SESSION I

NEW DEVELOPMENTS IN SAFETY

Session Chairman - Mr. Philip H. Bolger

"Communication of Risk"	Dr. Raymond M. Wilmotte
"System Safety Management - A New Discipline"	Mr. W. C. Pope
"Data Requirements Analysis in Support of System Safety"	Mr. I. Irving Pinkel
"Reflections on System Safety and the Law"	Mr. Daniel F. Hayes, Sr.

INTRODUCTION

All decisions are based consciously or unconsciously on the balance between benefits and risk. That is true for all of us, at all times. I am going to discuss this balance, and for that purpose will divide applied technology into two parts· Benefit-oriented and Risk or Uncertainty-oriented. Benefit technology includes design, development, manufacturing or construction, operations. Risk or uncertainty technology includes safety, reliability, quality assurance, test, maintenance, as shown in fig. 1. This picture is key to the decision-making process. The process may be invisible, taking place in the decision-maker's mind from his knowledge of the problem, or at the other extreme, it may involve a process with independent benefit and risk departments supporting and, at times, confronting each other. But always the decision will be affected by the balance with which relevant information of the benefit and risk technologies have reached the consciousness of the policy maker and stimulated his interest.

It is the importance of this balance, its present and potential status that is the subject of this paper. The premise of the discussion that follows is that for decision and policy making at all levels, knowledge of the consequences of risk is as important as knowledge and consequences of benefits.

Perhaps the purpose of the paper is best depicted in the two cartoons of fig. 2 and 3. Fig. 2 represents current unbalanced benefit of risk presentations, while fig. 3 represents balanced conditions, more helpful to the decision maker.

The discussion of risk brings different things to mind to different people. Here, I use the term very broadly. Risk exists because one is uncertain about some things. These uncertainties could range in technology from areas beyond the state of the art, and lack of knowledge about the environment, to analyses and tests not made, capabilities not used, and human errors of all kind.

I treat risk and uncertainties as synonymous. Technically I prefer uncertainties - Risk implies a number, often of vague meaning. Uncertainty gives a sense of needing to know more and wanting to do something about it. Professionally I think uncertainty; for public relations and lay communication I talk risk - it seems a nicer, more generally acceptable word.

In addressing this subject to the safety community, I should point out that system safety is a most important part of the risk technology and holds a specially politically sensitive position in the eyes of management.

COMMUNICATION: A PRIMARY NEED

Nearly all engineers are dedicated to their work; system safety engineers are no exception nor are other types of engineers working in the risk technologies. But being trusted is not enough; we must justify our utility in the eyes of the decision-makers in relation to that of others who bear other technical responsibilities. It is not sufficient to argue the importance of the work; we must convey its value. It must be expressed in realistic terms and attractive form; and it must make it possible for the decision-maker to compare the benefit-risk ratio of alternative courses of action.

The responsibility for deciding how much risk to take is generally viewed as the exclusive province of top or near-top management. And indeed top management's activities are almost exclusively focused on balancing risk against benefits on a macro scale, but down the line innumerable risk-benefit micro decisions are made without knowledge of higher management. Some of these turn out not to be micro at all, and become known only when their effects become visible, sometimes too late for correction or late enough for correction to be costly.

There are a number of reasons for judgment to be slanted in favor of benefit, meaning that there is a tendency to take more risk than would seem desirable. This condition can be reversed following a serious accident or crisis. Then, for a while, exceptional attention is given to understanding risk and reducing it. But the full effect is usually temporary. There is a natural tendency to return to the state of mind that existed prior to the crisis, to degrade or even forget some of the "lessons learned." The trend rapidly accelerates as the team that lived through the tense atmosphere of the crisis is dispersed among other programs. Some procedures which were adopted may be retained but the degree of attention given to them tends to drop, and the risk engineers have a harder time achieving effective communication.

Each type of risk activity includes a variety of steps, procedures and techniques, but they have a common ultimate purpose. It is to warn of the probability of impending trouble, the resources and time required to reduce that probability and reduce the probable damaging effects if it occurred. The warning is given to the appropriate levels of the benefit activity. With this information the decision-maker is in a position to decide whether the risk is sufficiently low to permit operation or whether it is preferable to take steps to reduce it.

The decision-maker's judgment as to the desirable benefit-risk ration depends on a number of considerations and their balance is affected by current material and political pressures. This judgment is a very personal matter. A gambler will under-value risk, a miser will overvalue it--at least from the point of the middle-of-the roader.

Facts and analytical logic limit the area within which judgment must rule. Outside this judgment area quantitative facts dominate. Experience shows that hard data tends to displace the soft and tenuous, even logic, sometimes with little regard to importance. In the soft area it often happens that the personality of him who presents the information has more impact than the information itself.

In most organizations which are not technically oriented, no group is assigned the specific responsibility of assessing risk; everyone is expected to know that risk exists and make decisions within the area of his productive responsibility in accordance with his best judgment. But does everyone at each decision level give consideration to the balance between benefits and risk? The answer is yes! Everyone does, but often it is done unconsciously with little conscious realization of the risk introduced. Seldom is the risk involved systematically communicated to higher management. The effect is cumulative; as one decision influences another the risks add, and many uncertainties -- assumptions, approximations, conflicts, etc. -- are lost to the decision-making process.

Expressed in this way, it would seem that current decision-making process is terrible. We know, however, that it is not so; decisions are on the whole good, except sometimes....

In technically oriented organizations, however, there exist departments specifically oriented to certain areas of risk. Some, like system safety and reliability, are mainly analytical; others like quality assurance and tests (of the qualifying and acceptance type) are largely processing. These areas provide information on uncertainties and tend to counteract the normal tendency to underestimate risk.

THINK-POSITIVE SYNDROME

The titles of the risk activities -- Safety, Reliability, Quality Assurance, Test, etc. -- appear on the doors of these department, but when one enters one hears about failures, accidents, defects and anomalies. Why? Because the terms "reliability," "safety," "quality assurance" and "tests" are reassuring, while "failures," "accidents," "defects" and "anomalies" are not. But professionally the specific work consists in reducing these uncertainties, and any effort to quantify them focuses on estimating the probability of their occurrence.

One can refer to these "risk departments" as "uncertainty control departments" as better describing the type of work. Risk gives one a sense of a number, often of uncertain meaning, while uncertainty brings to mind the specific elements that produce risk and even a desire to do something about each one. When uncertainty professionals talk to policy-makers they will use the terminology of their titles: they will state, for instance, that the reliability is .9992 and not that the probability of failure is 8×10^{-4} -- reliability sounds better than probability of failure, for the same reason that betting on a horse is based not on the probability of its losing but of its winning.

This type of phenomenon I have termed the "Think-Positive Syndrome.*

In industry, as in government, positive achievement is psychologically a must. As in the horse racing analogy, man loses interest in probabilities which involve considering losing rather than winning, even though the mathematical odds are not affected. Given the option,

*Wilmott, R. M. "Engineering Truth in Competitive Environment: IEEE Spectrum, Vol. 7, May 1970, pp 45-49 his interest will focus on benefits rather than uncertainties.

While the think-positive state of mind is essential to a program, it has some damaging consequences, the common basis of which is the tendency to unbalance the benefit-risk ratio in favor of the benefits.

The problems it engenders start with the statement of goals. These are mainly of the benefit type, most of which can be expressed quantitatively such as payload of so many pounds, cost so many dollars, schedule of so many days and equipment of specified physical characteristics to make measurements or observations. In the risk area the probability of failure is difficult to quantify. Numbers here, for reasons difficult to refute, are currently discredited. The desire to achieve benefit goals puts pressure to underestimate uncertainties and risk. The pressure is high because the goals are set at a level somewhat beyond the state of the art and risk estimates give way relatively easily because of the flexibility of current techniques for expressing uncertainties in numbers.

In one form or another the syndrome affects all stages of a program. It tends to make a whole organization lean toward giving more consideration to performance information (usually hard data) rather than to uncertainties (often soft or tenuous data) regardless of importance, or more pragmatically to lean toward underestimating rather than overestimating cost and time, and later in the program to sacrifice too readily risk-reducing activities to protect schedule and budget. The think-positive syndrome tends to make communication difficult and inefficient, because the analysis of risk inevitably focuses on uncertainties, which to the non-professional are negative aspects of engineering and management, although uncovering, assessing and doing something about them is clearly one of the most positive things an engineering group can do.

It is under stress, when funds and schedules are tight, when crises occur, that the undesirable features of the think-positive syndrome are most likely to be prominent. Under these conditions, the communication gap between policymakers and uncertainty engineers is particularly great, much greater than the gap that often exists with design and operations engineers. The pragmatic reason is that the latter are in a sense disposable. Design engineers are essential to build hardware, and operational engineers to operate it, but uncertaintly engineers are needed to point out how uncertainties could be reduced, but primarily only to help the policymaker with risk data and analyses; and policymakers have for centuries made policies without them. While a few managers, design and operating engineers are beginning to welcome the analyses and advice of system safety and reliability engineers, the majority find them to be a nagging interference with getting on with their work. They often consider that existing talent in design, operations and policymaking can meet substantially all such peripheral requirements. Under stress there is a great temptation to save money and time by reducing or even eliminating the risk departments.

Is it desirable to carry out such a policy? At first glance it would seem so, for in these areas there are no techniques which a design engineer would find difficult to understand and learn. Why, then, did such disciplines as system safety and reliability separate themselves from design engineering to a greater extent than such specialized functions as structures, thermal analysis, communications, etc.?

There are two reasons for maintaining risk and benefit technologies in separate departments. One is the importance to quality of the work interest of the individual worker and the other is the benefit that is derived from confrontation.

WORK INTEREST

The worker must be interested in his work for it to be consistently well done. If he has to cover two areas, in the first of which he has considerably more interest than in the second, he will inevitably give more than proportionate attention to the first. The difference is particularly noticeable when he is working under the pressure of a tight schedule. If consistently high quality is required, the two areas should be separated and given to different workers. The separation will have the advantage that each worker will become more knowledgeable in the area to which he has been assigned, but much more important is that each area will be the primary interest and will receive the primary attention of a worker. This situation exists strongly in the relation between the benefit and risk technologies. Design engineers are typically much more interested in the outputs and techniques of design than they are in those of system safety and reliability; they are not, therefore, likely to have equal interest or give consistent attention to the risk area, if they are required to cover both.

In the attached table I have listed my impression of the relative degree of interest of five groups -- Management, Design Engineering and the three risk assessment groups -- Safety, Reliability and Maintenance. Primary interest is indicated by a dark circle and secondary by a grey triangle. The number 1 indicates a somewhat greater interest than the number 2. The major difference in the interest is between the primary and secondary. This difference is to be judged not by verbal opinions but by action, by the extent to which under stress the secondary interest will be sacrificed for the primary; the extent to which system safety, for instance, will be sacrificed for schedule or for payload carried by a spacecraft; the extent to which as insistent a demand is made and expected for competence in system safety as in design; the importance given to introducing system safety considerations at the initial, the conceptual, as well as in the later stages of a program.

The table also shows that in the process of policy making three factors -- cost, time, and key performance parameters -- dominate the uncertainty control areas and the non-key performance parameters. Is the status of uncertainty control in policy-making process low because uncertainty control is not important?

The answer is that it is important, often the most important element when the whole life of the unit is the criterion, but often it is not important for the short term. And one must remember the forces on the policy-maker. For him the short term dominates, and long term effects and goals are considered only when short term needs are not pressing -- and the latter condition hardly ever occurs. There are few fields in which risk technologies have a standing at the top decision levels equals to that of benefit technologies. One outstanding exception is the Office of Manned Space Flight of NASA.

Even this handicap of long versus short term in giving greater attention to uncertainties might be overcome in time, if the risk areas were to provide information important and useful to making policy. They can warn of danger, they can advise Design regarding improvement, but it is difficult for them to develop a basis for statements such as "The design has deficiencies which will probably cost $X over its life, which could be reduced by $Y for a cost of $Z and a delay of T." Without this type of information how can a rational decision be made? This is the hard kind of data which design engineers can provide. Uncertainty engineers tend to provide soft data; safety engineers often provide only a list of some of the things that could happen. As already stated, experience indicates that hard data displaces soft almost regardless of importance.

BENEFIT FROM CONFRONTATION

A passive organization stagnates. Confrontation is essential to achievement, to progress and innovation. It can also be destructive, if it develops into personal conflicts. Ideally it is controlled and has a strong element of cooperation toward a common purpose. I apply the words confrontative and conflict in the clash of opinions to imply different attitudes. I visualize confrontation as an objective presentation of differences. Conflict includes an element of emotion and antagonism. Confrontative is constructive, conflict is destructive. In complex programs there is commonly a clash between functional and institutional managers. The initial confrontative sometimes degrades into conflict. On the whole the clash is beneficial. But the most potentially valuable confrontation for effective decision-making is between the benefit and risk areas. It would seem important, therefore, to keep them separate, each one as fully integrated as other practical considerations permit.

KNOWLEDGE: DESIGN AND UNCERTAINTIES

We know what we can design with a considerable degree of confidence, and this knowledge is the stimulus that impels us to go ahead with a program. However, we know little quantitatively of the risk we take in making these decisions. We know how to process all kinds of data, but while we have much data on how to do things, we have little on assessing risk. We have universally great confidence in the capability of those who design, but we look with a degree of suspicion on those who deal with uncertainties.

In the course of developing a system we are constantly reducing and deciding what uncertainties to retain. It would be folly to carry out all the analyses and tests we would like to make, but we should keep in mind that whenever we decide to eliminate something, some analysis or test, we are increasing the uncertainties. At the end of the process, in our review of what we have done, we should include also what we have not done. Otherwise we can hardly judge what uncertainties remain. The uncertainties that remain are never zero.

Uncertainty is made up of a lot of little things. It includes also big, clearly visible problems, but these are usually, though not always, well recognized and taken care of, but the little ones slip by and can easily be neglected or even deliberately disregarded, and the sum of them can be far from negligible. For that reason, developing statistics is often difficult. In the case of system safety, for instance, the number of accidents due to a specific deficiency during a particular operation may be too small for meaningful statistics. In operational anomalies, however, there lies a huge fund of valuable data largely unused. They could be aggregated, listed with their source, cause, and the analysis, reviews, tests, inspection where they could or should have been caught. We should not over-concentrate on major mission failures; other anomalies are just as important real-life data to support future design, reduction of uncertainties, risk assessment, and decisions and to select, on the basis of their efficiency, uncertainty removal techniques - analysis, tests, reviews, etc. Applying such data to analyses of the type of failure mode and effects, one could develop quantitative, occurrence estimates of the conditions that could produce accidents. We would then begin to derive some sense of the probability of accidents taking place though none had yet occurred and even before a system was put into operation. A substantial and effective data bank of derived uncertainty information might thus be built up.

The development of this technique and the building of such a data bank would change radically the importance and policy status of the uncertainty technology; it would rehabilitate the status of the "numbers game;" it would bring estimates of risk, of the consequence and penalties of potential deficiencies and uncertainties of a program to a level of management appreciation comparable to that of the projected benefits. Management would then at last have balanced information on benefits and risk, without which decisions have to be largely a matter of unsupported judgment. We can even consider that contractors could be induced to establish risk during the development of a complex system in some systematic manner, so that both he and the buyer can assess and monitor the true progress of a project at each of its critical stages.

CONCLUSIONS

No specific formula is presented on how to introduce into an organization the principles I have outlined regarding the utility of the risk technologies and their relationship to benefit technologies. Clearly the best operation will vary greatly with the industry and its current pattern of operation. Moreover, it is by no means obvious where improvement would be cost effective. Intuitively one can expect only slow advance in the science of risk technology while it remains fragmented. Strong advance could be expected by integrating its several elements into a single department with its manager responsible for warning of dangers arising out of uncertainties.

The importance to quality of worker interest and the value of confrontation points to the importance of separating the management of risk and benefit technologies. There is no clear argument, however, whether raising the level of efforts of the risk technologies would be beneficial or not.

Looking back over this discussion one cannot help but feel that in its development, its data base and the degree of attention from management, risk technologies lag far behind benefit technologies. The lag in these areas is undoubtedly the reason for the greater attraction that benefit technologies have for engineers. That lag of itself does not justify an increased effort in the risk area. Judging from the experience of some of the large programs one could reasonably come to the conclusion that adequate attention is being given to uncertainties, even taking into account the details of performance achieved, the anomalies experienced and the risks that they imply.

I have outlined a number of arguments describing existing conditions and pressures which lead to underestimating risk. All seem valid, but what value would accrue if these areas were improved, it is difficult to judge. The gain might indeed be little, but also it might be considerable. One might expect overall performance of many large programs to be sensitive to the quality of the decision process. If that is so, a small improvement should produce valuable results. Among the critical parameters of control one would expect to include risk at a level of attention no less than that given to any other parameter, including schedule and cost, and traded off on some reasonably comparable basis.

There is probably no controversy that an increased knowledge of risk in complex systems would help decision making. The controversial question is whether the improvement warrants the effort. Many managers feel that the present decision process is satisfactory; others don't. Among the latter is Undersecretary of Defense Packard. The fact is that we do not know; neither do we know what increased risk we incur when, under tight budgets, when crises are more likely to occur, we reduce the level of effort in the uncertainty areas.

It seems important to develop a better sense of the benefits that knowledge of risk could provide via the decision-making process. To carry this out will require an improved data base. By experiment and analysis on the effects of increasing the contribution of risk technologies, one could develop a better understanding of their potentiality and limitations.

The analysis in this paper has been written mainly with the idea of clarifying to technologists and analysts the place of the risk technologies in the managerial environment. Can it also indicate to management a possible line of approach to some of its needs? Judging from the demand of other countries for American management expertise we can reasonably consider ourselves equal to the best and possibly generally better in this field. But the urge for progress is in our blood. How do we progress in a field without guide lines, without goals, without means of measurement? The process we have followed is first to recognize some weak spots in our operation, and shortly sure enough, some ambitious top management tries an approach different from the current pattern for its type of operation. Whether it is an improvement or not is a matter of opinion, for it is almost always impossible to measure. Success is usually more felt than proven. To make such a move is generally dangerous to the individual, for criticism of managerial inovation, overt and covert, from managerial peers are easy to make and likely to abound, while praise comes more reluctantly. Experiments are difficult to carry out, for administrative changes may be strongly resisted by special groups and managerial levels. They generate barriers born of insecurity and fears - fear of being measured, of loss of authority and of freedom of action. The whole field is replete with prejudices and protective mechanisms.

So described the environment does not seem well suited to embrace a search for progress. Yet, these barriers are constantly being overcome, for progress has come consistently. This paper points to an area which is ready for progress. I believe it is a most important area, one in which a quantum step of progress can prehaps be achieved. The discussion of the paper was focused on technology, but the key element - the unbalance between benefits and risk in the decision making process - elements far beyond the boundaries of technology. If a systematic attack is to be made on this unbalance, technology is the logical first area to approach, for there the problem is most clearly definable, and its individual risk areas are well stocked, though still inadequately, with data, techniques and expert personnel.

My personal but unsupported opinion is that risk technology is a great and coming field. Advance there is needed more than in other technologies. It is not only needed in the hard area of engineering, but even more so in the soft area of the social sciences. It is rapidly changing from an art of judgment to a technology where we can begin to see the possibility of reliable numbers based on physics and real life experience. We still nave a long way to go before we can approach the values that this technology could provide. Risk assessment, supported by data and techniques for prediction, are receiving rapidly growing attention in many fields.

I would like to add one final opinion applicable to both the public and private sectors: If one does not include throughout a major project a systematic uncovering of uncertainties and at each major milestone a thorough official assessment of risk, one probably loses one of the most important benefits for the future the project can provide - developing real life statistical data and learning how to apply them to decision-making.

We still have much to learn!

UTILITY OF RISK DISCIPLINE TO MANAGEMENT

- PURPOSE OF RISK DISCIPLINES
  - ADVISE HOW TO REDUCE UNCERTAINTIES
  - WARN OF PROBABILITY OF IMPENDING TROUBLE
  - FOR DECISION PROCESS: ESTIMATE RESOURCES AND TIME REQUIRED TO REDUCE THAT PROBABILITY AND ITS DAMAGING EFFECT IF IT OCCURS.
- DECISION PROCESS
  - BALANCE BENEFITS AGAINST RISK.
  - REVIEW BENEFIT AND RISK-INFORMATION.
  - FILL GAPS ON BASIS OF EXPERIENCE AND APPLY JUDGMENT.
  - DECIDE WHETHER TO CONTINUE OPERATION OR REDUCE RISK.

FIGURE 6

THE BALANCE BETWEEN BENEFITS AND RISK

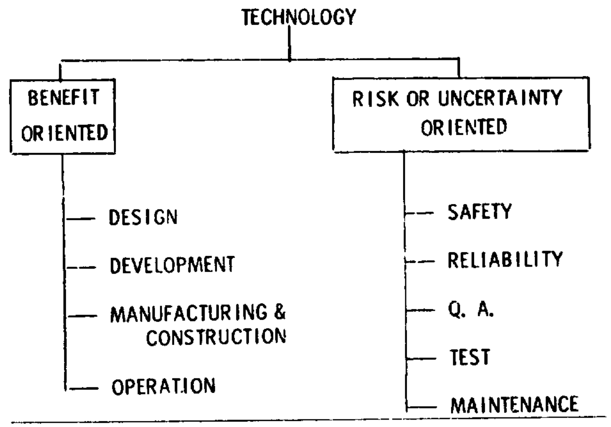

FIGURE 1

SLANT OF BALANCE TOWARD BENEFITS

- o RESULT:
  - TAKING MORE RISK THAN IS DESIRABLE.
  - PROBABILITY OF GREATER LOSSES THAN NECESSARY
- o REASONS:
  - THINK-POSITIVE SYNDROME (LATER)
  - BENEFITS WITH HARD DATA VS. RISK WITH SOFT DATA (INCLUDING LOGIC)
  - GRADUAL DEGRADATION FOLLOWING REACTION CAUSED BY SERIOUS ACCIDENT
  - LESSONS FORGOTTEN
  - MATERIAL AND POLITICAL PRESSURES
  - UNCERTAINTIES LOST IN DECISION PROCESS. MICRO DECISIONS, ASSUMPTIONS, APPROXIMATIONS ETC.

FIGURE 5

THINK-POSITIVE SYNDROME

EXPRESSIONS THAT DEFINE STATE OF MIND.

PREFERRED BENEFIT TYPE	RESISTED UNCERTAINTY TYPE
SAFETY	ACCIDENTS
RELIABILITY	FAILURES
QUALITY ASSURANCE	DEFECTS
TESTING	ANOMALIES
PROBABILITY OF WINNING	PROBABILITY OF LOSING
RELIABILITY .992	PROBABILITY OF FAILURE 8×10^{-3}

FIGURE 6

THINK POSITIVE IS A MUST IN ORDER TO

- PREVENT STAGNATION
- MAINTAIN INTEREST
- STIMULATE DESIRE FOR ACHIEVEMENT, PROGRESS OR INNOVATION

BUT

IT PERVADES ALL LEVELS OF AN ORGANIZATION AND UNBALANCES BENEFIT/RISK DECISION RATIO:

EXAMPLES:

AT START		
HARD PRESSURE TO ACHIEVE DIFFICULT GOALS	VS	SOFT CAPABILITY OF UNCERTAINTY ESTIMATES
UNDER STRESS		
DESIGN AND OPERATIONS ARE ESSENTIAL	VS	SAFETY AND RELIABILITY ARE DISPOSABLE

FIGURE 7

WHY RISK DEPARTMENTS?

AGAINST

- o UNCERTAINTY DISCIPLINES OFTEN CONSIDERED A NAGGING INTERFERENCE.
- o DESIGN ENGINEERS CAN READILY UNDERSTAND AND LEARN PHILOSOPHY AND TECHNIQUES OF RISK TECHNOLOGIES.
- o DECISION MAKERS HAVE DONE WITHOUT RISK DATA OR ANALYSIS FOR CENTURIES.

FOR

- o PRIME INTEREST IN WORK ESSENTIAL FOR QUALITY.
- o CONFRONTATION

BENEFIT VS RISK -

IS ESSENTIAL ELEMENT OF DECISION

FIGURE 8

o DATA ON ANOMALIES AS IMPORTANT TO FUTURE AS MAJOR MISSION FAILURES.

o A WEALTH OF UNUSED STATISTICS IS AVAILABLE WHICH COULD BE USED WITH FMEA FOR REAL LIFE PROBABILITY PREDICTIONS.

FIGURE 11

WORK INTEREST

PRINCIPLE

Relatively Poor Performance Results in Areas of Secondary Interest When Mixed With Areas of Primary Interest

TABLE OF DEGREE OF INTEREST

● 1 ● 2 PRIMARY

▲ 1 ▲ 2 SECONDARY

RISK-RELATED GROUP	$	T	PERF. PARAM. KEY	PERF. PARAM. NON-KEY	UNCERTAINTY CONTROL SAFETY	UNCERTAINTY CONTROL REL.	UNCERTAINTY CONTROL Q.A.	UNCERTAINTY CONTROL TEST	UNCERTAINTY CONTROL MAINT.
MGT (Decision)	● 1	● 1	● 1	▲ 2	▲ 1	▲ 2	▲ 2	▲ 1	▲ 2
DESIGN	● 2	● 2	● 1	● 1	▲ 2	▲ 2	▲ 2	● 2	▲ 2
SAFETY (RISK)	▲ 2	▲ 2	▲ 2	▲ 2	● 1	● 2	● [illegible]	● 2	● 2
RELIABILITY (RISK)	▲ 2	▲ 2	● 2	● [illegible]	● [illegible]	● 1	▲ 2	● 1	▲ 1
MAINTENANCE (RISK)	▲ 2	▲ 2	● 2	● [illegible]	▲ [illegible]	● [illegible]	● [illegible]	● 2	● 1

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FIGURE 9

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CONCLUSION

1. SEPARATION OF BENEFIT & RISK MANAGEMENTS DESIRABLE BECAUSE OF:
   - --WORK INTEREST
   - --BENEFIT OF CONFRONTATION
2. MOST OF RISK TECHNOLOGY LAGS FAR BEHIND BENEFIT TECHNOLOGY IN:
   - --STATE OF DEVELOPMENT
   - --DATA BASE
   - --DEGREE OF ATTENTION BY MANAGEMENT
3. RELIABLE QUANTITATIVE DATA BASE WOULD MAKE MAJOR CHANGE IN UTILITY OF RISK
   - ---ANALYSIS OF OPERATIONAL ANOMALIES MIGHT PROVIDE NEEDED BASE.
   - ---THEIR CAUSE AND WHERE THEY COULD HAVE BEEN CAUGHT
4. EXISTING LAG DOES NOT OF ITSELF JUSTIFY GREATER EFFORT
   - ---UTILITY TO DECISION-MAKING AN IMPORTANT CRITERION

FIGURE 12

CONFRONTATION

EFFECTIVE DECISIONMAKING REQUIRES:

--- CONFRONTATION OF DIFFERENT POINTS OF VIEW

--- INDEPENDENT THINKING

--- ADEQUATE DATA & ANALYTICAL BASE

· COMMUNICATION CAPABILITY

FIGURE 10

9. IMPORTANT TO DEVELOP A SENSE OF THE DECISION VALUE OF BETTER BALANCE IN KNOWLEDGE OF BENEFIT-RISK RATIO BY:

--IMPROVED DATA BASE

--TRIALS & ANALYSIS

--STIMULATION OF PRIVATE CONTRACTORS

FIGURE 14

5. ARGUMENTS INDICATE GREATER RISK GENERALLY TAKEN THAN INTENDED.

6. NO CONTROVERSY THAT IMPROVEMENT IS POSSIBLE.

7. CONTROVERSY WHETHER IMPROVEMENT IS WORTH THE EFFORT (IS COST EFFECTIVE)

--MANY MANAGERS FEEL PRESENT CONDITION SATISFACTORY

--OTHERS DON'T (INCLUDING DEFENSE UNDERSECRETARY PACKARD)

--RECOGNITION OF NEED OF RISK ASSESSMENT IS RAPIDLY GROWING

8. DECISION MAKING:

--BENEFIT-RISK INFORMATION IS UNBALANCED

--CURRENT DECISION EFFICIENCY: NOT KNOWN

--EFFECT OF IMPROVEMENT OF RISK TECHNOLOGIES: NOT KNOWN

--LOSS INCURRED BY REDUCTION OF EFFORT IN UNCERTAINTY AREAS FOR SCHEDULE & COST: NOT KNOWN

FIGURE 13

AN OPINION

APPLICABLE TO PUBLIC AND PRIVATE SECTORS:

IF ONE DOES NOT INCLUDE THROUGHOUT A MAJOR PROJECT

--SYSTEMATIC UNCOVERING OF UNCERTAINTIES

--THOROUGH OFFICIAL ASSESSMENT OF RISK AT EACH MAJOR MILESTONE.

ONE LOSES ONE OF THE MOST IMPORTANT VALUES FOR THE FUTURE THE PROJECT CAN PROVIDE--

--DEVELOPING REAL-LIFE STATISTICAL DATA

--LEARNING HOW TO APPLY THEM TO DECISION MAKING.

FIGURE 15