individual expertise in related technologies. The following subattributes were considered important in this study: solid state array design, ECM system development, digital controller development, advanced processing investigation, embedded system software and algorithm development, and MMIC device application.

TECHNICAL DISCUSSION - A measure to ensure the proposal does not restate the Statement of Work, but adds technical discussion pertinent to the understanding and successful solution of the problem.

TEST AND DEMONSTRATION REQUIREMENT - The proposed effort must meet minimum test and demonstration requirements unless otherwise justified in the proposal.

TEST AND DEMONSTRATION TASK - The proposed effort must show a low risk plan for testing critical features of the design. Considered a risk reduction task, hence the test plan should reflect identifying risky areas of design for test and evaluation.

UNDERSTANDING THE PROBLEM - The contractor must show in their proposal an understanding of the problem as related to the elements under this factor.

Appendix B

Introduction to Questionnaire

A PROCEDURE FOR EVALUATING TECHNICAL PROPOSALS

INSTRUCTIONS BOOKLET

By

Robert J. Keppler

February 1993

UNIVERSITY OF WISCONSIN AT MILWAUKEE

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

<u>**OBJECTIVE AND SCOPE OF RESEARCH:**</u>

The purpose of this study is to determine the most appropriate attributes that are associated with the evaluation of technical proposals and to formulate a procedure to evaluate and prioritize engineering proposals offered by contractors.

While the methods for evaluated proposals are well established and documented, the rating a proposal receives is sometimes arbitrarily or subjectively determined. The method proposed in this study will yield a systematically determined rating for each proposal. Also, the determination and ranking of the attributes used in the proposal evaluation can be done early in the procurement process and included in the Request for Proposal package sent to prospective offerors. This will allow the contractors to know which attributes are and their ranking in relation to one another.

For the purpose of evaluating proposals a multi-attribute evaluation model based on the analytical hierarchy process is developed. The analytical hierarchy process was developed by Thomas Saaty in 1972 and has been applied to a wide variety of problems, including capital medical equipment replacement in hospitals (Lo, 1992) and determining (after the fact) the best course of action to follow in the Iranian Hostage Crisis (Saaty, et al, 1985).

This model considers twenty three attributes based on evaluation criteria I obtained Kevin Geiger, WL/AAWW. In order to demonstrate application of the model, this study will examine three proposals that were sent in for the Antenna Element Manager program. The model follows a two step process: first, data on preferences among the various attributes is gathered through the use of pairwise comparisons and a questionnaire; second, the pairwise comparison data is used to determine the relative weights of all the attributes, the weights are then used to rank the proposals.

Questionnaire Instructions

These instructions will explain how the tables included in this questionnaire need to be filled out. Please read them carefully before attempting to fill out the tables.

Procedure:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table. Thus when comparing factor **UNDERSTANDING THE PROBLEM** under column A with factor **SOUNDNESS OF APPROACH** under column B, if **UNDERSTANDING THE PROBLEM** is more important as compared to **SOUNDNESS OF APPROACH** put a check mark under the appropriate number in the left half of the table. See the scale provided below to help determine how much more important **UNDERSTANDING THE PROBLEM** is in comparison with **SOUNDNESS OF APPROACH.**

Similarly, if you determine **SOUNDNESS OF APPROACH** is more important than **UNDERSTANDING THE PROBLEM**, put the check mark under the appropriate number on the right half of the table. Again, how much more important **SOUNDNESS OF APPROACH** is as compared to **UNDERSTANDING THE PROBLEM** is determined by selecting the proper number from the scale provided below. Please remember that there can be only **one** check mark (on the appropriate side of the table) along one row when comparing the two attributes. Continue to fill out each row in a given table in a similar manner.

SCALE FOR COMPARISC:"

Intensity of Importance	Definitior	Explanation
1	Equal importance of both elements	Two elements contribute equally to the property
3	Weak importance of one element over another	Experience and judgement slightly favor one over another
5	Essential or strong importance of one element	Experience and judgement strongly favor one element over another
7	Demonstrated importance of one element over another	An element is strongly favored and its dominance demonstrated in practice
9	Absolute importance of one element over another	The evidence favoring one element over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between two adjacent judgements	Compromise is needed between two judgements

The following example will illustrate the above comparison methodology.

Example:

Assume you are provided the following table and asked to make a comparison between the two factors **UNDERSTANDING THE PROBLEM** and **SOUNDNESS OF APPROACH.**

Step 1

Determine if UNDERSTANDING THE PROBLEM is more important than SOUNDNESS OF APPROACH, or vice versa.

Step 2

For the sake of this example, it is assumed that

UNDERSTANDING THE PROBLEM is more important than SOUNDNESS OF APPROACH, thus the left half of the table will be used.

<u>Step 3</u>

Choose a number from the above scale which best represents your judgement in terms of the importance of UNDERSTANDING THE PROBLEM over SOUNDNESS OF APPROACH. Place a check mark under the number in the appropriate half of the table. Assume the number is 8. Because it has already been determined that UNDERSTANDING THE PROBLEM is more important than SOUNDNESS OF APPROACH, place a check mark under 8 on the left half of the table. Proceed to carefully put check marks in all rows in a table until you reach the end.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
UNDERSTANDING		x																	SOUNDNESS

If SOUNDNESS OF APPROACH is the more important factor, we have the following table:

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
UNDERSTANDING																	x		SOUNDNESS

Note: A full explanation of the attributes found in the following tables is listed at the end of the questionnaire.

Appendix C
Questionnaire and Comparison Table for
Resource Allocation

PRELIMINARY QUESTIONNAIRE
AND
COMPARISONS TABLE
FOR
EVALUATION OF PROJECTS BEFORE THE ANALYSIS RAC

Please return this booklet after filling the questionnaire and tables.

PRELIMINARY INFORMATION

Name   Title
Office Symbol
Address
Phone   Date

Note:
Please complete this data sheet and return with completed table. This information will be kept completely confidential. Feel free to offer any comments about this model you deem appropriate. Thank you very much for your time!

TABLE FOR FACTORS UNDER PROJECT EVALUATION:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
NEED																			TECH. APPROACH
NEED																			ADDITIONAL
NEED																			ALTERNATIVES
NEED																			INNOVATION
TECH. APPROACH																			ADDITIONAL
TECH. APPROACH																			ALTERNATIVES
TECH. APPROACH																			INNOVATION
ADDITIONAL																			ALTERNATIVES
ADDITIONAL																			INNOVATION
ALTERNATIVES																			INNOVATION

Table 1: Factors Under Project Evaluation

EXPLANATION OF FACTORS - TABLE 1

NEED - This refers to the stated or perceived need for the proposed project.

TECH. APPROACH - Short for **TECHNICAL APPROACH.** This relates to the approach the project engineer proposes to meet the need/requirement.

ADDITIONAL - Additional factors generally accepted as being important to a project.

ALTERNATIVES - This refers to the fact that there may be more than one alternative to solve an individual need.

INNOVATION - This refers to the uniqueness of the approach proposed by the project engineer.

TABLE FOR FACTORS UNDER TECHNICAL APPROACH:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT DEFINITION																			PRACTICALITY
PROJECT DEFINITION																			FEASIBILITY
PRACTICALITY																			FEASIBILITY

Table 2: Factors Under Technical Approach

EXPLANATION OF FACTORS - TABLE 2

PROJECT DEFINITION - This is a measure of how well the engineer defines the problem and how the problem will be solved.

PRACTICALITY - Are the funds/manpower/resources available to achieve the program goal.

FEASIBILITY - A measure of whether the project will solve the given problem and whether management will be receptive of the solution.

TABLE FOR FACTORS UNDER NEED:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
GEN CRITICAL																			LIMITED CRITICAL
GEN CRITICAL																			GEN NON-CRITICAL
GEN CRITICAL																			LIMITED NON-CRIT
LIMITED CRITICAL																			GEN NON-CRITICAL
LIMITED CRITICAL																			LIMITED NON-CRIT
GEN NON-CRITICAL																			LIMITED NON-CRIT

Table 3: Factors Under Need

EXPLANATION OF FACTORS - TABLE 3

GEN CRITICAL - Abbreviation for **GENERALLY APPLICABLE - CRITICAL.** The proposed project is generally applicable to a variety of critical threats.

LIMITED CRITICAL - Short for **LIMITED APPLICABILITY - CRITICAL.** The proposed project has limited applicability to critical threats.

GEN NON-CRITICAL - Abbreviation for **GENERALLY APPLICABLE - NON-CRITICAL.** The proposed project is generally applicable to a variety of non-critical threats.

LIMITED NON-CRIT - Abbreviation of **LIMITED APPLICABILITY - NON-CRITICAL.** The proposed project has limited applicability to non-critical threats.

TABLE FOR FACTORS UNDER INNOVATION:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
HIGH PAYOFF																			NOVEL APPROACH
HIGH PAYOFF																			SOME NEW IDEAS
HIGH PAYOFF																			ROUTINE
NOVEL APPROACH																			SOME NEW IDEAS
NOVEL APPROACH																			ROUTINE
SOME NEW IDEAS																			ROUTINE

Table 4: Factors Under Innovation

EXPLANATION OF FACTORS - TABLE 4

HIGH PAYOFF - The proposed project offers a high payoff approach to a new area.

NOVEL APPROACH - The proposed project offers a novel approach to an old area.

SOME NEW IDEAS - This refers to whether the proposed project offers some new ideas.

ROUTINE - This refers to whether the proposed project is routine and offers no new ideas.

TABLE FOR FACTORS UNDER ALTERNATIVES:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
NONE																			OTHERS/THIS BETTER
NONE																			SEVERAL/EQUAL
NONE																			MANY/SOME BETTER
OTHERS/BETTER																			SEVERAL/EQUAL
OTHERS/BETTER																			MANY/SOME BETTER
SEVERAL/EQUAL																			MANY/SOME BETTER

Table 5: Factors Under Alternatives

EXPLANATION OF FACTORS - TABLE 5

NONE - This is the only program proposed to meet the given need.

OTHERS/THIS BETTER - Similar programs were proposed to meet the given need, but this is the better project.

SEVERAL/EQUAL - Several programs were proposed and they are all roughly equal.

MANY/SOME - Many other programs were proposed and some were better.

TABLE FOR FACTORS UNDER ADDITIONAL:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
FOLLOW-ON																			JOINT PROGRAM
FOLLOW-ON																			IN-HOUSE
FOLLOW-ON																			SUPPORTS OTHERS
FOLLOW-ON																			SUPRTS FORECAST
JOINT PROGRAM																			IN-HOUSE
JOINT PROGRAM																			SUPPORTS OTHERS
JOINT PROGRAM																			SUPRTS FORECAST
IN-HOUSE																			SUPPORTS OTHERS
IN-HOUSE																			SUPRTS FORECAST
SUPPORTS OTHERS																			SUPRTS FORECAST

Table 6: Factors Under Additional

EXPLANATION OF FACTORS - TABLE 6

FOLLOW-ON - This refers to whether or not the proposed project is a follow-on from a successful program.

JOINT PROGRAM - The proposed project will be done in conjunction with, or with assistance from, the other military services.

IN-HOUSE - If resources and manpower are available, the project can be done in-house.

SUPPORTS OTHERS - The proposed effort supports existing or future programs.

SUPRTS FORECAST - Short for SUPPORTS FORECAST II. The proposed project supports FORECAST II.

PAIRWISE COMPARISON OF TECHNICAL PROJECTS

The pairwise comparisons in the tables that follow are to be used to evaluate the projects based on the previously ranked attributes. As with the comparisons just completed, these will be used to develop the weights that will be used in ranking the projects.

I. The following comparisons are related to **NEED**.

1. From the view point of GENERALLY APPLICABLE - CRITICAL please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

2. From the view point of LIMITED APPLICABILITY - CRITICAL please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

3. From the view point of GENERALLY APPLICABLE - NON CRITICAL please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

4. From the view point of LIMITED APPLICABILITY - NON CRITICAL please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

II. The following comparisons are related to **TECHNICAL APPROACH**.

1. From the view point of PROJECT DEFINITION please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

2. From the view point of PRACTICALITY please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

3. From the view point of FEASIBILITY please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

III. The following comparisons are related to **INNOVATION**.

1. From the view point of HIGH PAYOFF APPROACH TO NEW AREA please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

2. From the view point of NOVEL APPROACH TO OLD AREA please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

3. From the view point of SOME NEW IDEAS please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

4. From the view point of ROUTINE please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

IV. The following comparisons are related to **ALTERNATIVES**.

1. From the view point of NONE please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

2. From the view point of OTHERS - BUT THIS IS BETTER please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

3. From the view point of SEVERAL OF EQUAL VALUE please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

4. From the view point of MANY OTHERS - SOME BETTER please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

V. The following comparisons are related to **ADDITIONAL**.

1. From the view point of FOLLOW-ON FROM SUCCESSFUL PROGRAM please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

2. From the view point of JOINT PROGRAM please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

3. From the view point of CAN BE DONE IN-HOUSE please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

4. From the view point of SUPPORTS EXISTING OR FUTURE PROGRAMS please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

5. From the view point of SUPPORTS FORECAST II please indicate the importance of one project vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
PROJECT 1																			PROJECT 2
PROJECT 1																			PROJECT 3
PROJECT 2																			PROJECT 3

Appendix D
Questionnaire and Comparison Table for Proposal Evaluation

PRELIMINARY QUESTIONNAIRE
AND
COMPARISONS TABLE
FOR
EVALUATION OF TECHNICAL PROPOSALS

Please return this booklet after filling the questionnaire and tables.

PRELIMINARY INFORMATION

Name	Title
Office Symbol	
Address	
Phone	Date

Note:

Please complete this data sheet and return with completed table. This information will be kept completely confidential. Feel free to offer any comments about this model you deem appropriate. Thank you very much for your time!

TABLE FOR FACTORS UNDER PROJECT EVALUATION:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
UNDERSTANDING																			SOUNDNESS
UNDERSTANDING																			COMPLIANCE
UNDERSTANDING																			SPECIAL FACTORS
SOUNDNESS																			COMPLIANCE
SOUNDNESS																			SPECIAL FACTORS
COMPLIANCE																			SPECIAL FACTORS

Table 1: Factors Under Project Evaluation

EXPLANATION OF FACTORS - TABLE 1

UNDERSTANDING - Short for UNDERSTANDING THE PROBLEM. The contractor must show in their proposal an understanding of the problem as related to the elements under this factor.

SOUNDNESS - Short for SOUNDNESS OF APPROACH. The contractors will be evaluated on the soundness of their approach towards providing a solution to the problem.

COMPLIANCE - Short for COMPLIANCE WITH REQUIREMENTS. The contractor shall comply with the requirements of the Statement of Work or Request for Proposal.

SPECIAL FACTORS - Short for SPECIAL TECHNICAL FACTORS. The contractor will be evaluated on experience and individual expertise in related technologies.

TABLE FOR FACTORS UNDER UNDERSTANDING THE PROBLEM:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
AIRCRAFT RQMTS																			ARRAY CONFIG
AIRCRAFT RQMTS																			DIGITAL CONTROL
AIRCRAFT RQMTS																			RF PROCESSING
AIRCRAFT RQMTS																			MISCELLANEOUS
ARRAY CONFIG																			DIGITAL CONTROL
ARRAY CONFIG																			RF PROCESSING
ARRAY CONFIG																			MISCELLANEOUS
DIGITAL CONTROL																			RF PROCESSING
DIGITAL CONTROL																			MISCELLANEOUS
RF PROCESSING																			MISCELLANEOUS

Table 2: Factors Under Understanding the Problem

EXPLANATION OF FACTORS - TABLE 2

AIRCRAFT RQMTS - Includes aircraft, aircraft subsystem and environmental requirements.

ARRAY CONFIG - Short for ARRAY ANTENNA CONFIGURATION TRADE-OFFS. Includes affects aperture technologies have in the placement and design of the array.

DIGITAL CONTROL - Short for PROCESSING AND DIGITAL CONTROL OF HIGH SPEED, REAL-TIME, RF APPLICATIONS.

RF PROCESSING - Short for RF SIGNAL PROCESSING AND SWITCHING. Includes knowledge of current technologies and general RF system design.

MISCELLANEOUS - Short for MISCELLANEOUS DEVICE TECHNOLOGY, POWER AND HEAT DISTRIBUTION ISSUES. Includes logistics and manufacturing technologies.

TABLE FOR FACTORS UNDER SOUNDNESS OF APPROACH:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
ANALYSIS TASK																			DESIGN TASK
ANALYSIS TASK																			T & D TASK
DESIGN TASK																			T & D TASK

Table 3: Factors Under Soundness of Approach

EXPLANATION OF FACTORS - TABLE 3

ANALYSIS TASK - Must show a plan for performing analysis, extracting important data, performing trade-offs, evaluating data, and interpreting results.

DESIGN TASK - Must show a plan for creating a top level design of control system and associated RF switching and array configuration.

T & D TASK - Short for TESTING AND DEMONSTRATION TASK. Must show a low risk plan for testing critical features of the design. Considered a risk reduction task, hence the test plan should reflect identifying risky areas of design for test and evaluation.

TABLE FOR FACTORS UNDER COMPLIANCE WITH REQUIREMENTS:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
ANALYSIS TOPICS																			DESIGN CRITERIA
ANALYSIS TOPICS																			TEST & DEMO RQMT
ANALYSIS TOPICS																			TECHNICAL DISCUS
ANALYSIS TOPICS																			PRESENTATION
DESIGN CRITERIA																			TEST & DEMO RQMT
DESIGN CRITERIA																			TECHNICAL DISCUS
DESIGN CRITERIA																			PRESENTATION
TEST & DEMO RQMT																			TECHNICAL DISCUS
TEST & DEMO RQMT																			PRESENTATION
TECHNICAL DISCUS																			PRESENTATION

Table 4: Factors Under Compliance with Requirements

EXPLANATION OF FACTORS - TABLE 4

ANALYSIS TOPICS - The proposed effort must address minimum analysis topics unless otherwise justified in the proposal.

DESIGN CRITERIA - The proposed effort will meet minimum design criteria unless otherwise justified in the proposal.

TEST & DEMO RQMT - The proposed effort must meet minimum test and demonstration requirements unless otherwise specified in the proposal.

TECHNICAL DISCUS - A measure to ensure the proposal does not restate the Statement of Work but adds technical discussion pertinent to the understanding and successful solution of the problem.

PRESENTATION - Proposals must be neat, organized, readable, understandable, and grammatically correct.

Table for Factors Under Special Technical Factors:

Please indicate how the following factors listed under A and B rank in importance to one another by placing a check mark under the rating on the appropriate half of the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
SS ARRAY DESIGN																			ECM SYSTEM DEV
SS ARRAY DESIGN																			DIGITAL CONTROL
SS ARRAY DESIGN																			ADVANCED PROCESS
SS ARRAY DESIGN																			ESS & A DEV
SS ARRAY DESIGN																			MMIC APPLICATION
ECM SYSTEM DEV																			DIGITAL CONTROL
ECM SYSTEM DEV																			ADVANCED PROCESS
ECM SYSTEM DEV																			ESS & A DEV
ECM SYSTEM DEV																			MMIC APPLICATION
DIGITAL CONTROL																			ADVANCED PROCESS
DIGITAL CONTROL																			ESS & A DEV
DIGITAL CONTROL																			MMIC APPLICATION
ADVANCED PROCESS																			ESS & A DEV
ADVANCED PROCESS																			MMIC APPLICATION
ESS & A DEV																			MMIC APPLICATION

Table 5: Factors Under Special Technical Factors

EXPLANATION OF FACTORS - TABLE 5

SS ARRAY DESIGN - Abbreviation for SOLID-STATE ARRAY DESIGN. Rating for overall and individual experience.

ECM SYSTEM DEV - Must have corporate and individual experience in ECM systems.

DIGITAL CONTROL - Short for DIGITAL CONTROLLER DEVELOPMENT. Must have corporate and individual experience in digital control and control system development.

ADVANCED PROCESS - Short for ADVANCED PROCESSING INVESTIGATION. Must have corporate and individual experience in advanced real time processing.

ESS & A DEV - Short for EMBEDDED SYSTEM SOFTWARE AND ALGORITHM DEVELOPMENT. Must have corporate and individual experience in signal processing algorithm development and software development.

MMIC APPLICATION - Must have corporate and individual experience in MMIC device application.

PAIRWISE COMPARISON OF TECHNICAL PROPOSAL RATINGS

The pairwise comparisons in the tables that follow are to be used to evaluate the ratings that are typically applied to technical proposals. This will permit item specific meanings for the proposal ratings. For example, the relative importance of "exceptional" and "unacceptable" likely will be different when rating AIRCRAFT PLATFORM REQUIREMENTS versus PRESENTATION.

I. The Following Comparisons are related to **UNDERSTANDING THE PROBLEM**.

1. From the viewpoint of AIRCRAFT REQUIREMENTS, please indicate the importance of one rating over the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

2. From the view point of ARRAY CONFIGURATION, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

3. From the view point of DIGITAL CONTROL, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

4. From the viewpoint of RF SIGNAL PROCESSING AND SWITCHING, please indicate the importance of one rating over the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

5. From the view point of MISCELLANEOUS, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

II. The Following Comparisons are related to **SOUNDNESS OF APPROACH**.

1. From the viewpoint of ANALYSIS TASK, please indicate the importance of one rating over the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

2. From the view point of DESIGN TASK, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

3. From the view point of TESTING AND DEMONSTRATION TASK, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

III. The Following Comparisons are related to **COMPLIANCE WITH RQMTS**.

1. From the viewpoint of ANALYSIS TOPICS, please indicate the importance of one rating over the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

2. From the view point of DESIGN CRITERIA, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

3. From the view point of TEST AND DEMONSTRATION REQUIREMENT, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

4. From the viewpoint of TECHNICAL DISCUSSION, please indicate the importance of one rating over the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

5. From the view point of PRESENTATION, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

IV. The Following Comparisons are related to **SPECIAL TECH FACTORS**.

1. From the viewpoint of SOLID STATE ARRAY DESIGN, please indicate the importance of one rating over the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

2. From the view point of ECM SYSTEM DEVELOPMENT, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

3. From the view point of CONTROLLER DEVELOPMENT, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

4. From the viewpoint of ADVANCED PROCESSING INVESTIGATION, please indicate the importance of one rating over the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

5. From the view point of EMBEDDED SYSTEM SOFTWARE AND ALGO DEV, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

6. From the view point of MMIC DEVICE APPLICATION, please indicate the importance of one rating vs the others in the table.

A	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	B
EXCEPTIONAL																			ACCEPTABLE
EXCEPTIONAL																			MARGINAL
EXCEPTIONAL																			UNACCEPTABLE
ACCEPTABLE																			MARGINAL
ACCEPTABLE																			UNACCEPTABLE
MARGINAL																			UNACCEPTABLE

EVALUATION OF PROPOSALS

The ratings in the tables that follow are to be used to evaluate the proposals against the criteria previously developed. The ratings provided will be used to determine the final score for each proposal. For a given table, each rating may be used more than once or not at all.

I. The following evaluations are related to **UNDERSTANDING THE PROBLEM**.

1. From the view point of AIRCRAFT REQUIREMENTS, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

2. From the view point of ARRAY CONFIGURATION, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

3. From the view point of DIGITAL CONTROL, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

4. From the view point of RF SIGNAL PROCESSING AND SWITCHING, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

5. From the view point of MISCELLANEOUS, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

II. The following evaluations are related to **SOUNDNESS OF APPROACH**.

1. From the view point of ANALYSIS TASK, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

2. From the view point of DESIGN TASK, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

3. From the view point of TESTING AND DEMONSTRATION TASK, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

III. The following evaluations are related to **COMPLIANCE WITH RQMTS.**

1. From the view point of ANALYSIS TOPICS, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

2. From the view point of DESIGN CRITERIA, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

3. From the view point of TEST AND DEMONSTRATION REQUIREMENT, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

4. From the view point of TECHNICAL DISCISSION, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

5. From the view point of PRESENTATION, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

IV. The following evaluations are related to **SPECIAL TECH FACTORS**.
1. From the view point of SOLID STATE ARRAY DESIGN, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

2. From the view point of ECM SYSTEM DEVELOPMENT, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

3. From the view point of DIGITAL CONTROLLER DEVELOPMENT, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

4. From the view point of ADVANCED PROCESSING INVESTIGATION, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

5. From the view point of EMBEDDED SYSTEM SOFTWARE AND ALGORITHM DEVELOPMENT, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				

6. From the view point of MMIC DEVICE APPLICATION, please indicate the rating each proposal should receive.

	EXCEPTIONAL	ACCEPTABLE	MARGINAL	UNACCEPTABLE
PROPOSAL 1				
PROPOSAL 2				
PROPOSAL 3				