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1994 NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

JOHN F. KENNEDY SPACE CENTER
UNIVERSITY OF CENTRAL FLORIDA

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APPLYING COSTS, RISKS AND VALUES EVALUATION (CRAVE) METHODOLOGY TO ENGINEERING SUPPORT REQUEST (ESR) PRIORITIZATION

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DATE:	August 5, 1994
CONTRACT NUMBER:	University of Central Florida NASA-NGT-60002 Supplement: 17

Acknowledgments

I am thankful to the NASA/ASEE fellowship program for this second year of research opportunity. Although my intention this year was to apply the Costs Risks and Values Evaluation (CRAVE) methodology to specific software development projects, at the instance of Bob Lang, Director of Vehicle Engineering, I decided to apply my methodology to the problem of prioritization of Engineering Support Requests (ESR). In retrospect, this choice of the area of application turns out to be more productive in demonstrating the applicability of my methodology, and in providing concrete recommendations for improvement in the decision processes at KSC. I am thankful to **Bob Lang**, both for focusing my attention on ESRs and for his patience in listening to my final presentation to management.

I appreciate the generosity, and candidness of the many NASA and Lockheed employees I interviewed this summer. I have very freely used many of their ideas in this report without explicitly crediting them for the same. But I do want to thank them for the same. Special thanks are due to **Mark Allison** (LSOC D/17-12, GSE PEO), **Jim Haggard** (TV-PEO-32), and other members of the GSWT steering committee for making almost all of their files and data available to me.

As they did last year, **Loren Anderson** (UCF), and **Kari Stiles** (UCF), again provided valuable and very effective administrative support, as well as educational and entertainment opportunities. **Gene Thurston's** (TV-PEO-1) constant encouragement and guidance allowed me to cope with project re-direction(s) and keep my enthusiasm undiminished. I express my heartfelt gratitude to each one of these special individuals.

Finally, once again, **Art Beller** (TV-PEO-12) has proved to be an outstanding mentor, thinker, facilitator, and a close friend. He provided any and all help I needed, professional as well as personal. Words are inadequate to express my gratitude to him.

APPLYING
COSTS, RISKS, AND VALUES EVALUATION (CRAVE) METHODOLOGY
TO
ENGINEERING SUPPORT REQUEST (ESR) PRIORITIZATION

Executive Summary

Given limited budget, the problem of prioritization among Engineering Support Requests (ESRs) with varied sizes, shapes, and colors is a difficult one. At the Kennedy Space Center (KSC), the recently developed 4-Matrix (4-M) method represents a step in the right direction as it attempts to combine the traditional criteria of technical merits only with the new concern for cost-effectiveness. However, the 4-M method was not adequately successful in the actual prioritization of ESRs for the fiscal year, 1995 (FY95). This research identifies a number of design issues that should help us develop better methods. It emphasizes that given the variety and diversity of ESRs one should not expect that a single method could help in the assessment of all ESRs. One conclusion is that a methodology such as Costs, Risks, and Values Evaluation (CRAVE) should be adopted. It also is clear that the development of methods such as 4-M requires input not only from engineers with technical expertise in ESRs but also from personnel with adequate background in the theory and practice of cost-effectiveness analysis.

At KSC, ESR prioritization is one part of the Ground Support Working Teams (GSWT) Integration Process. It was discovered that the more important barriers to the incorporation of cost-effectiveness considerations in ESR prioritization lie in this process. The culture of integration, and the corresponding structure of review by a committee of peers, is not conducive to the analysis and confrontation necessary in the assessment and prioritization of ESRs. Without assistance from appropriately trained analyst(s) charged with the responsibility to analyze and be confrontational about each ESR, the GSWT steering committee will continue to make its decisions based on incomplete understanding, inconsistent numbers, and at times, colored facts. The current organizational separation of the prioritization and the funding processes is also identified as an important barrier to the pursuit of cost-effectiveness. Perhaps the greatest barrier is that, at the working level, KSC's culture is so preoccupied with technical concerns that it seems almost oblivious to any cost concerns, let alone cost-effectiveness concerns. It is recommended that we must urgently begin to change that culture and seek a better balance between these two concerns.

Abbreviations and Acronyms List

4-M	The 4-Matrix method
AHP	Analytic Hierarchy Process
ASW	Advanced software
CBA	Cost Benefit Analysis
CRAVE	Costs, Risks, and Values Evaluation
DE	Design Engineering
ESR	Engineering Support Request
GSWT	Ground Systems Working Teams
GTD	Global Technology Deployment
KSC	Kennedy Space Center
OPF	Operations Processing Facility
O&M	Operations and Maintenance
SF	Shop Floor
TV	Technical Vehicle Engineering Directorate at KSC

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1. BACKGROUND

"Our team pledges the highest level of performance at the lowest possible cost within the framework of absolute dedication to safety and quality to meet the National Space Initiatives and challenges of today and the 21st Century."

From p.3 of the March 24, 1994 document,
Implementation of the KSC 1994 Strategic Management Plan

To keep this pledge, at KSC, decisions such as which engineering support requests (ESRs) to fund and at what level must be based on sound cost-benefit / cost-effectiveness analyses (CBA). Toraskar and Joglekar [1993] have shown that although CBA theory contains rich concepts and sound principles, its practice is often based on overly simplified and narrow techniques supplemented with numerous convenient but incorrect assumptions. Consequently, often the practice of CBA is trapped in the type of vicious circle [See **Exhibit** 1] I observed last year, here at KSC, in the context of advanced software decision-making [Joglekar, 1993].

In order to break out of such vicious circles, we must use a methodology such as Costs, Risks, and Values Evaluation (CRAVE). A methodology is a way of thinking — armed with certain fundamental principles and concepts — and a way of analyzing available decision alternatives using situationally appropriate techniques and tools from a large body of methods consistent with the fundamental principles and concepts. A methodology focuses on both the techniques and the processes used in relevant decision-making. Joglekar and Toraskar [1994] have explained exactly what CRAVE is, and how it is supposed to work. **Exhibit** 2 captures Joglekar and Toraskar's prescription for the process of applying CRAVE written in the context of global technology deployment (GTD) decisions. The six-stage process emphasizes some of the fundamentals of CRAVE, such as

- the need for context articulation,
- the recognition that cost-benefit estimation is in itself a costly process and sometimes the benefits of estimation do not justify the costs,
- the recognition that it is not necessary to force quantification on certain consequences that are truly non-quantifiable
- the recognition that measurement and valuation should not be confused as one and the same; valuation of a consequence is in the eye of the beholder; and hence a multi- perspective analysis is more desirable than a single perspective analysis.

As **Exhibit 3** shows, CRAVE retains some of the fundamental principles and looks forward to the use of many rich typologies and concepts of classical CBA. Yet, CRAVE attempts to overcome the typical flaws in the practice of traditional CBA. **Exhibit 4** shows how CRAVE differs from classical CBA practice. [For a fuller understanding of CRAVE, see Joglekar and Toraskar, 1994].

2. THE TASK THIS YEAR

This year, Bob Lang, Director of Vehicle Engineering, asked me to
(a) See how CRAVE could be applied to the problem of ESR prioritization, and
(b) Recommend a method for future use.

Given that task, I tried to understand:

1. What exactly an ESR is, how varied ESRs are from one another, and what kinds of peculiarities characterize some of the ESRs;
2. What explicit and implicit criteria are currently used in the prioritization of ESRs; and
3. What process is currently used in the prioritization of ESRs.

Clearly, my understanding of these three topics was not a linear but a parallel process, with the understanding of one topic influencing the understanding of other topics, and vice versa. It follows that readers who want to truly grasp my total understanding may want to read this report and its appendices at least twice in its entirety.

Briefly, an ESR is a proposal to upgrade an equipment or a facility used in the "ground processing" (all the work done between one landing and the next launch) of a space shuttle. An ESR seeks one or more of desired goals such as improving flight safety, improving safety of ground processing operations, overcoming system obsolescence, avoiding schedule delays, and reducing processing costs. At KSC, there are over thirty engineering systems (represented by their GSWT teams) that are together seeking funding for some 200 different ESRs, each costing anywhere between a few thousand to a few million dollars. Given limited resources, only a few of these ESRs can be fully or partly funded in any given year.

The benefits sought by some ESRs are considered so critical to the strategic objectives of KSC that these ESRs are designated as Category 1 (i.e., mandatory), and they are implemented expeditiously. This research is focused on the prioritization of Category 2 (i.e., desirable but optional) ESRs, where cost-effectiveness analysis ought to be useful. However, as **Appendix** A explains, historically, even Category 2 ESRs were prioritized by using a system called "P-cut rating," which extended the notion of "required" versus "desirable" within Category 2. Cost-effectiveness considerations were simply left out. (See **attachments A-1 and A-2**).

Therefore, I was pleasantly surprised to know that, to incorporate cost-effectiveness considerations in the prioritization of Category 2 ESRs, recently, GSWT steering committee had developed a new approach, named "the 4-Matrix (4-M) method." (See **Attachment** A-3). Clearly, the 4-M method represents a step in the right direction, and its designers must be applauded for their courage in breaking away from the tradition of focusing exclusively on the technical merits of an ESR.

On the other hand, it seems that the designers had no help from anyone with the proper background in the theory and practice of cost-effectiveness analysis. Consequently, the design shows numerous flaws detailed in **Appendix A**, including:

1. The 4-M method ignores two over-riding considerations at KSC, namely safety and obsolescence.
2. The 4-M method actually focuses on two primary factors:
   (a) Expected annual impact on flow schedule, and
   (b) Payback period.
3. A multiplicative model is inappropriate for the 4-M method.
4. The design of the rating categories and score ranges is inappropriate.
5. The absence of relevant probability considerations on the Cost Assessment Worksheet is inappropriate.
6. The language is ambiguous, and instructions / explanations are lacking.

As a consequence of these design flaws, the 4-M method was not successful in assisting the prioritization of FY95 ESRs. **Table 1** and **Figures 1, 2, and 3** confirm this lack of success by showing that there is no relationship between the steering committee's actual priorities and either the cost or the payback or the ESR scores.

These and other design flaws are also manifest in the assessments of specific ESRs reviewed in **Appendix B**. As can be seen, the design of 4-M leads to a variety of instances of misrepresentations and overestimation of the benefits. At the same time, there are instances of ESRs for which 4-M worksheets are very difficult to use. Some of the comments in Appendix B further show that we seem to aggravate the problem of comparing ESRs by lumping together ESRs costing $4M with those costing $4K. **Figure 4** graphically shows how a single one of the top 17 ESRs accounts for over 66% of the funding needed by all 17 put together. Clearly, ESRs requiring capital expenditures ought to be evaluated and funded separately from ESRs requiring a few thousand dollars.

Most importantly, the variety of sizes, shapes, and colors of ESRs captured by Appendix B makes it clear that the presumption of being able to create a single method to fit all ESRs is unrealistic. What we need is a methodology, and not a method. A methodology allows for the use of several different methods of analysis depending on the nature of the technical system, the type of modification sought, and the relevant costs and benefits. Despite the shortcomings of the 4-M method, we must not abandon the pursuit of cost-benefit analysis, or return to the arbitrary decision making of the past. Instead, we must evolve towards the adoption of a methodology such as Costs, Risks, and Values Evaluation (CRAVE).

In any case, the most important reasons for the lack of success of the 4-M method lie in the GSWT integration process. The latter part of **Appendix A** discusses these process issues in depth. Here, by way of conclusion, I simply want to list several process related barriers to the application of CRAVE, and my recommendations to management for overcoming those barriers.

BARRIERS AND CORRESPONDING RECOMMENDATIONS

Barrier 1.

We are trying to develop a single method to assess all ESRs.
However, ESRs come in a variety of sizes, shapes and colors.
Their assessment calls for a **methodology** -- a collection of methods, along with the knowledge of which one to use when.

Recommendation:

Adopt CRAVE.

Barrier 2.

We leave the development of a cost-benefit analysis (CBA) method to engineers who do not have the necessary background in the theory and practice of CBA.

Recommendations:

Get expert help.
Develop internal expertise through training.

Barrier 3.

The culture of "integration" (and the corresponding structure of review by a committee of peers) is not conducive to the analysis and confrontation necessary for objective assessment of each ESR, and the subsequent rational prioritization among them.

This is true whether the assessment criteria include cost considerations or not.

Recommendation:

Let the GSWT steering committee be assisted by appropriately trained, objective analysts, charged with the responsibility to analyze and be confrontational about each ESR.

Barrier 4.

Organizational separation of the prioritization, funding, and implementation processes is not conducive to the pursuit of cost-effectiveness.

Recommendation:

To the extent possible, centralize the authority to prioritize, fund, and monitor implementation of ESRs.

At least, coordinate sufficiently to make sure that decisions in these three processes are based on the same criteria, and on an appreciation of each others' reasoning and deliberations.

Barrier 5 (The Most Important One).

At the working level, KSC's culture is almost oblivious to any cost concerns, let alone cost-effectiveness concerns.

Recommendation:

Begin to change the culture by

- insisting on a discussion of costs, and paybacks at meetings to review priority list, and at funding decision meetings,
- tracking and monitoring the estimated and actual costs of ESRs approved in prior years,
- setting up a program of training in CBA / CRAVE concepts and principles.

REFERENCES

- **Toraskar, Kranti & Joglekar, Prafulla (1993),** "Applying Cost Benefit Analysis (CBA) Methodology for Information Technology Decisions," in R. Banker, R. Kauffman, M. Mahmood (eds.), *New Perspectives on the Strategic and Economic Value of Information Technology Investment,* Harrisburg, PA: Idea Publishing Group, January 1993, pp. 119-142.

- **Joglekar, Prafulla (1993),** "Cost Benefits of Advanced Software: A Review of Methodology used at Kennedy Space Center," in E. Hosler and C. Valdes (eds.) *NASA/ASEE Summer Faculty Fellowship Program, Contractor Report No. CR-194678,* Kennedy Space Center, FL., October 1993, pp. 229-267.

- **Joglekar, Prafulla & Toraskar, Kranti (1994),** "Costs Risks, and Values Evaluation (CRAVE): A Methodology for Global Technology Deployment Decisions," in A. Chakravarti (ed.) *Proceedings of Symposium on Emerging Paradigms in Globalizing Technology, Manufacturing, and Service Operations,* Goldering Institute, Tulane University, New Orleans, LA., January, 1994, pp. 1-39.

Exhibit 1

The Vicious Circle

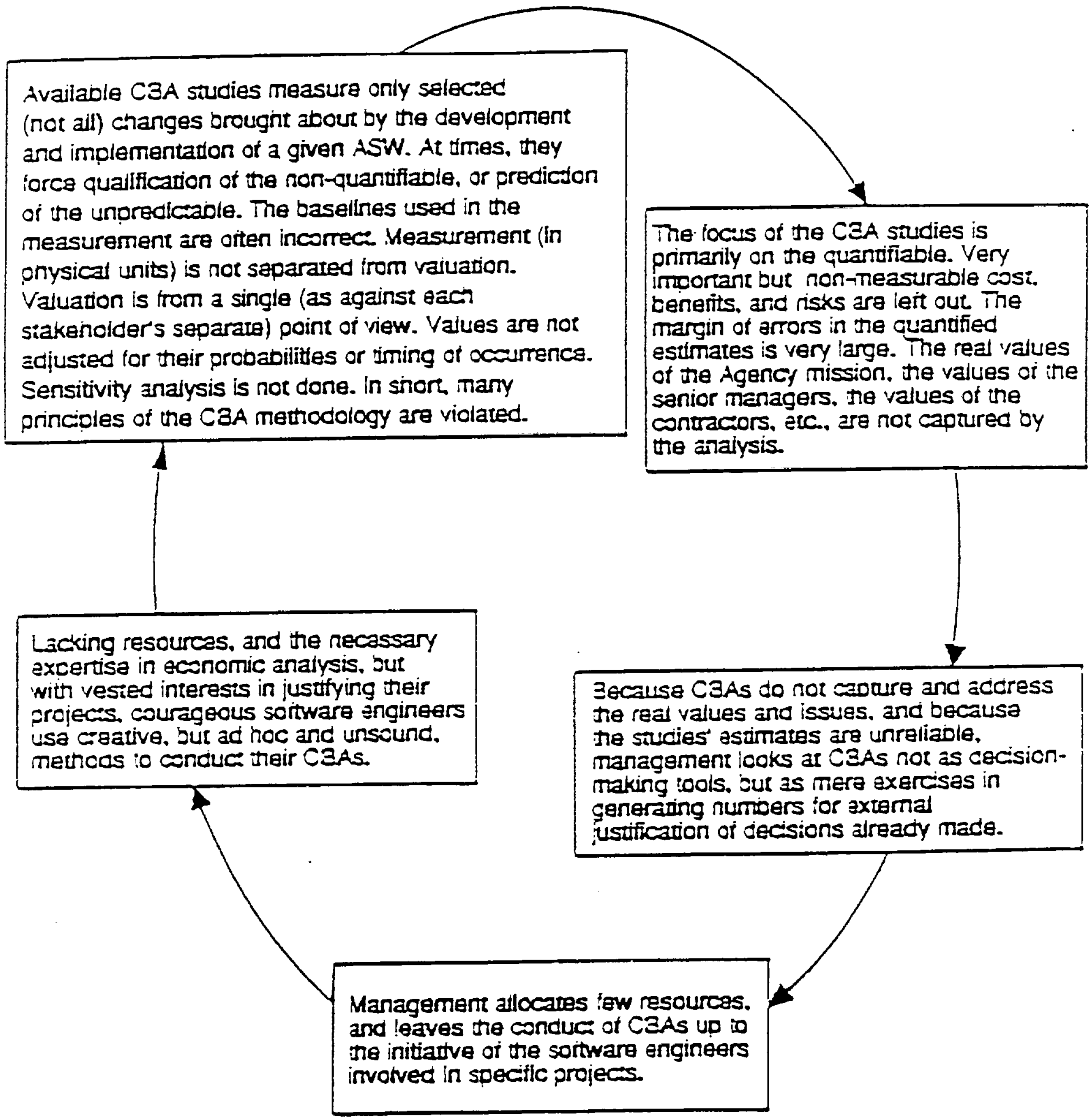


Exhibit 2

A Process for Applying CRAVE Methodology to GTD Decisions

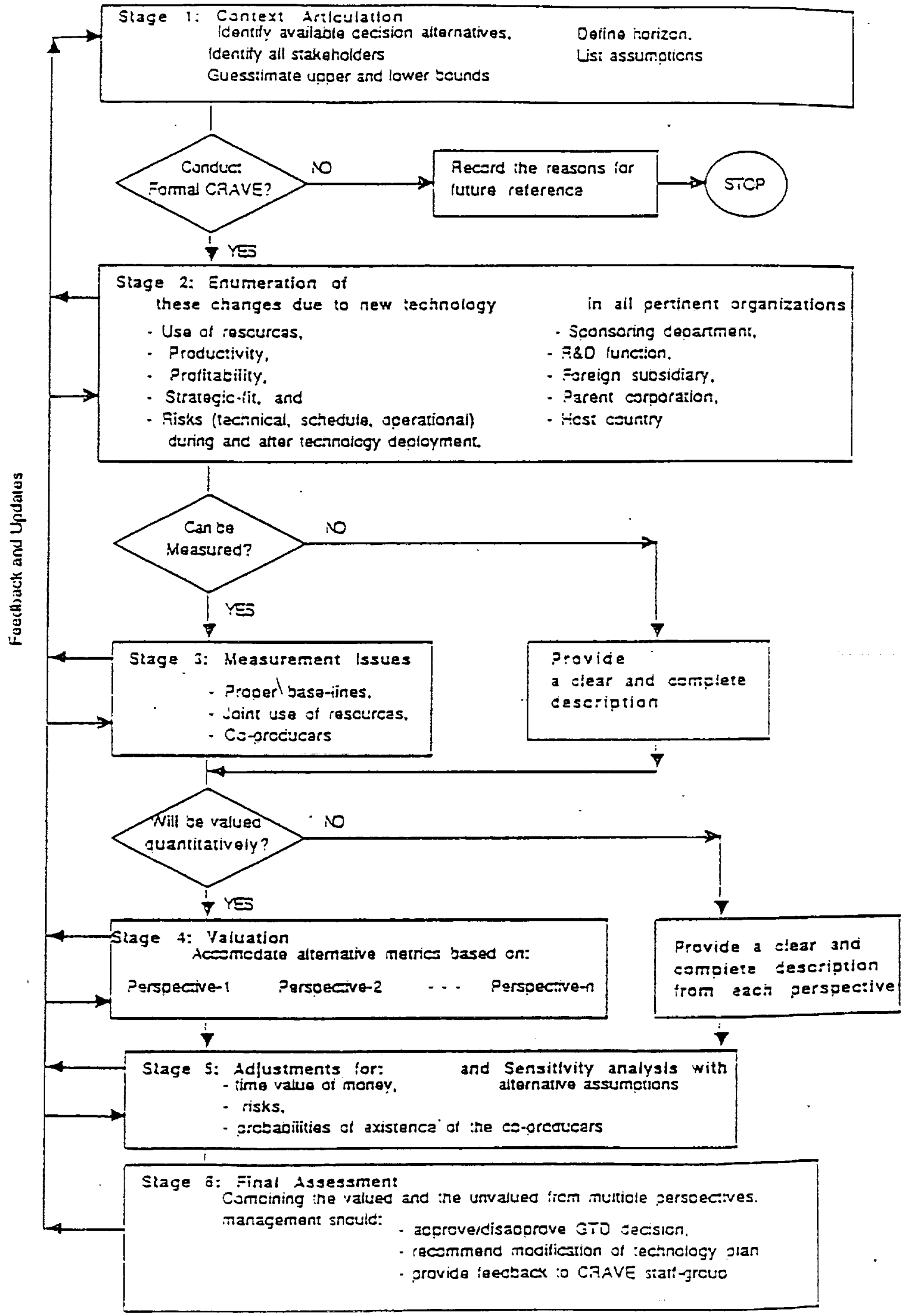


Exhibit 3

Some Commonalties in CBA and CRAVE Methodologies

1. **Fundamental principles such as:**
    - Formal and explicit analysis
    - Accounting for all incremental costs and benefits
    - Accounting for costs and benefits to whomsoever they accrue
    - Adjusting for time value of various costs and benefits
    - Explicit recognition of assumptions, and performance of sensitivity analysis for alternative assumptions

2. **Use of typologies of costs and benefits such as:**
    - Fixed and variable.
    - Direct and indirect,
    - Obvious and hidden,
    - Primary, secondary, tertiary
    - One-time and recurrent
    - Controllable and non-controllable

3. **Use of rich concepts such as:**
    - Opportunity costs
    - Pareto-superiority
    - Joint use of resources
    - Cause-effect versus multi-producers-single-product relationships

Exhibit 4

A COMPARISON OF CURRENT CBA PRACTICE WITH CRAVE METHODOLOGY

CBA PRACTICE	CRAVE METHODOLOGY
Justification focus	Decision Assistance focus
Retrospective	Prospective
Technique-oriented	It is a methodology
Single-perspective assessment	Multi-perspective assessment
Consolidation of multiple stakeholders' criteria (possibly AHP type)	No simple consolidation (concept of Pareto superiority)
Forced quantification of the non-quantifiable	Quantification only when possible
Left to the proponents of specific GTDs	Actively directed by the MNC managers / decision makers
Left to non-experts with certain recipes	Guided by a methodologist
Potential for advocacy ignored	Potential for advocacy actively managed
Economic values only	Economic and non-economic values
Risks of non-existence of co-producers ignored	Risks of non-existence of co-producers explicitly accounted for
Consideration of internal risks only	Consideration of both internal and external risks
Stringent financial criteria Short-sighted perspective	More realistic criteria Balanced perspective
Product-oriented (i.e. C/B ratio, or IRR)	Process-oriented
Zero valuation of non-quantified intangibles	Explicit consideration of non-quantified intangibles
Measurement and valuation confused with one another	Measurement separated from valuation
Evaluating given alternatives	Helping construction of better alternatives
Often unrealistically long horizons	Well-defined, reasonably long but limited horizons
Ad hoc methods and assumptions	Consistent methodology and assumptions

Table 1

Summary Data on The Steering Committee's Top 17 ESRs

Priority #	ESR #	Costs ($' 000)	Payback (months)	ESR Score	Category / P-cut	Old Category
1	k15040	$108	12	144	2-s	1-s
2	k15813	$16	17	80	2-s	1-M
3	k15399	$29	3,484	36	2-s	
4	k14453	$3,800	63	60	2	1-M
5	k11794	$340	0	375	2	1-s
6	k15783	$305	NA	60	2	1-M
7	k15505	$4	NA	40	2-s	
8	k15836	$58	7	240		
9	k15569	$35	264	9		
10	k15825	NA	NA	60	P4-3	
11	k14887	$22	10	180		
12	k15317	$470	12	240	P4-1	
13	k15818	$46	7	180		
14	k15835	$2	3	256		
15	k14213	$84	84,000	30		
16	k15626	$472	34	40		
17	k15602	$26	16	60		

FIGURE 1

ESR Costs and Priorities

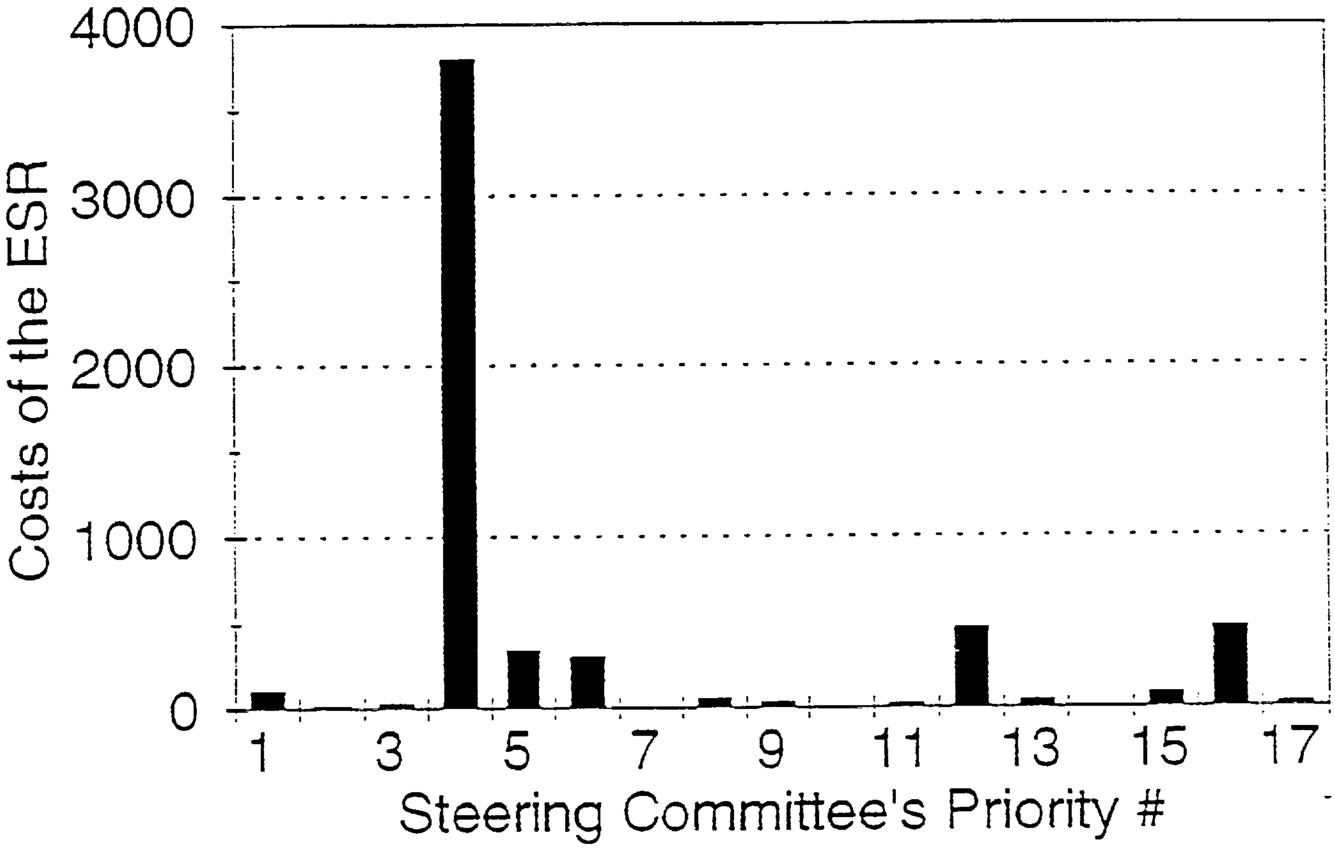


FIGURE 2

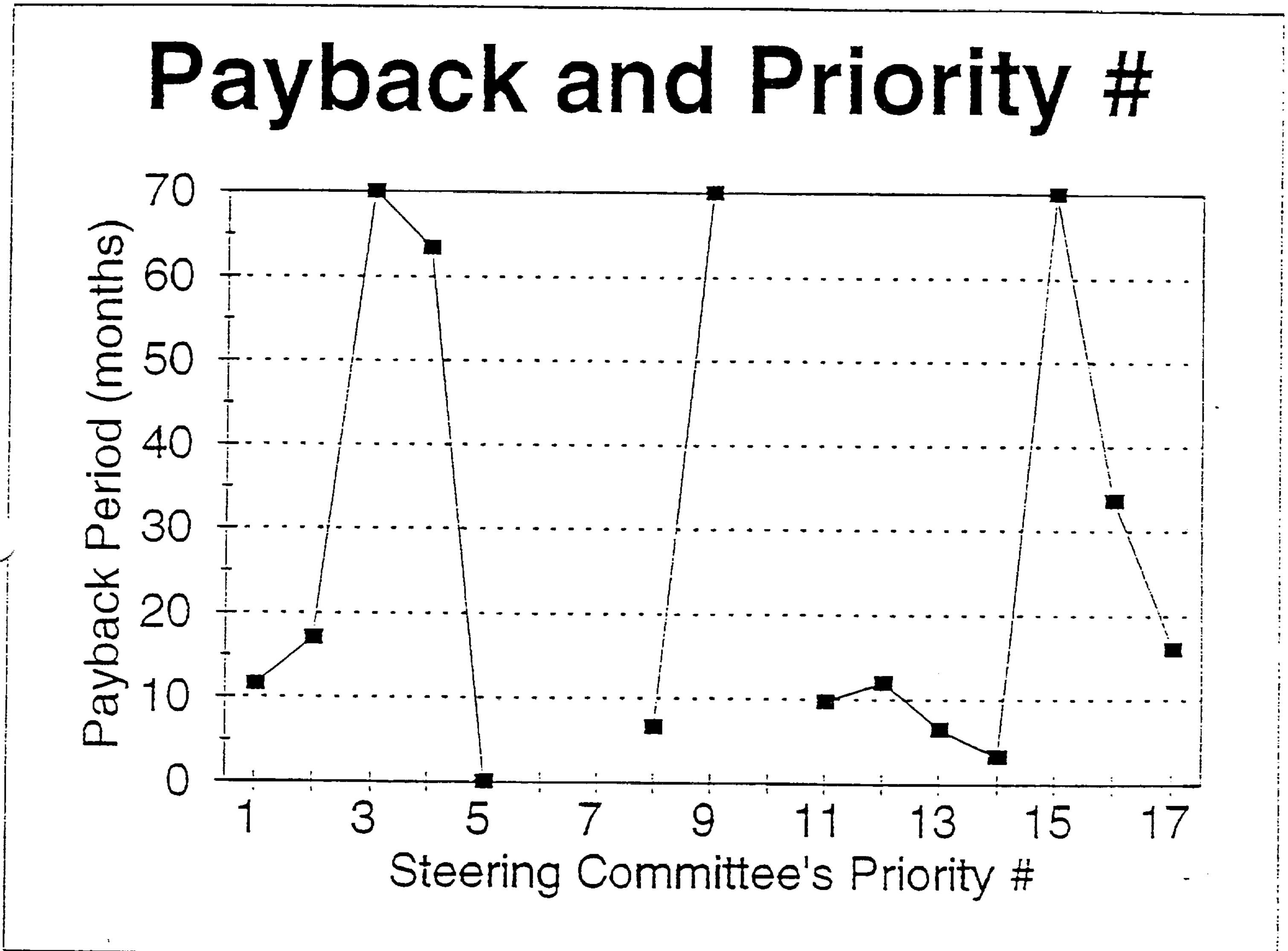

Payback and Priority #
Payback Period (months)
0
10
20
30
40
50
60
70
1
3
5
7
9
11
13
15
17
Steering Committee's Priority #

FIGURE 3

ESR Scores and Priority #s

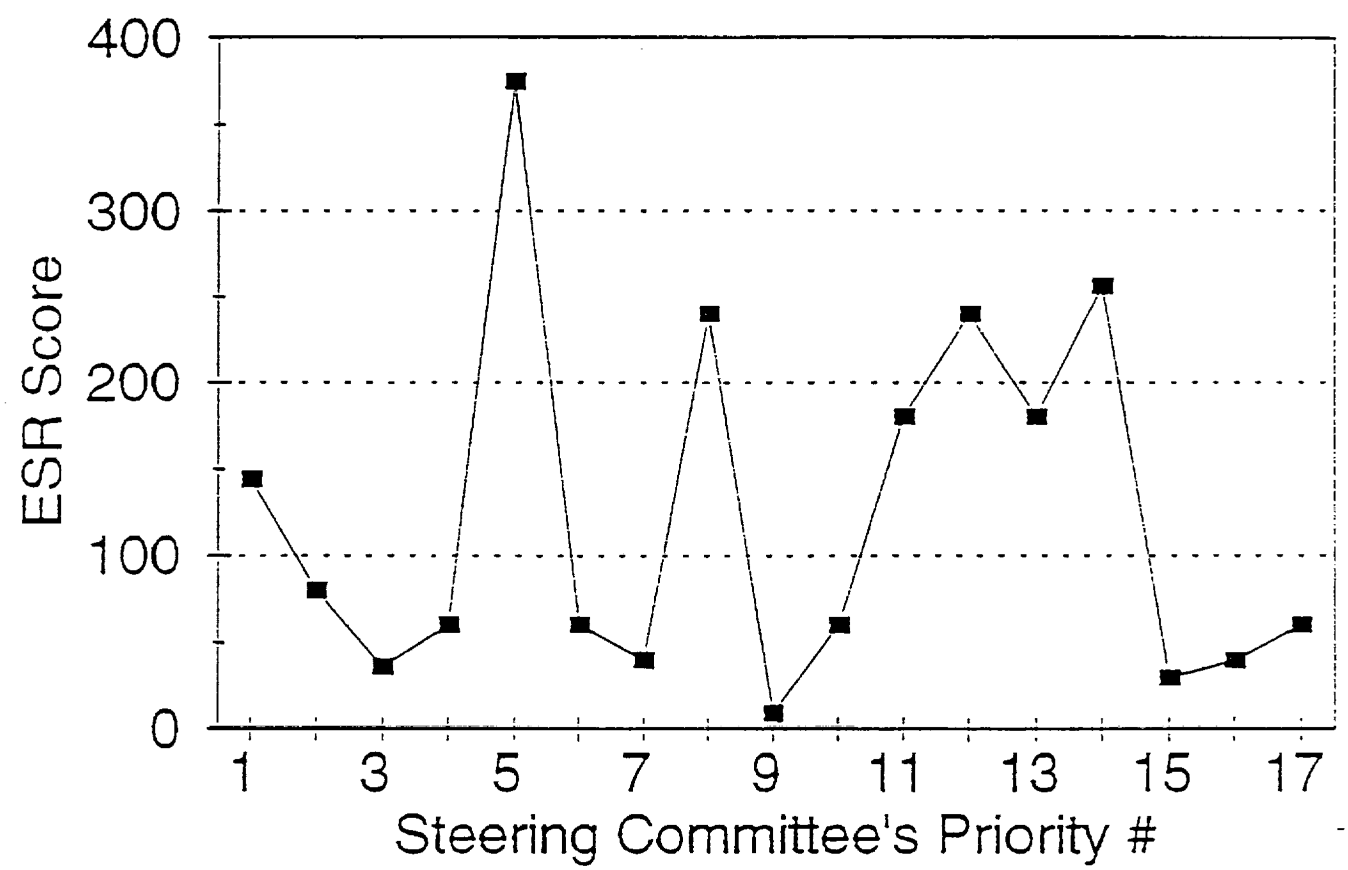
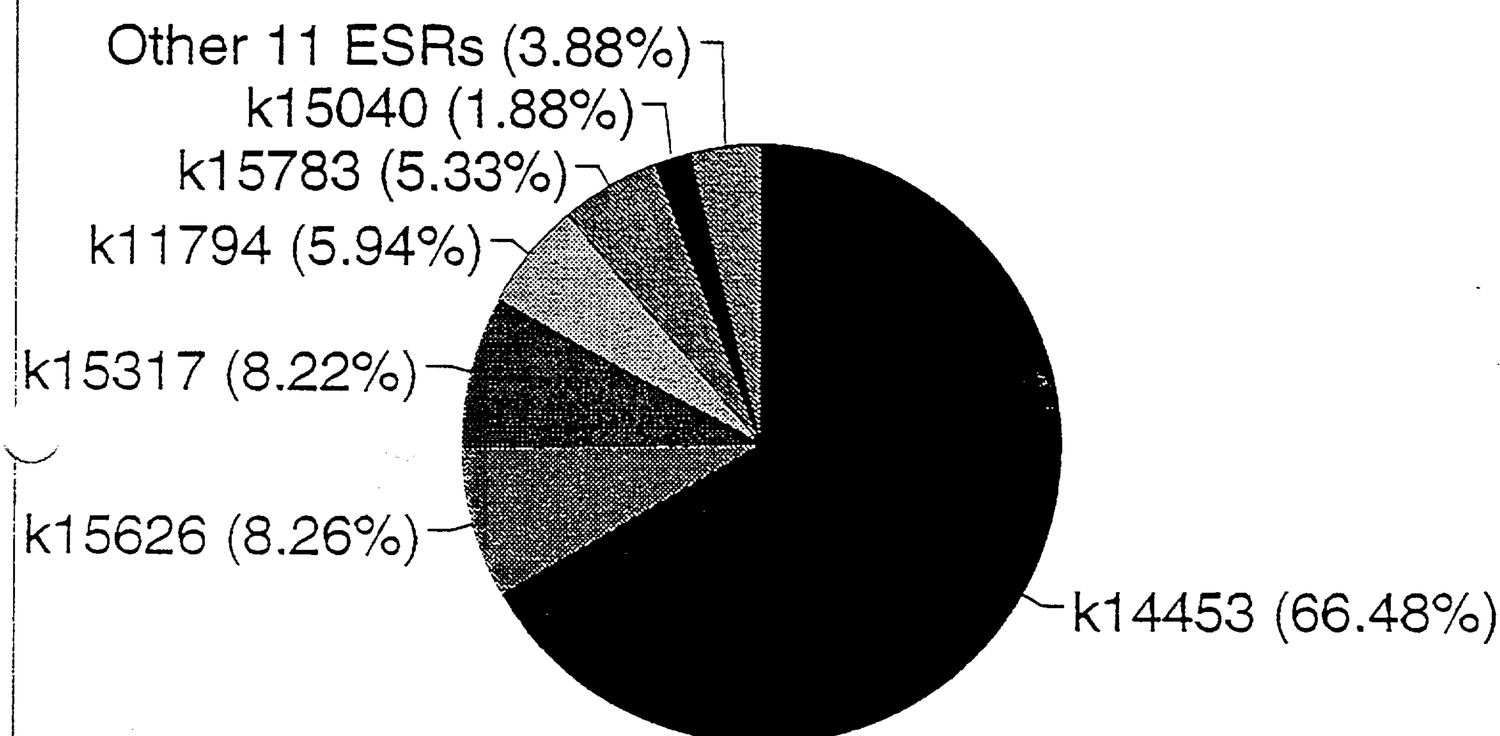


FIGURE 4

ESR Shares of Total Costs



Appendix A

A Critique of the 4-Matrix (4-M) Method of ESR Assessment

by
Praf Joglekar

The Ground Systems Working Teams (GSWT) Steering Committee has a difficult task: Prioritization among hundreds of worthy Engineering Support Requests (ESR). These ESRs come from some 31 different vehicle, payload, and facility systems. Individual ESRs cost anywhere between a few thousand to a few million dollars, and seek one or more of KSC's goals of improving safety, avoiding delays in flow-critical activities, reducing obsolescence, and reducing operations and maintenance (O&M) costs. At the same time, an important concern at KSC is that the modifications done by one engineering system must not adversely affect the functioning of other engineering systems vital to the processing of the shuttle. Thus, the process of ESR prioritization is actually called, **"GSWT Integration." Attachment A-1 describes this process** and its ground rules as of August 1993.

To understand the first ground rule, it should be realized that there is a system of designating ESRs as either Category 1 (i.e., mandatory) or Category 2 (i.e., highly desirable, but not mandatory). Suffixes such as S, M, or E are added to these categories to indicate whether ESR attempts to address a safety, or management, or environmental requirement. The ultimate authority for all ESR category designation rests with the Ground Review Board (GRB). The funding and approval of Category 1 ESRs is outside the GSWT process, which **focuses on prioritizing within Category 2 ESRs.**

To compare ESRs with one another and prioritize them is similar to comparing and rank-ordering hundreds of apples, oranges, bananas, strawberries, and watermelons, fruit by fruit! Each fruit comes in a variety of sizes, shapes, colors, and ripening stages. To complicate the matter further, the fruits come in a variety of semi-transparent packages designed to exaggerate their attractiveness. Some fruits sell by the pound, other by the piece, still other by the package. For some quantity discounts are available, for some others their are cost-premiums associated with the timing of purchase. We want to maximize the nutritional value, the taste, the flavor and still be within our budget, which will be determined at future dates by several different funding authorities!

As I understand it, in the past, this comparison and rank-ordering was not a major problem. We had resources to buy plenty of each kind of fruit. Even ESRs that were not funded in a given year were seen as simply deferred for implementation in a year or two. Thus, as described in Attachment A-1, we prioritized ESRs on the basis of their **technical merit** (perhaps a euphemism for subjective judgment based on such inputs as which team makes the best presentation, who is championing an ESR, which team is screaming the loudest, etc.), **with practically no regard to what they cost.**

To assist the steering committee in its assessment of the technical merits, GSWT teams were encouraged to assign a **"P-cut"** rating to individual ESRs. **Attachment** A-2 presents the P-cut definitions. Although, the GSWT steering committee is charged to consider only Category 2 (desirable but not mandatory) ESRs, the P-cut system extended the concept of mandatory versus desirable nature of ESRs to several levels within Category 2 by focusing on the reasons underlying the modifications sought by the ESRs, and within Category 2 ESRs getting P1, P2, or P3 ratings were seen as required!. The differences in the costs of various ESRs were not seen as an important consideration, and even highly cost-efficient ESRs (those promising a payback in less than one year) received a low priority of P4-2, practically ensuring that we will never get around to these ESRs with the limited available funds.

Over the last three years, the resources available for NASA, in general, and for ESRs in particular have shrunk dramatically. Now, we must be cost-conscious and choose between competing ESRs systematically and rationally. In other words, **today we must base our decisions not only on technical merit but also on cost-effectiveness considerations.** Recognizing this need for cost-effectiveness considerations, the GSWT Steering Committee recently developed and implemented a method called **the 4-Matrix (4-M) method of ESR assessment. See Attachment A-3 for the description** of the method, the forms used, and the accompanying instructions.

The designers of 4-M method must be applauded for their courage in breaking away from the established culture at KSC which is oblivious to any cost considerations, let alone consideration of cost-effectiveness. 4-M represents a first attempt at bringing a degree of rationality to the process of rank-ordering ESRs. This method must evolve and lead to a sounder methodology in the future. The critique here is intended to assist in that evolution. It must not undermine the credit for a pioneering effort on the part of the designers of 4-M.

I had the opportunity to study how the 4-M method worked in the steering committee's rank-ordering of the top 17 Vehicle Engineering (TV) related ESRs for FY95. **Table 1** summarizes the data on cost, payback period, and ESR score, for each of the top 17 ESRs. In addition, I have included the Category / P-cut rating, where available. Finally, I was told that some of these top 17 ESRs were originally in Category 1 but were downgraded to Category 2. The Column "Old Category" reports this information.

As can be seen from Table 1, an ESR's priority does not seem to be related to either the size of the project (as defined by its cost), or its payback period, or the ESR score. **Figures 1, 2, and 3** graphically demonstrate the lack of these relationships. In short, the steering committee's priority order cannot be explained by any of these factors. It follows that the 4-M method does not seem to help in the rank-ordering of ESRs. There are several reasons why. Here, these reasons are grouped in two major areas: issues pertaining to the **design** of the 4-M method, and those pertaining to the GSWT **process**.

DESIGN ISSUES:

1. **The 4-M method ignores two over-riding considerations at KSC, namely SAFETY and OBSOLESCENCE.**

There is no factor to assess the severity of the consequences of potential mishaps caused by the existing equipment or facilities in terms of injury to personnel, or damage to the orbiter or the payloads. Nor is there a factor to assess the obsolescence and lack of supportability of the existing equipment or facilities. Thus, in addition to the ESR scores, the GSWT Steering Committee has to consider these factors. Since at KSC, safety is indeed our Number 1 concern, it is natural that we give a high priority to safety related ESRs regardless of their 4-M scores. The "category" and "old category" information in Table 1 confirms this. ESRs that had an Old Category 1, and those with 2-s designation seem to be at the top of the list of 17 regardless of their costs, ESR scores, or payback periods.

2. **The 4-M method actually focuses on two primary factors:**
   (a) Expected annual impact on flow schedule, and
   (b) Payback period.

Note that three of the four factors in the 4-M method, namely

i. Frequency of Operation
ii. Processing Impact/ Improvement
iii. Likelihood of Occurrence

when multiplied together, basically give us a score for the **expected annual impact on flow schedule.**

The **payback period** is calculated separately in the Cost Assessment Worksheet.

3. **A multiplicative model is inappropriate for the 4-M method.**

In theory, **if all incremental costs, risks, and benefits can be identified, measured, and valued in dollar terms, the calculated *Payback* period should be the sole criterion** for rank-ordering ESRs. The shorter the *Payback*, the more desirable the ESR.

However, often it is difficult, if not impossible, to measure and value in dollar terms factors such as *Safety Improvement, Obsolescence Reduction, and Avoidance of Schedule Delays*. In that case, it makes sense to use a **factor scoring and weighting method**. But the scores on such factors should not be multiplied with each other or with the score on *Payback*. What we need is a weighted average of the scores. The weights have to be carefully chosen to reflect the values of the organization. A method called the **Analytical Hierarchy Process** (AHP) is most helpful in the development of proper weights, and KSC should explore its application.

4. **The design of the rating categories and score ranges is inappropriate.**

4-M's multiplicative approach is particularly inappropriate since, by design, the score for *Expected Schedule Impact* can range from 1 to 100 while the score for *Payback* can range only from 1 to 5. Thus, 4-M is biased towards minimizing the importance of *Payback*. This bias is further accentuated by the fact that all ESRs providing a longer than 2-year payback (including those that may never payback) receive a rating of 1, while ESRs providing a payback within 3 months receive a rating of only 5. I believe this is totally inappropriate.

The way I see it, **provided the payback calculations are reasonably valid and accurate, all ESRs promising a payback within one year deserve to be immediately funded**. That will have more money (or other resources) at the end of the year than we had at the beginning, and those increased resources would be available for the pursuit of our other goals such as increased safety. Even ESRs promising a payback within 4 years are highly desirable. They represent better than 20% per year compounded rate of return. On the other hand ESRs that take longer than 5 years to payback should be considered undesirable unless they promise significant improvements on one or more of the non-quantifiable dimensions of safety, obsolescence, or schedule.

Thus, I believe that 4-M's design of the rating categories as well as possible range of scores for the *Payback* factor are inappropriate.

An important attribute of properly designed rating categories is that they are **mutually exclusive** (i.e., non-overlapping) and **collectively exhaustive** (i.e., no possibility should be left out). Unfortunately, in 4-M we see **both** of these attributes **violated**:

- The critical path (i.e., serial flow) nature of an operation seems to be **double-counted,** once in the *Frequency of Operation* factor, and again in the *Processing Impact/ Improvement factor*.

- The categories in the *Likelihood of Occurrence* factor provide **no room for the rating** of a mishap that is expected to happen no earlier than 18 months and no later than 24 months. Thus, the categories here are **not collectively exhaustive.**

- Given that we have already accounted for the frequency of an operation, the likelihood of occurrence factor should refer to likelihood *per operation*, rather than likelihood *per year*. This is a second example of **double-counting** certain factors.

5. **The absence of relevant probability considerations on the Cost Assessment Worksheet is inappropriate.**

Many ESRs are designed to avoid potential mishaps likely to be caused by existing equipment or facilities, and hence will contribute their estimated savings in "annual corrective manhours and materials" only with the probability of occurrence of the mishap.

The expected savings are the product of this probability times the estimated savings. Yet, the Cost Assessment Worksheet does not require an estimation of the relevant probability. Consequently, the computation implicitly assumes that the mishap would occur with certainty. The net result is that typically, 4-M's Cost Assessment Worksheet underestimates the payback period. (For an example, see comments on *k15836* in **Appendix** B).

6. The language is ambiguous, and instructions / explanations are lacking.

One well-known short-coming of cost-benefit analysis is that it can easily become *an instrument of intentional or unintentional biases* introduced by the champions and advocates of specific projects. Therefore, in designing a cost-benefit assessment method, one has to be extra careful and try to minimize opportunities for the introduction of such biases, and convenient misinterpretations of the words and phrases chosen. Unfortunately, **4-M is fertile with many opportunities for the introduction of such biases:**

- One factor is defined simply as *"Processing Impact / Improvement,"* without any further instruction. The designers of 4-M assume that there will never be an ESR that will actually negatively impact the flow schedule. But the fact is, in some cases for the sake of safety, we may introduce new procedures that could actually delay a shuttle's serial flow. For such an ESR, the designers of 4-M would like to see that the lowest rating of 1 is used. However, the lead engineer who knows that the concerned operation is a serial one, refuses to use a 1 or a 2. Indeed, one cannot blame a lead engineer whose ESR introduces a 24-hour serial delay if he/she chose to rate the ESR as a "5."

- 4-M asks that an operation's frequency be rated either as a "5 Multiple times per flow / month," or as a "4 Once per flow / month." Given the ambiguity in the phrase "per flow / month," we just cannot blame a champion, whose ESR truly deserves a "4," if he/she rates it a "5." After all, if the operation is once a month, then it is clearly multiple times per flow since a flow lasts for several months. If the operation is once per flow, given the overlapping nature of several shuttle flows, in many months in a year the operation may be done multiple times a month!

- The designers of 4-M use the phrase "likelihood of occurrence" to refer to the *"probability that a mishap or 'problem condition' would occur unless an ESR was implemented"*. Yet, several lead engineers I have talked to assume it to mean the *"probability that the operation will be done within the next so many flows."* (See comments on *k15813* in Appendix B).

- Among those who realize that "likelihood of occurrence" referred to the probability of a mishap, many say that faced with the choice between rating their ESR a "3 Could happen within next 4 flows / 6 months" or a "2 Could happen within next 8 flows / 12 months," they invariably choose a "3" rather than a "2." As one lead engineer puts it,

PROCESS ISSUES:

1. **KSC culture is not cost-conscious.**

The greatest single barrier to the implementation of any method of cost-effectiveness analysis at KSC is KSC's culture which is **almost oblivious to any cost concerns, let alone cost-effectiveness concerns**. In the GSWT process this lack of cost-consciousness is evident in many ways:

- As Table 1 and my Appendix B comments on *k14453* show, **the GSWT process does not distinguish between a $4K ESR and a $4M ESR.**

- Note from Table 1 that the steering committee has included *k15825* in its list of Top 17 ESRs **even though there is no rough order of magnitude (ROM) estimate** of its cost. In other words, the ESR could cost anywhere between a few thousand to a few million dollars, and it would still be Priority #10 on the list.

- At the Thursday morning meetings of the steering committee, often a report is given on the status of ESRs approved in prior years. While that report includes information on which ESRs are complete, which ones are behind schedule and by how much, etc., there is **no information on the original cost estimates and actual expenditures** on the various ESRs. In fact, I am told that the way our accounting system is set up, it just cannot track and monitor ESR by ESR expenses.

- At the June 28, 1994 meeting to review TV's FY 95 priority list, **management did not raise any questions about costs, paybacks, or the 4-M scores of any of the ESRs.** The steering committee also did not make any attempt to defend its priority list using any one of these cost-related considerations.

Given this culture, **most engineers do not take ESR cost estimates seriously**. Even those who are charged with arriving at the estimates freely admit that their **estimates could be wrong by 50-60%.** Others put the expected margins of errors to be as high as 80-100%! Given that, for many ESRs, benefits are inherently more difficult to quantify and measure, sometimes we even see instances of carelessly exaggerated claims. (See Appendix B comments on *k11794*). Others see no need to even attempt to quantify the benefits of their ESRs, or report any 4-M scores. They know very well that as long as their ESR can claim to be a "mission-stopper," it will be funded regardless of costs. Some team members speculated that the **4-M method creates the paperwork necessary to pretend to Washington DC that we are cost-conscious.**

Thus, I was not surprised that many teams had not read 4-M instructions carefully, and made such elementary mistakes as addition in place of multiplication, or reporting payback in years as payback in months (See Appendix B comments on *k15040*).

2. **Organizational separation of the prioritization, funding, and implementation processes is not conducive to the pursuit of cost-effectiveness.**

The second most important reason why any method of cost-effectiveness analysis would be very difficult to implement in the GSWT process is the organizational separation of the process that does the prioritization from the process that provides the funding, which in turn, is separated from the process that ensures actual implementation of an ESR. While GSWT teams and steering committee are asked to prioritize the ESRs, they have no authority to actually fund or implement any ESR. **The consequences of this separation are:**

- **It perpetuates the culture of a lack of cost-consciousness**, and GSWT teams and steering committee are likely to continue to focus exclusively on technical merit and ignore all cost considerations.

- **It causes considerable frustration for the teams and the steering committee** insofar as the funding mechanism can override the priorities set by the GSWT integration process, and the implementation mechanism (i.e., Design Engineering [DE] and Shop Floor [SF]) can easily re-arrange those priorities by allocating or not allocating the necessary manpower to specific ESRs. Furthermore, even if the steering committee wants to use cost-effectiveness as an important criterion, given that our long standing culture is so deeply ingrained throughout KSC, DE and/or SF may continue to use technical merit as the sole criterion in deciding which ESRs to work first, if at all.

- Both, the total manpower spent, and the calendar time needed, for all this prioritization, funding, and implementation is inordinately high. In other words, **the bureaucracy is perpetuated.**

3. **The culture of integration is not conducive to the analysis and confrontation necessary in a rational prioritization among competing investment alternatives.**

At KSC, the ESR prioritization process is called "GSWT integration process," and it is left to a committee consisting of representatives of several GSWT teams (i.e., a committee of peers). This is consistent with KSC's long standing tradition of decision-making by consensus developing teams. The GSWT integration process should help ensure that one team's ESR does not interfere with the functioning of other team's systems. However, it may not be the most productive process for prioritization among competing demands on limited resources. Appendix B clearly shows that for a rational prioritization of ESRs, we need considerable analysis and confrontation.

As members of "an integration process," individuals on the steering committee are inclined to respect the expertise and trust the integrity and judgment of individual teams. For example, from Attachment A-1, page 2, note that a team's internal priorities of its ESRs are not to be questioned by the steering committee. Yet, as is clear from Appendix B, these teams have no expertise in cost-benefit estimation. Consequently, a team's cost-benefit estimates may be way off the mark, and its internal priorities may be based on such erroneous estimates. On the other hand, GSWT teams do have substantial vested interests in making their ESR look as attractive as possible. Consequently, a team may be misrepresenting the true benefits (see Appendix B comments on *k15040*), or overestimating the magnitude of those benefits (see Appendix B comments on *k15813, k11794, and k15836*).

4. The need for a properly trained and impartial analyst to assist the steering committee.

Of course, even if we renamed the GSWT Steering Committee as "ESR Prioritization Committee," we will not get the necessary degree of analysis and confrontation from this committee, for several reasons:

- First, most members of the committee do not have the necessary background or training to do the kind of analysis I have done.

- Second, given that
  - a) serving on the steering committee is only one tenth of one's job, and
  - b) the number of ESRs to consider is very large (48 were considered in prioritizing the TV list),

  no one has the time to check the claims, the assumptions, and the computational accuracy of each one of the ESRs.

- Third, in a structured team, members of the team could be assigned to check out specific ESRs, ensuring that each ESR is checked by one or more team members. In a committee of peers, such a division of labor is very difficult.

- Finally, a committee of peers thrives on the collegiality of its members. Such a committee hates confrontational members, and no individual is likely to volunteer to be a confrontational member.

Thus, if the GSWT steering committee truly wants to use cost-effectiveness as a criterion in its prioritization of ESRs, it must **seek assistance from a properly trained, impartial analyst who is charged to be confrontational about every ESR**, its logic, cost-benefit estimates, computational accuracy, etc.

"Almost anything that could happen over the next 12 months, could also happen over the next 6 months, except perhaps an increase in my salary."

- Although the instructions are to *multiply* the scores on the four matrices to obtain the total score, the use of *the word "total" seems to have led some teams to add* the scores on the four matrices. (See comments on *k15813* in Appendix B).

7. The presumption of being able to create a single method to fit all ESRs is unrealistic.

When we force different discipline engineers to all use particular forms, and a given set of cost categories, we soon discover that our method does not quite fit all the systems we are trying to evaluate. There are many tell-tale signs that the 4-M method does not fit all ESRs.

- 7 (15%) of the top 48 ESRs for FY95 were submitted without an attempt to fill out either of the two forms of the 4-M method.
- 6 (13%) more filled out the ESR score form, but not the Cost Assessment Worksheet.
- Regardless, 3 of these "defiant" 13 wound up on the Steering Committee's list of the top 17 ESRs.
- Those who did fill in the forms, often had to modify the cost assessment worksheet to report the some of the unique costs or benefits of their system.
- For more specific examples of the inapplicability of 4-M method, see Appendix B.

The variety of technical disciplines the ESRs originate in, the diversity of benefits they seek, the variety of risks they reduce, the many different types of costs they impose, together suggest that to evaluate and rank-order these ESRs, **what we need is a methodology, and not a method.** A methodology allows for the use of several different methods of analysis depending on the nature of the technical system, the type of modification sought, and the relevant costs and benefits. Thus, despite the shortcomings of the 4-M method, we must not abandon the pursuit of cost-benefit analysis, or return to the arbitrary decision making of the past. Instead, **we must evolve towards the adoption of a methodology such as Costs, Risks, and Values Evaluation** (CRAVE).

GSWT INTEGRATION PROCESS

- 0 GROUNDRULES
  - 0 ONLY CATEGORY 2, 2E, OR 2S ESR'S ARE CONSIDERED
  - 0 TECHNICAL MERIT IS THE ONLY CRITERIA USED TO EVALUATE ESR'S THROUGHOUT THE INTEGRATION PROCESS
- 0 THE INTEGRATION PROCESS STARTS WITH THE **TEAM LIST**.
  - 0 THE GSWT TEAM CONSISTING OF A NASA & LSOC SE AND AN SDE FROM GSDE PRIORITIZE THE ESR'S WITHIN THEIR SYSTEM BY TECHNICAL MERIT AND FISCAL YEAR.
- 0 THE NEXT LEVEL OF INTEGRATION (CALLED THE **TV LIST**) OCCURS ONCE A YEAR .
  - 0 THE GSWT STEERING COMMITTEE (S/C) REPRESENTATIVES FROM TV, 17-01, AND 15-01 TAKE THE TEAM LISTS FROM THEIR RESPECTIVE ORGANIZATIONS AND INTEGRATE THESE ESR'S INTO A SINGLE LIST.

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ATTACHMENT A-1

Lockheed
Space Operations Company

GSWT INTEGRATION PROCESS

0 THE PROCESS WORKS AS FOLLOWS;

0 THE #1 PRIORITY ESR FROM EACH TEAM'S LIST ARE LAID ON THE TABLE. THIS IS A TOTAL OF 22 ESR'S.

0 THE ESR'S ARE GROUPED BY P-CUT AN INDEX ASSIGNED TO THE ESR BY THE GSWT TEAM. IT INDICATES THE SEVERITY OF THE IMPACT OF **NOT** DOING THE REQUESTED MODIFICATION.

0 USING THE P-CUT, THEIR UNDERSTANDING OF THE PROBLEM CONDITION AND THEIR EXPERIENCE AS A GUIDE, THE THREE S/C REP'S SELECT WHAT THEY CONSIDER TO BE THE MOST IMPORTANT ESR FROM THE ITEMS ON THE TABLE.

0 THE #2 PRIORITY FROM THAT TEAM (WHOSE ESR WAS SELECTED AS MOST IMPORTANT) IS THEN BROUGHT UP ON THE TABLE AND COMPETES AGAINST THE OTHER 21 ESR ALREADY ON THE TABLE.

0 THIS PROCESS CONTINUES UNTIL A SET NUMBER OF ITEMS HAVE BEEN SELECTED. THIS IS THE TV LIST.

GSWT INTEGRATION PROCESS

- 0 THE TV LIST IS THEN SUBMITTED TO THE ENGINEERING DIRECTORS FROM 17-01AND15-01,THE LSOC CHIEF ENGINEER, THE TV ENGINEERING DIRECTOR, AND ALL TV DIVISION CHIEFS.
  - 0 A MEETING IS CONVENED TO ALLOW REDLINES TO THE LIST TO BE DISCUSSED AND INCORPORATED.
- 0 DURING THIS TIME, THE SUPPORT OPS AND TE ORGANIZATIONS ARE PERFORMING THE SAME INTEGRATION FOR ESR'S FROM THEIR TEAMS USING A SIMILAR PROCESS. THEIR EFFORT COMPILES THE TE LIST.
- 0 THE LAST STEP IN THE INTEGRATION IS PERFORMED BY THE GSWT S/C INTEGRATION TEAM AND RESULTS IN THE **FYXX GSWT INTEGRATED PRIORITY LIST.**
  - 0 THIS TEAM CONSISTS OF THE S/C REPRESENTATIVES FROM TV, TE, 30-0, AND 17-01 (ALSO REPRESENTING 15-01). THE S/C CHAIRMAN ATTENDS AND ACTS AS A TIE BREAKER IF REQUIRED.

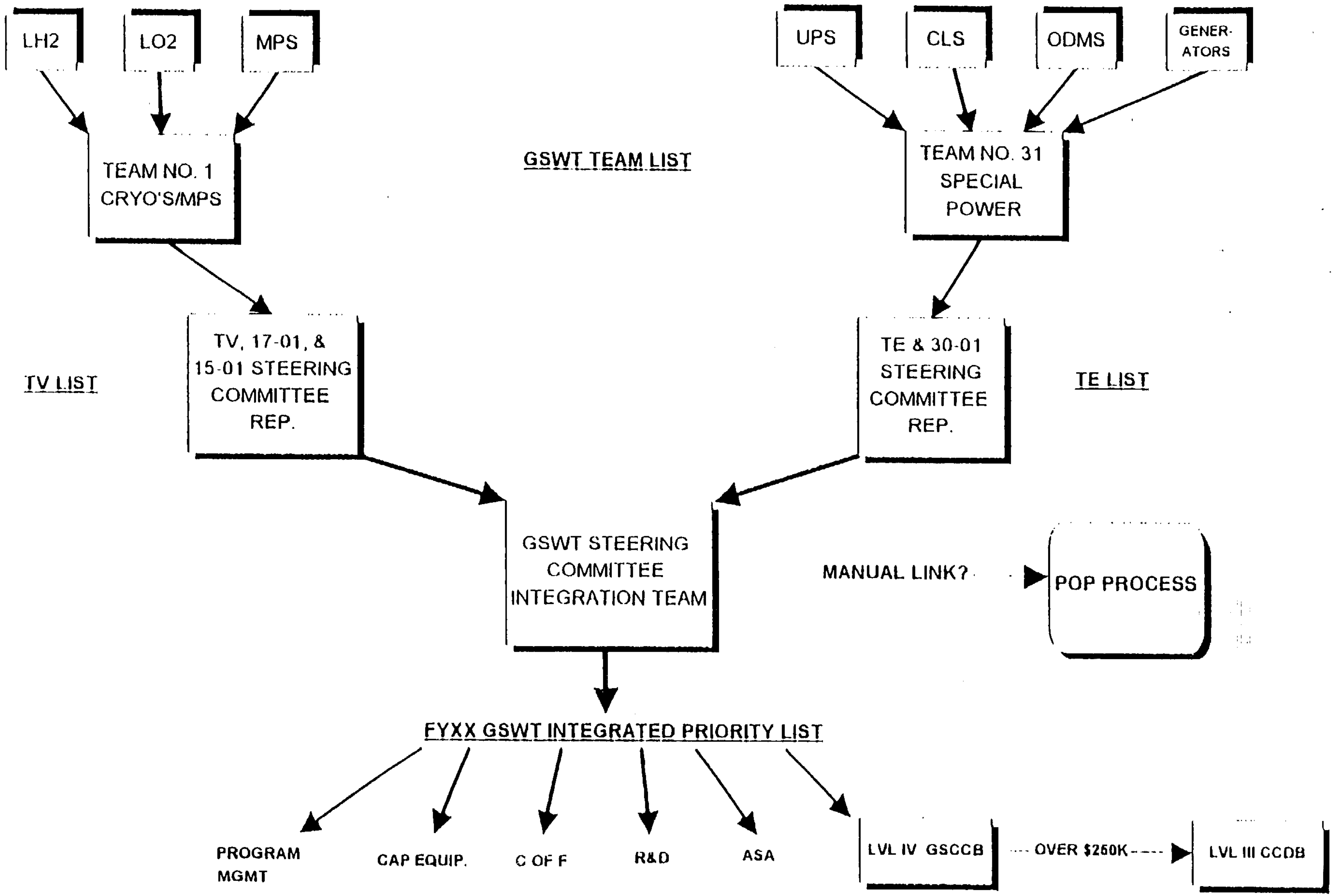
GSWT INTEGRATION PROCESS

- 0 THE TV AND TE LISTS ARE USED AT THIS LEVEL AND THE INTEGRATION PROCESS IS THE SAME AS EARILER EXCEPT THERE ARE ONLY 2 ESR'S ON THE TABLE AT ANY GIVEN TIME.

- 0 THE NUMBER OF ITEMS TO COMPRISE THE LIST IS DETERMINED BY THE TEAM AT THE START OF THE PROCESS AND THE INTEGRATION CONTINUES UNTIL THIS NUMBER IS REACHED.

0 WHEN THE PROCESS IS COMPLETE THE LIST IS DISTRIBUTED BY THE STEERING COMMITTEE CHAIRMAN.

GSWT INTEGRATION PROCESS



8/20/93

GSWT STEERING COMMITTEE – PRIORITY DEFINITIONS

REQUIRED ITEMS THAT ARE:

- P1-1 – Requirements dictated by drawing, specification, or directive to support a specific mission effectivity
- P1-2 – Modifications required to support a specific flight system/payload requirement dictated by drawing, specification, or directive
- P1-3 – Modifications which prevent potential loss of life, severe injury, or significant damage to flight hardware where no procedural or operational workarounds exist
- P1-4 Modifications which prevent significant (> 8 hrs) processing impact

REQUIRED ITEMS THAT:

- P2-1 – Meet upgraded design requirements (with hazardous implications)
- P2-2 – Correct design deficiencies in primary system (with hazardous implications

REQUIRED ITEMS THAT:

- P3-1 – P1 or P2 item where workaround is possible
- P3-2 – Correct design deficiencies in backup systems
- P3-3 – Meet upgraded requirements
- P3-4 – Correct design or documentation inconsistencies
- P3-5 – Reduce the potential of injury to personnel or potential damage to flight hardware where a procedural or operational workaround exists.

DESIRABLE ITEMS THAT ARE NEEDED TO:

- P4-1 – Prevent obsolescence-caused problems
- P4-2 – Enhance operations with short-term payback (less than 1 year)
- P4-3 – Improve processing operations to reduce schedule risk.

DESIRABLE ITEMS WITH NO QUANTIFIABLE EFFECT ON PROCESSING BUT WILL:

- P5-1 – Create improved practices or efficiencies
- P5-2 – Enhance processing with long-term payback (more than 1 year)
- P5-3 – Upgrade systems to align with current Government regulations.

9/7/90

Geoffrey F. White, Chairman
GSWT Steering Committee

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ATTACHMENT A-3

LOCKHEED SPACE OPERATIONS COMPANY
INTERDEPARTMENTAL COMMUNICATION

DATE: March 29, 1994
CONTROL NUMBER: 3201-94-049

TO:	Distribution	DEPT. NO.	BLDG. NO.	MAIL CODE	
FROM:	J. F. White	DEPT. NO. 32-01	BLDG. NO. LST-2	MAIL CODE LSO-042	PHONE 383-2200 Ext. 2759

SUBJECT: REPLACEMENT OF THE P-CUT DURING ESR PRIORITIZATION

Currently a P-CUT is assigned to each ESR as it is entered in CMOS. The P-CUT is useful to the Steering Committee Integration Team during the yearly prioritization process, but has not been helpful to the GSWT's in prioritizing the ESRs on their individual team lists.

The GSWT Steering Committee is introducing a new methodology to use in determining the priority of ESRs within the GSWT system that will replace the P-CUT. This new system called "the 4-matrix method" is simpler and more straight forward and should benefit your GSWT in evaluating where an ESR should fit on your respective team lists. A copy of the method is attached and a brief description of each major matrix follows:

Frequency of Operation:

Each ESR has a problem condition or event that is described in Block 16 of the ESR form. This problem condition is normally the result of the performance of some operation such as a particular sequence of an OMI or WAC. This matrix correlates the number of times this operation occurs per flow or month to a numerical value. The more frequent the occurrence the higher the value.

Processing Impact/Improvement:

This matrix equates the Block 16 problem to a Vehicle processing impact. This impact should be a direct result of the problem condition, a "single point failure" scenario rather than relying on a series of failures to cause a worst case situation.

Likelihood of Occurrence:

This matrix concerns the probability of the problem condition or event occurring within a given time frame. A higher potential of occurrence is assigned a higher value in the matrix.

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Cost Assessment:

The first step in performing this matrix is to fill out the ESR Evaluation-Cost impact sheet. This data is similar to the ROM data that has been required in the past. When the sheet is complete, you will have calculated the months to pay back required to perform the "Cost Assessment" matrix. On the "Cost Assessment" matrix, select the appropriate pay back period and numerical value associated with the pay back period.

Multiply the numerical values obtained from the four matrices together to obtain a score for the ESR under evaluation. This score, when compared to the scores on other ESRs on your list, should help you understand where this ESR should be prioritized.

Please implement this system immediately. Beginning with the upcoming FY95 Integrated Priority Process starting in April of this year, at least the top three priorities on your team list need to have been evaluated and selected using the 4-matrix method. (Retain the work sheets for these three ESRs to provide background data to support your priority). This process is to be used on all new ESRs. Use the attached sheets to perform this evaluation. Update the CMOS P-CUT field for these first three with the numerical score obtained from the matrices. In the summer, the GSWT data fields in CMOS will be revised to allow you to input this information directly into CMOS. Also, SPI BM-310 (2)K is in the process of being revised to reflect this change. In the interim, make the changes to your team list using the attached information. If you have any questions, contact your GSWT Steering Committee Representative.

J. F. White, Director
Ground Systems Design Engineering
Chairman, GSWT Steering Committee

JFW:lm

Attachments: A/S

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ESR ASSESSMENT CRITERIA

SCORE

FREQUENCY OF OPERATION ________

5 Multiple Times Per Flow/Month
4 Once Per Flow/Month - Critical Path
3 Once Per Flow/Month - Non Critical Path
2 1-5/OMDP/2 Years
1 Contingency Operation Only

PROCESSING IMPACT/IMPROVEMENT ________

5 More Then 24 Hour Serial Flow Time
4 More Then 8 Less Then 24 Hour Serial Flow Time
3 Less Then 8 Hour Serial Flow Time
2 More Then 24 Hour Parallel Flow Time
1 Less Then 24 Hour Parallel Flow Time

LIKELIHOOD OF OCCURRENCE ________

4 Expected To Happen Within The Next Flow/Month
3 Could Happen Within The Next Flows/6 Months
2 Could Happen Within Next 12 Flows/18 Months
1 Not Expected To Happen In The Next 16 Flows/2 Years

COST ASSESSMENT (SCORE FROM REVERSE SIDE) ________

5 Payback Within 3 Months
4 Payback Between 3 and 6 Months
3 Payback Between 6 and 12 Months
2 Payback Between 1 and 2 Years
1 Payback Longer Then 2 Years

TOTAL [ ]

Determine the appropriate classification of the ESR within each category. Multiply the score of each category together to determine the ESR rating. The rating will be compared with other ESR's to prioritize next year's modification budget. The ratings will be independently verified during the GSWT Integration Process.

COST ASSESSMENT WORKSHEET

COST OF PROPOSAL: (ROM)

Engineering ________________ M.H. @ $40.00 $ ________________

Material $ ________________

Labor ____________ M.H. @ $40.00 $ ________________

FPC $________________

TOTAL COST $ ________________ (A)

****BENEFIT OF PROPOSAL***

OPERATIONAL SAVINGS: (ANNUAL)

(______ M.H. (Old Way) - _______ M.H. (New Way) X $40.00 = $__________

(______ Consumables (Old) - $_______ Consumables (New) = $__________

($______ Energy (Old) - $_______ Energy (New) = $__________

TOTAL __________ (B)

MAINTENANCE SAVINGS: (ANNUAL)

(P.M. MH.s/Yr (Old) ______ - P.M. M.H.s/Yr (New) X $40.00 = $__________

(P.M. Mat'l (Old) ______ - P.M. Mat'l (New) ______) = $__________

Corrective M.H. (Old) ______ - Corrective M.H. (New) ____ X $40.00 = $__________

(Corrective Mat'l (Old) ______ - Correctible Mat'l (New) ______) = $__________

TOTAL __________ (C)

OTHER SAVINGS (ANNUAL) $ ____________ (D)

PAYBACK:

$$P = \frac{A}{B + C + D} \times 12 = \underline{\qquad\qquad}$$ Months To Payback

If savings are negative for any factor, add total algebraically.

To be used with ESR Assessment Matrix

Appendix B

Comments on Selected ESRs from the Costs, Risks, and Values Evaluation (CRAVE) Perspective

by
Praf Joglekar

Costs, Risks, and Values Evaluation (CRAVE) is a **methodology**. That is, it is a way of thinking — armed with certain fundamental principles and concepts — and a way of analyzing available decision alternatives using situationally appropriate techniques and tools from a large body of methods consistent with the fundamental principles and concepts. A methodology focuses on both the techniques and the processes used in relevant decision-making.

Consequently, **the first step in applying CRAVE to the problem of ESR rank-ordering is to understand the complexity, diversity, and situational specificity of the ESRs** in terms of

a) the magnitudes of costs, risks, and benefits involved,
b) the degree to which these magnitudes could be quantitatively measured,
c) the degree to which related decisions affect an ESR's costs and benefits,
d) the degree to which sub-decision elements (such as the timing of implementation or availability of quantity discounts) affect the pertinent costs and benefits, and
e) any other critical elements.

Only when we understand this complexity and diversity can we create a suitable adaptation of the CRAVE methodology to ESR prioritization. Towards that end, I studied several ESRs in terms of the modifications they were proposing, their estimated costs, risks, benefits, ESR scores, payback periods, etc. I talked to several lead engineers, ESR champions, steering committee members, accounting professionals, and third parties familiar with specific ESRs and/or familiar with the GSWT process.

The following comments reflect my informed assessments of the selected ESRs, as well as my observations about the ESR prioritization process. Some readers may find these comments too cryptic, but of necessity, I have assumed that readers are reasonably familiar with the selected ESRs and their respective 4-M assessments.

K14453. "New Hydraulic Pump Units"

1. **An ESR that does not belong.**

In terms of costs, this ESR stands out as the most important one to analyze carefully. Insofar as **its estimated costs** ($3.8M for Option A and $2.8M for Option A1) **exceed the combined costs of all 16 remaining ESRs** on TV's FY95 priority list (See **Figure 4**), it is unfair and irrational to treat this as just another ESR to be rank-ordered as Priority 1, or 4 (as the Steering Committee did), or 17. Thus, in my opinion this ESR does not belong to the GSWT prioritization process. If a comparison with other ESRs must be done, the appropriate question would be whether or not the benefits of this ESR exceed the sum total of the benefits of all remaining ESRs. But such a comparison would be similar to asking whether the value of buying a house exceeds the value of feeding and clothing ourselves for several years. With that kind of a comparison, we would never buy a house!

In our personal lives, although some sacrifices in the amounts we spend on food and clothing are necessary to buy a house, through devices such as a mortgage, we manage to buy a house without starving. Similarly, organizations must find ways to spend on capital equipment without jeopardizing their short-term survival. The best way to do that is to set aside two separate funds for capital expenditures and operational expenditures, and to avoid any comparison of a project in the capital expenditure category with projects in the operational expenditure category.

At KSC, we do have different funds and funding mechanisms to take care of capital versus operational items. Unfortunately, **in the GSWT prioritization process, we have not stopped comparing capital ESRs with operational ESRs.**

2. **Let them fight with their equals.**

If at all, I would have compared this ESR with others costing $1M or more.

3. **Widely different cost estimates.**

As I dug deeper into this ESR, I came across several different cost estimates ranging from $1.8M to 3.8M without much explanation for why the estimates were so widely different. I was told not to be surprised if it ends up costing $5M by the time it is actually implemented. More importantly, it seems that with the accounting system at KSC, even in retrospect, we may never find out how much an ESR really costs. The most disturbing thing for me is the fact that the GSWT Steering Committee concerns itself neither with the magnitude of the cost estimates nor with the reliability of those estimates. Finally, **I am disturbed to note that KSC culture is so oblivious to cost consideration.**

4. If I were King:

If I were King, considering that

a) this ESR offers a payback from its quantified benefits (from savings in reduced PRs and reduced O&M expenses) within six to eight years,

b) additionally, it offers intangible benefits such as avoidance of flight-critical delays, reduction of noise, and reduction of electric shock hazard, that have not been quantified,

c) the current equipment is 17 years old and it must be replaced within the next two or three years, and

d) proper timing (coordinated with the construction of Fluid Support Stations in the two OPF bays) is very important in the case of this ESR, and can save as much as $1M,

I would have approved this ESR for FY94. Perhaps it is still not too late.

K15040. PGHM Anti-Free Wheel Mod

1. Disguised motivation.

It seems that the GSWT team's real motivation is to modernize and automate PGHM operations — a very desirable goal. However, knowing the KSC culture of approving primarily (perhaps only) safety related ESRs, the champions of this ESR have framed its justification in terms of avoiding potential damage to cryogenic or hypergolic payloads. The fact is that given the precautions we take and the manpower we allocate to PGHM operations, the likelihood of Z wheel operations causing any major damage to payload is one in several thousand.

2. Inconsistent cost and payback estimates.

Although an October 1993 study estimates the cost of this ESR to be $49K, the ESR score calculations are based on a cost of $108K. No one on the GSWT Steering Committee is charged specifically with the responsibility to identify and correct such inconsistencies. Indeed, the steering committee does not know how much expenditure it is authorizing by putting an ESR on its priority list.

Similarly, the GSWT team seems to have made a mistake in reporting that this ESRs payback as *11.6 months when they meant 11.6 years!* Once again, the mistake went undetected by the steering committee.

3. Bite the bullet or forget it!

I am not an engineer, but it seems to me that if we are going to spend $108K, we ought to attain a much greater degree of automation than replacing a ball and screw mechanism with a machine screw!

K15813. EPDM Cover Installation Tool

1. The steering committee does catch some mistakes.

Instead of *multiplying*, the GSWT team had *added* the scores on the four matrices. The steering committee corrected that mistake. The steering committee also seems to have challenged the team's claim of a rating of 4 on the Processing Impact factor and corrected it to a rating of 2.

2. Likelihood factor incorrectly rated.

On the other hand, the steering committee seems to have missed the fact that the GSWT team interpreted this factor to mean "likelihood that the operation will be performed" rather than "likelihood that a mishap or problem condition would occur."

3. Operational savings overestimated.

A reality check suggests that the estimated saving of eight man-hours per EPDM cover installation exceeds the actual man-hours currently required for this operation! A payback period of four years may be more accurate. Of course, that is sufficient considering the reduction in the risk of damaging the covers — a benefit not quantified in the payback calculation.

K153991. Main Door Windlocks Pin Insertion

1. Isn't there a cheaper way?

While it makes sense to avoid a broomstick approach (particularly in the Space Program), certainly the replacement should not cost $28K.

2. Look for economies of scale.

This ESR highlights the need to make certain changes in Pad A and Pad B configurations simultaneously rather than one at a time. Had we done that, the incremental cost of the device for Pad A could have been of the order of $5K rather than $28K.

K11794. An Additional Winch to Recover from ESP/ECP Platform Tilt

1. Counting benefits that are impossible to obtain through the proposed ESR.

This ESR estimates the payback period for its investment to be .067 months (or two days)! To me this ESR represents the case of a carelessly exaggerated claims. An assumption underlying this claim is that by recovering from a tilt of the ESP/ECP platform we will save the cost of an SSME ($60M). The fact is, the damage due to the tilt would be already done and straightening out the platform will not in itself save the SSME. We will have to undertake all the necessary repairs, and tests as well. If having an additional winch would prevent a potential tilt, then we could count the avoided damage times the probability that the damage would occur in the absence of the new winch as a saving due to this ESR.

Another implied assumption in this payback calculation is that a ESP/ECP platform tilt will occur with certainty. Although with aging winches, the probability of a tilt occurring is increasing, I would say that it is still of the order of one in a hundred.

Yes, we need to refurbish our aging winches, but this is hardly a rational way of justifying that. I am most surprised that the steering committee did not challenge these payback calculations.

2. Inadequacy of the cost assessment worksheet

It is clear that 4-M's design of the Cost Assessment Worksheet cannot accommodate the capture of all relevant risk and benefits associated with this ESR.

3. Why insist on an exact duplicate of existing winches?

I am told that for the $340K cost of this ESR, instead of buying one winch that duplicates existing winches in form and function, one could easily buy four commercial off-the-shelf (COTS) winches that incorporate better technology and avoids single point failures.

Such a purchase of four new winches would allow us

a) to use them together for the safest hoisting of crucial loads, and
b) to disassemble, inspect, and refurbish at least ten of the existing twelve winches, with parts to spare from the other two.

4. The option generating nature of CRAVE.

The suggestion in Comment 3 above shows that the CRAVE methodology not only helps in the assessment of a given ESR, it has the potential to generate better options.

K15783. KU-Band DEMOD Replacement.

1. Internal inconsistency.

On the one hand, this ESR claims a processing improvement of more than 24 hours of serial flow time. On the other hand, it says that there will be no monetary payback. This seems inconsistent. Surely there must be a quantifiable lower bound on the value of a 24-hour serial flow improvement.

2. **The importance of establishing upper and lower bounds on the values of certain types of benefits.**

It seems important that a trained cost-benefit analyst should establish upper and lower bounds for the value of the various categories in the Processing Impact/Improvement factor. This is a very doable task, and it should help us in more rigorous and quantitative assessments of many ESRs.

3. **Work around possible.**

As it turns out, this ESR will not contribute to an improvement of 24 hours of serial flow time. This is because when the DEMOD does not work, we do have a way to communicate between firing room and OPF. The trouble is that communication involves routing through JSC and satellite, etc. Commercially, such a communication could cost as much as $100 per minute. Luckily, NASA does not have to pay anybody for this communication. However, we may be impeding or slowing down other vital communication that truly needs the satellite system. Considering all these factors and the fact its estimated cost is $305K, I found this ESR to be the most difficult one to decide on.

K15505. Additional HPD Platforms

1. **We must develop a simpler and speedier low cost mod (LCM) process.**

This is one of the least costly ($4K) of the ESRs I studied. It seems unfair to burden such low cost proposals with the same degree of rigor of assessment and rank-ordering as ESRs costing ten or a hundred times its cost.

2. **Estimate minimum benefits in quantitative terms.**

Although this ESR made no attempt to calculate its payback period, it would have been easy to obtain a lower bound on the benefits and an upper bound on that payback. Given that two injuries have occurred during the last two years, the average cost of these injuries can be seen as the minimum savings brought by this ESR. Of course, one of my presumptions is that we have reasonable records from Personnel Department to be able to estimate the costs of those injuries.

3. **If I must rank-order the sample of ESRs I have studied:**

Considering the facts that

a) we have already spent the money for the design of the platforms,
b) the incremental costs of the remaining work are so small, and

c) it will avoid the types of injuries to workers that have occurred twice during the last two years,

this ESR would be my Priority #1.

4. Why re-evaluate?

What I do not understand is why this ESR is being re-evaluated at this stage. The original version of this ESR calling for the design and implementation was estimated to cost $35K, and we have already done the design work. I would have assumed that implementation of that design would not be a new decision point!

15836. Replace Diver Operated Plug (DOP) s/n 4

1. Reasonably quantifiable costs, risks, and benefits.

This a good example of ESRs whose costs, risks, and benefits are reasonably quantifiable. The use of the 4-M ESR score in such cases would be **totally inappropriate**. The sole criterion for rank-ordering among these ESRs should be the payback period—the shorter the better.

2. Benefits overestimated.

This ESR claims a payback in seven months by estimating an annual saving of $103K when the cost of a new DOP is only $58K. Based on available information, I would re-estimate the benefits as below:

The last time DOP s/n 4 failed was two years back. So let us assume that its probability of failure in a year is 0.5. In the event of a failure, we would spend

One day of sea labor	$7,700
One day of sea boat rental	5,000
PR Generation & Disposition	1,600
Materials & Labor to Fix DOP s/n 4	19,800
	$34,100

Thus, assuming that a new DOP will have zero probability of failure, the purchase of a new DOP will help us avoid a cost of $34K with a probability of 0.5. Hence, the expected savings are (.5)(34K) = 17K per year. This gives us a payback of 41 months.

To the extent that the probability of DOP s/n 4 failing goes up from year to year, the payback period may be shorter than my calculation indicates. But certainly it is not as short as seven months. Of course, as I have indicated elsewhere, if the payback is four years or less, I consider an ESR to be desirable. Such ESRs should be prioritized in the increasing order of their (correctly estimated) payback periods.

3. **Look for economies of scale.**

Here is another example illustrating the need to take advantage of economies of scale. We will need one more DOP within a year or two. It would be considerably cheaper if we ordered two at a time, rather than one now and one a year or two later.

4. **The need for a qualified analyst to assist GSWT Steering Committee.**

I do not expect a steering committee to be able to do the kind of reassessment of benefits I have done in Comment 2 above. I believe that if we are serious about incorporating cost-effectiveness considerations in our ESR prioritization, the steering committee must be assisted by a properly trained and impartial analyst whose charge is to challenge the GSWT teams' logic and the numbers on each ESR.

K15818. Digital Control Cards for LOX Pumps

1. **An ESR we cannot afford not to invest in.**

This ESR proposes to spend $46K in order to save three cold flows (LOX) per year, worth $25K per flow. Assuming these numbers are correct, KSC must take $46K from its liquid oxygen (LOX) budget to fund this ESR immediately, so that we will save $29K this year and we will have $75K extra in future years for other desirable projects.

2. **Use the right funding source.**

As I see it, this ESR should be funded from the LOX budget. It should not compete with other ESRs for other sources of funds. Any comparison of this ESR with other ESRs would be unfair to both.

K14515. Prime Backup HGDS Infinite Zero Gas Source

1. **Not on GSWT steering committee's priority list, very correctly.**

This ESR is not one of the Top 17 on TV's list, but it is on the "open ESR" database. Yet, I have included it in this review primarily because I want to make the following points.

2. **Reasonably quantifiable costs and benefits.**

From the data on this ESR, it seems clear that the costs, risks, and benefits are reasonably quantifiable, and hence payback ought to be the sole criterion for this ESRs rank-ordering.

3. **An ESR that deserves to be rejected once and for all, closed, and deleted from the database.**

This ESR proposes to spend $118K to be able to use facility GN2 gas in place of ultra pure GN2 in everyday standby purge operations, so as to obtain an estimated savings of $7K per year. There are no other intangible benefits associated with this ESR. Thus, this ESR will take 16 years to payback!

I believe that such ESRs ought to be rejected once and for all, closed, and deleted from the "open ESR database" so that the GSWT steering committee is not burdened with its consideration year after year, and our computer systems are not burdened with carrying unnecessary data.