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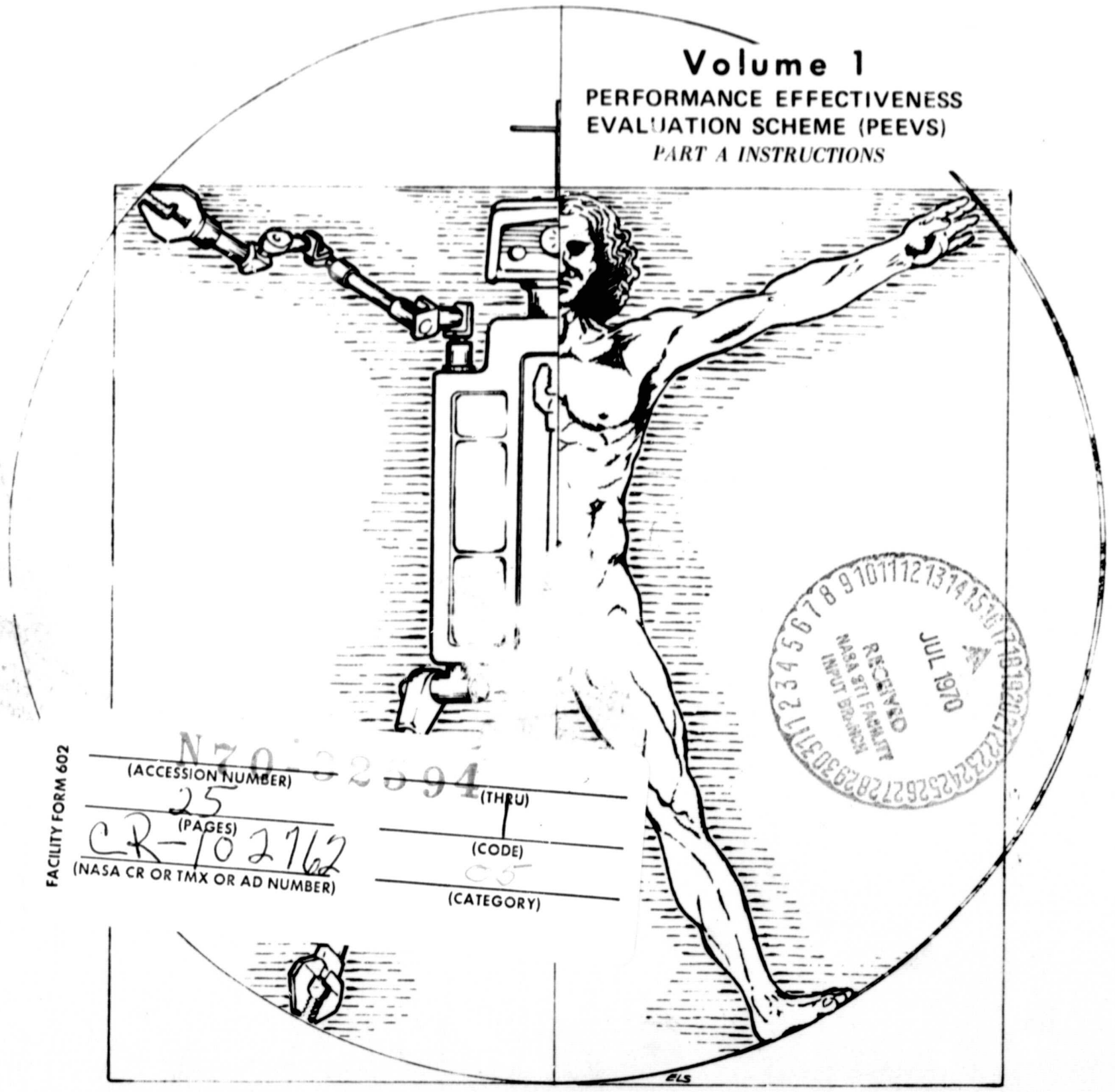
SELECTION OF SYSTEMS TO PERFORM EXTRAVEHICULAR ACTIVITIES

Man and Manipulator

Volume 1

PERFORMANCE EFFECTIVENESS EVALUATION SCHEME (PEEVS)

PART A INSTRUCTIONS



MATRIX RESEARCH
HUMAN FACTORS DIVISION
A URS Systems Affiliate

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SELECTION OF SYSTEMS TO PERFORM EXTRAVEHICULAR ACTIVITIES
Man and Manipulator
Contract No. NAS8-24384

Volume 1 - Performance Effectiveness Evaluation Scheme (PEEVS)

Part A - Instructions

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FOREWORD

The following represents work which was performed on a study of Man vs Manipulator Functions and is the Guidebook on Contract NAS8-24384, National Aeronautics and Space Administration, Marshall Space Flight Center, Alabama.

This volume (one of two volumes) has three separately bound parts. Part A contains instructions for using the Performance Effectiveness Evaluation Scheme (PEEVS). Part B contains PEEVS Reference Data Sheets. Part C contains the work-sheets required to use PEEVS.

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SECTION

1.0 GENERAL INTRODUCTION

The purpose of this Guidebook is to aid planners and designers of future zero-gravity space missions in the selection of extravehicular systems. The enclosed materials include specifications on several extravehicular or Free Space Activity Systems (FSAS) as well as procedures for comparing systems with respect to specific mission requirements.

If used as specified, these materials should provide a mission planner or system designer with the capability to identify one or more FSAS suited to his mission. Furthermore, these data may be used to outline the research and development required to produce a usable and reliable FSAS. Finally, the data included in the system specifications may be used as initial estimates of system performance capabilities and costs.

The following FSAS evaluation procedures are designed for use by persons not acquainted with state-of-the-art in FSAS, either manned or unmanned. The validity of the final selection made through this procedure is determined by the user's knowledge of his space mission and by his fidelity in the application of the procedures.

To summarize, use of the Performance Effectiveness Evaluation Scheme (PEEVS) to identify FSAS applicable to a specific space mission requires:

a) A knowledge of the mission's requirements;

b) No special training in FSAS, cost/effectiveness trade-off procedures, or PEEVS; and

c) No procedures or data other than that provided in the PEEVS Guidebook and worksheets.

The following procedures have been prepared for use in planning extravehicular, "zero-gravity" missions; therefore, their applicability to missions other than these is questionable. Also, the FSAS and EV function classifications used throughout the procedures are based on a 1969-1970 overview of past, present, and projected space missions and systems. The rationale for selecting these classes can be found in Volume 2 of this report.

The PEEVS Guidebook is divided into five (5) sections:

Part A

1.0 GENERAL INTRODUCTION

2.0 HOW TO USE PEEVS

Part B

3.0 DEFINITION OF EXTRAVEHICULAR (EV) FUNCTIONS

4.0 DEFINITION OF PERFORMANCE EFFECTIVENESS AND COST MEASURES

5.0 FREE SPACE ACTIVITY SYSTEM SPECIFICATION AND DATA SHEETS

Part C of the Guidebook contains a worked example of the PEEVS procedure and a complete set of PEEVS worksheets (reproducable).

2.0 HOW TO USE PEEVS

2.1 GENERAL APPROACH

PEEVS is a four-step procedure for identifying Free Space Activity Systems which could be used in a specific mission. An optional fifth step provides a means to test the sensitivity of system selection to both the assumptions made in procedure and data which might be missing from the evaluation.

In general, the steps are:

Step I. Identification of EV functions which are included in a specific mission.

Step II. Identification of highly developed FSAS which could perform the EV functions.

Step III. Selection of system performance effectiveness and cost measures important to that mission.

Step IV. Identification of an FSAS which has the required capabilities and minimizes costs.

Step V. (Optional) Testing of the sensitivity of the system selection to assumptions and missing data.

2.2 SPECIFIC STEPS

The PEEVS sample worksheets (Volume 1, Part C) should be at hand. They will be helpful in following the instructions below. Read each step completely before beginning.

STEP I

Listed on the worksheet in Step I are twelve (12) extravehicular functions. Each of these functions is defined in Section 3.0, DEFINITION OF EXTRAVEHICULAR (EV) FUNCTIONS.

(1) Review the twelve (12) function definitions in Section 3.0.

(2) For each function which must be performed in the specific mission, "ink in" the arrowhead to the right of the EV function name in Step I on the worksheet. Ink in the same function arrowheads for worksheet Steps II and III.

STEP II

In Step I, the functions which must be performed in the EV mission of interest were identified. The procedure in this step will identify the FSAS

generally suited to perform these functions. In addition, the systems requiring the least development will be determined.

In this step FSAS are handled as two types--Astronaut EVA Subsystems and Integrated EV Systems. In the first type, Astronaut EVA Subsystems, the astronaut is EVA (outside the prime vehicle), and hardware required for him to perform his functions has been developed at the subsystem level (i.e., translation, worksite stabilization, transportation, and actuation subsystems). Translation devices allow an astronaut to move between points. Worksite stabilization devices aid an astronaut in maintaining his body position at a worksite. Transportation devices aid an astronaut in carrying material from one point to another. Actuation refers to the mode by which an astronaut performs his functions at a worksite.

The second type of FSAS, Integrated EV Systems, includes all EV systems (whether the astronaut is outside or inside the prime vehicle) in which the subsystems required to satisfy the four activities are integrated into a unit. For example, the Bendix EVA Maneuvering Work Platform houses subsystems for translation, transportation, worksite stabilization, and actuation.

Through the procedures listed below, Astronaut EVA Subsystems will be combined into generally acceptable EVA systems, and generally acceptable Integrated EV Systems will be identified.

(1) Every EVA subsystem category (e.g., transportation, actuation, etc.) may not be required to satisfy the functions you selected in Step I. To check this, take each category in turn and check its applicability to the selected EV functions. Whether or not an EVA subsystem category is applicable to an EV function is given in the APPLICABILITY column in each category. If a category is applicable to any of the selected EV functions, it must be checked off (in the block over the word APPLICABILITY) and included in the forthcoming analyses. If a category is not applicable to any of the selected functions, do not check it off and do not include it in the analyses below.

(2) For each subsystem belonging to an APPLICABLE category and listed as a column heading in the Step II, Sheet A matrix, count the number of functions identified in Step I for which the subsystem is generally acceptable. A function which can be performed using a given subsystem is indicated by a dot in the "Function x Subsystem" cell. Record the final count in the "Totals" row beneath the "EV Function" rows.

(3) Review the totals from substep (2) and check off those subsystems applicable to all of the functions identified in Step I.

(4) Check each of the four subsystem categories to make sure that at least one subsystem per category meets all of the Step I functions. If there is a category where no single subsystem satisfies all functions, go to substep (10). Otherwise, continue to substep (5) below.

(5) *Generate each combination of subsystems which satisfies all selected Functions. The total number of combinations will be the product of the number of checked subsystems in each applicable EVA subsystem category. Subsystem combinations are generated by selecting one checked subsystem from each of the applicable categories. The resulting combination is recorded in the Step II, Sheet B matrix. Continue to select new arrangements* of the subsystems until all combinations are included in the Step II, Sheet B matrix.*

(6) *For each subsystem listed on the Step II, Sheet B matrix, place the development level number in the small space to the right of the subsystem. The development level number is given below each subsystem in the Step II, Sheet A matrix (on the bottom row).*

(7) *For each subsystem combination (Astronaut EVA System) listed in Step II, Sheet B, add the development level numbers across the subsystems. Record the result in the space directly below the subsystem development level numbers in the "Development Level" row.*

(8) *Using the following table, assign development level numbers to each Astronaut EVA system. The columns in this table are the "Number of Applicable EVA Subsystem Categories." The cell entries are the "Range of Totals" for each "EVA System Development Level," given as rows. For example, if there were four applicable EVA subsystem categories and the development level total beneath one system were "19", that EVA system would have a development level of "4".*

EVA SYSTEM	NUMBER OF APPLICABLE EVA SUBSYSTEM CATEGORIES			
	1	2	3	4
Development Level 1 - Preliminary Concept	1	2 - 3	3 - 5	4 - 7
Development Level 2 - Design Concept	2	4 - 5	6 - 8	8 - 11
Development Level 3 - Prototype Model	3	6 - 7	9 - 11	12 - 15
Development Level 4 - Production Model	4	8 - 9	12 - 14	16 - 19
Development Level 5 - Space Qualified	5	10	15	20

For each Astronaut EVA system, record the system development level number in the left-hand cell of its "Development Level" block.

**Scrutiny of the development levels for each EVA subsystem (bottom row Step II, Sheet A matrix) will reveal the subsystem combinations with the highest development levels. Record these first.*

(9) Review all of the development levels and check off those with a level of "5". If less than 25% of the total number of Astronaut EVA systems has been checked, check off systems with a level of "4". Continue down the development level scale (i.e., 3, 2, 1) until at least 25% of the EVA systems are checked off.

(10) Turn to worksheet Step II, Sheet C.

(11) In the left-hand matrix, for each Integrated Extravehicular (EV) system, count the number of EV functions checked in Step I which are generally satisfied (as indicated by a dot in the EV "System x Function" cell). Record the totals in the "Totals" row under the "EV Functions."

(12) Check off all systems which meet all of the selected EV functions. If none of the systems meet all functions, go to substep (15). If one or more meet all functions, continue to substep (13) below.

(13) Remembering the minimum development level required to include 25% or more of the Astronaut EVA systems, check off all checked Integrated EV systems with at least that development level. If less than 25% of the checked Integrated EV systems have been checked off, continue down the development level scale until at least 25% have been checked off.

(14) Go to substep (17).

(15) There is no single Integrated EV system which will meet all of the functions of this mission. If there was no Astronaut EVA system capable of satisfying the mission functions, go to substep (16). If satisfactory EVA subsystems were listed on the worksheet Step II, Sheet A matrix, go to substep (17).

(16) There is no Astronaut EVA system or Integrated EV system which will meet all of the functions of this mission. The analysis may be continued by eliminating selected functions in Step I, or the evaluation may be terminated. If functions are eliminated, return to the beginning of Step I.

(17) List all of the selected Astronaut EVA systems and the Integrated EV systems in the Step II, Sheet C "FSAS SELECTED FOR FINAL EVALUATION" block. For Astronaut EVA Systems, list system number and subsystem names.

STEP III

One or more FSAS may generally satisfy the functions selected in Step I. In order to select systems which may be more specifically applicable, it is necessary to compare the "pros" and "cons" of all systems. In the following step, the performance effectiveness measures and cost factors will be selected

for use in the final systems comparison.

(1) Make sure that applicable EV Functions on each of the Step III worksheets have been checked off.

(2) For each Step III worksheet page, review the definitions of measures applicable to each of the selected EV Functions. Check off each measure to be included in the Final Analysis.

STEP IV

The systems which will be used in the final cost/effectiveness evaluation have now been identified as well as the performance effectiveness and cost measures on which these systems will be compared.

To perform the final comparison, use the following procedures:

(1) For every Astronaut EVA subsystem listed on the Step II, Sheet C worksheet, identify the applicable workbook Section 5.1 data sheet. Data sheet page numbers are listed by EVA subsystem in the workbook Table of Contents.

(2) For each Astronaut EVA system listed on the Step II, Sheet C worksheet, an "EVA System Data Sheet," Step IV, Sheet A, must be prepared. The purpose of this sheet is to combine performance and cost data from the EVA subsystem data sheets into an EVA system data sheet.

(3) Taking each Astronaut EVA system in turn, fill in the names of the EVA subsystems comprising the system in the appropriate Step IV, Sheet A blocks (top row). For each subsystem, fill in the appropriate Section 5.1 data page number.

(4) Each cell in the Step IV, Sheet A matrix has a performance effectiveness or cost measure as a name. In the block beside the name, check off each measure selected in Step III as checked on the Step III worksheets. Check off these selected measures on the EVA System Data Sheet prepared for each candidate Astronaut EVA system.

(5) For every measure checked off on each EVA System Data Sheet, use the included subsystem data combination rule to arrive at the system data entry.

(6) Record the selected performance effectiveness and cost measures in the spaces provided on the Step IV, Sheet B of the worksheet.

(7) Review all of the measures and select the most important. Assign this item a rank of "1" in the measure rank column on the Step IV, Sheet B worksheet.

(8) *Review the remainder of the items and assign ranks in descending order of importance (i.e., the larger the rank, the lesser the importance). If several items are of equal importance, assign them the same rank.*

(9) *List the selected FSAS from Step II, Sheet C, in the column heading of the worksheet Step IV, Sheet B matrix.*

(10) *For each selected Integrated EV system, identify the EV System Data Sheets from the PEEVS Guidebook, Section 5.2 (page numbers are given in the Table of Contents).*

(11) *Record the data from these data sheets into the appropriate (FSAS measure) worksheet cell. Using each EVA System Data Sheet (Step IV, Sheet A), record the data from the data sheets into the appropriate (FSAS measure) worksheet cell. Include rating and interval scale data.*

(12) *Review each cell entry. If there are specific effectiveness or cost criteria (i.e., a maximum system mass), FSAS not meeting these criteria should be eliminated immediately.*

(13) *For each measure, rank all FSAS. Use either rating scale data or interval scale data but do not attempt to rank a mixture of the two. The best system receives a rank of "1", the next best a rank of "2", etc. If systems are equal, assign equal ranks. If the data are insufficient to rank a system, assign the system the median rank* (i.e., N = the number of candidate FSAS. If N is odd, the median rank is (N-1)/2. If N is even, the median rank is N/2.). The rank should be written into the gray half of the subcell in the upper left-hand corner of the "FSAS x Measure" matrix cell.*

(14) *Once all gray cells have been filled in, multiply the number in each gray cell by the rank of its measure. Record the product in the white half of the subcell.*

(15) *Sum the products (in the white halves of the subcells) for each FSAS across all measures. Record the result in the "Total" cell at the bottom of each FSAS column.*

(16) *Identify the smallest number in the "Total" row. This number is T(min). Record T(min) in the "Analysis" block of Step IV, Sheet C.*

(17) *For each rank in the "Measure Rank" column, count the number of measures with that rank. Record the rank and the number of items in the "Analysis" block of Step IV, Sheet C.*

(18) *Multiply each rank by the number of measures with that rank and record the product in the "Lower Limit" column of the "Analysis" block of Step IV, Sheet C.*

**If interval scale data is used for ranking, consider any system with only a rating as having insufficient data; therefore, give it a median rank.*

(19) Count the number of EV systems compared. This number is N.

(20) Multiply each number in the "Lower Limit" (LL) column by .6N.

(21) Record the product in the "Expected Upper Limit" (EUL) column of the "Analysis" block of Step IV, Sheet C.

(22) Sum the numbers in the "Lower Limit" column and record in the "Total" cell at the bottom. This sum is S(LL).

(23) Sum the number in the "Expected Upper Limit" column and record in the "Total" cell at the bottom. This sum is S(EUL).

(24) Subtract S(LL) from S(EUL). The result is R.

(25) Calculate T(min) + .1R = L, and record L in the appropriate cell in the "Analysis" block.

(26) Returning to the "Total" row beneath the measure FSAS matrix, Step IV, Sheet B, check off all totals less than L.

(27) Record the names of the FSAS checked off in the "Summary" block of the PEEVS worksheet, Step IV, Sheet C.

RESULT: The system(s) included in the Summary section is suited to perform this mission at minimum cost. If more than one system is included, a more exhaustive comparison will be required for a final selection.

It is suggested that when more than one system is available, all FSAS data be verified through the manufacturer.

A more detailed analysis can be made with this data if the data on the EVA System Data Sheets and the Integrated EV System Data Sheets are transformed from absolute measures to relative cost/effectiveness measures. This may be done by determining unit cost (e.g., weight) per unit effectiveness (e.g., translation velocity). The result would be "pounds per foot per second." Use of this procedure would probably increase the number of measures included in the evaluation seven (7) to ten (10) fold.

STEP V
(OPTIONAL)

With the completion of Step IV, some number of FSAS suitable to this mission have been identified. The selection of these systems was based on a subjective ranking of measures. Also, important data on one or more FSAS might have been missing. The sensitivity of the selection process to these two factors may have a bearing on the systems identified as "suitable." More likely, this sensitivity will influence the relative ranking (e.g., first, second, etc.) of each system.

Testing to determine the influence of subjective ranking and missing data is a simple process described below.

TESTING THE EFFECT OF SUBJECTIVE RANKING

(1) List all selected measures on a separate sheet of paper (from Step IV, Sheet B matrix).

(2) Without reference to the original ranks, assign ranks to the trade-off items once again (it may be profitable to get another opinion on the ranks).

(3) Record the new ranks onto the PEEVS worksheet using a different color of ink.

(4) Perform Step IV substeps numbered (14) through (27) using the new rank orderings and the different colored ink.

(5) If there are changes in the FSAS listed in the "Summary" block, be very sure of the rankings. If no changes occur, either the second rank-ordering was quite similar to the first, or the selection is not very sensitive to measure ranks.

TESTING THE EFFECT OF MISSING DATA

(1) Assign the following ranks to each Step IV, Sheet B cell where a median rank was assigned in Step IV. If the rating of the candidate FSAS on the row measure was "3", assign the cell a rank equalling the number of candidate FSAS; if it was "2", leave the median rank as is; if it was "1", assign a rank of "1". Leave all "interval scale" cells with the original ranks.

(2) Perform Step IV, substeps (14) through (27).

(3) If the "Summary" block is different from the original "Summary" block, the manufacturer of each FSAS as listed on each data sheet should be contacted for additional information.

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